APPENDIX A:
TERMS AND DEFINITIONS

CORE DEFINITIONS

C-1. **Awareness-Location-Repair (ALR) Time[2]:** The concept of awareness, location and repair times for a main break or leakage event forms the basis of leakage component analysis. The component periods in the life of a leak are:

a. **Awareness Time[2, 5]:** This is the time needed for the operator to become aware that a leak exists; a parameter strongly influenced by the presence or absence of an active leakage control/monitoring program.

b. **Location Time[2]:** This is the time taken to pinpoint the source of the leak once the operator is aware of its existence.

c. **Repair Time[2, 5]:** This is the time to affect a repair that halts the leakage flow, once the leak location has been identified. This is not just the time of the shutoff and repair action, but all time needed to route the repair work order, schedule the repair, notify customers, and other pre-repair activities, which can take days or weeks depending on the polices of the water utility. Repair time ends when water service is restored to customers. It does not include surface restoration

C-2. **Backflow[1]:** A hydraulic condition, caused by a difference in pressures that causes non-potable water or other fluid to flow into a potable water system.

C-3. **Backsiphonage[1]:** A form of back flow caused by a negative or sub-atmospheric pressure within a water system.

C-4. **Blowout/Rupture[1, 5]:** A condition of bursting water main under hydrostatic pressure that is normally associated with severe water pressure loss. Most of the utilities associate "Blowout" with a rapid and large failure in water main that has large potential to cause property damage or traffic disruption. Immediate attention by the utilities is normally required.

C-5. **Chlorine Residual[1]:** A concentration of chlorine species present in water after the oxidant demand has been satisfied.

a. **Disinfectant Residual[5]:** The concentration of any chemical disinfectant present in water after the oxidant demand has been satisfied.

I. **Chloramines[1]:** Disinfectants produced from the mixing of chlorine (Cl_2) and ammonia (NH_3). Typically, monochloramine (NH_2Cl) and a small percentage of dichloramine ($NHCl_2$) are formed, depending on the pH and the chlorine to ammonia ratio that reacts.

II. **Free Chlorine/Free Available Chlorine[1]:** The amount of chlorine available as dissolved gas (Cl_2), hypochlorous acid (HOCl), and hypochlorite ion (OCl^-), that is not combined with ammonia (NH_3) or other compounds in water.

b. **Combined Residual[1]:** A compound of an additive (such as chlorine) that has combined with something else and that remains in the water. Chloramines, where chlorine has combined with ammonia, are combined residuals.

C-6. **Clamp/Repair Clamp[1, 5]:** A thin flexible, circular metal strip with a gasket inside used to repair a leaking pipe by applying compression around the pipe exterior by bolts that join the metal strip and wrap the pipe.

C-7. **Contaminant[1]:** Any undesirable physical, chemical, biological, or radiological substance or matter in water.

C-8. **Cross Connection[1]:** The physical connection of a safe or potable water supply with another water supply of unknown or contaminated quality or such that the potable water could be contaminated or polluted.

C-9. **Dechlorination[1]:** The process of removing chlorine (HOCl, OCl^-) from solution. Dechlorination is typically achieved through chemical addition of a reducing agent.

C-10. **Depressurization[5]:** Events or conditions when negative or low pressure in the distribution system that can potentially allow untreated water to backflow into the distribution main through faulty joints, small leaks or breaks. Depressurization also has potential to collapse the pipe if inadequately protected from negative pressure.

C-11. **Disinfectant[1, 5]:** An agent that destroys or inactivates harmful microorganisms. Chlorine is the disinfectant normally used in water main repair activities.

C-12. **Disinfection[1]:** The process of destroying or inactivating pathogenic organisms (bacteria, viruses, fungi, and protozoa) by either chemical or physical means. A minimum contact time is normally specified along with a disinfectant residual to effective disinfection.

C-13. **Distribution Valves[5]:** A control device that is primarily designed to isolate a section of finished water system pipe from another. The valves are mostly gate valves, usually left in a fully opened or closed position, and are normally 12-inch or smaller. The use of the valve as a throttle may damage internal parts and compromise the effectiveness of the valve.

C-14. **Fecal Coliform (FC)[1]:** Members of total coliform group of bacteria that are characterized by their ability to ferment lactose at 44.5^o C and are considered more specific indicators of fecal contamination than are coliforms that ferment lactose only at 35^o C.

C-15. **Fecal Contamination[1]:** Contamination of soil or water by feces from warm blooded animals. Sewage or wastewater is fecal contaminated.

C-16. **Flushing/Distribution System Flushing[1]:** The act of running water through a distribution system or water main to remove debris, discolored water, or chemical solutions to clean the line or system.

C-17. **Hydrant[1]:** A device connected to a water main and provided with necessary valves and outlets so that a fire hose may be attached for discharging water at a high rate of flow for the purpose of extinguishing fires, washing down streets, or flushing out the water main.

C-18. **Intrusion[5]:** Flow of any contaminant or unknown/contaminated quality of water into distribution main through faulty joints, small leaks or breaks due to difference in pressures.

C-19. **Joint[1]:** A connection between two lengths of pipe, made either with or without the use of a third part.

C-20. **Leak/Leakage[5]:** Uncontrolled loss of water through a breach, flaw or crack in a pipeline, connection or joint in a water system.

C-21. **Leak Detection[1]:** The precise locating of underground water leaks in a water system by the use of sounding or sonic devices where leakage is known or suspected.

C-22. **Main Breaks/Water Main Break/Pipe Rupture/ Break in a Pipeline[5]:** In a water pipe, localized pipe failure which can be associated with a sudden pressure surge, hydrostatic pressure, poor quality pipe, structural failure, corrosion, fatigue, external forces, loss of bedding, joint separation, freezing, temperature change or other causes. This can include the main and fittings as well as couplings and joints along the main. See Figure A-1 for more information.

a. **Large Main Break[5]:** Main breaks associated with pipes greater than 12-inch diameter.

b. **Small Main Break[5]:** Main breaks associated with 12-inch diameter or smaller pipelines.

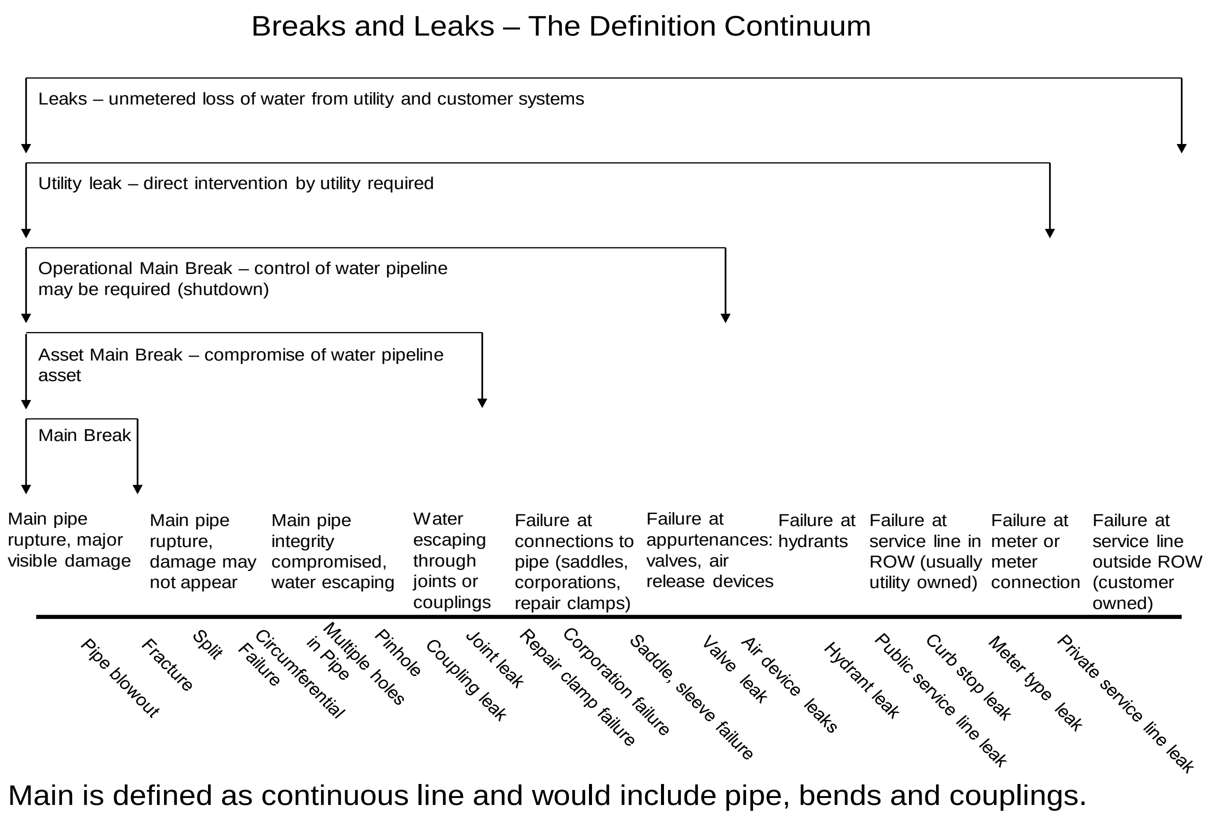


Figure A.1[5]: Breaks and Leaks – Definition Continuum

*ROW: Right of Way

Main Break/Water Main Break Types:

c. **Blowout/Rupture:** See terminology # C-4.

d. **Circumferential (Beam) Break[5]:** A break in the pipe wall that propagates perpendicular with the run of pipe and usually propagates the full circumference of the pipe.

e. **Crushed Pipe[5]:** Failure of pipe when the compressive strength or load on the pipe exceeds the crushing strength of the pipe.

f. **Fracture[5]:** A break in the pipe wall that propagates along multiple cracks rather than along a single horizontal or vertical direction.

g. **Joint Blowout/Joint Failure/Split Joint[5]:** A break or failure at pipe joint due to corrosion, internal pressure, improper joint/material, thermal fatigue, bending stress, inadequate thrust restraint or excessive deflection of pipe.

h. **Longitudinal Crack[5, 14]:** A crack along the pipe axis due to internal pressure or compressive forces acting along the pipe. The length of the crack varies from a few inches to the full length of the pipe.

   a. **Longitudinal Split[14]:** A crack along the pipe axis due to internal pressure or compressive forces acting along the pipe extending to the full length of the pipe.

i. **Pinhole Leak/Corrosion Hole[5]:** A failure in the pipe wall that tends to be restricted to a small opening, usually as a result of internal or external corrosion.

j. **Shearing Failure[5, 14]:** Excessive compressive force tends to produce a crack in pipe that propagates along the length of the pipe. When this compressive strength couples with a bending force, that exceeds the shearing strength of the pipe material, it causes shearing failure. Shearing failure usually occurs at 45^{o} plane of the pipe axis.

k. **Spiral Failure[5, 14]:** Type of failure where the crack in the pipe appears to start in a circumferential fashion and then propagates down the length of the pipe in a spiral fashion. This failure mode is produced by a combination of bending forces and internal pressure.

l. **Split Bell[5, 14]:** Due to thermal expansion or compressive strength, the crack propagates as longitudinal fashion and terminates just below the bell of the pipe.

m. **Tap/Corp Blowout[5]:** A failure at pipe tapping saddle or corporation stop.

C-23. **Microbials[1]:** Microbiological contaminants of any sort.

C-24. **Microbiological Analysis[1]/Bacteriological Testing[5]:** The use of various media, techniques and equipments to determine the presence/absence, density or numbers of microorganisms/bacteria in a sample.

C-25. **Multiple Barrier Approach[3,5]:** The use of more than one public health protection approach to promote good distribution piping system design, sanitized piping material, protection of the sanitized water within the piping, inspections, flushing and water quality testing.

C-26. **Pipe[5]:** A conduit that conducts water from one location to another.

C-27. **Pipe Fittings[5]:** Pipe transition materials for connecting lengths of pipes (couplings, unions), changing the direction of pipes (bends), and providing branches (tees, wyes, crosses), & end pipes (plugs and caps). Common pipe fittings are Bends and Offsets, Couplings, Transition fittings, Tee, Cross, Wye, Reducer etc.

C-28. **Pressure[1]:** The force pushing on a unit area. Water pressure is normally measured in pounds per square inch, kilopascals, or feet or meters of head.

C-29. **Pressure Management[5]:** The technique of maintaining water pressures in a water distribution system in an optimum range such that service level requirements for water supply and fire protection are provided, while excessive pressure and transients that cause excessive leakage and ruptures, are avoided.

C-30. **Risk[1, 5]:** It is a measure of potential human injury, environmental damage or economic loss in terms of both the incident likelihood (frequency) and magnitude of the loss or injury. Statistically, risk is expressed as the product of the likelihood of events and their consequences.

C-31. **Risk Management[5]:** Risk management is a systematic approach, including policies, procedures and practices involved in the identification, analysis, assessment, control, and avoidance, minimization, or elimination of unacceptable risks.

C-32. **Sanitation[1, 5]:** The improvement of environmental conditions favorable to public health protection and disease prevention.

C-33. **Scour or Scour Velocity[16]:** Clean or the flow velocity to clean the internal pipe surface in water distribution systems.

C-34. **Sewage[1]/Wastewater:** The used water and water-carried solids from a community or household use. Normally conveyed in a pipe to a wastewater treatment plant or septic system.

C-35. **Service Line[1]:** The pipe and all appurtenances that run between the utility's water main and the customer's place of use, including fire lines.

C-36. **Swabbing[5]:** Water main swabbing is the forceful introduction of cleaning swab/tool through a pipe to remove debris such as stones and sand prior to the ultimate activation of the water main.

C-37. **Tap[5]:** The connection to a main for a lateral service line, hydrant, or other inlet or outlet.

C-38. **Total Coliforms (TC)[1]:** The group of bacteria used as warm-blooded animal fecal pollution indicator organisms of drinking water quality. Total coliforms are regulated by the EPA and most state health departments.

C-39. **Trench[1]:** An excavation made for installing pipes and masonry walls, as well as for other purposes.

C-40. **Trench Water[5]:** When construction or repair of pipes occurs in open trenches or excavations; water from different sources, i.e., groundwater, rainfall, surface or storm or agricultural water runoffs, sewer, water main break may enter the trench. This water inside the trench is generally referred to as "trench water".

C-41. **Tuberculation[17]:** The process in which blister-like growths of metal oxides develop in pipes as a result of the corrosion of the pipe metal. Iron oxide tubercles often develop over pits in iron or steel pipe, and can seriously restrict the flow of water.

C-42. **Turbidity[1]:** A condition in water caused by the presence of suspended matter including dirt, clay, dissolved gasses etc., resulting in the scattering and absorbance of light. It is an analytical quantity, usually reported in nephelometric turbidity units (NTU).

SUPPORTING DEFINITIONS

S-1. **Air Gap**[1]: A dedicated air space between a pressurized water supply and a source of contamination, used to ensure that an incompatible liquid or contamination source is physically disconnected from the piping system and therefore, cannot be siphoned into the system.

S-2. **Air Release Valve**[5]: A connection on a pipeline to drain, flush, reduce pressure, or release air from a pipe. Devices may be automatic or manually operated. Often called a blow-off or air relief valve.

S-3. **Air Relief Valve**[15]: Air relief valves function to release air accumulated at each high point of a full pressured pipeline. Air relief valves open whenever air is accumulated. These valves are essential for pipeline efficiency and water hammer protection.

S-4. **Backflow Prevention Device**[5]**:** A device, method, or construction that is placed along the run of a pipe or service to prevent flow in the reverse direction into a potable water system.

S-5. **Blocking and Restraints**[5]**:** Materials that provide structural support to hold pipe in place. Blocking/thrust block/thrust restraint is typically a large mass (concrete) that prevents pipe from shifting while restraints are systems that attach pipe and hold segments together.

S-6. **Boil Water**[5]**:** Heating water at such a temperature that the vapor pressure of the water equals the atmospheric pressure. The standard temperature at which this occurs is 100^o C or 212^o F at sea level. Boiling is considered the safest and most effective method of water disinfection in an emergency.

S-7. **Boil Water Advisory**[5, 7]**:** A Boil Water Advisory (BWA) is a public statement advising customers to boil tap (e.g., bring the water to a rolling boil and hold it there for at least one minute) water before consuming, using for food preparation, using for making ice, or using for brushing teeth. Advisories are issued when an event has occurred allowing the possibility for the water distribution system to become contaminated. An advisory does not mean that the water is contaminated, but rather that it could be contaminated; because the water quality is unknown.

S-8. **Boil Water Notice**[5, 7]**:** A Boil Water Notice is a public notification that customers must boil their water before consuming it. A boil water notice is issued when contamination is confirmed in the water system.

S-9. **Cap/Pipe Cap/End Cap**[5]**:** A type of pipe fitting for the end of a pipe used to protect the pipe ends and keep out dirt and other foreign materials.

S-10. **Components of Leakage and Water Main Breaks**[5]**:** Failures in water distribution pipeline systems occur in three primary manners. In any given system, these types of failures occur in varying proportions, depending upon the operational and physical conditions of the network. Water utilities can assess the occurrence of the three types of leakage and quantify the average awareness, location and repair times to address leakage and water main break events in order to estimate volumes of lost water over the course of a year. This technique is known as *Leakage Component Analysis*[2]. Data from the Leakage Component Analysis assists in forming the basis of the leakage and main break control strategy, by allowing the water utility to select the proper proportion of efforts toward active leakage control, pressure management and water main rehabilitation.

   a. **Reported Leaks and Breaks**[2]**:** Leaks that are reported by customers, traffic authorities, or any other outside party because of their visible and/or disruptive nature. Also, those leaks detected by Supervisory Control and Data Acquisition (SCADA) Systems can be categorized as reported leaks.

b. **Unreported Leaks and Breaks[2]:** Leaks that escape public knowledge and are only identified through the active leakage control work of the water utility. The leak detection survey is the most common means currently used in North America to identify unreported leaks.

c. **Background Leakage[2]:** The tiny weeps and seeps at joints and fittings that defy detection through conventional acoustic means. Such tiny leaks are usually numerous and widespread in a given distribution system but are not readily detectable individually. However, this type of leakage is sensitive to water pressure levels and can be economically controlled by optimizing pressure levels.

S-11. **Consequence of Failure[5]:** Evaluation of impact to operations of a failure in terms of water loss, repair costs and property damage as well as social, environmental and economic consequences such as significant interruption to commerce, interruption of water service, property damage, and public safety. Typically applied to water pipe failures but can be used for any operating asset that impacts operations.

S-12. **Contact Time[1]:** The time in which a chemical or constituent is in contact with another reacting chemical or constituent.

S-13. **Corporation Stop (Tap)/Corporation Cock/Ferrule [5]:** A connection valve on a water main that facilitates connecting (tapping) and controlling a service pipe to a water main.

S-14. **Cost of Failure[5]:** Evaluation of the cost of failure, often based on a relative scale from insignificant to catastrophic.

S-15. **Couplings and Transition Fittings[5]:** Watertight materials that allow un-joined pipe to be joined. Transition fittings will accommodate un-joined pipes that may be of differing materials or sizes.

S-16. **Cradle[1]/Pipe Cradle:** A continuous concrete bed placed in the bottom of a trench to support and partially envelope a pipe, particularly where the trench is soft ground or where bearing support is inadequate to carry the load of pipe and backfill material.

S-17. **Curb Stop[5]:** An outside stop tap or boundary stop tap which include a shutoff valve along a water service line buried near the property line (curb) of a customer's premise and normally accessible at ground level (via a curb valve box).

S-18. **Dechloramination[12, 5]:** The process of removing chloramines (monochloramine, NH_2Cl; dichloramine, $NHCl_2$; trichloramine, NCl_3) from solution. Dechloramination is typically achieved through chemical addition of a reducing agent, the most common of which are sulfur dioxide (SO_2), sodium bisulfite ($NaHSO_3$) and sodium metabisulfate ($Na_2S_2O_5$).

S-19. **Dewater/Dewatering[1, 5]:** The process of partially removing water. It may refer to removal of water from a pipeline, basin, tank, reservoir, or other storage unit, or to the separation of water from solid material.

S-20. **Dewatering Pump[5, 6]**: Pumps that are designed for dewatering application and can handle hard and soft solids such as mud, leaves, twigs, sand, and sludge. As a general rule, dewatering pumps are limited to a 10% solids concentration and a solids size of one-fourth the diameter of the suction inlet.

S-21. **Do Not Drink Advisory[5]:** Communication to customers to avoid tap water and use other sources of water for consumption.

S-22. **Do Not Use Advisory[5]:** Communication to customers not to use tap water for any purpose including sanitation and fire protection.

S-23. **Drinking Water Advisory[5]:** Communication to customers explaining specific actions to take regarding drinking water use. An advisory may be mandatory (required by the regulatory or public health agency) or precautionary. An advisory is issued when an event (such as a loss of positive pressure) has occurred that could have allowed the drinking water to become contaminated with microbial or chemical contaminants of public health concern. An advisory is issued because actual contamination has not been confirmed.

S-24. **Gasket[1]:** A ring of material used to make a joint or connection water tight.

S-25. **Outage[5]**: An event in which the customer is deprived of a proper level of service; for water service, it typically implies loss of flow and pressure to multiple customers for extended periods.

S-26. **Pig/Polypig[1]:** A flexible polyurethane cleaning swab that is flushed through a distribution line with water to scrape, remove foreign matter, and assist in flushing or cleaning water mains. Foam pigs are generally used for liquid removal, swabbing, drying, and many cleaning duties from all pipe materials. Polyurethane foam pigs are flexible and bi-directional and are often suited to pipeline systems with very tight radii or mitred bends and where significant reductions in internal diameter exist.

S-27. **Pigging[1]:** The process of forcing an in-line scraper or polypig through a water line by the force of moving water or flush water to remove scale, sand, and other foreign matter from the interior surface of the pipe.

S-28. **Pipe Corrosion[1]:** The destruction of a pipe as a result of a chemical reaction with its surroundings. Pipe corrosion is generally a physiochemical interaction between a pipe's material and its environment that results in an alteration of the pipe material's properties.

  a. **Internal Pipe Corrosion[1]**: Internal pipe corrosion refers to destruction associated with the inside of the pipe, which is in contact with the substance being conveyed, e.g., potable water. Internal corrosion may be uniform over the surface or it may form pits and tubercles.

  b. **External Pipe Corrosion[1]**: External pipe corrosion refers to destruction from the outside of the pipe towards interior. External pipe corrosion is often associated with stray current or certain soil conditions.

S-29. **Pipe Liner[5]:** A protective cover over all portion of the interior perimeter of a conduit to prevent seepage losses, withstand pressure, reduce friction losses, and resist corrosion. The liner may be on the pipe at the time of production or added in the field (in situ) as a means of pipe rehabilitation.

S-30. **Pipe Segment[5]:** Measureable section of pipe. Pipe is segmented for purposes of evaluating condition and performance for which a failure at any point has the same consequences.

S-31. **Pipe Sleeves[5]:** A tube into which a pipe is inserted (also called a carrier pipe). Also, a pipe fitting for connecting two pipes of the same diameter in a straight line.

S-32. **Pipe system[5]:** A system of pipes, fittings and valves within which a fluid flows. *Components:* Pipe Liner, Joint Materials, Blocking and restraints, Pipe, Pipe Segment, Pressure Zone, Shut off Block, Pipe Fittings.

S-33. **Public Notice[5]:** A Public Notice (PN) is a communication to all or specified customers of a drinking water supply as required by State and EPA public notification regulations, such as when an acute public health maximum contaminant level is exceeded or it is determined that a waterborne disease outbreak has been detected.

S-34. **Repair[5]:** The restoration of an existing asset/pipeline by replacing or using minor components or materials, such as patches or clamps, designed to restore a sound condition of the asset/pipeline.

S-35. **Sterilization[1, 5]:** The process of destroying all forms of microbial life on and in an object or within a liquid by physical, chemical, or thermal process.

S-36. **Stick of Pipe[5]:** A full length of pipe as manufactured.

S-37. **Storm water[11, 5]:** Storm water runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground. As the runoff flows over the land or impervious surfaces (paved streets, parking lots, and building rooftops), it accumulates debris, chemicals, sediment or other pollutants that could adversely affect water quality and might flow directly into a local stream, bay, or lake. Or, it may go into a storm drain and continue through storm pipes until it is released untreated into a local waterway.

S-38. **Susceptible Populations[5]:** Groups of people with medical needs or conditions that make them susceptible to adverse effects of poor water quality issues. Susceptible populations include babies and young children, pregnant women, and people who are immune-compromised, elderly, or on dialysis.

S-39. **Tank[5]:** A vessel or container used to hold water or other liquid.

S-40. **Tee, Cross, Wye[5]:** Fittings that allow for adding and changing directions of a pipe. These fittings may also serve as pipe reducers.

S-41. **Transmission Main[5]:** A large water main that transports water from the main supply or source to a distant area where the water is then further distributed. Finished water transmission mains usually have no or few connections.

S-42. **Trash Pump[5, 6]:** Pumps that are designed to pump large amounts of water that contains hard and soft solids such as mud, leaves, twigs, sand, and sludge. Typical solid handling capability of 25% by volume. As a rule of thumb, trash pumps can handle spherical solids up to one-half the diameter of the suction inlet.

S-43. **Vacuum Breaker Valve[5]:** Valve typically observed with a 90-degree elbow and a hood. Inside the elbow is a poppet valve that is held "up" by water pressure, closing the air entrance to the device. If the pressure in the "upstream side" is reduced to atmospheric pressure or below, the poppet valve drops and allows air to enter the system, breaking the siphon.

S-44. **Wrap and Coating[5, 1]:** Tubular length of flexible fiberglass or polyethylene wrap or PVC plastic tape with special high tack adhesive wrapped around a pipe or a material applied to the outside of a pipe to protect it primarily from corrosion.

SOURCES OF INFORMATION CONSULTED IN DEVELOPING DEFINITIONS

1. The Drinking Water Dictionary, AWWA, 2000
2. Water Audits and Loss Control Programs, Manual M36, AWWA, 2009
3. Practices to Prevent Microbiological Contamination of Water Mains, AWWARF, 2001 (http://books.google.com/books?hl=en&lr=&id=XvwmUboOIpMC&oi=fnd&pg=PR12&dq=drinking+water+main+break+and+depressurization&ots=bIV3xA_jJZ&sig=mympRwVqjG65oE-pW4nQ6kxauO4#v=onepage&q&f=false)
4. Dictionary of Water and Waste Management, IWA, 2005 (http://books.google.com/books?hl=en&lr=&id=8Ts0SxVy8a0C&oi=fnd&pg=PA1&dq=awwa+water+dictionary&ots=rYnLAbK8PR&sig=OeWiVplt5miM_5pLSOT-9eHL3qo#v=onepage&q&f=false)
5. Developed by the Project Team from various sources.
6. http://www.onsite-energy.com/glossary/pumpgloss.html
7. http://www.charlestonwater.com/custserv_svc_intptns_boil_advisory.htm
8. http://www.meatprocess.com/Products/New-water-treatment-process-hailed-as-more-efficient
9. http://www.dep.state.pa.us/dep/deputate/watermgt/wsm/wsm_tao/InnovTech/ProjReviews/LinPor.htm
10. Decentralized Systems Technology Fact Sheet - Types of Filter, EPA, September 2000.
11. http://cfpub.epa.gov/npdes/home.cfm?program_id=6
12. Optimizing Chloramine Treatment, 2nd Edition, AWWARF, 2004 http://books.google.com/books?id=nBCqLMCk6ooC&printsec=frontcover&dq=Optimizing+Chloramine+Treatment+By+Gregory+J.+Kirmeyer,+AWWA+Research+Foundation&hl=en&ei=GqIPTePbFImNnQes8fW2Dg&sa=X&oi=book_result&ct=result&resnum=1&ved=0CCYQ6AEwAA#v=onepage&q&f=false
13. Tardelli Filho, J. 2004. SABESP. Sao Paulo, Brazil: Internal reports.
14. Marker, J.M. et al., 2001. Failure Modes and Mechanisms in Gray Cast Iron Pipes, Underground Infrastructure Research: Municipal, Industrial and Environmental Applications, Proceedings of the International Conference on Underground Infrastructure Research, Ontario. http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc44218/nrcc44218.pdf
15. http://www.apcovalves.com/airvalve.htm
16. Friedman, M.J., K. Martel, A. Hill, D. Holt, S. Smith. T. Ta, C. Sherwin, D. Hiltebrand, P. Pommerenk, Z. Hinedi, and A. Camper. 2003. *Establishing Site-Specific Flushing Velocities*. Water Research Foundation. Denver, CO.
17. http://www.corrosion-doctors.org/Glossary/Letters/Glossary-T.htm

APPENDIX B:
SURVEY OF UTILITY WATER MAIN REPAIR PRACTICES

INTRODUCTION

The existing or current water main repair practices among the utilities are empirical, highly variable, lack of risk management structure and unknown level of risks controlled. Many of the current practices are either inadequate (e.g. flushing the water main at 2.5 ft/sec) or excessive (disinfection with 300 mg/L of free chlorination for 15 minutes). Some of the practices are inconvenient to customers (e.g. 48-hour waiting time for 2 consecutive bacterial samples, precautionary boil water notice, etc.). A utility survey questionnaire was developed and distributed among the participating utilities in order to establish the current baseline of practice for the industry and to identify the utility partners that will be asked to serve as Featured Case Study Programs for the project. A sample utility survey questionnaire is provided at the end of this Appendix as Attachment 1.

The survey questionnaire was distributed among 35 participating utilities in the North America and United Kingdom. A copy of the questionnaire was also sent to the Association of State Drinking Water Administrators (ASDWA) for their information. An Excel spreadsheet was developed to track the questionnaires and input results from the utilities. Data analysis was conducted for the development of summary statistics, pie charts and graphs where applicable, and the documentation of written comments.

The project team received an excellent rate of return on the questionnaires and a great deal of information to support the project. Twenty seven (27) utilities (79%) out of 34 participating utilities in the North America participated in the survey and returned the filled out survey questionnaire (Figure B.1). One utility participated in the survey from the United Kingdom. A brief overview and final results of the utility questionnaire are provided below in two parts: 1) compiled results from the North American utilities and 2) results from the UK utility participant for comparison.

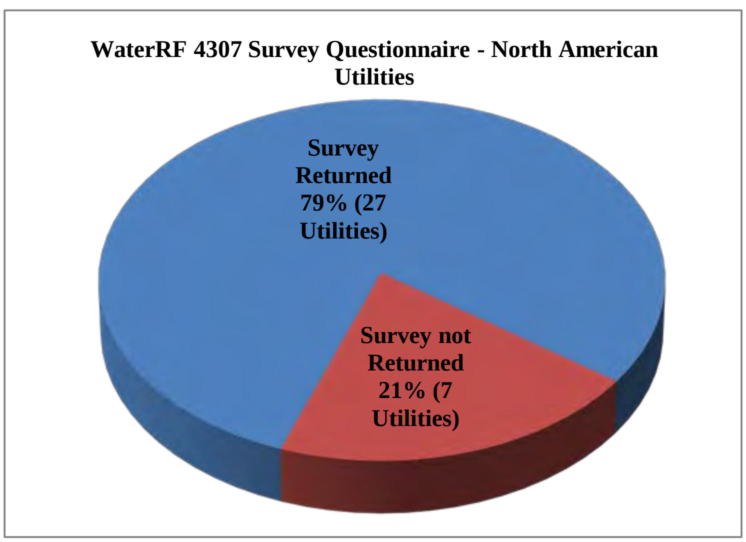


Figure B.1 Survey questionnaire response rate – North American Utilities

NORTH AMERICAN UTILITIES

As evidenced by the list of participating utilities provided in this report, the project team has access to a geographically diverse set of water utilities for this project. Responses to the questionnaire indicate that these utility operations also cover a wide range of utility sizes. Figures B.2, B.3, B.4, and B.5 present the results for service area population, number of service connections, total length of system pipelines, and water production information, respectively.

The utilities selected for the survey vary in population served, number of service connections, length of pipelines and average production capacity. The service area population varies from 7,800 to 4.1M; the number of service connection ranges from 2,400 to 7, 00,000; the length of pipeline varies from 13 miles to 8,000 miles with an average of 2,017 miles of pipelines and the average daily production ranges from 1 MGD to 766 MGD.

Note that each Figure presents the data in order by magnitude, from smallest to largest, within each applicable category. Further, the names of the utilities are not included to preserve their anonymity. It is important to note that the data do not correlate perfectly for a particular utility across each category. For example, the utility with the tenth largest service area population does not necessarily have the tenth highest number of services connections, length of pipeline, or water production. In fact, this is commonly not the case.

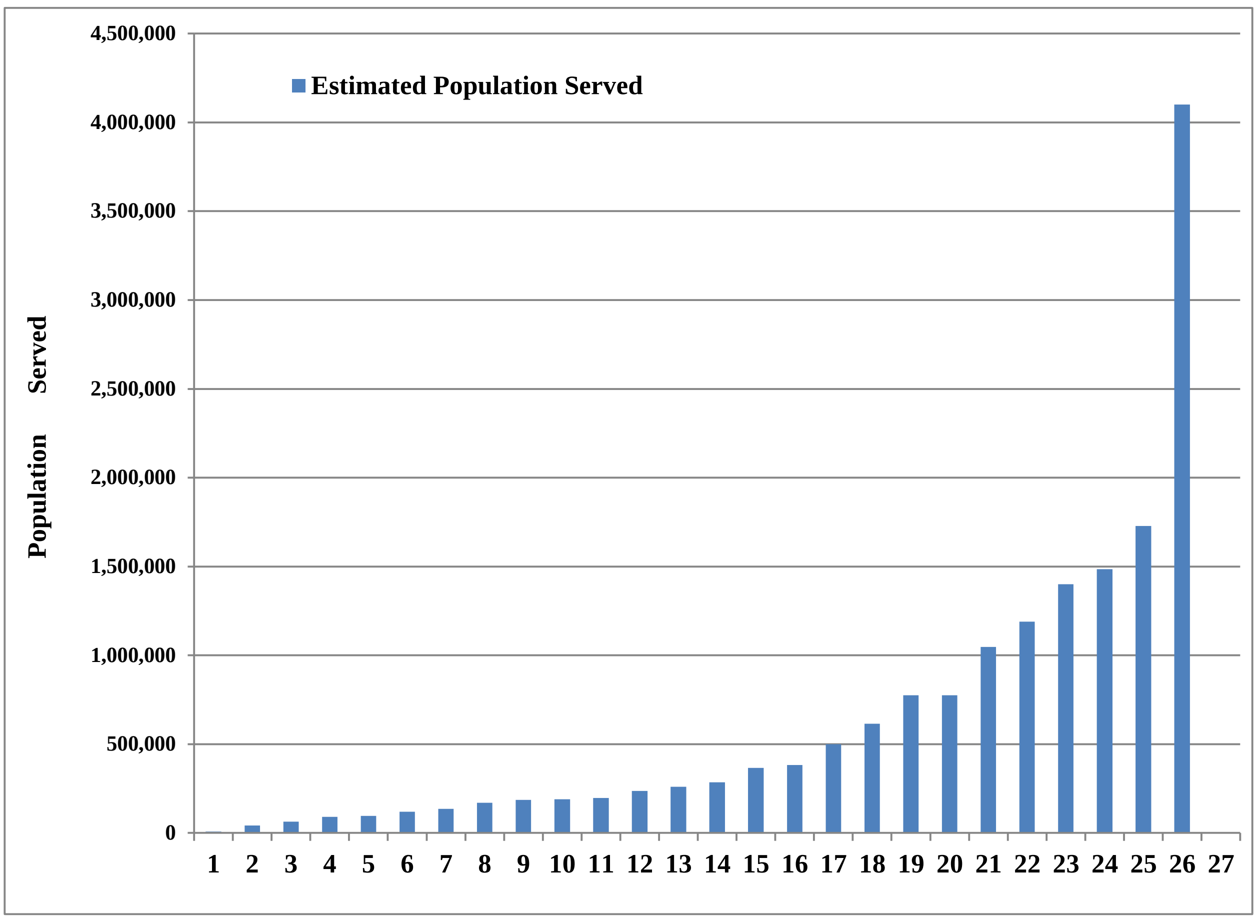


Figure B.2 Service area population – North American utilities

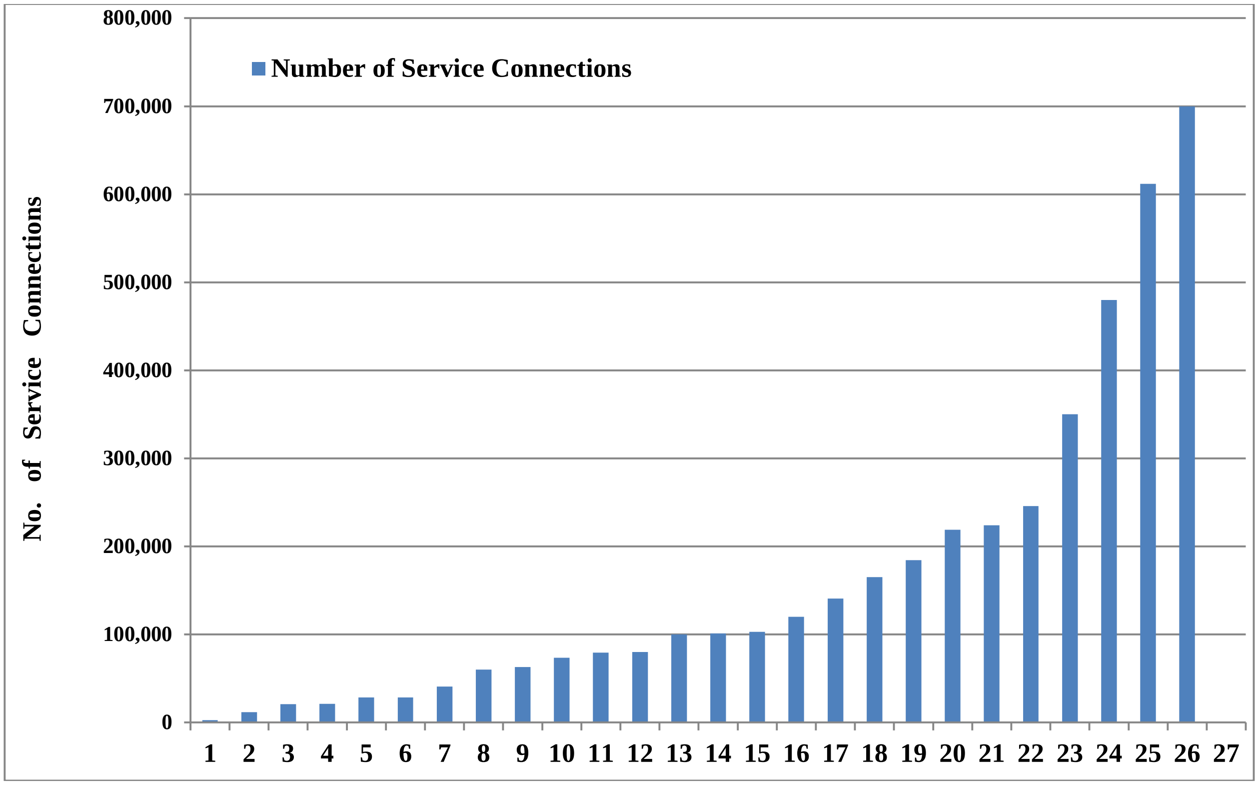


Figure B.3 Service connections – North American utilities

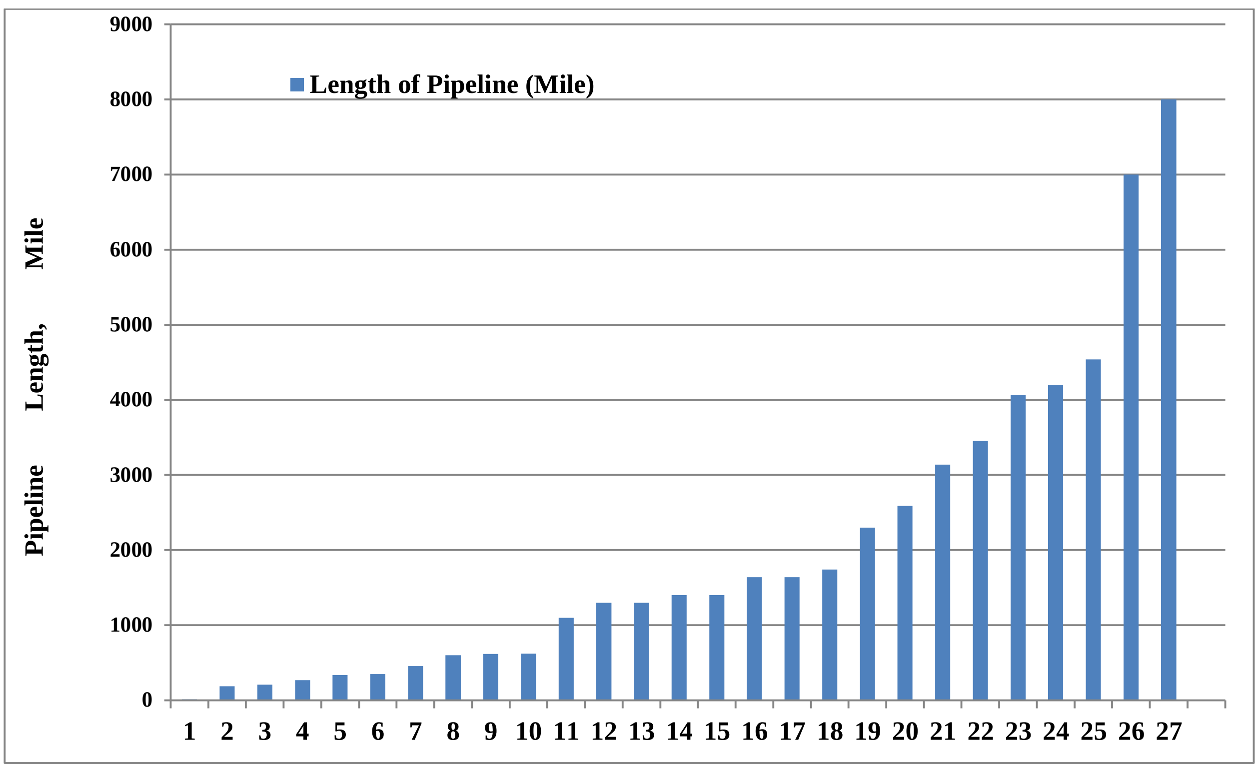


Figure B.4 Total pipeline length – North American utilities

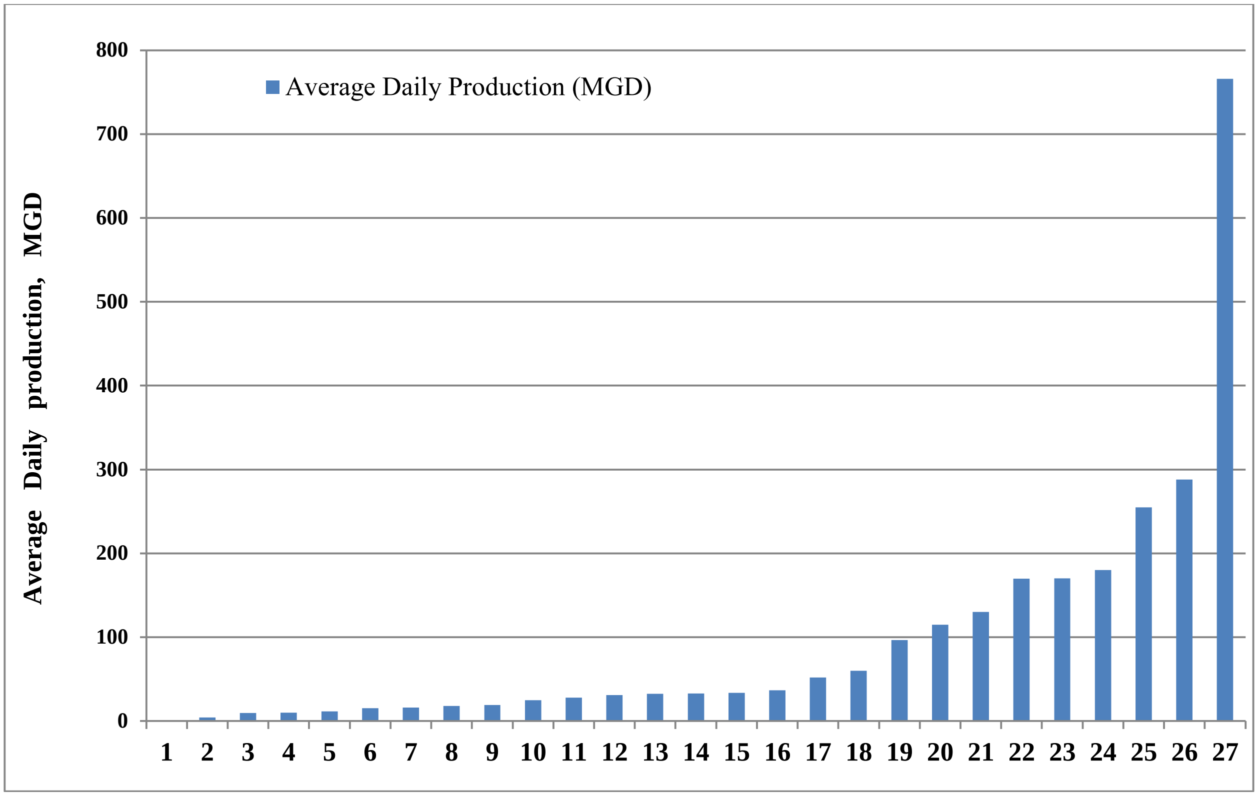


Figure B.5 Water system production – North American utilities

The results for questions related to the number of main breaks for each system are also provided with this report. Figure B.6 is a bar chart which displays the number of main breaks per year reported by each responding utility. This information is displayed on Figure B.7 to show the typical ranges of main breaks found within the partner utilities. Figure B.6 shows that the number of main breaks per year vary widely, from 1 break/year to 3,000 breaks/year with an average of 657 breaks/year. Figure B.7 exhibits that 26% of the participating utilities experience less than 50 breaks/year; while 15% of the utilities experience more than 1,500 breaks/year.

Figure B.8 presents the aggregate main break data normalized to the length of pipeline present within each system. This facilitates for more direct comparison of main break frequency between water utilities of varying sizes. As shown in the figure, main breaks per mile of pipeline per year ranges from 0.01 to 1.44. The majority of the utilities that responded to the questionnaire have less than 0.30 main breaks per mile of pipeline per year, with a median value of about 0.18 and an average of 0.26. These results are comparable to prior work which reports a national average of 0.27 main breaks per mile per year (EPA 2002).

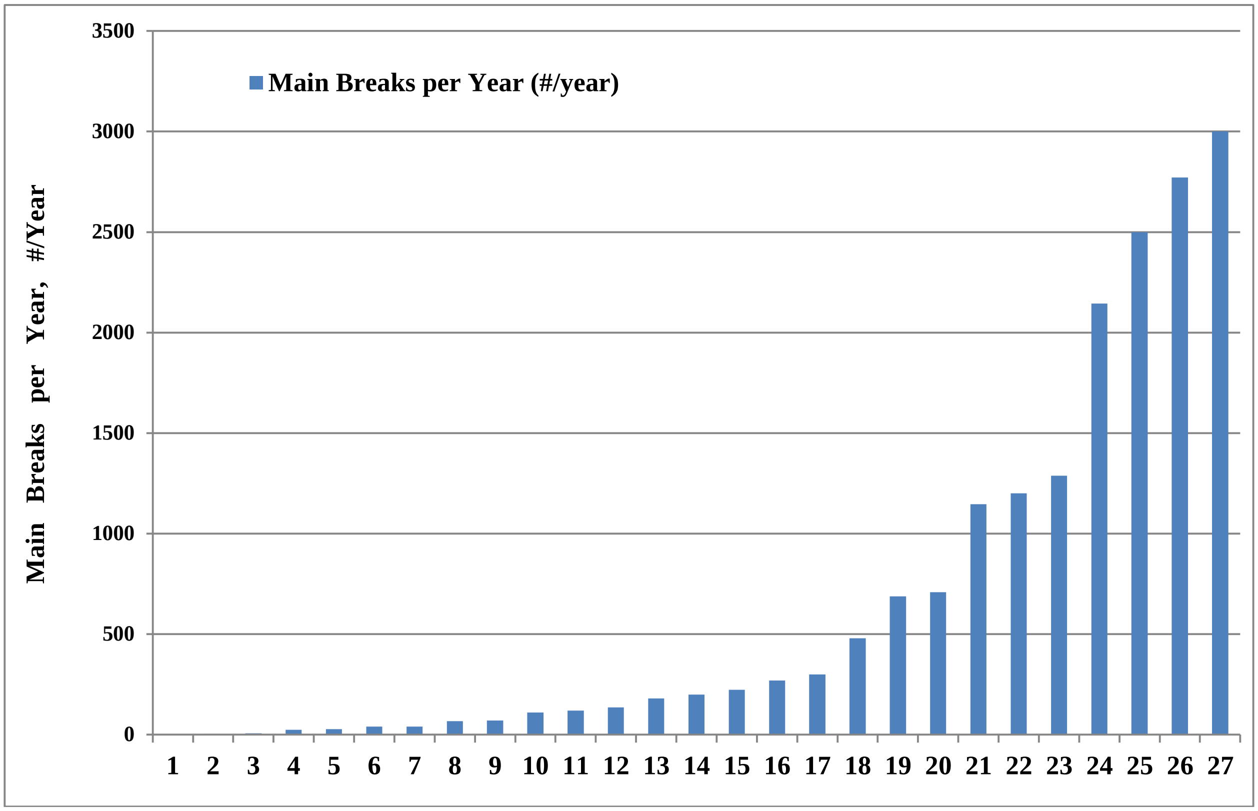


Figure B.6 Main breaks per year, total per utility – North American utilities

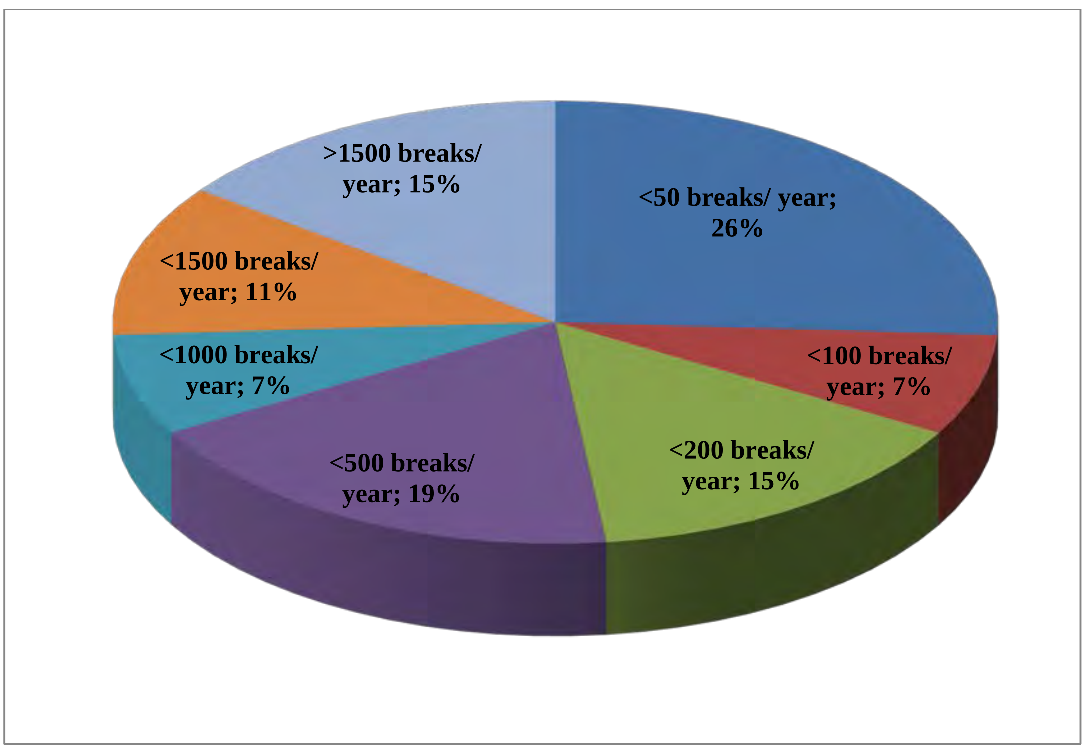


Figure B.7 Main breaks per year, compiled – North American utilities

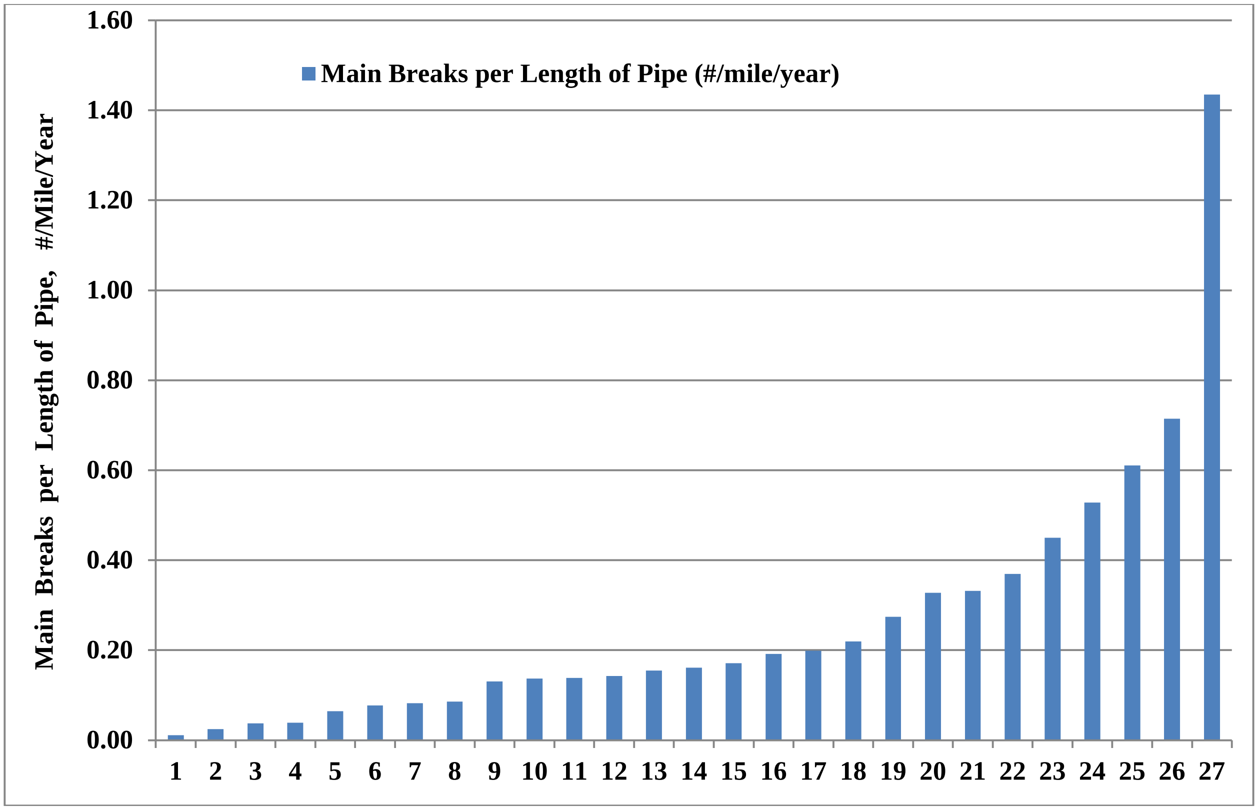


Figure B.8 Main breaks per mile of pipe per year – North American utilities

Table B.1 presents results for whether there was a seasonal component to main breaks in each system. About 70% of utilities indicated that there is a seasonal component, with the winter season having the highest incidence due to cold weather. On average, 38% of main breaks occur in the winter season, with one utility reporting that almost 80% of main breaks occur in the winter. Note that this can lead to inexperienced or contracted crews being relied upon to handle the increased work-load of main break repairs during the winter season. This is a challenge to maintaining consistency in response procedures.

Table B.1
Seasonal occurrence of main breaks

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

37% of the utilities participated in the survey use chlorine, 48% of the utilities use chloramines and 15% of the utilities use both chlorine and chloramines in their system as disinfectant. Responses to questions on how utilities respond to main breaks include:

- 67% of respondents have written procedures for the repair of main breaks.
- A wide variety of repair procedures was noted.
- 96% of utilities provide training on sanitary practices during water main break repairs.
- 65% of utilities provide refreshers for the sanitary practices during water main break repairs.
- The majority of training is conducted informally.
- 89% reported that they follow portions of AWWA Standard C651.
- All respondents indicated that flushing is done as part of the main break repair return-to-service (which is a part of AWWA Standard C651). Table B.2 presents results for whether the utilities use any of the methods described in AWWA Standard C651.
- All respondents indicated that flushing is conducted as the main criteria for release-to-service after repairing a water main break. Turbidity check and monitoring of chlorine residual are also conducted as a supplement to flushing by 41% and 59% of the utilities, respectively.
- About 50% of utilities require water quality sampling before a return-to-service
- 45% of the utilities maintain minimal pressure in the pipeline during main break repair, while 22% of the utilities isolate the break section completely with no flow during the repair. 33% of the utilities follow any of the above techniques depending on the type of break.
- 62% of the utilities Dechlorinate flushed water before discharging.
- 41% of the utilities monitor pressure away from the break location to ensure that there is no depressurization elsewhere in the system due to the main break.

Table B.2
Utilities following methods in AWWA standard C651

AWWA method	Utilities
Trench treatment	33%
Swabbing of pipe	70%
Flushing	100%
Disinfection operation	63%
Bacteriological test	63%

The questionnaire requested information on Boil Water Advisory (BWA) occurrence. As shown on Table B.3, almost 70% of the utilities included in the questionnaire have BWA’s very rarely or never. There are several that do have BWA’s every one to five years or even one or more per year.

Table B.3
Frequency of boil water advisory

Boil water advisory frequency	Utilities
1 or more per year	19%
Every 1 to 5 years	12%
Very rare	42%
Never	27%

Utilities were asked to report the typical crew size used for main break repairs. In Table B.4, typical crew sizes for small main breaks (12-inch diameter and smaller) and large main breaks (>12-inch diameter) are presented. Note that a crew size of four is most typical.

Table B.4
Typical main break repair crew Size for small and large pipeline

Small main breaks		Large main breaks	
Typical crew size	Utilities	Typical crew size	Utilities
1	0%	1	0%
2	4%	2	0%
3	22%	3	8%
4	44%	4	42%
5	19%	5	31%
6	11%	6	11%
>6	0	>6	8%

Finally, the questionnaire requested information on the types of customer interactions each utility has with customers in response to main break repairs. As shown on Table B.5, most provide at least notification, with many providing instructions to customers to flush their premise plumbing upon return-to-service.

Table B.5
Customer interactions related to main break repairs

Types of customer contacts	Utilities
Instructions to flush premise plumbing on return-to-service	30%
Notification only	41%
Instructions to flush premise plumbing and/or notification	14.5%
None	14.5%

UK PARTICIPANT

Results for the participating utility from the UK are summarized in this section. Demographics of the UK participant include:

- Estimated Population Served – 7,200,000
- No. of Service Connections – 2,500,000
- Length of Pipeline – 25,000 Miles

The UK utility reported a main break frequency of 0.06 main breaks per mile of pipeline per year. This is toward the low end of the data collected from the North American utilities. The seasonal component to the break frequency was reported as follows:

- Winter 40%
- Spring 20%
- Summer 20%
- Fall 20%

Noted that the winter main break frequency of 40% is equivalent to the overall average frequency of winter main breaks reported for the North American utilities.

The UK participant does have written procedures for the repair of main breaks. These procedures do not reference AWWA C651; rather, they are in compliance with the UK's Principles of Water Supply Hygiene and Associated Technical Guidance Notes (http://www.water.org.uk/). Note that the Principles include the same five procedures that are outlined in AWWA C651: Trench Treatment; Swabbing of Pipe; Flushing; Disinfection Operation; and Biological Tests.

Finally, the UK utility does have occasional Boil Water Advisories that occur every one to five years.

ATTACHMENT 1
Research Foundation Project #4307
Effective Microbial Control Strategies for Main Breaks and Depressurization

Utility Questionnaire: Water Main Breaks and Repairs

INTRODUCTION

HDR Engineering, in association with American Water, was selected by the Water Research Foundation (WaterRF) and its funding partner, the United Kingdom Drinking Water Inspectorate (UKDWI), to conduct a research study to identify best practices for water utilities in managing the public health risks associated with water main breaks and depressurization events. These events occur hundreds of times each day in the United States, the United Kingdom, and elsewhere. The purpose of this project is to improve utility responses to main breaks and depressurization events to better protect public health. The project objectives are to 1) evaluate the effectiveness of disinfection and operational practices to mitigate risks and 2) identify water quality monitoring parameters to quantify the level of control achieved.

Your Utility is one of approximately 30 utility operations across North America and the United Kingdom that agreed to participate in the project. This Questionnaire is part of the first step of the study and is intended to help establish the baseline of practice for responses to main break and depressurization events in the industry. Your responses to this Questionnaire will be pooled with the other participating utilities to provide a snap shot of current practices and your utility will not be listed by name in survey results or the final report.

INSTRUCTIONS

Please complete the Questionnaire either in the MS Word electronic file (and return via e-mail) or in hard copy (and return via postal service) to the following:

Tim Thomure, PE, PMP
Project Manager
HDR Engineering, Inc.
5210 E. Williams Circle, Suite 530
Tucson, AZ 85741
Phone: 520.584.3640
Timothy.thomure@hdrinc.com

This questionnaire should take about 8 hours to complete. If you should have any questions regarding this Questionnaire, feel free to contact the Project Manager listed above. We look forward to receiving your responses and truly appreciate your efforts to support this study.

CONTACT INFORMATION (person completing form)

Date:	
Utility Name:	
Address:	
Contact Name/Title:	
Office Phone:	
Mobile Phone:	
Fax:	
E-mail:	

BACKGROUND INFORMATION

Estimated population served:	Retail:	______
	Wholesale:	______
Number of service connections:	Retail:	______
	Wholesale:	______
How many miles of pipeline do you have (not including service lines)?	______	miles
What is your Average Daily Production?	______	(MGD or ML/day)*
*Is this both retail and wholesale?	Retail	☐
	Wholesale	☐
	Combined	☐

QUESTIONS

1. How many main breaks do you experience annually?

   _________ #/year

2. Is there a seasonal component to the break frequency?

   Yes ☐ No ☐

   a. If yes, what is the % breakdown by season?

Winter %	Spring %	Summer %	Fall %	Total % 100

3. Does your utility have written procedures for the repair of water main breaks? (If yes, continue to Question 3a. If no, go to Question 4.)

   Yes ☐ No ☐

   a. Do procedures vary depending on type of break (i.e., circle, split, or other)?

      Yes ☐ No ☐

   b. Do procedures vary depending on size of pipe?

      Yes ☐ No ☐

   c. Do procedures vary depending on whether there is a loss of pressure?

      Yes ☐ No ☐

   d. Please attach a copy of the written procedures

4. Does your utility provide formal or informal training to the repair crews with regard to sanitary practices and the prevention of water contamination during a water main break repair?

Formal ☐ Informal ☐ No Training ☐

a. If training is provided, do you provide refreshers?

Yes ☐ No ☐

b. What is the frequency of refreshers?

Annual ☐ Other ☐ Explain ______________________________

____

____

5. Do your field crews use any written checklists of procedures to follow for repairing main breaks?

Yes ☐ No ☐

If yes, please attach a copy

6. What type of disinfectant residual is used in your system?

Chlorine ☐

Chloramine ☐

Mixed ☐ Please explain ______________________________________

____

____

Other ☐ Please explain ______________________________________

____

7. Do your field crews collect the following information when a main break occurs?

Pipe Material Associated with Main Break	Yes ☐	No ☐	N/A ☐
Pipe Diameter Associated with Main Break	Yes ☐	No ☐	N/A ☐
Type of Pipe Protection Associated with Main Break [Wrapped, Cathodic, etc.]	Yes ☐	No ☐	N/A ☐
Type of Pipe Joint Associated with Main Break [Rigid, Flexible, etc.]	Yes ☐	No ☐	N/A ☐
Exterior Corrosion Condition of Pipe	Yes ☐	No ☐	N/A ☐
Degree of Corrosion on Exterior of Pipe [Negligible (0%-20%), Light (20%-50%), Moderate (50%-80%), Severe (>80%)]	Yes ☐	No ☐	N/A ☐
Interior Corrosion Condition of Pipe (Unlined)	Yes ☐	No ☐	N/A ☐
Degree of Corrosion on Interior of Pipe (Unlined) [Negligible (0%-20%), Light (20%-50%), Moderate (50%-80%), Severe (>80%)]	Yes ☐	No ☐	N/A ☐
Interior Condition of Pipe (Lined)	Yes ☐	No ☐	N/A ☐
Surface and Traffic Conditions at Break Site	Yes ☐	No ☐	N/A ☐
Pipe Bedding Type and Condition	Yes ☐	No ☐	N/A ☐
Type of Break [Blow out, split, circumferential failure, other]	Yes ☐	No ☐	N/A ☐
Probable Cause of Failure / Main Break	Yes ☐	No ☐	N/A ☐
Depth of Pipe (Surface to Top of Pipe)	Yes ☐	No ☐	N/A ☐
Normal Operating Pressure	Yes ☐	No ☐	N/A ☐
Installation Date	Yes ☐	No ☐	N/A ☐
Frost Depth (From Ground Surface)	Yes ☐	No ☐	N/A ☐
Other (Please List Below):	Yes ☐	No ☐	N/A ☐

8. For US utilities, do you use any of the methods described in AWWA Standard C651 "Disinfecting Water Mains" as part of the repair procedures for smaller main breaks?*

Yes ☐ No ☐

a. If yes, which elements of AWWA C651 are applied?

Trench Treatment	Yes	☐	No	☐
Swabbing of Pipe	Yes	☐	No	☐
Flushing	Yes	☐	No	☐
Type of Disinfection	Yes	☐	No	☐
Bacteriological Tests	Yes	☐	No	☐

*For utilities in the UK, do you consider the principles of water supply hygiene and associated technical guidance notes found at: http://www.water.org.uk/?

Yes ☐ No ☐

b. If yes, are any of the following applied?

Trench Treatment	Yes	☐	No	☐
Swabbing of Pipe	Yes	☐	No	☐
Flushing	Yes	☐	No	☐
Type of Disinfection	Yes	☐	No	☐
Bacteriological Tests	Yes	☐	No	☐

9. Do you use any of the following criteria for release-to-service after repairing a water main break?

Flushing	Yes	☐	No	☐
Turbidity	Yes	☐	No	☐
Chlorine Residual	Yes	☐	No	☐
Other – Please Explain	Yes	☐	No	☐

____
____
____
____

10. Does your utility require water quality sampling for release-to-service?

Yes ☐ No ☐

a. If yes, please explain how you determine where the water samples are taken.

____
____
____

11. Does your system contain multiple pressure zones?

Yes ☐ No ☐

12. What is your targeted range of delivery pressure?

Minimum Pressure __________ (psi or meters static head)

Maximum Pressure __________ (psi or meters static head)

13. Does your system use pressure management techniques?

Continuous pressure monitoring system(s) ☐

Reduced pressure during off-peak season ☐

Other ☐

Please describe:

____

____

____

14. Do you maintain a minimal pressure during the repair of small breaks, or is the break location completely isolated with no flow?

Maintain Minimal Pressure ☐

Isolation with No Flow ☐

Other – Please explain ☐

____

____

____

15. Do you monitor pressure away from the break location?

Yes ☐ No ☐

a. If so, what information do you use and what actions do you take?

____

____

____

16. Does your state require issuing boil water advisories related to main breaks or depressurization?

Yes ☐ No ☐

a. If so, what are the triggers for issuing a boil water advisory?

____
____
____

b. Have you issued boil water advisories of any size in the past, and if so, how often?

Yes (1 or More per Year) ☐

Yes (Every 1 to 5 Years) ☐

Yes (Very Rare) ☐

Never ☐

Comments: ____
____
____

c. What criteria do you use to determine the extent of the BWA?

____
____
____

17. What is the typical crew size for repairing water main breaks for pipes 12-inches (30.5 cm) in diameter and smaller?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ >6 ☐

18. What is the typical crew size for repairing water main breaks for pipes larger than 12-inches (30.5 cm) in diameter?

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ >6 ☐

19. Are supervisory personnel on-site to monitor repair procedures?

Yes ☐ No ☐

20. Do you dechlorinate the flushed water after main repairs?

Yes ☐ No ☐

21. Does your state have any regulations that require dechlorination of flushed water?

Yes ☐ No ☐

22. Do your crews maintain and repair both water and sewer mains?

Yes ☐ No ☐

a. If yes, do they use separate tools for water main breaks and sewer repairs?

Yes ☐ No ☐

b. If separate tools are not used, are the tools disinfected before and after use and how?

Yes ☐ No ☐

Describe procedure

____

____

____

____

23. What types of customer contacts are made regarding water quality during a main break?

Instructions to flush premise plumbing on return to service ☐

Notification Only ☐

None ☐

Other – Please explain ☐

____

____

____

24. Are you aware of any customer illnesses (reported or confirmed) that have ever resulted from contamination due to a water main break / repair in your system?

Yes ☐ No ☐

a. If so, how many incidences are you aware of?

1 ☐ 2 - 5 ☐ 6 -10 ☐ >10 ☐

25. Does your utility use any special procedures to minimize risk of intrusion when performing scheduled maintenance tasks such as installing meters, valves, or curb stops, and fire hydrant maintenance?

Yes ☐ No ☐

If yes, please describe

____
____
____
____

26. In your letter of commitment, your Utility expressed interest in participating in this study at the levels indicated below. Is your Utility interested in participating at additional level(s) of effort as the project progresses?

Level	**Description**	**Existing Commitment**	**Additional Interest?**		
1	Share Data and Procedures	Yes (This Questionnaire)			
2	Serve as a Featured Program		Yes ☐	No ☐	Maybe ☐
3	Participate in Project Workshop		Yes ☐	No ☐	Maybe ☐
4	Participate in Field Investigations		Yes ☐	No ☐	Maybe ☐
5	Conduct Readiness Review		Yes ☐	No ☐	Maybe ☐

APPENDIX C: SUMMARY OF FEATURED CASE STUDY PROGRAMS

INTRODUCTION

A series of case studies have been developed following the Utility Survey/Questionnaire step. The case studies were designed to highlight "Featured Programs" for main break responses. These featured programs contain one or more of the best management practices of what could be considered a model utility main break response program. These best management practices address the following aspects of response to water main breaks:

- Risk assessment
- Main break notification
- Main break/leak investigation and isolation
- Pollution prevention
- Responses to unauthorized discharge of potable water
- Main break repair
- Release-to-service criteria after main break, and
- Boil water advisory

The individual utilities across the U.S. and U.K. that responded to the questionnaire typically do not practice the entire range of best management practices for main break repair. However, when reviewed collectively, the participating utilities offer a wide spectrum of practices that can serve as models for others in the water supply industry. The following utilities were selected to serve as featured programs:

1) City of Fort Worth, TX. The Fort Worth program includes complete descriptions for many responses to main breaks including emergency response, leak detection procedures, excavation pit procedures, responses tied to type of break, and a flow chart for Boil Water Advisory (BWA) actions.
2) Los Angeles Department of Water and Power (LADWP), CA. The Los Angeles program offers complete procedures on pollution prevention, disinfection and dechlorination, training materials with quizzes, flushing protocols, and safety consideration.
3) New Jersey American Water (NJAW), NJ. New Jersey American provides a comprehensive Boil Water Advisory (BWA) Guideline.
4) City of Boulder, CO. Boulder's program developed protocols for main break notification and communication.
5) Charlotte-Mecklenburg Utility Department (CMUD), NC. The CMUD program includes comprehensive training materials and performance evaluation forms for their main break repair procedures.
6) Denver Water (DW), CO. The Denver program centers on a flowchart for risk assessment that helps guide main break response activities.

The following featured program descriptions contain language taken directly from the specific program written materials or were paraphrased by the study team for brevity. If the reader would like more information on any one of the programs described herein, the following contacts are suggested:

I. Fort Worth, TX - Ray G. Moreno, Water Systems Superintendent; email: Ray.Moreno@fortworthtexas.gov
II. LADWP, CA - Charles Sparks, Water-Education-Safety-Training; email: charles.sparks@ladwp.com
III. NJAW, NJ - Scott Baxter-Green / Water Quality Manager; email: scott.baxter-green@amwater.com
IV. Boulder, CO – Ken Clark, Regulatory Compliance Specialist; email: clarkke@bouldercolorado.gov
V. CMUD, NC - Angela Lee, Field Operations Division Manager; email: alee@ci.charlotte.nc.us
VI. Denver Water, CO - Stephen Lohman, Laboratory Director email: Steve.Lohman@denverwater.org

CITY OF FORT WORTH, TX

Fort Worth experiences main breaks at random throughout the city with an annual average number of 1,146. The most common causes of water main breaks identified by the City include, but may not be limited to, shifting soils during extended periods of wet or dry weather, internal/external corrosion of the pipe wall, pipe age, water hammer effects, or damage caused by third parties (contractors, etc.). The City of Fort Worth has adopted three types of mitigation actions as a response to main break events.

- Responses to Unauthorized Discharge of Potable and Hyper-chlorinated Water
- Responses to Water Main Break Repair
- Boil Water Advisory

Responses to Unauthorized Discharge of Potable and Hyper-Chlorinated Water

The City of Fort Worth's potable water supply typically contains from 1 to 4 mg/L chlorine. Water main breaks can potentially result in the discharge of potable water to storm sewers and waterways. The EPA Water Quality Criteria 1-hour chlorine exposure guideline for prevention of impact to aquatic life is 0.019 mg/L total residual chlorine. To mitigate potential impacts, the City adopted a series of measures in response to unauthorized discharge of potable and hyper-chlorinated water and these are described as follows:

Field Operations Division Response

The City's Field Operations Division is charged with the responsibility to respond to reported water main breaks in a timely manner to minimize water loss, damage to public and private property, disruption to water services, and impacts to the environment. The Division has staff, equipment, and materials to reduce or stop the discharge of potable water and initiate de-chlorination, if required.

Division Responsibilities

In the ongoing effort to remain compliant with Texas Commission of Environmental Quality (TCEQ) reporting requirements, the Field Operations Division adopted the following criteria and procedures for notifying TCEQ within 24 hours of said discharges:

- Upon verification that said discharges may impact the quality of receiving waters or aquatic life in receiving waters, formal notification shall be provided to TCEQ by calling the TCEQ Main Number at 1-800-832-8224 (after hours, weekends and holidays) with the following information:

  - Time water main break was reported to Dispatch.
  - Time that water supply was shut down.
  - Location of main break.
  - Diameter of pipe that has broken or ruptured.
  - Estimated volume of water that was discharged.
  - Name and location of receiving waters.

- The supervisor on duty at the time that said discharge or discharges occur will be responsible for initiating the TCEQ notification process.
- In addition to providing notification to TCEQ via telephone, the form in Attachment 1 shall be submitted to TCEQ within 5 days of each discharge. The TCEQ fax number is listed in the protocol.
- In any event that impact to the environment or aquatic life is confirmed, additional internal contacts are listed including utility management and the public information office.

First Responder Onsite Actions

At the time that Dispatch provides notification of a reported water main break or leak, that notification is provided to an Investigator and that Investigator is dispatched to the reported location for the purpose of surveying the location and then reporting back to Dispatch, if in fact there is a water main break or leak.

If a main break or leak is confirmed and potable water is being discharged to the storm sewer system, a watercourse, or a body of water; the Investigator will report that confirmation to Dispatch and also report that he/she is initiating the de-chlorination process at that time.

All Investigators will carry the necessary equipment and chemicals to adequately execute the de-chlorination process, as required. The de-chlorination process will be maintained by the Investigator until the potable water being discharged by the broken water main is shut off or until the Investigator is relieved of that duty by Field Operations personnel who are first responders to that location.

Onsite Main Break Repair and Mitigation

Field Operations personnel who are first responders to water main breaks that may impact water quality or aquatic life will work to stop the flow of potable water to storm sewers and waterways as quickly as possible. In the event that it is necessary to allow the flow of water from the main break to continue, onsite de-chlorination will be maintained until the water main break or leak is repaired and the discharged water is shut off. The onsite de-chlorination process will include the following steps:

- Evaluate chlorine residual with test kit in order to determine type and amount of de-chlorination chemical to be used.
- Set up de-chlorination devices (3'x 4' Dechlor Mat or 6"x 36" Dechlor Strip or Fabricated Baskets).
- As required, monitor chlorine levels and de-chlorination devices.
- Once the flow of water from the main break is shut off, all control materials that were used will be appropriately cleaned and/or disposed of.

At the same time that onsite activities are in progress, an offsite assessment will be executed to determine the watercourses and/or receiving waters that may have been impacted by the potable water being discharged or that was discharged.

The offsite assessment will be executed by Field Operations personnel and will include the following steps:

- Identify the receiving waters.
- Identify watercourse between the locations of the main break and the receiving water site.
- Establish water sampling locations along the watercourse(s) and/or at the receiving water site.
- Initiate sampling of waters in the watercourse(s) and/or at the receiving water site to measure chlorine levels and determine effectiveness of the ongoing de-chlorination process at the location of the main break. Sampling of waters in the watercourse(s) and the receiving waters shall occur every 2 hours until chlorine level(s) can no longer be detected.

In addition to monitoring for chlorine levels, the receiving waters will also be periodically inspected to detect effects on aquatic life in those waters. The inspection process shall continue until it can be determined that aquatic life has or has not been affected.
In the event that aquatic life has been affected, the dead fish will then be accounted for by number, length, and species. Once collected, the fish will be disposed of by burial at the city owned landfill.

In the event that that responding Field Operations Division personnel are unable to execute assessment of watercourses or the receiving waters during any event, the appropriate supervisor on duty at that time will notify the Water Central Laboratory [Pager number provided] (24/7 basis) to request assistance in sampling, sample analysis, and environmental assessment(s) of the receiving waters, as necessary.

Following completion of the required repairs to the water main, the water to be flushed to return the water main to service will be de-chlorinated prior to that water entering the storm sewer or waterway. In the event that chlorine levels exceed 0.1 mg/L in the flushed water, that water will be de-chlorinated to below 0.1 mg/L. Under no circumstances will flushed waters from repaired water mains be allowed to enter any waterway without de-chlorination and testing.

Responses to Water Main Break Repair

The water main break repair will be executed by Field Operations personnel and will include the following steps:

Locating Leaks/Breaks

- After arriving on the scene of a break, secure the area in question with the proper traffic control devices. Then start the notification process (See section 1.2.4) for low pressure or water off.
- Services located nearest to the suspected leak/break location should be “listened on” first, before any drilling is conducted. If leak/break sounds can be heard on several services, then the leak/break is usually on the main. If sound is heard on only one service, then the leak/break is usually on that service.
- Measure distance from curb to valve and mark location in street or on ground. In the older parts of town, the mains usually lay 6' to 7' from the curb, usually in the north and east quadrants of the street. In newer parts of town, the mains will usually lay behind the curb or in the median.
- Drill holes and use appropriate length test bar to locate pipe. Several holes may be

- needed before pipe is located. Valves can also be used to gauge main depths.
- Fire hydrants or valves can be "tapped on" to create sound, while another individual is listening on test bar, to verify it is actually on the pipe.
- Each main repair crew will carry a minimum of six (6) test bars, of various lengths. When the pipe is located, holes will be drilled both above and below the original hole, in an effort to locate the leak/break. Drill holes should be 2' to 3' apart.
- If water is coming out of the street, then the leak/break is usually nearest the hole with the most water streaming out of it, and where the loudest sound is detected.
- A minimum of fourteen test holes (on the pipe) will be drilled before the "Leak Detection" unit is called, to aid in locating the leak/break.
- Normally "raised paving" will be the leak/break location (if working on a level road surface). Listening with test bars is the only sure way of knowing the exact location. This is accomplished by listening on the paving at and around the area of raised paving. If this is unsuccessful, then drilling may be the only means to accurately pinpoint the leak/break source.
- All concrete streets should be drilled on.
- It cannot be assumed that water mains always run in a straight line.
- Lines < 2" should not be drilled on, the line must be dug up, to locate leak/breaks. (If the line is shallow, then listening on the paving may be utilized to pinpoint the leak/break source).
- If trying to locate a leak/break on a line 16" - 24" cast iron pipe, crews should look for "J" marks on the curb before drilling for leaks/breaks. These marks indicate a joint location, which was left by a previous crew. Most leaks/breaks on large mains are found on the pipe joints. Larger lines usually have 12' joints. Drilling on large mains should be done at the corresponding joint locations. After repairs are affected, then additional "J's" should be inscribed on the curb to help crews in the future to locate pipe joints. The position of the “J’s” usually indicates the direction that the face of the joint is pointing.
- If there is more than one water main in the area of the leak/ break and the repair crews have to lower the pressure to identify which line the leak/break is on, investigations shall be started with the smallest line first.

Pictures

- Before starting the excavation, the repair crews need to take pictures of the utility locate markings and any visible existing damage.
- Repair crews shall take pictures of the locates, existing damage, the repair before they wrap it in plastic, the street cut, and barricades.
- Memory sticks (flash drives) will be turned in daily during the week. For weekend days, the repair crews will hold onto the data device until the Supervisor can provide another one.

Excavation

- The side of the main opposite of any suspected water services should be excavated first.
- If working a broken main, the initial clean-up can begin, if utilities are not located.
- If more than two (2) hours have passed since the initial call to locate utilities, they need to be recalled. If a locator cannot respond in a reasonable time frame, the digging may begin with supervisory approval. In this situation, every caution should be taken to ensure that other utilities are not damaged. If the work is being done in an area where a known hazard, or marked fiber optic cable is nearby, then the crew must wait for a locator to arrive on site.
- Any damaged sewer or water service should be fixed by the crew working on the main repair (all rubber sewer repair couplings need to be concreted in). Exceptions will need to be authorized by a Supervisor. If there is suspected introduction of sewerage or other liquid substances into the water line, your Supervisor should be immediately be notified. They will in turn notify the Water Lab and additional disinfection of the main may be needed. If disinfection is needed, the introduction of 500 mg/l of HTH for 30 minutes or 50 mg/l for 24 hours will need to be administered.
- Excavations should not be "over dug". Only enough trench should be opened that will allow for a safe and proper repair.
- All excavations that exceed 4’ require atmospheric testing and a ladder extending 3’ out of the excavation, no more than 20’ from the work area.
- Any excavation 5’ or greater will be shored or sloped to protect employees (as per in-house and OSHA specifications).

Shutting Water Off

- Before any water is shut off in a residential area, repair crews must announce by public address 15 minutes prior to turning off any water. In an area where businesses, schools, industries, hospitals, or dialysis centers are located, "in person" notification will be conducted. If a hospital, doctor’s office, or dialysis center is located in the shut out (shutdown) area, an “in person” notification is required and a Supervisor must be notified. In situations where up-front planning is possible, advance notification should take place, either in person, or by door notice.
- Map books are to be utilized to identify the valves needed for the shut out.
- When operating valves, the rounds should be counted to ensure the valve being operated is accurate. The industry standard for 4" - 12" valves, and 16" valves with a single operating nut, is three times the size plus two or three. Larger valves usually require more rounds, and are usually dependent on the ratio of the spur gear.
- Dispatch should be notified when the shut out has been completed, and contacted again when the water is turned back on.
- SCADA must be contacted before any line 16" or greater is valved down. The Operator will grant approval to shut down the main. They must also be notified before the line is loaded. No exceptions.
- The shut out should begin with the valves furthest from the excavation, and end with the valve closest to the hole.

-
- If a successful shut out cannot be accomplished, the immediate Supervisor should be notified. If he/she cannot make a shut out, then a valve crew may be called.
- An air release should be identified during the shut down procedure. The air release should be the highest point on the line. A fire hydrant is the best devise to use to release air, but water services can also be utilized. Any time a service is used, caution should be taken to not introduce foreign material into the customer's plumbing. A plug will be used to isolate the plumbing from the air release.

Water Main Repair

The following need to be considered for any water main break repair:

- When a repair takes more than 3 - 4 hours, a Supervisor should be consulted.
- Crews should call in/out of service on all jobs.
- All hard to operate, defective, or broken valves should be reported to a field supervisor.
- Only one band, or other cut in, is to be in any one hole. If a leak/break is excavated and a band is found, pipe must be cut in.
- Once the hole size is identified, the water loss calculation needs to be documented on paperwork. Water loss is documented in GPM (gallons per minute).
- All repair parts used, bands, sleeves, pipe, tees, bends, etc. will need to be disinfected. Anything that is in contact with the pipe and/or water inside the pipe.
- Utilizing a 1% solution of disinfectant will disinfect all pipe ends and fittings. The typical mixture is 1 gallon of water mixed with 3 cups (24 ounces) of household bleach. A fresh mixture of disinfectant should be prepared daily.

Repairs (Bands).

- The pipe needs to be clean of all loose material before attempting to install a stainless steel band.
- A trash pump will be running during the entire repair. This will help to ensure that contaminated water is not introduced into the main.
- The pipe should be marked to ensure that the band being utilized would cover the affected area. A minimum overlap of 2" is required.
- The band should be rotated around the pipe to ensure that the gasket is making proper contact with the pipe surface. After rotating the band, the treaded ends should be facing up.
- Bolts should be tightened from the middle, working out toward each side. After the initial tightening with an impact wrench, the bolts should be retightened by hand to ensure they are still snug.
- All bands should be wrapped in plastic wrap.
- Bands need to be installed according to manufacturer specifications.

Repairs (Cut-ins).

- Ratchet cutters should be utilized when possible, especially on cast-iron lines 4" - 12". Larger lines may require the use of a pipe saw or other cutting device. Working in a trench with a gasoline pipe saw can be dangerous. There is an exposure to carbon monoxide and other hazards associated with working with a rotating blade in a confined space. Any time a gasoline saw is utilized, a ventilation blower will be in the trench, running continuously, and a gas monitor will be used to monitor oxygen, carbon monoxide, etc.
- A leaking or blown bell joint may be cut out and replaced with a small piece of pipe encased in a long repair band.
- Breaks/Leaks in front of driveways will require cutting in enough pipe so that the repair will equal the width of the driveway or approach (exceptions will have to be approved by Supervisor).
- Solid sleeves are to be used whenever pipe is cut-in, unless the pipe is over-sized or other elements will not allow the use of a solid sleeve. You may then use a variable size repair coupling.
- When using variable size repair couplings, a Tree Tape must be used to determine the pipe size. This will allow choosing the proper couplings and rubber seals based on the size variance.
- All cut-ins will be braced or supported from the bottom of the trench. This will ensure that the repair does not settle during the back-filling process.
- Cut in repairs on lines 16" or greater will require the installation of a minimum one full joint of pipe. Exceptions will have to be authorized by Supervisor.
- Pipe ends need to be thoroughly cleaned, and any pits removed, by extending the cut in.
- Bolts will be tightened by hand in a crisscross manner, just like a wheel on a car.
- The area where the coupling is to be installed needs to be marked on the pipe, so the coverage is correct.
- All cuts-in repairs should be equal in length to the length of the excavation from bank to bank.
- All couplings should be wrapped in plastic wrap.
- Couplings need to be installed according to manufacture specifications.

Repair (Bell Joint Leak Clamp).

- The lead joint needs to be caulked before attempting to install the clamp. The lead should be pushed back into the joint until the lead is smooth with the face of the bell. This does not include "leadite" joints, which cannot be caulked.
- A joint clamp must be installed on any exposed joint on lines 16" or greater.
- Joint clamps need to be installed as per manufacturer specifications.

Repair (AC/asbestos cement).

- When working on AC (asbestos cement) pipe, a Supervisor will need to be notified.
- Can be repaired the same as cast iron pipe, but AC has a thicker wall thickness, and sleeves may be needed to affect repairs.
- No power equipment should be used to cut AC pipe. Power tools disturb the fibers in the asbestos, and studies have shown this can be hazardous to humans. Mask or respirators should be worn when working with this pipe material.
- AC pipe should be cut with a hand saw with water poured on the blade during the cut.

Loading Line

- Before loading the line, the repair crews need to flush out any debris that may have entered the pipe during the break or repair process.
- This will be done by opening a fire hydrant at the bottom of the hill (below the repair) and flushed from a valve above the repair, until the water is clear or free of any debris.
- Proper air releases are needed until water clears up, all the air is out of the line, and a field test kit verifies chlorine residual is a minimum of 1.5. Milky water is usually an indication of air in the line, (which may require additional flushing to clear out). Discolored water usually is an indication of turbidity (suspended material) in the water, which may also require additional flushing.
- Lines should be loaded slowly, usually by opening the downhill valve two to three rounds.
- Copper tubing used as an air release should be pointed toward the street, and facing down when possible.
- All remaining valves should be opened after flushing has been completed.
- Repairs should be checked after the line is pressurized.
- Dispatch should be notified when line has been loaded and is back in service.
- Most second and third breaks are directly related to improper loading techniques. Proper air releases and valve operation will eliminate most repeat main breaks

Street Cut

- All cuts will be benched (6" to 8" below the bottom of the existing paving) a minimum around the excavation.
- The paved area around the cut is to be squared, by using an air paving saw or air hammer. A chalk line or string should be used to help square the cut to match existing pavement and curb/gutter line.
- Cuts that are in close proximity to curbs should be dug out or peeled off to the curb. Do not leave a 1' to 2' strip between the cut and existing curb.
- Any damaged curb/gutter, sidewalk, or driveway should be dug out and left low and ready for replacement whenever possible and practical.
- Street plates can be used to cover holes left low and ready for capping.

Clean-up

- Clean up should begin while crews are waiting on materials or utility locates.

Paperwork and Call-in

- Once the job is completed, all information needs to be reported to Dispatch.
- When reporting information to dispatch, crews need to report only the information pertaining to the repair (failure reporting, follow up work, any damages or customer info).
- When a job is left incomplete the work order should be placed on hold in the proper manner so that the remaining work can be completed.
- Any work that is left incomplete will need to be documented on daily paperwork and turned in at the end of shift.
- In the event of an equipment failure or a need to deviate from the procedures mentioned above, the on duty Supervisor will be notified and this will need to be documented on daily paperwork.
- Before a crew leaves the jobsite after completing the work, they will attach door hangers to the four houses or businesses in the immediate area. This will provide the customers a point-of-contact should they have any questions about the work that was done.

Boil Water Advisory

Boil water advisory (BWA) is required when a water main break results in low or negative pressures in the system. Attachment 2 shows City of Fort Worth's boil water advisory sequence of events.

LOS ANGELES DEPARTMENT OF WATER AND POWER, CA

The Los Angeles Department of Water and Power (LADWP) experiences an average of 1,200 breaks per year and has a mature mains repair program. The standard program requires that once the source of the leak or break is isolated, the crew shall saw cut into the asphalt surrounding the leak and repair the leak by either plugging the leak, placing a sleeve around the failed pipeline portion, or replacing the failed line with new pipe. The trenches are then backfilled with sand slurry and the street is paved. LADWP has adopted an extensive program for mitigating the risks associated with leaks and water main breaks which includes the following:

- Pollution Prevention Practices and Best Management Practices
- De-chlorination
- Water Main Repair Disinfection
- Water Main Repair Sampling

Pollution Prevention Practices (PPP) and Best Management Practices (BMP)

PPPs and BMPs are implemented to ensure that a minimum of regulated contaminants are discharged into storm drains or natural water ways to protect the aquatic system and environment. LADWP implements the following PPPs:

I. Flow Path: Flow path is the direction the water goes before entering the catch basin, which needs to be cleared of debris and should be done before flushing takes place.
II. Sediment Berms/Barriers: Barriers need to be placed in front of the catch basin to eliminate any debris from entering the storm drain. Sand bags or fire hoses filled with sand are used as berms/barriers to catch sediment.
III. Geotextile Fabric: Geotextile fabric is used to cover the openings of the catch basin to minimize introduction of sediments and debris into the storm drain.
IV. Pump Discharge Hose: Burlap bags are attached to the pump discharge hoses to catch sediments from pipe trenches.
V. Spoils: Spoils that may need to be left in the field for an extended period of time should be covered with a plastic sheet or canvas to minimize release to the environment.

The above PPPs are implemented during the following BMPs related to main break repairs:

I. Main Flushing: Prior to flushing any water main, the utility crews need to check the flow path for any contaminants or debris and take reasonable steps to minimize chance of introducing contaminants into a storm drain.
II. Main/Service Installation and Replacement: Crews need to check the gutter and place berms/barriers, burlap bags, goetextile, etc as needed to prevent contaminants from entering into the storm drain.
III. Main/Service Leak and Break Repair: Following a main break or leak, contaminants typically enter into the storm drain system. As soon as the repair crews take control of the main breaks or leaks, they shall ensure that all possible PPPs are implemented so that no further contaminants are introduced into the storm drain.

The quiz materials on PPPs and BMPs for the training of main break response crews at LADWP are compiled in Attachment 3.

De-chlorination

The release of chlorinated or potable water to the storm drain or natural water ways poses a threat to aquatic life. Potable water distributed by LADWP may have residual chlorine up 2 to 4 mg/L (ppm) and requires dechlorination to a residual level of 0.1 mg/L (ppm) or less before discharging. Chemical de-chlorination is the most widely used process and several solid, liquid, and gaseous de-chlorination chemicals, such as sulfur dioxide, sodium bisulfate, sodium sulfite, sodium thiosulfate, ascorbic acid, etc are commercially available and widely used in the industry.

Ascorbic acid, or Vita-D-Chlor, has been widely used recently by many utilities. Approximately 2 lbs of Vita-D-Chlor will neutralize 100,000 gallons of water with 1 ppm of chlorine. Vita-D-Chlor is the safest and least toxic of the various dechlorination chemicals and has not been reported to scavenge dissolved oxygen (DO) from water.

Safety and De-chlorination Equipment

The following personal protective equipment (PPE) and de-chlorination equipment are required for de-chlorination activities:

- Personal Protective Equipment
    - Safety glasses
    - Gloves
    - Dust respirator
- De-chlorination Equipment
    - Hach colorimetric residual chlorine measurement kit
    - De-chlorination diffuser
    - Vita-D-Chlor or ascorbic acid tablets

De-chlorination Procedures

De-chlorination is achieved following the procedures described below and depicted in Figure C.1.

- Survey project site and identify
    - The entire affected area
    - Location of buildings and paved areas
    - Location of major activities
    - Drainage areas and direction of runoff flows
    - Discharge points from the job area
    - Points of entrance into the storm drain or water ways
- Set traffic delineation for jobsite protection and set BMP's in place.
- Utilize an Eddy valve on the fire hydrant to control flow of water being discharged.
- Install de-chlorination diffuser onto the closed Eddy valve.
- Use fire hose between Eddy valve and the De-chlorination diffuser if needed.

- Place Ascorbic acid tablets or Vita-D-Chlor into 3.5” chamber of the de-chlorination diffuser.
- Open the fire hydrant outlet completely.
- Open and throttle the Eddy valve slowly to desired flow.
- The tablets can handle a flow from 200 to 1,250 gpm, and hydrant pressure up to 200 psi.
- One tablet can neutralize 2,500 gallon of water with 1 ppm of chlorine.

Figure C.1 De-chlorination procedure

The quiz materials on de-chlorination for the training of main break response crews at LADWP are compiled in Attachment 4.

Water Main Repair Disinfection

The method endorsed by LADWP to prevent potable water contamination during a main break is to repair the break under continual positive pressure. But in many instances, a water main break may lead to depressurization and cause a direct opportunity of contamination of potable water. Therefore, disinfection of the main and materials used in the repair is a good practice to mitigate risks of contamination and provide safe water.

Disinfection Procedures

Three types of mitigating actions for disinfection of the water mains are:

- Spraying: Spraying the interior of all pipes, fittings, couplings, and sleeves with 1% to 5% hypochlorite solution before they are installed.
- Swabbing: Swabbing the interior of all pipes, fittings, couplings, and sleeves with 1% to 5% hypochlorite solution.
- Flushing: Thorough flushing of water mains to remove any debris or contaminants from the line.

Spraying and flushing procedures are described in more detail below.

Disinfection Procedures by Spraying.

Disinfection by spraying is achieved following the procedures described below and depicted in Figure C.2.

- The following PPE are required for spraying disinfection activities:
  - Hard hat
  - Face shield
  - Rubber gloves
  - Protective clothing (rain gear)
  - Rubber boots
  - Chemical splash goggles
  - Emergency eye wash
  - Respirator with organic vapor/acid gas cartridge
- Ensure that there is a clear path to the eye wash.
- Mix 4 oz of calcium hypochlorite (65% available chlorine) to every one (1) gallon of water in a 2.5 gallon sprayer, which will provide 2% of available chlorine solution.
  - Do not breathe calcium hypochlorite fumes when opening the lid of the container.
  - Ensure to relieve the pressure in the sprayer before opening.
- Spray inside of both the ends of the existing pipe and all connections.
- Reach as far as possible with the wand of the adjustable nozzle inside the pipe to insure that the entire surface has been sprayed.
- Spray inside of the pipes and fittings to be used for repair.

- Keep disinfected materials clean during installation. Do not lay the fittings in dirt. If necessary lay fittings on plastic sheeting.
- Avoid unnecessary handling of pipe and fittings to be used. Do not lay the fittings in dirt. If necessary lay fittings on plastic sheeting.

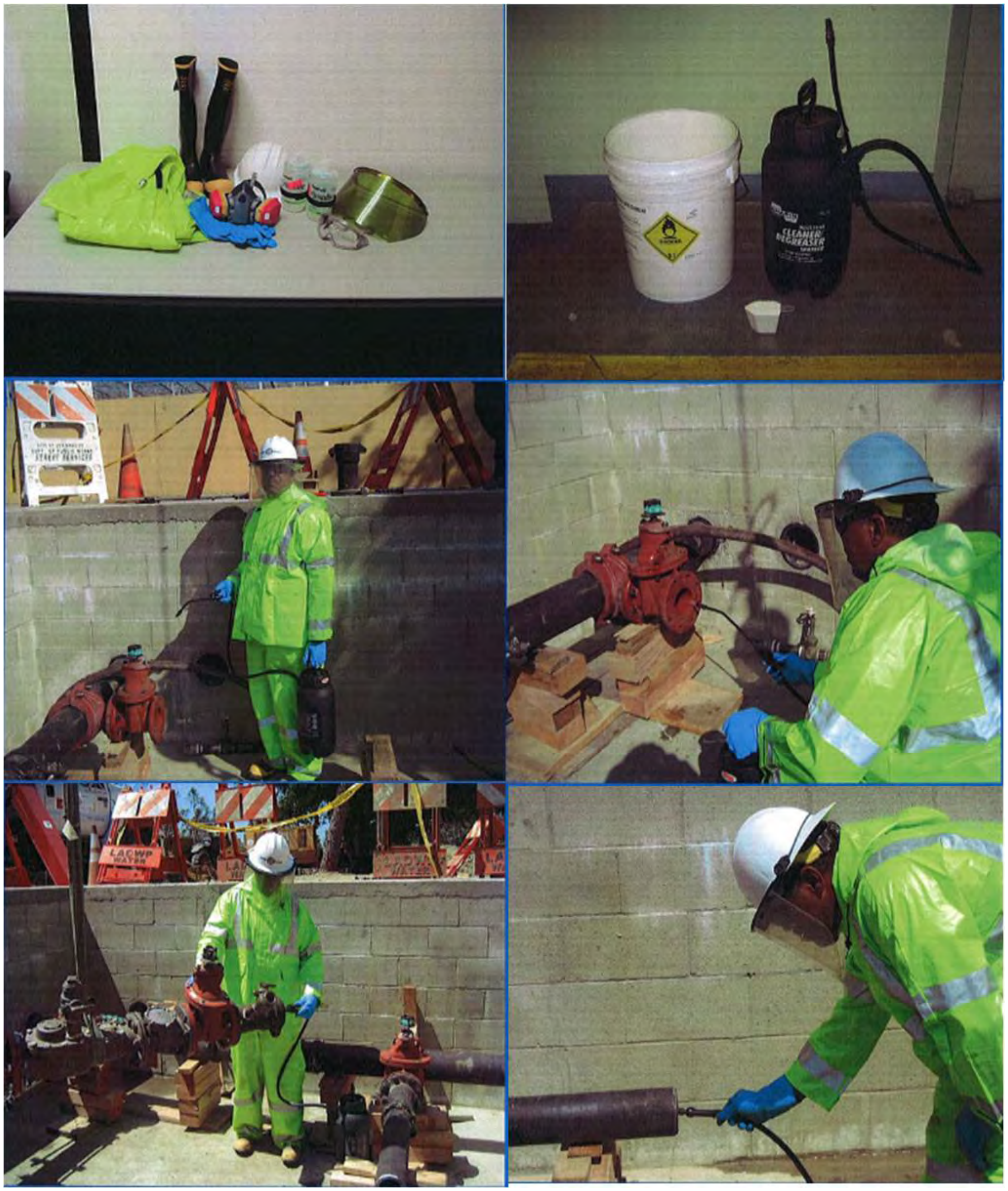


Figure C.2 Disinfection by spraying procedure

Distribution Main Flushing.

- Distribution system flushing is conducted both before and after main break repair to remove debris and contaminants from the pipe.
- Flushing shall be started as soon as the repairs are completed and shall continue until discolored water is eliminated.
- According to California Waterworks Standards, Chapter 15, Article 5, flushing valves (hydrants) shall be capable of flushing the mains with a minimum continuous flow:
  - 6-inch Main – 225 gal/min
  - 8-inch main – 400 gal/min
  - 10-inch main – 600 gal/min
- If valve and fire hydrant (FH) locations permit, flushing toward the work location from both directions is recommended for best results. See Figure C.3 for how to flush using two hydrants around a main break.
  - For a main break on 8-inch line in Figure C.3 (red arrow), there are two nearby fire hydrants (FH 131 and EF 178) (yellow arrows).
  - FH 131 and EF 178 should be used for flushing after main break repair and disinfection.
- Flushed water shall be de-chlorinated as described previously.

The quiz materials on water main repair disinfection for the training of main break response crews at LADWP are compiled in Attachment 5.

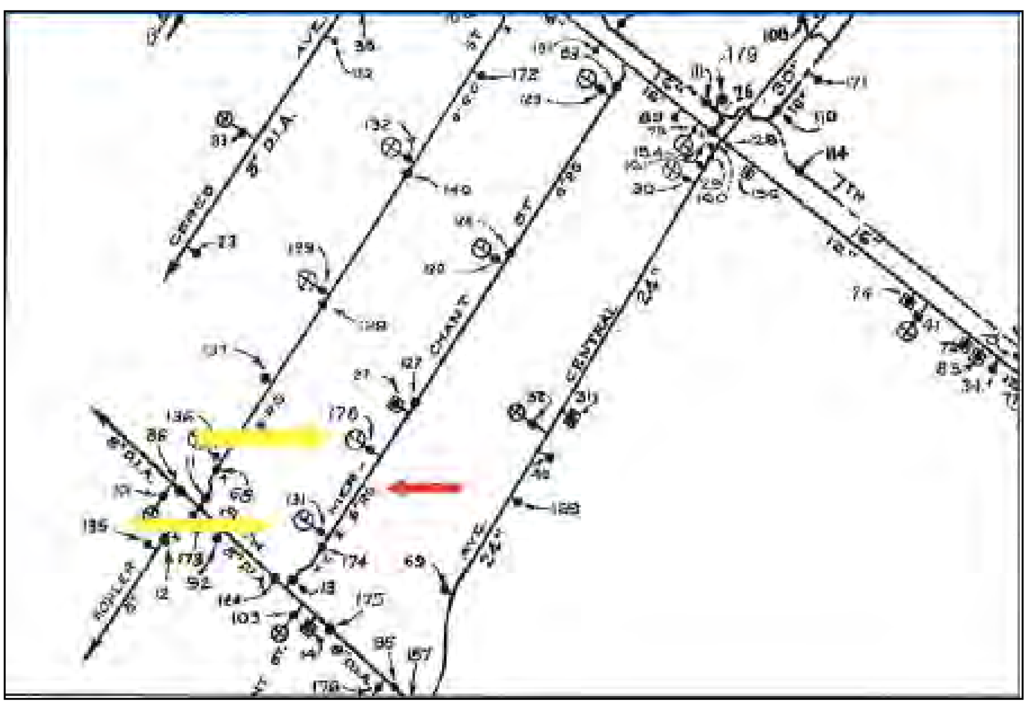


Figure C.3 Flushing from both directions using fire hydrants

Water Main Repair Sampling

Disinfection verification is required after completion of a main break repair, especially when the main was completely shut down or system pressure dropped below 5 psi at any time. Therefore, samples are collected to verify:

- Chlorine (disinfectant) residuals
- Bacteriological water quality

Chlorine (Disinfectant) Residuals

- Sampling for both free and total chlorine from a flushing hydrant or consumer hose bib.
- Checking for free and total chlorine using the DPD [diethyl-p- phenylenediamine] method and HACH Chlorine Test Kit.
    - Collect 10 ml of sample either for free or total chlorine in sample cell.
    - Add the contents of DPD free chlorine Powder Pillow or one DPD total chlorine Powder Pillow to the sample cell and check for chlorine using HACH test kit.

Bacteriological Water Quality

Bacteriological water quality testing is considered by LADWP to be very important for risk mitigation since:

- Verifies that the main repair was properly disinfected.
- Verifies that the main was properly flushed.
- Verifies that an adequate chlorine residual exists.
- Maintains a record of quality assurance.
- Demonstrates that the water quality is safe to drink.

Sampling Location.

- Sample location should be selected that will represent the impacted area of the repair, preferably from fire hydrant sample tap and not from a service line. Unacceptable sample locations are as follows:
    - Hose bib that is shielded by vegetation
    - Garden hose
    - Hose bib too low to ground
    - Drinking fountains or restroom taps
    - Hose bib far from water main
    - Fire hydrant ports. Use hydrant sample tap
    - Air relief valves
- Ensure that the sample is collected from the main, not from a service line.

Bacteriological Sampling Kit.

- Bacteriological sampling kit includes the following:
  - Small ice chest
  - Sterile sample bottles (obtained from WQ Lab)
  - Hydrant cap sampling tap
  - Chlorine residual test kit
  - Sample labels and zip-lock plastic bags
  - Waterproof pen
- Sterile bacteriological sample bottle
  - 250-ml polypropylene (PP) wide mouth bottle
  - Sterilized by autoclaving at WQ Lab
  - Filled with 5 drops of sodium thiosulfate (dechlor)
  - Covered by aluminum foil to protect cap
  - Have additional 2-4 bottles
  - If the bottle or cap is contaminated, DO NOT USE!

Sampling Procedure.

- Sample for total coliform bacteria using a sterile bottle and technique.
  - Flush hydrant or hose bib until a representative sample from the main can be assured.
  - Adjust to a moderate flow to prevent overspray.
  - Remove cap and fill sample bottle to shoulder.
  - Do not rinse the bottle or overflow above shoulder.
  - Replace cap securely and shake to mix dechlor.
- Label sample with the following information and transport in ice chest
  - Sample date
  - Sample time
  - Sample collector
  - Sample location (address or hydrant number)
  - Sample designation (upstream or downstream)
  - Chlorine residual
  - Time delivered to Water Quality Laboratory
- Fill out the form in Attachment 6.
- Deliver to laboratory within six (6) hours after collection
- Complete total coliform analyses within 24 hours

The quiz materials on water main repair sampling for the training of main break repair crews at LADWP are compiled in Attachment 7.

NEW JERSEY AMERICAN WATER, NEW JERSEY

New Jersey American Water (NJAW) serves approximately 1.4 million people with more than 8,000 miles of pipelines (excluding service lines). On average, NJAW experiences 1,288 main breaks per year and needs to issue a Boil Water Advisory (BWA) every 1 to 5 years. Over the years, NJAW has developed standard practices for main break repairs, for reporting "Reportable Incidents" to regulating agencies, and for issuing a BWA.

Disinfection of Water Main

Disinfection of the water main following a main break may or may not be required by NJAW depending on the repair procedure.

- If the water main break is repaired with clamping devices (or other devices) while the main remains full and pressurized, the break presents little danger of contamination and should not require disinfection.
- If a repair requires a main to be isolated or partially dewatered, the main must be disinfected before being placed into service in accordance with NJ Administrative Code (NJAC) 7:10-11.6(d).
    - According to NJAC 7:10-11.6(d), upon the completion of construction (including water main repairs) all surfaces that come in contact with potable water shall be disinfected.
    - NJ America Water disinfects all the water mains after repair in accordance with the American Water Works Association (AWWA) standard that follows methods described in AWWA C651-05.
- Pipe Swabbing: Interior of pipe and fittings used for repair needs to be swabbed or sprayed with a 1 percent hypochlorite solution (1000 ppm) before installation.
- Flushing: Flushing the main toward the repair location from both directions is recommended and shall continue until discolored water is eliminated.
- Slug Chlorination: The section of main needs to be isolated, all service connections shut off, and shall be chlorinated as follows:
    - Place calcium hypochlorite granules/tablets in the main; completely fill the main to eliminate air pockets; expose the interior surfaces to a chlorine concentration of 100 mg/L for 3 hours.
    - The slug of chlorinated water should be measured at regular intervals and should be restored to 100 mg/L free chlorine if at any time the residual drops below 50 mg/l.
    - The chlorine does may be increased to 300 mg/L and the contact time reduced to 15 minutes.
    - After the appropriate chlorination contact time, flushing shall be performed until the chlorine concentration in the water is no higher than typical chlorine residuals.
- Samples (customer taps preferably) shall be taken for bacteriological tests to determine the effectiveness of the disinfection procedures.

- Typically one sample is collected downstream of the main break. If flow direction is unknown, one sample is collected each direction. Daily sampling shall be continued until two consecutive negative samples are recorded.

Reporting "Reportable Incidences"

Water main breaks that constitute "Reportable Incidents" must be reported to New Jersey Department of Environmental Protection (NJDEP) (877-927-6337) or Bureau of Safe Drinking Water (BSDW) (609-292-5550). Reportable incidents refer to the followings:

- Instances where the main break does not cause a complete loss of pressure and the water main can be repaired in-service (under pressure), a BWA is not necessary.
- Instances where the main break does not result in the complete loss of pressure, but the section of main must be isolated (valved off) to repair (controlled shutdown), a BWA is not necessary.
- Instances where the water main break results in the system or portions of the system being without water or with negative pressure zones, a BWA is required.

Water main breaks reported to regulating agencies need to provide the information contained in Attachment 8.

Boil Water Advisory

When water main breaks result in loss of pressure in the system (system pressure less than 20 psi), NJAW performs bacteriological tests. Repaired mains can be returned to service prior to the completion of the bacteriological testing in order to minimize the time customers are without water; however, the NJAW provides a precautionary BWA to the affected customers until the sample results are available in order to meet compliance. The standard language used for a BWA is provided in Attachment 9.

CITY OF BOULDER, COLORADO

City of Boulder (COB) serves approximately 169,500 people with more than 455 miles of pipelines (excluding service lines). The number of main breaks per year for COB is relatively low at about 71 main breaks per year. COB's standard practices for responses to water main breaks include:

- Notification
- Investigation and Isolation
- Risk Assessment Procedures
- Communication
- Repair Procedures, and
- Job Completion

Notification

COB has developed water main break notification charts for regular and outside regular working hours. During regular working hours, the notification is processed through the Public Works Utilities Maintenance receptionist where he/she will notify the appropriate personnel. Outside of regular working hours, the notification is processed through the Water Treatment Plant (WTP) Operations. Figures C.4 and C.5 present the respective notification charts.

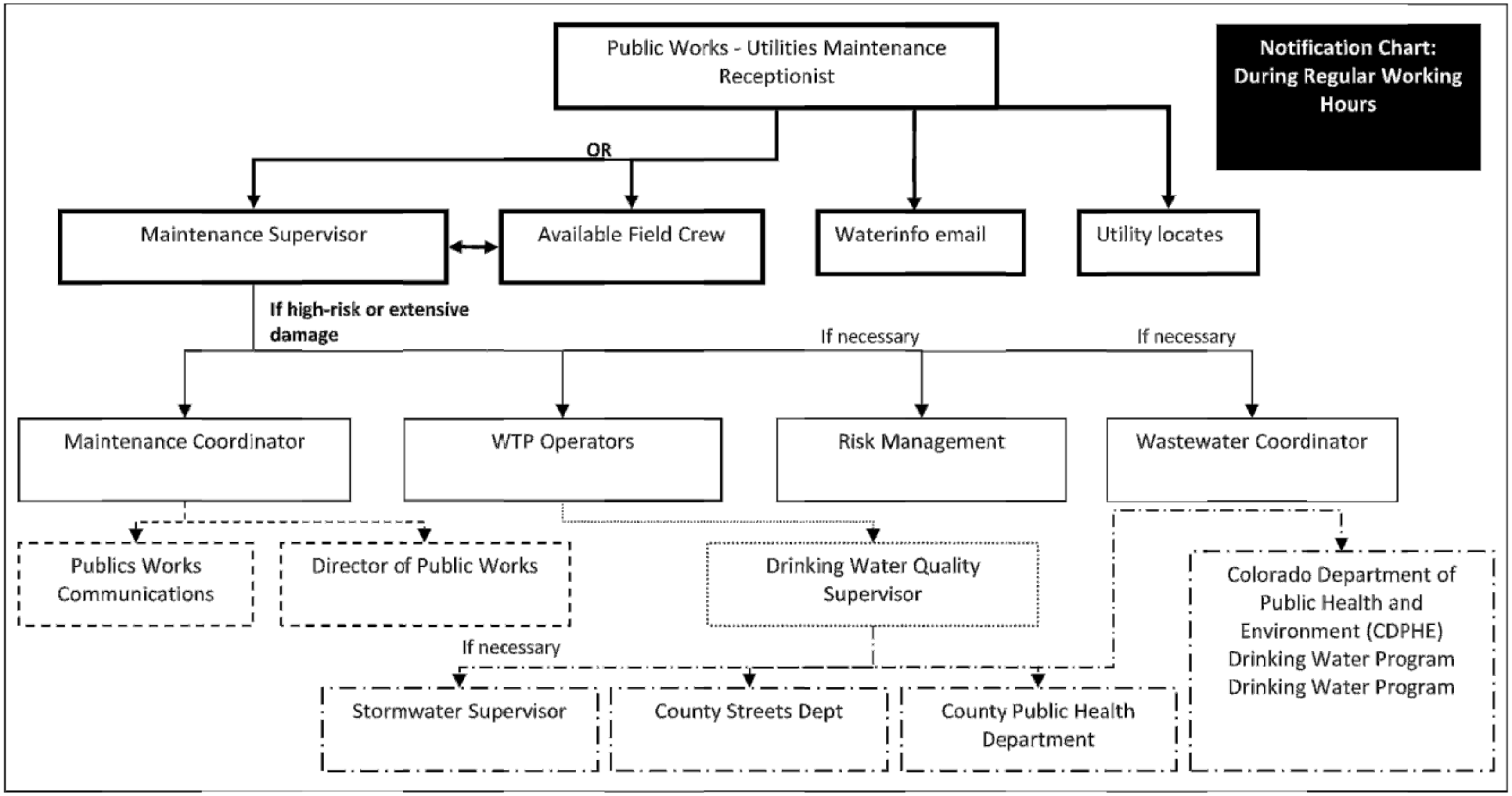


Figure C.4 Main break notification chart for regular working hours

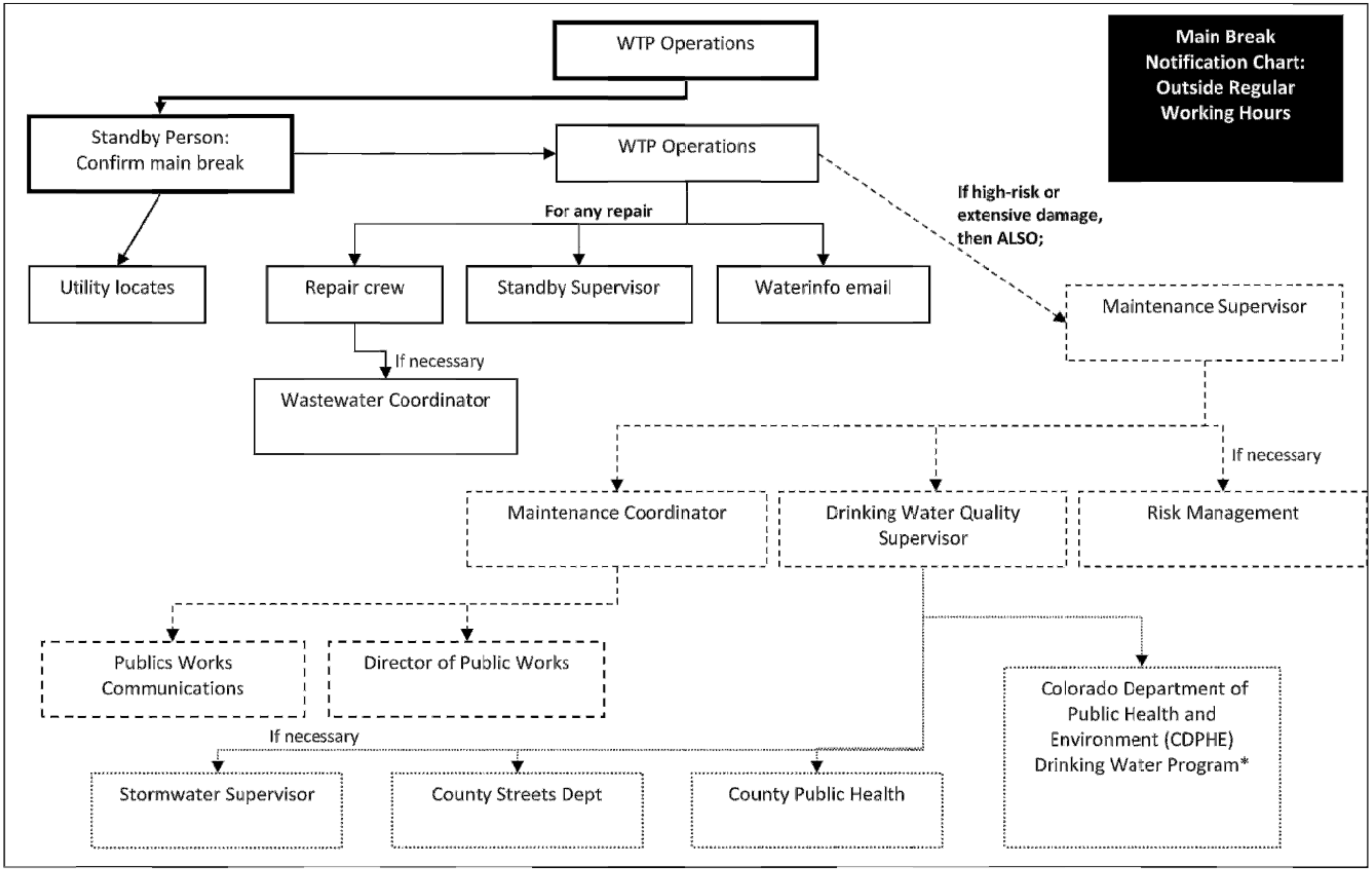


Figure C. 5 Main break notification chart for outside regular working hours

Investigation and Isolation

Repair staff members are usually onsite for investigation within one hour of the report/ notification of the leak or break. They perform the following:

- Stop or reroute traffic if possible. Call for assistance if necessary from law enforcement and/or additional city staff.
- Isolate the affected section of main from the distribution system.
- Repair that must be done immediately: Call Utility Notification Center of Colorado (UNCC) for emergency underground utility location.
- Repair that can be scheduled: Call for an underground utility locate if the repair can be scheduled to minimize impact on customer service.
- Determine if any water reached surface waters. If so, refer to Spill Response SOP in **Attachment 10.**
- Determine the area and number of customers that are without water.

Risk Assessment Procedures

- If any of the risk factors listed in Table C.1 are present, follow the "high risk or extensive damage" section of the notification flowcharts provided as Figures C.4 and C.5.

Table C.1
Risk factor table

Condition	Risk factor not present	Risk factor present
Pressure on SCADA	Did not drop below 20 psi	Dropped below 20 psi
At-risk customers identified (schools, medical, seniors, restaurants)?	No at-risk customers identified	At-risk customers affected
Size of pipe	Smaller than 12"	Greater than or equal to 12"
Did the break occur at a low point in the system?	Relatively flat or higher than surrounding area	Low point adjacent to higher areas
Area affected and number of customers without water	Less than one block	More than one block in any direction

- If a potential contamination risk is present, staff may reference the Contaminant Introduced in the Distribution System Standard Operating Procedure (SOP) in Attachment 11.
- If any of the above risk factors are present, the Drinking Water Program (DWP) will measure chlorine levels and sample for total coliform at locations representative of the

affected area. As needed, DWP may measure turbidity or sample for metals, pH, alkalinity, hardness, or other parameters.

Communication

If risk factors are present, Colorado Department of Public Heath and Environment (CDPHE) needs to be notified with the following information:

- Location of main break and number of customers without water
- Area and duration of lowest pressure
- At-risk customers identified
- Size of pipe
- Estimated amount of water lost
- Amount of damage
- Time to isolate break
- Location and results of any sampling
- Status of backflow prevention assemblies in the affected area

For any risk factors present, notify businesses and high-risk customers:

- Verbally when possible
- With COB Emergency Repair Door Hangers depending on the time of day, safety factors, and time constraints

Repair Procedures

- Once all the crew, vehicles, and equipment are mobilized, crew will excavate and repair the leak utilizing all applicable Personal Protective Equipment (PPE), shoring, and safety procedures.
- When feasible, take pictures of the repaired main.
  - Excavation and dewatering:
  - Excavate as needed
  - Pump excess water out of the trench. Direct water to a sewer if feasible, to a grassy area, or to a storm sewer, in order of preference
- Repair and disinfect pipes as described below.
- Following repair, open valves slowly (connection startup).

Repair

- Repair of main breaks will be dependent on types of breaks per Table C.2.
- Maintain protective coverings on equipment until ready for installation
- Keep pipe, fittings, and valves away from excavated soil or backfill materials
- Swab interior of existing and new pipe materials, fittings, and repair clamps which contact soil or backfill with a minimum 1% chlorine solution (household bleach)
- Maintain flow or positive pressure to prevent backflow into pipe when feasible

- Minimize soil contamination of working equipment

Table C.2
Main break repair

Hole or crack	Split	Blowout
▪ Repair clamp	▪ Remove damaged pipe ▪ Replace pipe ▪ Install fittings	▪ Cut damaged ends of pipe ▪ Replace pipe as necessary ▪ Install fittings

Disinfection

Repairs using repair clamps on fully pressurized water mains (>25 psi) do not need to be further disinfected following the swabbing or spraying of the repair area and the interior of the repair clamp with a minimum 1% hypochlorite solution. If at any time the water main is shut down and depressurized, disinfect as follows:

- Thoroughly flush the water main (minimum velocity of 2.5 fps) immediately after the repair is completed to remove any contaminants that may have been introduced during repair.
- Flushing should be conducted towards the repair location from both directions, if possible, and should continue until the water is clear.
- For high risk breaks, test free chlorine residuals at areas within and adjacent to the break during flushing. Continue flushing until chlorine residual is at least 0.2 mg/L.
- For high risk breaks, collect distribution water samples at areas within and adjacent to the break during or following flushing and analyze for total coliform.

Job Completion

- Complete maintenance management system task form for a main break
- Complete Cut Slip for street department
- If necessary, request cleanup of the storm drain and/or street from the gravity group and/or street sweepers
- Notify Waterinfo email list that water service has been restored.
- If any risk factors were present, Drinking Water Quality Program and Utilities Maintenance staff will coordinate with CDPHE to determine when to notify customers that the risk has been removed.

CHARLOTTE MECKLENBURG UTILITIES, NORTH CAROLINA

Charlotte Mecklenburg Utilities (CMU) serves approximately 776,100 people with more than 4,000 miles of pipelines (excluding service lines). The number of main breaks per year for CMUD is relatively high, 2,145 main breaks per year. Over the years, CMUD has developed a comprehensive training and certification program for skill evaluation of the repair crews. CMUD also has a well documented main break repair procedure.

Training and Certification Program

The typical crew size for repairing water main breaks at CMUD is four. CMUD provides formal training as well as annual refreshers to all repair crews. The following training and certification programs are provided to the repair crews.

- #156: Lead Work Team in Planning and Performance Tasks
- #141: Estimate Material, Labor, and Equipment Requirements
- #135: Locate Infrastructure
- #48: Lead Construction Repair Situations
- #33A: Lead in Repairing Distribution System Mains

Attachment 12 compiles the training and certification materials that CMUD uses to evaluate the skills of the water main repair crews.

Water Main Repair

The sequence of tasks to be performed for water main repair includes:

- Planning
- Safety
- Customer Notification
- Locating the Break and Excavation
- Main Break Repair

Planning

- Once the main break has been reported, use maps to decide the type and size of pipe that will be required for the job.
- Estimate material requirements and check out the required quantity from stock room and stock truck. Check out air monitor as well.

Safety

- Put on personnel safety equipment.
- Set up traffic safety equipment.
- Place traffic signs at each end of the work zone.
- Give proper notice to oncoming traffic.

- Take a brief survey of the scene to identify possible property damage or flooding of homes due to main break.
- Contact Field Operations or the Department of Insurance, Risk, and Management to come on-site if needed.

Customer Notification

- Contact affected customers.
- Inform the affected customers what CMUD will be doing and the expected timeframe for completing the job.
- Notify customers of any water loss they may experience.

Locating the Break and Excavation

- Pinpoint the water line and area of break using geophone and m-scope.
- Locate nearby utility lines to ensure that they are not affected during main repair.
- Begin excavation of ground and use pump to pump water out of trench.
- If a street cut is needed, contact headquarters and notify the Streets Department. Use jack hammer or saw cut street with a minimum of 3-ft width.
- If the excavation is deeper than 4-ft, a ladder and air monitor will be required.
- If the excavation is deeper than 5-ft, excavate at a 3:1 ratio so that the trench wall is not too steep.
- A safety box can be used in the trench to prevent collapsing of the wall.

Water Main Repair

- After excavation, clean pipe enough to determine whether a service clamp or a section of pipe will be replaced.

    - If the crack is circular going around the circumference of the pipe, a service clamp may be used.
    - If the crack runs horizontally, it should be replaced with a section of new pipe.

- If a service clamp is used:

    - Excavate deeper than main on both sides and drain water from trench using pump.
    - Determine whether water will need to be shut off depending on the severity of water pressure coming out of break.
    - If the repair can be made without shutting off the main

        - Expose main by digging dirt from underneath the main at the area of the break.
        - Clean pipe down to metal.
        - Install service clamp over the break on main and tighten bolts.
        - Check for leaks around the area of repair.

    - If the repair requires to shut off the main

- Determine the best way to isolate the section of pipe to be worked on and locate valves to be used.
- Expose main by digging dirt from underneath the main at the area of the break.
- Clean pipe down to metal.
- Install service clamp over the break on main and tighten bolts.
- Flush the system after repair by using a hydrant or service connection to get rid of the air in the pipe.
- Check for leaks around the area of repair.
- Test water quality.

- If a section of pipe is going to be replaced:

    - Water must shut off to the break area using the method that will interrupt the fewest customers' water service.
    - Excavate deeper than main on both sides and drain water from trench using pump.
    - Clean pipe down to metal.
    - Place pipe cutter on main and cut old main after the defective area on each side and remove the old piece of pipe.
    - Measure the section of new pipe required to fit tight with no more than half-inch gap between old and new pipes.
    - Swab the new section of pipe with chlorine to sanitize.
    - Use two 441 dresser couplings to connect the new section of pipe with the old pipe.
    - Partially cover pipe, turn the water on and check for leaks.
    - Flush the system after repair by using a hydrant or service connection to get rid of the air in the pipe.
    - Test chlorine level of the water at the repair and also next to hydrant down from the repair to ensure that the water is safe.

- After repair, fill the excavated trench with same soil or use dry soil with gravel.

DENVER WATER, COLORADO

The Denver Water (DW) distribution system consists of more than 3,000 miles of pipelines. DW crews install or replace an average of 70,000 feet of pipe per year to repair or avoid main breaks; alleviate water quality problems; increase available hydrant fire flow; and improve overall area delivery. DW promptly responds to and investigates reports of distribution main breaks and leaks and generally, repairs of main breaks are scheduled immediately. Repairs of leaks will be scheduled for regular working hours if the leak can be managed in such a way to have no impact on customer service. DW's main break response program includes an assessment of the risk of contamination to the distribution system as the result of a main break or leak. DW will take specific and pre-determined precautionary measures when a significant risk of contamination to the distribution system is present.

Investigation, Isolation, and Customer Notification Procedures

All reports of distribution main breaks and leaks are to be promptly investigated by one or more Water Control staff, with primary responsibility assigned to members of the Emergency Services and Distribution Services groups. For the purposes of this procedure, "promptly" shall be taken to mean that an investigator is dispatched within 15 minutes of receipt of the report and is generally on-site within an hour. Exceptions to this stated goal would be made in instances where multiple reports are received concurrently. The Emergency Services Dispatcher will make appropriate arrangements with the Transmission and Distribution (T&D) Section within O&M Division to begin the process of initiating repairs to the system.

In the instance of a main break that will not hold, field response procedures will consist of:

- Protection of public safety by stopping or rerouting traffic from the vicinity of the break. Assistance may be required from law enforcement and/or additional DW staff to accomplish this safely.
- Isolation of the affected section of main from the distribution system. Double-valve shutouts are required whenever possible (i.e. when the double-valve shutout does not put additional customers out of water). Double-valve shutouts are defined as the use of secondary, backup valves behind the primary valves that are used to stop the flow of water.
- A field survey to inventory all customers that are put out of water as a result of isolating the main.
- Notification of customers affected by the shut-out by use of door hangers and, where possible, by direct, verbal contact.
- A field survey to inventory all customers that might be impacted in some way, other than a complete outage, by changes to the operation of the distribution system.

Repair Procedures

Normal Business Hours

In the instance of normal business hours (7:00 AM – 3:30 PM):

- Emergency Call
  - The Emergency Service Dispatcher will notify the appropriate T&D Distribution Supervisor.
- T&D Response
  - Distribution Supervisor will contact the Foreman to respond to the main break.
  - Foreman will call for utility locates.
  - Foreman will contact all crew members. First crew member should arrive within 1 hour.
  - Once all the crew, vehicles, and equipment are mobilized, crew will excavate and repair the leak utilizing all applicable PPE, shoring, and safety procedures.
  - All pipe and fittings that come in contact with potable water will be disinfected.
  - After the repair is complete, the system will be flushed to clear the main.
  - Once the repair is made, all valves previously closed will be opened up to place customers back in service.
  - Foreman will notify Emergency Services Dispatcher that customers are back in service.
  - Foreman will notify Warehouse that repair is complete and their services are no longer needed.
  - Foreman will call T&D Notification Line [phone number provided] to alert all interested parties with regard to street excavation dimensions, Work Order requests, sod cuts, etc.
- Contact Water Quality Lab if
  - Sanitary sewer line and/or storm sewer line contaminates the water main or service line.
  - Pipe length for spray disinfecting replacement pipe exceeds 20 linear feet.
  - Pipe diameter exceeds 16 inches.

Off Hours

In the instance of a main break outside of normal business hours (3:30 PM - 7:00 AM):

- Emergency Call
  - The Emergency Service Dispatcher will contact next on-call Foreman.
  - Emergency Services Dispatch will call for utility locates.
- T&D Response
  - Foreman will contact all crew members. First crew member should arrive within 1-hour.

- Once all the crew, vehicles and equipment are mobilized, crew will excavate and repair the leak utilizing all applicable PPE, shoring, and safety procedures.
- All pipe and fittings that come in contact with potable water will be disinfected.
- After the repair is complete, the system will be flushed to clear the main.
- Once the repair is made, all valves previously closed will be opened up to place customers back in service.
- Foreman will notify Emergency Services Dispatcher that customers are back in service.
- Foreman will notify Warehouse that repair is complete and their services are no longer needed.
- Foreman will call T&D Notification Line [phone number provided] to alert all interested parties with regard to street excavation dimensions, Work Order requests, sod cuts, etc.

- Contact Water Quality Lab if
  - Sanitary sewer line and/or storm sewer line contaminates the water main or service line.
  - Pipe length for spray disinfecting replacement pipe exceeds 20 linear feet.
  - Pipe diameter exceeds 16 inches.

Risk Assessment Procedures

When the structural integrity of the system is compromised, main breaks in the distribution system occur and the risk of contamination to the distribution system increases to the point that preventative measures, including Colorado Department of Public Health and Environment (CDPHE) and public notification are warranted. DW has developed a flowchart (**Figure C.6**) to outline a process by which specific risk factors can be assessed and the outcome of that analysis is used to trigger the need to implement specified preventative measures.

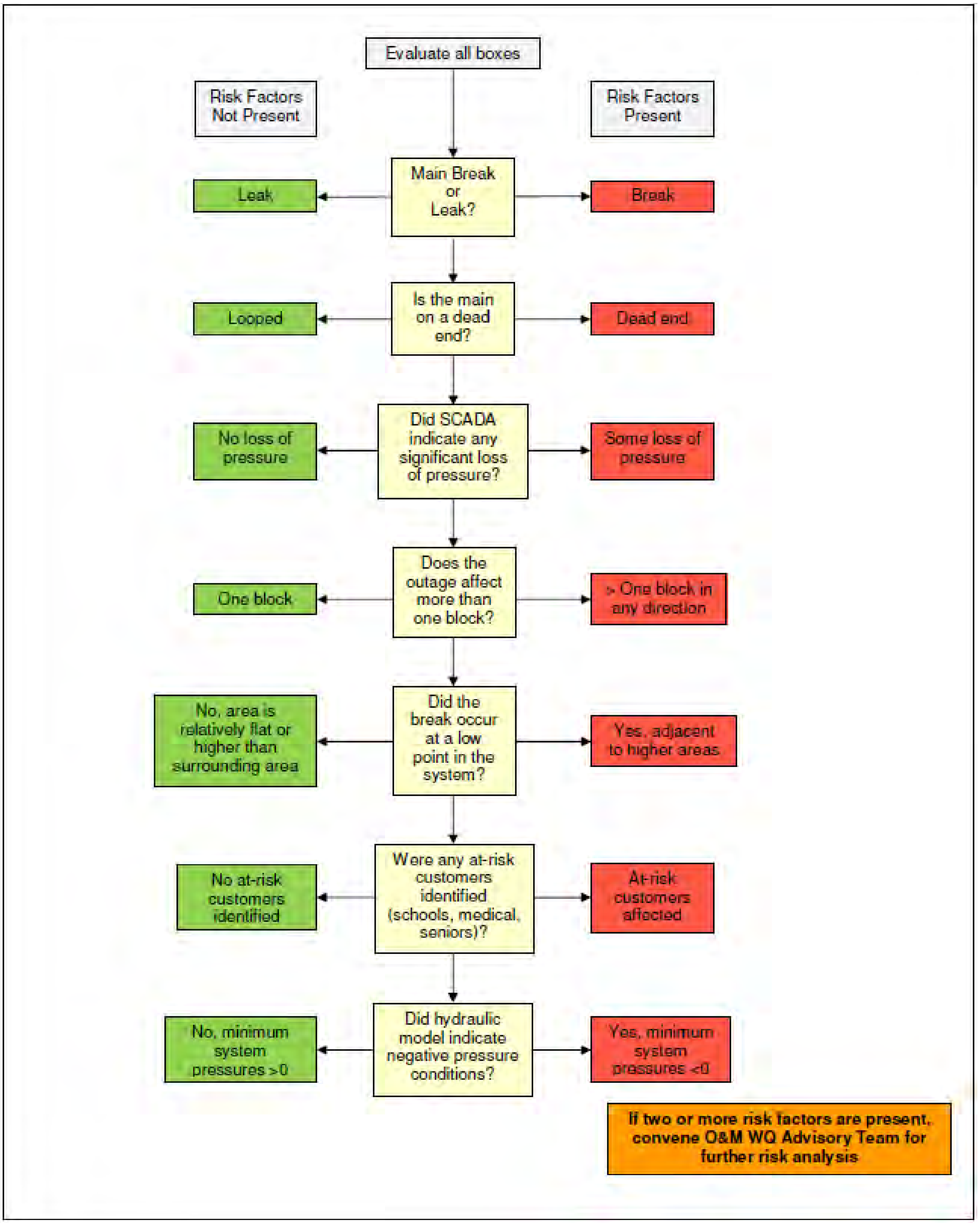


Figure C.6 Risk assessment flowchart

The Emergency Services Foreman or Assistant Foreman is responsible for notifying the Water Control On-Call Supervisor in every instance of a main break or leak and conveying to the Supervisor all relevant information about the break/leak. If multiple risk factors or a large magnitude event of a single risk factor is present, as indicated in the flowchart, the On-Call Supervisor will notify the Superintendent of Water Control, who in turn, will notify the other members of the Water Quality Advisory Team consisting of the following members:

- Director of Operations & Maintenance
- Manager of Water Quality
- Superintendent of Water Treatment (optional)
- Superintendent of Water Control
- Superintendent of Transmission & Distribution

If the O&M Water Quality Advisory Team determines that a significant public health risk is present, the following actions will be taken:

- Notification will be made to the CDPHE.
- DW may activate its Emergency Operations Center.
- A communication plan will be developed and implemented in consultation with Public Affairs.
- A plan for procuring and delivering alternate water supplies to affected customers will be developed and implemented.

Working through the DW's Emergency Operation Center (EOC) and in consultation with CDPHE, Incident Action Plans will be developed and implemented to manage the incident.

ATTACHMENT 1

Unauthorized Potable Water Discharge Notification Form

[City of Fort Worth]

Unauthorized Potable Water Discharge

☑ Unauthorized Discharge ☐ Other

General Information

Entity Name: **City of Fort Worth Water Dept.**

1608 11th Avenue, Field Operations

Telephone Number: **(817) 871-8275**

☑ Permittee ☐ Subscriber

TCEQ Region: **Region 4** County: **Tarrant** TCEQ ID: **2200012**

Noncompliance Summary

Estimated Volume if an unauthorized discharge: ____________

Description of Noncompliance (include location, discharge route):

Type description here

Cause of Noncompliance:

Duration: Estimated Discharge Start Date and Time: ____________

Actual Date and time Discharge Shut Down: ____________

Or Date to be Corrected: ____________

Potential Impact to Receiving Waters an/or Aquatic Life:

Actions Taken

Monitoring Data: Data should be attached or submitted to TCEQ when available.

☐ Yes	☑ No	Field Measurement
☐ Yes	☑ No	Laboratory Samples
☐ Yes	☑ No	Fish Kill If yes, estimated number of fish killed:
☐ Yes	☑ No	Health Risk

Actions Required to Mitigate Adverse Effects: De-chlorination of discharged and/or receiving waters as required.

Actions Taken to Correct the Problem

Prevent Recurrence:

Verification Information

Information Reported by (Name and Title): Ray Moreno - Water Systems Supt FWWD

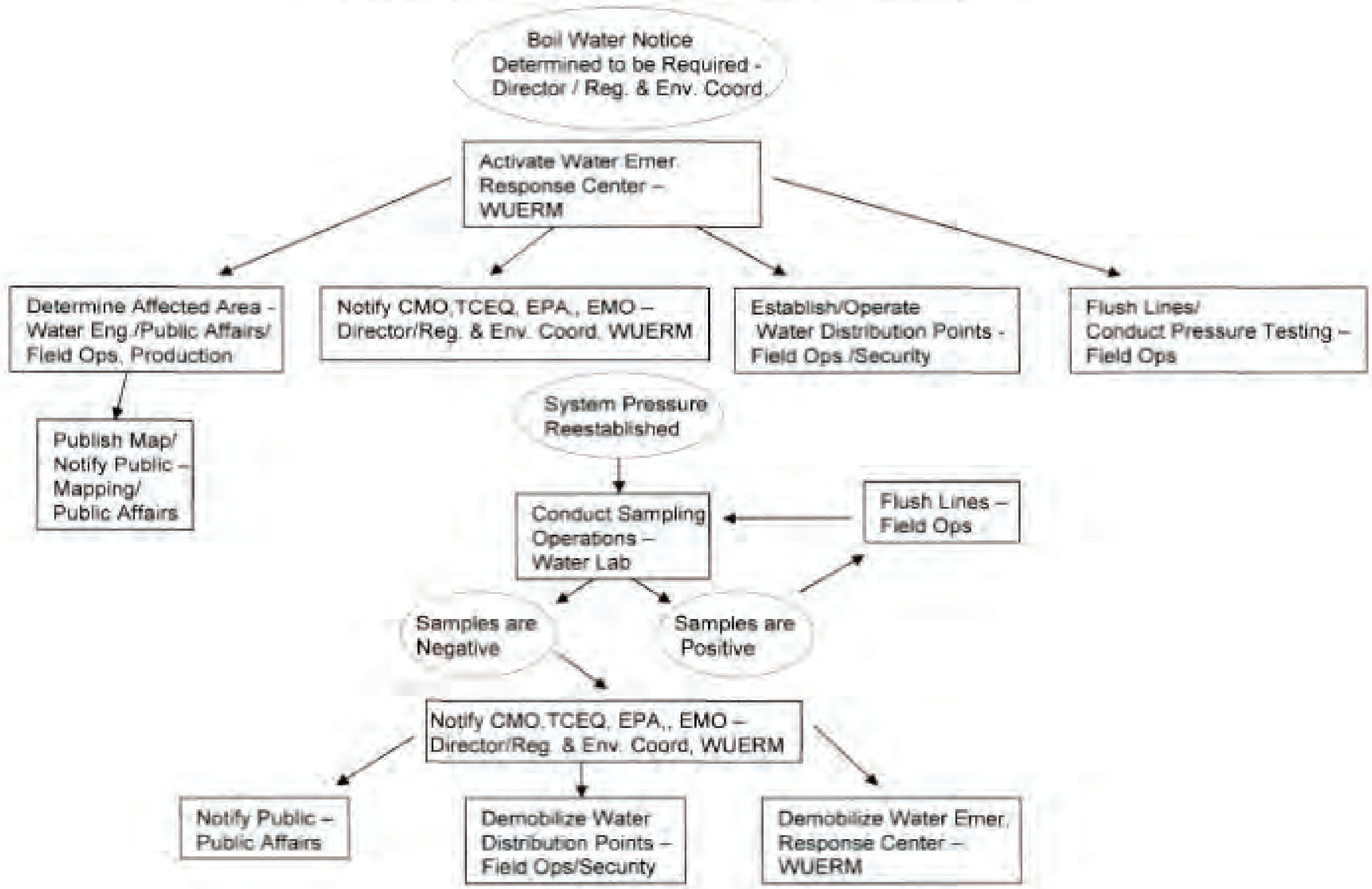
Date Reported: Signature: ____________

ATTACHMENT 2

Boil Water Advisory Sequence

[City of Fort Worth]

Boil Water Sequence of Events Due to Low System Pressure



ATTACHMENT 3

Quiz Materials on PPPs and BMPs

[LADWP]

Sylmar W.E.S.T.

Pollution Prevention Plan Quiz

Name: ____________________________

Date: ______________________________

Employee I D: ____________________

District: ___________________________

1. The Los Angeles Department of Water and Power is required to either prohibit, or control by National Pollutant Discharge Elimination System (NPDES) permits, the contribution of pollutants to surface waters or the storm drain system. Failure to comply with these requirements may result in a fine of up to _______ per day of violation and possible imprisonment.

a. $10,000 per day.
b. $15,000 per day.
c. $25,000 per day.
d. $50,000 per day.

2. Who enacted the Clean Water Act (CWA)?

a. The President of the United States.
b. The Governor of California.
c. The CDPH
d. AWWA
e. Congress
f. None of the above

3. What is flow path according to PPP?

a. The direction of a river or stream.
b. Right of centerline on a street.
c. The route that the discharged water will travel.
d. The path of least resistance.

4. What do the letters BMP stand for?

a. Best Maintenance Procedures
b. Best Management Procedures
c. Best Management Practices
d. None of the above

5. What are two most common types of sediment berms/barriers the DWP uses?

a. A temporary dirt berm and burlap bag on discharge hose
b. K-rail and sand bags
c. Sand bags and section of Fire hose filled with sand
d. None of the above

6. Where would you most commonly place Geotextile Fabric?

   Answer: ______________________________

7. Spoils that may need to be left in the field for an extended period of time shall be covered with__________________________ or ____________________________ in the event of rain and/or high winds.

8. The pump discharge hose shall have a ___________________________________ attached at the in order to catch sediment.

9. What are the practices that protect storm water called?

a. EPA's
b. MSDS's
c. SOP's
d. BMP's

10. What precautions should be taken prior to flushing any water main using a fire hydrant?

a. Install an eddy valve on the fire hydrant
b. Use a diffuser on the end of discharge hose
c. Check and clear the flow path of contaminates and debris
d. All of the above
e. Only c.

BMP Quiz

Answer Sheet

Name: ___________________________
Date: __________
Employee I D: ______________
District: _______________

1. The Los Angeles Department of Water and Power is required to either prohibit, or control by National Pollutant Discharge Elimination System (NPDES) permits, the contribution of pollutants to surface waters or the storm drain system. Failure to comply with these requirements may result in a fine of up to _______ per day of violation and possible imprisonment.

a. $10,000 per day.
b. $15,000 per day.
c. $25,000 per day.
d. $50,000 per day.

2. Who enacted the Clean Water Act (CWA)?

a. The President of the United States.
b. The Governor of California.
c. The CDPH
d. AWWA
e. Congress
f. None of the above

3. What is flow path according to PPP?

a. The direction of a river or stream.
b. Right of centerline on a street.
c. The route that the discharged water will travel.
d. The path of least resistance.

4. What do the letters BMP stand for?

a. Best Maintenance Procedures
b. Best Management Procedures
c. Best Management Practices
d. None of the above

5. What are two most common types of sediment berms/barriers the DWP uses?

a. A temporary dirt berm and burlap bag on discharge hose
b. K-rail and sand bags
c. Sand bags and section of Fire hose filled with sand
d. None of the above

6. Where would you most commonly place Geotextile Fabric?

Answer: over storm drain opening

7. Spoils that may need to be left in the field for an extended period of time shall be covered with plastic sheeting or a canvas tarp in the event of rain and/or high winds.

8. The pump discharge hose shall have a burlap bag attached at the end in order to catch sediment.

9. What are the practices that protect storm water called?

a. EPA's
b. MSDS's
c. SOP's
d. BMP's

10. What precautions should be taken prior to flushing any water main using a fire hydrant?

a. Install an eddy valve on the fire hydrant
b. Use a diffuser on the end of discharge hose
c. Check and clear the flow path of contaminates and debris
d. All of the above
e. Only c.

ATTACHMENT 4

Quiz Materials on Dechlorination

[LADWP]

Sylmar W.E.S.T.

De-chlorination Quiz

Name: ______________________

Date: ______________________

Employee I D: _______________

District: ____________________

1. Vita-D-Chlor tablets can handle flows from ____ to ____ GPM, and Hydrant pressures up to ____ PSI.

   a. 50 to 100 GPM, and 175 PSI
   b. 150 to 600 GPM, and 200 PSI
   c. 200 to 1,250 GPM, and 200 PSI
   d. 700 to 2000 GPM, and 250 PSI

2. One Vita-D-Chlor tablet will neutralize the chlorine from _____ gallons.

   a. 1,000 gallons
   b. 1,500 gallons
   c. 2,000 gallons
   d. 2,500 gallons

3. Vita-D-Chlor is the safest and least toxic of de-chlorination chemicals on the market.

   True____ False____

4. The emphasis of this procedure is to promote the implementation of BMP's that ____________ and/or _____________ the introduction of pollutants from potable drinking water release to receiving waters.

5. When ever it is not possible to dispose of chlorinated waters safely by non-chemical methods, chlorine may be neutralized using chemicals. What are the three different forms of de-chlorination chemicals available and are widely used by water and waste water utilities?

   1. _________ form
   2. _________ form
   3. _________ form

6. What is Ascorbic Acid?

   a. 100% Chlorine
   b. 65% Chlorine
   c. Vitamin A
   d. Vitamin B
   e. Vitamin C

7. Prior to implementing any scheduled discharge activity, survey the project site and identify;

   1.____

   2.____

   3.____

   4.____

   5.____

   6.____

De-chlorination Quiz

Answer Sheet

Name: ____________________
Date: _____________
Employee I D: ________________
District: ________________

1. Vita-D-Chlor tablets can handle flows from ____ to ____ GPM, and Hydrant pressures up to ____ PSI.

   a. 50 to 100 GPM, and 175 PSI
   b. 150 to 600 GPM, and 200 PSI
   c. 200 to 1,250 GPM, and 200 PSI
   d. 700 to 2000 GPM, and 250 PSI

2. One Vita-D-Chlor tablet will neutralize the chlorine from _____ gallons.

   a. 1,000 gallons
   b. 1,500 gallons
   c. 2,000 gallons
   d. 2,500 gallons
   e.

3. Vita-D-Chlor is the safest and least toxic of de-chlorination chemicals on the market.

   True False

4. The emphasis of this procedure is to promote the implementation of BMP's that reduce and/or eliminate the introduction of pollutants from potable drinking water release to receiving waters.

5. When ever it is not possible to dispose of chlorinated waters safely by non-chemical methods, chlorine may be neutralized using chemicals. What are the three different forms of de-chlorination chemicals available and are widely used by water and waste water utilities?

   1. Solid
   2. Liquid
   3. Gaseous

6. What is Ascorbic Acid?

   a. 100% Chlorine
   b. 65% Chlorine
   c. Vitamin A
   d. Vitamin B
   e. Vitamin C

7. Prior to implementing any scheduled discharge activity, survey the project site and identify;

   1. The entire affected area.
   2. The location of buildings and paved areas.
   3. The location of major activities.
   4. Drainage areas and the direction of runoff flows.
   5. The discharge points from the job; and
   6. Points of entrance into the storm drain.

ATTACHMENT 5

Quiz Materials on Water Main Repair Disinfection

[LADWP]

Sylmar W.E.S.T.

Main Repair Disinfection Quiz

Name: ______________________________ Date: ____________________

Employee No. ________________________

District:______________________________

1) Why do we disinfect a water main after a main break?

a) Because it is a requirement by the state.

b) To prevent contamination.

c) To maintain the proper chlorine levels in water main.

d) Stops the rusty water from coming out of the Fire Hydrant.

2) When do we disinfect a water main when repairing a main leak?

a) install a screw pin

b) when making a repair with a 360 repair clamp

c) when the main has been dewatered and contamination is possible

d) always

3) What % of chlorine do we want to use when disinfecting material used to repair a main break?

a) 4% to 7%

b) 1% to 5%

c) below 1%

d) greater than 7%

4) If valve and hydrant locations permit you should

a) flush from one direction only

b) do not flush at all

c) flush only after repairs are made

d) flushing toward the work location from both directions is recommended.

5) How much chlorine (calcium hypochlorite 65% available chlorine) do you mix with one gallon of water to make 2% available chlorine?

a) 4 ounces

b) 2 ounces

c) 4 pounds

d) 4 scoops

6) What do you spray with the calcium hypochlorite solution?

____

7) When would you disinfect with a swab method besides on a main break?

a) Large Service Installation

b) Fire Hydrant Installation

c) Connection of new water main to existing water main

d) All of the above

8) Would you disinfect when cutting in a tee or when using a Tapping Sleeve?

a) YES

b) NO

9) Please list one reference material used to prepare this training.

____

10) Please list PPE's used when spraying hypochlorite solution

a)____________________________________

b)____________________________________

c)____________________________________

d)____________________________________

e)____________________________________

Disinfection Quiz

Answer Sheet

1) Why do we disinfect a water main after a main break?

   a) Because it is a requirement by the state.

   b) To prevent contamination.

   c) To maintain the proper chlorine levels in water main.

   d) Stops the rusty water from coming out of the Fire Hydrant.

2) When do we disinfect a water main when repairing a main leak?

   a) install a screw pin

   b) when making a repair with a 360 repair clamp

   c) when the main has been dewatered and contamination is possible

   d) always

3) What % of chlorine do we want to use when disinfecting material used to repair a main break?

   a) 4% to 7%

   b) 1% to 5%

   c) below 1%

   d) greater than 7%

4) If valve and hydrant locations permit you should

   a) flush from one direction only

   b) do not flush at all

   c) flush only after repairs are made

   d) flushing toward the work location from both directions is recommended.

5) How much chlorine (calcium hypochlorite 65% available chlorine) do you mix with one gallon of water to make 2% available chlorine?

a) 4 ounces

b) 2 ounces

c) 4 pounds

d) 4 scoops

6) What do you spray with the calcium hypochlorite solution?

The interior of all pipe and fittings (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed

OR

Disinfection of fittings, joints, valves, and exposed connections

7) When would you disinfect with a swab method besides on a main break?

a) Large Service Installation

b) Fire Hydrant Installation

c) Connection of new water main to existing water main

d) All of the above

8) Would you disinfect when cutting in a tee or when using a Tapping Sleeve?

a) YES

b) NO

9) Please list one reference material used to prepare this training.

AWWA Standard for Disinfecting Water Mains

OR

ANSI/AWWA C651-99 Section 4.7 Disinfection Procedure When Cutting Into or Repairing Existing Mains

OR

Procedure for Emergency Disinfection of Mains - AWWA article 2000
http://www.awwa.org/files/Emergency_Disinfection_of_Mains.pdf

OR

United States Environmental Protection Agency-Office of Ground Water and Drinking Water

10) Please list PPE's used when spraying hypochlorite solution

a) Hard Hat
b) Face Shield
c) Rubber Gloves
d) Protective Clothing (Rain Gear)
e) Rubber Boots

b)____

c)____

d)____

e)____

ATTACHMENT 6

Field Sampling Form

[LADWP]

The City of Los Angeles Department of Water and Power

Custody – Field Form for Sampling Following a Water Main Outage

IMPORTANT NOTE: The sample collector must fill-in all information marked with the symbol ▶.

Deliver sample(s) to the Water Quality Laboratory located at 555 E. Walnut Street in Pasadena. The cross street is Madison Avenue – Thomas Guide 565-J4. Telephone 213-367-8480. Parking and entrance is located in the back of building; enter from Madison Avenue.

▶Collected By: (Print)__________ ▶(sign)__________ ▶Date: ______

▶Weather: __________ ▶Date in Lab: ______ ▶Time in Lab: ______
(During sample collection)

Relinquished To: (print) __________ (sign)__________ Date: _____ Time: _____

Location	▶ Time Sampled (24 hr Time)	▶ Water Operating District	▶ Thomas Guide Page/Grid	LADWP Project Code	▶ Free Chlorine FI2063C	▶ Total Chlorine FI2064C
[PASTE LABEL HERE]				+OUTAGE+		
	Location Code: OUTAGE ▶Location Description: __________ (Address where sample was taken) Comments: __________ (If any)					
Lab Schedule: OUTAGE2 OUTAGE2 BCT250						

Location	▶ Time Sampled (24 hr Time)	▶ Water Operating District	▶ Thomas Guide Page/Grid	LADWP Project Code	▶ Free Chlorine FI2063C	▶ Total Chlorine FI2064C
[PASTE LABEL HERE]				+OUTAGE+		
	Location Code: OUTAGE ▶Location Description: __________ (Address where sample was taken) Comments: __________ (If any)					
Lab Schedule: OUTAGE2 OUTAGE2 BCT250						

Bacterial Travel Blank (Date/Initials): ______ / ______ Temperature Blank: ______ °C

ATTACHMENT 7

Quiz Materials on Water Main Repair Sampling

[LADWP]

Water Main Repair Sampling Quiz

Sylmar W.E.S.T.

Name: ____________________ Date: ____________________
Employee No. ____________________
District: ____________________

1. Fill in the blanks
   "Our mission is to deliver a dependable supply of ________, __________ __________ to our customers in an efficient and publicly responsible manner"

2. When do you have to take a Bacteriological sample?

   a. Every time you make a leak repair

   b. After main installation or repair

   c. After any system pressure loss to less than five psi.

   d. b and c

3. When you take a water sample after cutting in a section of water main, where do you take the sample from?

   a. any where in the area

   b. must be 5 houses from main repair

   c. two blocks from main repair

   d. samples collected shall represent the water quality in the affected portions of the system that was repaired

4. Do you have to take a Bacteriological sample if the water main does not drop below 5 psi?

   a. YES

   b. NO

5. Where is the best location to take a water sample from?

   a. Hose Bib

   b. Fire Hydrant ports

   c. garden hose

   d. Fire Hydrant sample tap

6. What information must you know to put on Water Sample Custody form

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

7. What size is the cell you fill when using the HACH chlorine test kit?

a. 20 ml

b. 5 ml

c. 10 ml

d none of the above

8. Why do you test for total chlorine?

a. you are in a chloramines system

b. you want to know how much ammonia is in the water

c. because you have both tablets

d. none of the above

9. When testing free chlorine how long do you have to process the sample?

a. 5 minutes

b. 8 hours

c. there is no time limit

d. 1 minute

10. When testing total chlorine how long do you have to process sample?

a. wait 8 to 10 minutes after adding DPD

b. process right away

c. wait 3 to 6 minutes after adding DPD

d. there is no specific time

Sampling Procedure Quiz
Answer Sheet

1. Fill in the blanks
   "Our mission is to deliver a dependable supply of _safe__,
   quality Water to our customers in an efficient and publicly responsible manner"

2. When do you have to take a Bacteriological sample?

   a. Every time you make a leak repair

   b. After main installation or repair

   c. After any system pressure loss to less than five psi.

   d. b and c

3. When you take a water sample after cutting in a section of water main, where do you take the sample from?

   a. any where in the area

   b. must be 5 houses from main repair

   c. two blocks from main repair

   d. samples collected shall represent the water quality in the affected portions of the system that was repaired

4. Do you have to take a Bacteriological sample if the water main does not drop below 5 psi?

   a. YES

   b. NO

5. Where is the best location to take a water sample from?

   a. Hose Bib

   b. Fire Hydrant ports

   c. garden hose

   d. Fire Hydrant sample tap

6. What information must you know to put on Water Sample Custody form

a. Sample Date

b. Sample Time

c. Sample Collector

d. Sample Location

e. Sample Designation

f. Chlorine Residual

g. Time Delivered to WQ Laboratory

7. What size is the cell you fill when using the HACH chlorine test kit?

a. 20 ml

b. 5 ml

c. 10 ml

d none of the above

8. Why do you test for total chlorine?

a. you are in a chloramines system

b. you want to know how much ammonia is in the water

c. because you have both tablets

d. none of the above

9. When testing free chlorine how long do you have to process the sample?

a. 5 minutes

b. 8 hours

c. there is no time limit

d. 1 minute

10. When testing total chlorine how long do you have to process sample?

a. wait 8 to 10 minutes after adding DPD

b. process right away

c. wait 3 to 6 minutes after adding DPD

d. there is no specific time

ATTACHMENT 8

Water Main Break Notification Format

[NJAW]

Water Main Break – Detail Report

Incident Description: (Water System) (PWSID No.) reports that a water main break has caused the system (or portions of the system) to be without water or with negative pressure zones.

System Contact: (Name, title, work/cell numbers)

Location of incident: (Street Address, Town, County)

Delineation of Area Affected: (Provide Northern, Southern, Western, and Eastern Boundaries)

Cause of Break: (pipe fatigue, physical damage due to construction, etc.)

Time of Occurrence: (Day, Date, Time)

Sizing of water main affected: (diameter, service main/feeder main)

Counties/Municipalities Impacted:

Number of Service Connections/Population Affected:

Estimated time to Repair/Restore Service:

Provisions for Alternate Water Supply: (interconnection, bottled water, water tanker, etc.)

Corrective Actions Implemented:

Note: Corrective Actions may include the following:

a. Boil Water Advisory Issued
b. Establish Method of Delivery: Reverse 911, TV/Radio Broadcasts, Hand Delivery, other)
c. Method of Repair to Water Main: Replacing a section of pipe, sleeving a section of pipe, etc.
d. Disinfection/Flushing of repaired main (Industry Standard: AWWA Standard C651, other method)
e. Sampling for total coliform/chlorine residual (BSDW Policy-Number of samples based on population affected) following repair/disinfection of water main to verify restoration of water quality.

ATTACHMENT 9

Suggested Boil Water Advisory Language

[NJAW]

Suggested Boil Water Advisory Language

(Description of Incident)

(Standard Language)

As a precaution, the New Jersey Department of Environmental Protection requires us to issue the following advisory:

The Department of Environmental Protection has determined that a potential or actual threat to the quality of water being provided to you currently exits. Therefore until further notice, bring tap water to a rolling boil for one minute and allow cooling before using for consumption, drinking, ice cubes, washing vegetables and fruit, and for brushing teeth. Please continue to boil your water until you are notified that the water quality is acceptable.

The following measures are also recommended:

- Throw away uncooked food or beverages or ice cubes if made with tap water during the day of the advisory;
- Do not swallow water while showering or bathing;
- Do not use home filtering devices in place of boiling or using bottled water, most home water filters will not provide adequate protection from microorganisms;
- Use only water that has been boiled (and cooled) to treat minor injuries;
- Rinse hand-washed dishes with a diluted bleach solution (one tablespoon of house hold bleach per gallon of tap water) or clean your dishes in a dishwasher using the hot wash cycle and dry cycle;
- Upon boiling water for potable use, it is suggested that 2-3 gallons of boiled (and cooled) water be stored in the refrigerator in one gallon-containers for use in cooking, drinking, etc. Water can be stored in this manner for 2-3 days;
- Pets should be provided with drinking water that has been boiled (and cooled) in the manner indicated above.

Please be advised that the New Jersey Department of Environmental Protection and (Water System) are working to restore your water quality. This advisory will remain in effect until repairs are made and testing shows the water quality to be safe. You will be notified when the advisory is lifted. Thank you for your patience. If you have any questions please contact (Water System Representative) at (Water System Number).

ATTACHMENT 10

Spill Response SOP

[City of Boulder]

City of Boulder
Water Quality and Environmental Services
Spill Response
2011

The Fire Department and Boulder County Public Health (BCPH) are the principal agencies which respond to spills of hazardous materials. Both agencies are the Designated Emergency Response Agency (DERA) in issues relating to hazardous material releases. Water Quality and Environmental Services (WQES) staff will provide technical advisory support to both of these agencies on an as-needed basis. In general, WQES staff response to spills is as follows:

Water Quality and Environmental Services Response

Type of Material	WQES Response
Hazardous	No on-site response, will assist in advisory role only
Unknown	Yes - Will provide on-site response if needed provided that emergency response (fire, county) authorizes
Known, Non-hazardous	Yes - Will provide on-site response if needed and assist in source detection and environmental impact assessment

Type of Incident	Agency Response	Possible Enforcement Action
In Progress - report of something being discharged	Instruct complainant to call city or county non-emergency dispatch to report spill	
	Dispatch contacts Fire Dept. and/or Police	
	Police/Environmental Enforcement issues citation	Police or Environmental Enforcement may issue citation (under BRC# 11-3-4); $1000 fine and/or 90 days in jail
	Fire Department secures area, evaluates situation	Fire Department recoups cost of clean-up from violator
	BCPH identifies material and oversees clean-up	Files incident report, notifies CDPHE or EPA
	WQES aids in identification of material and provides information on storm/sanitary sewer locations & impacts to environment	Issues notice of violation if no citation is issued

City of Boulder
Water Quality and Environmental Services
Spill Response
2011

Type of Incident	Agency Response	Possible Enforcement Action
After the Fact - report of "stuff" in Boulder Creek	Instruct complainant to call city or county non-emergency dispatch to report spill	
	Dispatch contacts Fire Department. and/or Police	
	Fire secures area, evaluates situation	Fire recoups cost of clean-up from violator
	BCPH identifies material and oversees clean-up	Files incident report, notifies CDPHE or EPA
	WQES aids in identification of material and provides information on storm/sanitary sewer locations & impacts to environment	Issues notice of violation if source is determined
On-going Problem - report of business/individual repeating a spill	Instruct complainant to call WQES to report spill	Issues notice of violation or other enforcement
	Storm sewer - Streams, Lakes, Ditches - Stormwater Quality	
	Sanitary sewer, businesses/industries - Industrial Pretreatment	
	Reservoirs - Drinking Water Program	

City of Boulder
Water Quality and Environmental Services
Spill Response
2011

Contact Name	Work Group
Emergency Dispatch (County)	County of Boulder
Emergency Dispatch (City)	City of Boulder
	Boulder County Public Health
	Boulder County Public Health
	Boulder County Public Health
WQES Main Office	City of Boulder
Boulder Reservoir at 63rd St Water Treatment Facility	City of Boulder
Betasso Water Treatment Facility	City of Boulder
City Environmental Enforcement	City of Boulder
WQES - Stormwater	City of Boulder
WQES - Industrial Pretreatment	City of Boulder
Utilities Maintenance	City of Boulder
P.W. Superintendant	City of Lafayette
P.W. Superintendant	City of Louisville
University of Colorado Police Services	University of Colorado
CDPHE Spill Hotline	Colorado Department of Public Health & Environment

When possible, e-mail communication of spill related information (reports, pictures, etc.) should be sent through the **Stormwater and Creek Contamination Response Group**.

ATTACHMENT 11

Distribution System SOP

[City of Boulder]

SOP for Contaminant Introduced in the Distribution System

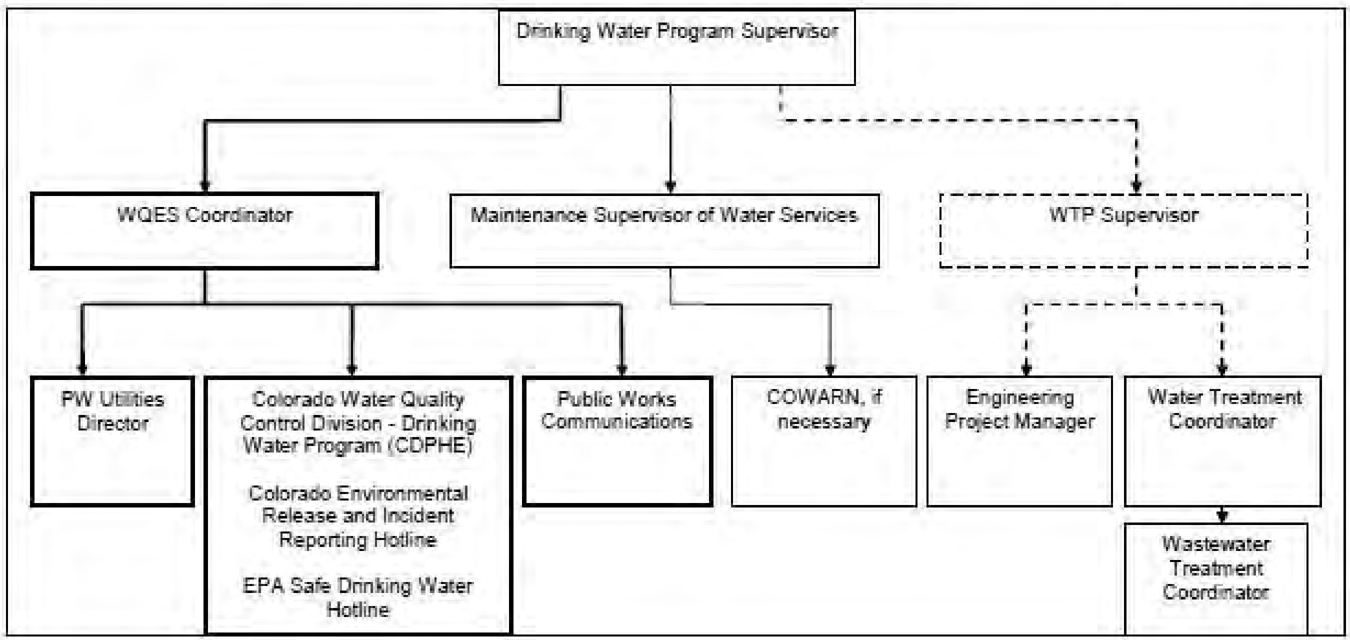
POTENTIAL CONTAMINANT IN THE DISTRIBUTION SYSTEM

PRESSURE LESS THAN 20 PSI, POTENTIAL BACKFLOW EVENT, CONTAMINANT FROM A WTP, OR OTHER KNOWN/SUSPECTED CONTAMINATION

SOP ORIGINATION DATE: January 2009 SOP REVISED DATE: November 2010

COMMUNICATION: CONTAMINATION INTRODUCED IN THE DISTRIBUTION SYSTEM

SEE COMMUNITY PLANNING AND PW EMPLOYEE ROSTER IN APPENDIX A FOR CONTACT INFORMATION



The incident coordinator will assign the following tasks and coordinate all communications.

1. **Confirm contamination:** For high hazard conditions, specially trained responders with HazMat training are required.
2. **Determine potential for health impacts:** infectivity, toxicity, waterborne disease outbreak.
   a. Coordinate with Boulder County Health Department and CDPHE.
   b. If emergency public notification is warranted, determine affected area per description in Section 3.a.
      i. Reverse 911 calls: Provide Boulder Police with extent of affected geographical area and the exact wording for the call. When feasible, the message should also be translated into Spanish.
      ii. Wording must first be verified by the Public Works Utilities Director, the Public Works Communications group, and potentially the Executive Director of Public Works and the City Manager, and may include:
         - Potential adverse health effects from the contaminant of concern.
         - The population at risk.
         - Whether alternate water supplies should be used or water should be boiled.
         - What actions consumers should take, including when to seek medical help, if known.
         - A statement encouraging recipients to distribute the information to other persons served.
      iii. The Public Works Communications group will also alert other media groups of the message.
      iv. Additional notification:
         - If contamination represents a MCL exceedance as defined by Colorado Primary Drinking Water Regulations (CPDWR) or is determined by CDPHE to present a risk to public health then Tier 1 Public Notification will be required within 24 hours of the determination.
         - If contamination represents a treatment technique or other violation of CPDWR then CDPHE may require Tier 2 Public Notification (within 30 days of determination) or Tier 3 Public Notification (within 1 year of determination).
         - If the contamination represents a substance identified with a secondary (not enforceable) limit by CPDWR then no public notification will necessarily be required. The City may elect not to issue public notification to avoid undue alarm.

3. **Contaminant Containment, Flushing and Valve Operations:** if the suspected contaminant poses no risks to employee safety:
   a. Determine and isolate area affected by contaminant, considering:
      i. Flow leaving the plants and system demands
      ii. Storage tank fill/empty status

iii. Flows at zone boundaries
iv. Hydroelectric and PRV station flows
v. Opened or closed valves in the distribution system
vi. System monitoring results

b. Begin flushing immediately:
   i. Flushing considerations:
      - First focus on large diameter pipes.
      - May be conducted at several hydrants in the system.
      - Hydrants can be located using GIS or quarter section maps.
      - For reporting purposes, record the number of hydrants open, their location, and their estimated flow and duration of flow. A fully open hydrant in the City of Boulder may have a flow of 500 – 1,000 gpm.
      - Must be started as soon as possible and may last several hours.
   ii. Disposal of flushed water:
      - Direct to sanitary sewers if approved by the Wastewater Coordinator and if sewer capacity are available.
         - ➢ If notified in advance, the WWTP can sequester up to four million gallons of contaminated water.
      - Otherwise, direct to storm drain
         - ➢ Dechlorinate.
         - ➢ Notify the state immediately.
         - ➢ Downstream users must be notified.
c. Treatment. Consider if temporarily increasing chlorine levels might help decontaminate the system.
d. Monitoring. The boundaries of the area being isolated and/or flushed as well as flushed water shall be monitored for the following until staff is confident the plume has been contained:
   i. Chlorine
   ii. pH
   iii. Turbidity
   iv. Conductivity
   v. Alkalinity or total hardness
   vi. Suspected contaminants
e. When possible, the situation may be modeled using the MWHSoft Infowater product.

4. Communications

a. Public Works Communications group will determine who should receive information, what types of information they should be given, and when and how they should be notified.

5. Security Issues

a. If there a possibility of intentional contamination by tampering/security breach, coordinate with:

   i. General Utility Security (GUS) coordinator
   ii. CDPHE
   iii. Law enforcement authorities

6. Contaminant Source

a. Determine source of contamination, considering:
   i. Source water known events
   ii. Changes or unusual spikes in treatment plant performance, such as filter effluent particle count data, turbidity data, plant effluent chlorine levels.
   iii. Whether contaminant suspected or identified in multiple locations in the distribution system.

7. Follow-up Monitoring

a. Begin in affected area.
b. Expand to cover entire system using TCR sampling sites or other sites as determined by staff.

ATTACHMENT 12

Training and Certification Materials

[CMUD]

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#156 – Lead Work Team in Planning and Performance of Tasks Assigned to the Team (Plan a Job)

Tasks	Performance Expectation	Performance Acceptable	Performance Not Acceptable
1. Based on source of work, manage and prioritize	• Verify where the work is coming from and that the work is valid (if water related, the work is not duplicated)		
2. Create a work or service order for the work in the CMMS	•		
3. Utilize Rapid Response/Tail-piece Crew or team leader to help verify the nature of the work and conditions of the site	•		
4. Locate the site (if dispatcher has not done so already)	• Document the locate number with the work or service order		
5. Compile a work package	• Work order or service order, appropriate topo maps and polaris map for address verification		
6. Assign work to crew	• Evaluate need to increase or decrease crew size • Verify equipment and material are available and stocked		
7. Following completion of work, close out the work or service order in the CMMS	• Verify the work order or job report is completed and accurate		

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#141 - Estimate Material, Labor and Equipment Requirements

Name of Person Being Evaluated:	
Skill/Task Being Evaluated:	#141 - Estimate material, labor, and equipment requirements
Category/Level of Skill	General, Level 3, Core Skill
Typical Demonstration of Skill/Task:	Person being evaluated shall demonstrate ability to Estimate material, labor, and equipment requirements
Pre-Requisites for this Skill/Task	112 - Perform basic, work-related mathematical calculations 113 - Read and understand directional maps (roads, streets) 144 - Complete routine documentation such as work order, job reports, spill reports, PRDs, truck safety inspections 145 - Read and understand topo maps
Tools, Equipment, Materials needed for demonstration:	Measuring tape, materials sheet, calculator, grade rod, topo maps
Average time allowed for this demonstration:	2 hours
Preferred location/condition to conduct demonstration:	Classroom
Notes:	For new construction

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#141 - Estimate Material, Labor and Equipment Requirements

Tasks	Performance Expectation	Performance Acceptable	Performance Not Acceptable
1. Assess conditions of work site	•		
2. Measure for materials and determine types and quantity of materials	•		
3. Determine crew size and level of skills	•		
4. Estimate the job cost based on findings	•		

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#135 - Locate Infrastructure Such as Lines or Valves (using Standard Equipment)

Name of Person Being Evaluated:	
Skill/Task Being Evaluated:	#135 - Locate infrastructure such as lines or valves (using standard equipment)
Category/Level of Skill	General, Level 3, Core Skill
Typical Demonstration of Skill/Task:	Person being evaluated shall demonstrate ability to locate infrastructure using the radio frequency detection equipment (MetroTech)
Pre-Requisites for this Skill/Task	145 - Read and understand topo maps
Tools, Equipment, Materials needed for demonstration:	Radio frequency detection equipment (MetroTech) transmitter and receiver, blue spray paint, Topo maps, batteries
Average time allowed for this demonstration:	30 minutes
Preferred location/condition to conduct demonstration:	Demonstration to be conducted in the yard or field
Notes:	Implement a training course (using vendor video tape) on the MetroTech equipment and locating procedures

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#135 - Locate Infrastructure Such as Lines or Valves (using Standard Equipment)

Tasks	Performance Expectation	Performance Acceptable	Performance Not Acceptable
1. Review Topo map for location of pipe (or valve), and pipe size	•		
2. Determine access point (key box, hydrant, meter, etc)	• For PVC, look for tracer wire (not always present)		
3. Connect transmitter to the access point	•		
4. Turn ON MetroTech	• If battery indicator is low, replace batteries		
5. Sweep area with receiver to locate a conductive signal	•		
6. Once correct conductive signal is found, mark line using "blue" spray paint	•		

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#48 - Lead in Construction/Repair Situations

Name of Person Being Evaluated:	
Skill/Task Being Evaluated:	#48 - Lead in construction/repair situations where experience is necessary due to depth, traffic, other utility lines, condition of infrastructure, size of infrastructure, extenuating circumstances
Category/Level of Skill	Construction/Repair, Level 4, Core Skill
Typical Demonstration of Skill/Task:	Person being evaluated shall demonstrate ability to lead in construction/repair situations
Pre-Requisites for this Skill/Task	1 – Dig out utilities by hand (non-CMU utilities) 74 – Knowledge of off-street conditions such as terrain, hazards 78 – Identify erosion that can cause system damage 83 – Operate an arrow board 97 – Operate a rubber tire backhoe for excavating and back filling 98 – Operate a mini-excavator (does not qualify for a trackhoe) 112 – Perform basic, work-related mathematical calculations 118 – Demonstrated ability to use 2-way radio 122 – Knowledge of gas monitor operation 137 – Work zone safety training 138 – Act as a competent person 139 – Proper use of confined space safety procedures 142 – Initiate a work order based on the identified problem in the field 145 – Read and understand topo maps
Tools, Equipment, Materials needed for demonstration:	Topo maps, Safety zone equipment, arrow board, 2-way radio, valve wrench, backhoe, shovel, street saw, track hoe, work order form
Average time allowed for this demonstration:	2 - 3 hours

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

Preferred location/condition to conduct demonstration:	Demonstration to be conducted in the field
Notes:	Reactive

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

#48 - Lead in Construction/Repair Situations

Tasks	Performance Expectation	Performance Acceptable	Performance Not Acceptable
1. Observe the conditions of the work site and establish a plan of action	• Posses the experience/knowledge to access extenuating circumstances		
2. Make notifications as needed	• Posses the experience/knowledge to access extenuating circumstances		
3. Call for local utility locate	•		
4. Observe and setup safety equipment to maintain safety work zone	•		
5. Once above items are completed, begin repairs to include cutting off water (water), calling in street cut (as needed), excavating, obtaining parts for repairs, repairing pipe, backfilling, prepping cut for asphalt (as needed), turning water service back on (water)	• Posses the experience/knowledge to access extenuating circumstances		
6. Make notifications of complete repair, street patch, hydrants, street opening, etc.	•		
7. Take down safety zone	•		

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

CR 33A – Lead in Repairing Distribution System Mains

Name of Person Being Evaluated:	
Skill/Task Being Evaluated:	**CR 33A** – Lead in Repairing Distribution System Mains
Category/Level of Skill	Construction and Repair, UTIII Level I Core Skill
Typical Demonstration of Skill/Task:	Person being evaluated shall demonstrate ability to lead in repairing distribution mains.
Pre-Requisites for this Skill/Task	**97 -** Operate a rubber tire backhoe for excavating and back filling. **106** - Use hand tools to complete job site tasks (shovel, rake, broom, etc.) **119** - Safety training **115-**Field Customer Service **116**-Public notification procedures **10,128**-Chlorine Analyzer and Turbidimeter tests procedures **54**-Water Distribution valve Operation procedures **39, 137, 138, 139**-Lead level safety skills involving competent person, work zone safety, trenching and shoring, confined space safety procedures.
Tools, Equipment, Materials needed for demonstration:	PPE. Identified hand tools, excavation equipment, trenching and shoring equipment, indentified pipe and repair fittings.
Average time allowed for this demonstration:	Field Demonstration: 1-3 hours depending on type of repair and circumstances involved.
Preferred location/condition to conduct demonstration:	Field Demonstration and evaluation.
Notes:	

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

CR 33A – Lead in Repairing Distribution System Mains

Tasks	Performance Expectation	Performance Acceptable	Performance Not Acceptable
1. Individual safety PPE required.	• Ensure safety of workers involved in the water line repair		
2. Follow standard public notification procedures for water service interruption.	• Meet customer service public notification standards of work to be performed.		
3. Set up safety zone as required for repair and exaction site.	• Understand work zone safety procedures.		
4. Have available necessary trench and shoring equipment for site excavation as required.	• Knowledge of soil type and conditions. Able to identify necessary trench and shoring requirements.		
5. Assist locating utilities and verify utilities are marked.	• Knowledge of color markings.		
6. Identify and operate distribution system valves for water main isolation.	• Understanding of valve operation procedures.		
7. Use appropriate hand tools such as punch rod, shovel, and sharp-shooter to locate utilities	• Dig around utilities so that they are clearly visible to backhoe operator.		
8. Remove top layer of soil or grass with appropriate hand tools and soft-dig for utilities.	• Use of appropriate tools for digging to prevent utility damage.		
9. Continue digging with hand tools and/or excavating equipment until water main is located and expose section of pipe to be repaired.	• Identify area and type of repair.		
10. Cut and remove section of pipe to be repaired	• Use of appropriate pipe cutting equipment.		

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

11. Prepare pipe and/or repair fittings. Disinfect pipe and repair fittings by swabbing with chlorine solution.	• Identify appropriate repair fittings and pipe material necessary for main repair.		
12. Install disinfected repair pipe and/or repair fittings and tighten securely.	• Understand pipe and repair fitting procedures.		
13. Operate identified isolation valves to put main back in service.	• Bleed air from line. • Check repair site for leaks.		
14. Perform and document standard chlorine and turbidimeter tests results.	• Ensure water quality and chlorine residual standards of distribution system after repair.		
15. Back fill repair site with appropriate fill material and compact in lifts to ensure soil compaction.	• Ensure soil compaction standards		
Landscape repair site or make identified street repairs	• Meet repair site standards to meet customer service expectations		

Charlotte-Mecklenburg Utilities
Training and Certification Program - Skill Evaluation

Verification of Evaluation
This skill evaluation was completed and evaluated on _______________ (date). ______________________________ ___________________________________ Signature of Employee Signature of Evaluator (Team Leader)
Provide additional comments in this space.

APPENDIX D:
RISK MODELING, LABORATORY AND PILOT STUDIES

There are estimated over 700 water main breaks and repairs in the United States every day and many more in United Kingdom. Many of these breaks are small and repaired with a clamp with pressure maintained in the pipe. There is little chance for contaminants to enter the distribution network. At the other end of the spectrum, some breaks are much larger, even catastrophic events that may result in widespread depressurization and involve removing and replacing sections of pipe and valves. This type of breaks has the potential to allow entry of microbial (and chemical) contaminants both at the repair site and also in the depressurized areas of the distribution system away from the break area.

Recently, LeChevallier et al. (2011) completed a quantitative microbial risk assessment (QMRA) for virus (norovirus and rotavirus) intrusion during negative pressure events in distribution systems. The research coupled Monte-Carlo simulations of pathogen intrusion and transport within distribution systems with hydraulic, water quality, and surge models to capture the impact of system-specific vulnerabilities, system hydraulics, disinfectant decay, and pathogen inactivation kinetics. It enabled the development of risk-based best practices for operation and maintenance protocols to reduce the microbial infection risks due to negative pressure transients. Since a main break was just a special case of intrusion, we built on this prior experience in this study and considered other pathogens (bacterial and protozoa), a wider array of disinfection kinetics (suspended and particle-associated), and the effects of flushing. However, this study was somewhat simplified. The risk was estimated at the first customer downstream of the main break. The transport and mixing of contaminants within the distribution system were not modeled. This allowed us to focus on detailed studies of disinfection and flushing as procedures to mitigate contamination risks due to main breaks. This part of the report summarizes the risk modeling, the laboratory studies for disinfectant decay, microbial inactivation, and flushing.

QUANTITATIVE MICROBIAL RISK ASSESSMENT

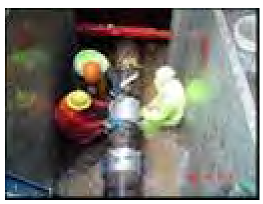
Overview

The construction and repair of water mains are activities that occur regularly in all water systems. It provides the potential for direct contamination of the distribution system, which can be linked with direct public health risks. The potential risk is a function of the extent and severity of a main break event. During depressurization, pathogens external to water pipes may enter isolated pipe segments. Infection risks from pathogens (bacteria, virus, and protozoa) can be estimated for the first downstream customer. Derived from the chemical risk assessment framework, typical steps of a QMRA include hazard identification, exposure assessment, dose-response assessment, and risk characterization (NRC 1983; ILSI 2000). A framework of risk assessment for main break and depressurization has been developed and summarized as shown in Figure D.1:

1. Evaluate pathogen levels near water mains (meta-analysis of occurrence levels collected from literature)

2. Main breaks and depressurization (intrusion and dilution)

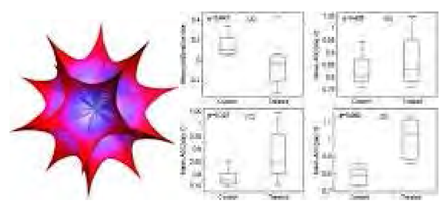
3. Evaluate main break repairs and back to service
    a. Pathogen levels reduced by flushing
    b. Pathogen levels reduced by disinfection



4. Incorporate individual water intake by the first downstream customer

5. Collect dose-response models from literature

6. Characterize risks by Monte-Carlo simulations in Mathematica 8.0



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

Figure D.1 Schematic of QMRA for a main break and depressurization event

Exposure Assessment

Source of Contamination

Estimating microbial risks from intrusion began with an investigation of pathogen concentrations exterior to water distribution systems. Karim et al. (2003) examined 66 soil and water samples immediately adjacent to drinking water pipelines from eight utilities in six states. Total coliform and fecal coliform bacteria were detected in about half of the water and soil samples, indicating the presence of fecal contamination. About 56% of the samples were found positive for human enteric viruses. In addition, total fecal coliform levels in some soil samples were greater than 1.6×10^4 CFU/100 grams of soil, suggesting that the sampling locations were under the influence of potential leaking sewage pipes. The occurrence levels of norovirus, *E coli O157*, and *Cryptosporidium* (representing bacteria, virus, and protozoa, respectively) in wastewater were collected from literature as shown in Table D.1. It served as the baseline worst case conditions for the risk modeling (i.e. when water main breaks are in direct contact with raw sewage).

Table D.1
Reported occurrence levels of norovirus, *E coli O157*, and *Cryptosporidium* in sewage

	Literature Study	Minimum	Maximum	Mean	Unit
Norovirus (virus)	Lodder and de Roda Husman (2005)	5.1×10^3	8.5×10^5	N/A	PDU/L
	Pusch et al. (2005)	$<1.0 \times 10^6$	1.6×10^9	N/A	gen/L
	Ottoson et al. (2006)	$<5.5 \times 10^2$	4.5×10^3	3.0×10^2	MPN/L
	Haramoto et al. (2006)	1.7×10^2	2.6×10^6	N/A	gen/L
E coli O157 (bacteria)	Lee et al. (2006)	N/A	N/A	7.2×10^2	gen/100mL
	Ibekwe et al. (2002)	4.8×10^1	3.1×10^7	N/A	CFU/mL
	Shannon et al. (2007)	N/A	$<2.2 \times 10^1$	N/A	gen/L
	Heijnen and Medema (2006)	4.0×10^2	5.0×10^3	N/A	MPN/L
Cryptosporidium (protozoa)	Payment et al. (2001)	1.0×10^0	5.6×10^2	2.6×10^1	oocysts/L
	Robertson et al. (2000)	1.8×10^1	1.4×10^2	9.6×10^1	oocysts/L
	Ottoson et al. (2006)	$<2.0 \times 10^0$	2.2×10^2	5.0×10^0	oocysts/L
	Lim et al. (2007)	1.0×10^0	8.0×10^1	N/A	oocysts/L
	Robertson et al. (2006)	1.0×10^2	1.1×10^3	2.4×10^2	oocysts/L
	Montemayor et al. (2005)	4.0×10^1	3.4×10^2	1.3×10^2	oocysts/L
	Farias et al. (2002)	5.0×10^1	1.2×10^3	4.8×10^2	oocysts/L
	Morsy et al. (2007)	N/A	N/A	4.4×10^1	oocysts/L
	Quinonez-Diaz et al. (2001)	N/A	N/A	1.4×10^2	oocysts/L
	Carraro et al. (2000)	N/A	N/A	5.0×10^0	oocysts/L
	Kfir et al. (1995)	0.0×10^0	5.0×10^1	3.0×10^0	oocysts/L
	Roach et al. (1993)	$<1.0 \times 10^0$	7.4×10^1	N/A	oocysts/L
	Suwa and Suzuki (2001)	8.0×10^0	5.0×10^1	N/A	oocysts/L
	Crockett (2007)	5.0×10^0	5.0×10^4	N/A	oocysts/L

Note: MPN/L = Most probable numbers per liter; PDU/L = PCR detectable units per liter; gen/L = genome copies per liter; N/A = not available.

Various studies have reported concentrations of enteric viruses in sewage using a range of detection methods with different units. Qualitative differences between concentrations estimated by different enumeration methods were considered, as culture methods (e.g., MPN/L) might yield lower estimates than methods based on detection of genetic material (polymerase chain reaction - PCR). To summarize these results for risk modeling, pathogen levels were characterized by quantiles of concentrations and combined in a two level "meta-analysis" model, producing a predictive distribution of pathogen concentrations in sewage near water distribution piping. The hierarchical structure of the two-level model is shown in Figure D.2: a collection of studies (i = 1, …, $n_{studies}$) with the observed "Max", "Min" and "Mean" (some of which may be missing) were characterized by their individual means and standard deviations μ_i and σ_i. The joint distributions of means μ_i and standard deviation σ_i were again characterized by their means (μ_μ the mean of means; and μ_σ the mean of standard deviations), and standard deviations (σ_μ the standard deviation of means; and σ_σ the standard deviation of standard deviations). Re-sampling from these "hyper"–distributions of (μ, σ) generalized the distribution of pathogen concentrations from all the studies. Distributions of pathogen concentrations were assumed to be lognormal and log10 pathogen concentrations were then normally distributed.

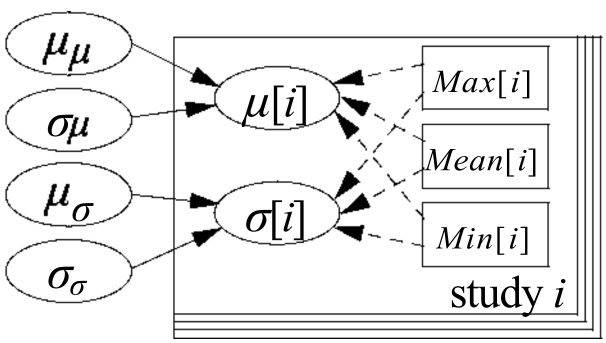
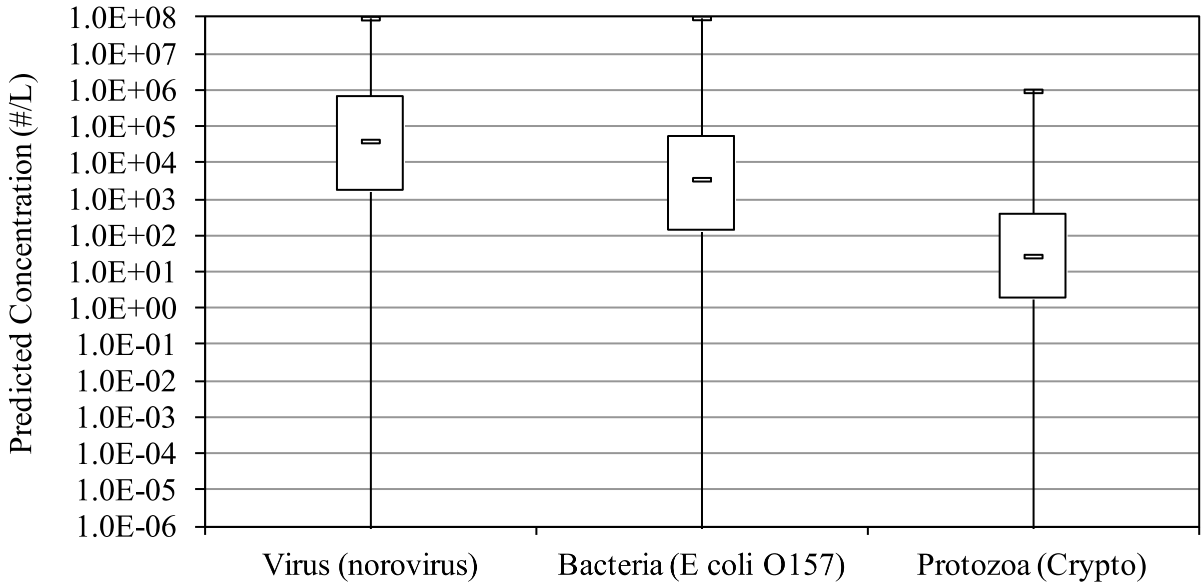


Figure D.2 Directed acyclic graph of the two–level model for analysis of multiple study results

The simulated concentrations (#/L) of pathogens in raw sewage are shown in Table D.2. There are considerable variations of pathogen concentrations in sewage reflected by the wide range of predicted concentrations. This heterogeneity suggests that the levels of pathogen concentrations exterior to distribution pipes can be highly variable. Because pathogen concentrations in sewage higher than the reported maximum values were not considered plausible, the predicted norovirus, *E coli O157*, and *Cryptosporidium* concentrations were censored at 10^8, 10^8, and 10^6 #/L, respectively, as shown in Figure D.3.

Table D.2
Summary of predicted concentrations of pathogens in sewage

Pathogens Levels (#/L)	Geometric Mean	$Q_{0.025}$	Median	$Q_{0.0975}$
Norovirus (virus)	1.59×10^{4}	1.98×10^{-4}	2.38×10^{4}	1.39×10^{10}
E coli O157 (bacteria)	3.19×10^{3}	1.57×10^{-7}	5.21×10^{3}	2.47×10^{11}
Cryptosporidium (protozoa)	2.58×10^{1}	2.03×10^{-3}	2.84×10^{1}	2.41×10^{5}



Note: The box represents values between the 25th and 75th percentile, while the bar at the center of the box represents the median. The high bars represent the maximum Monte-Carlo simulated values. The simulated minimum values are in the range of 10^{-19} (not shown in the plot).

Figure D.3 Simulated concentrations of pathogens in sewage

Pathogen Intrusion and Dilution

Intrusion of raw sewage is assumed during depressurization and main break repairs. Pathogen levels in raw sewage are simulated by the meta-analysis of occurrence levels as previously described. After repairs, the pipe is charged and pressurized before resuming service to customers. Pathogen levels will be diluted by potable water, which is assumed a normal distribution between 0.01% and 1.0% of volume ratio (i.e., 2-4 log of dilution). This sets the boundary condition of the maximum 1.0% sewage intrusion for the risk modeling. In field, intrusion volumes of tens to hundreds gallons of raw sewage would be needed (unrealistic) to have a volume ratio of greater than 1.0% for 300 feet of 4-24 inch pipes shut down for main break repairs (Table D.3).

Table D.3
Volume ratios of intrusion in 300 feet isolated pipe

Pipe Diameter (inch)	Intrusion Volume (gallon)			
	0.1	1	10	100
4	0.05%	0.51%	5.1%	51%
6	0.02%	0.23%	2.3%	23%
8	0.01%	0.13%	1.3%	13%
10	0.01%	0.08%	0.82%	8.2%
12	0.01%	0.06%	0.57%	5.7%
16	0.00%	0.03%	0.32%	3.2%
24	0.00%	0.01%	0.14%	1.4%
36	0.00%	0.01%	0.06%	0.63%
72	0.00%	0.00%	0.02%	0.16%

Figure D.4 shows the predicted pathogen concentrations after dilution, about 3-log reduction from the levels in raw sewage. For norovirus, the simulated concentrations after dilution were comparable to the values reported in a recent study (Borchardt et al., 2012), where drinking water concentrations of enteroviruses and norovirus were on the order of ones to hundreds of genomic copies per liter found in 14 non-disinfected distribution systems.

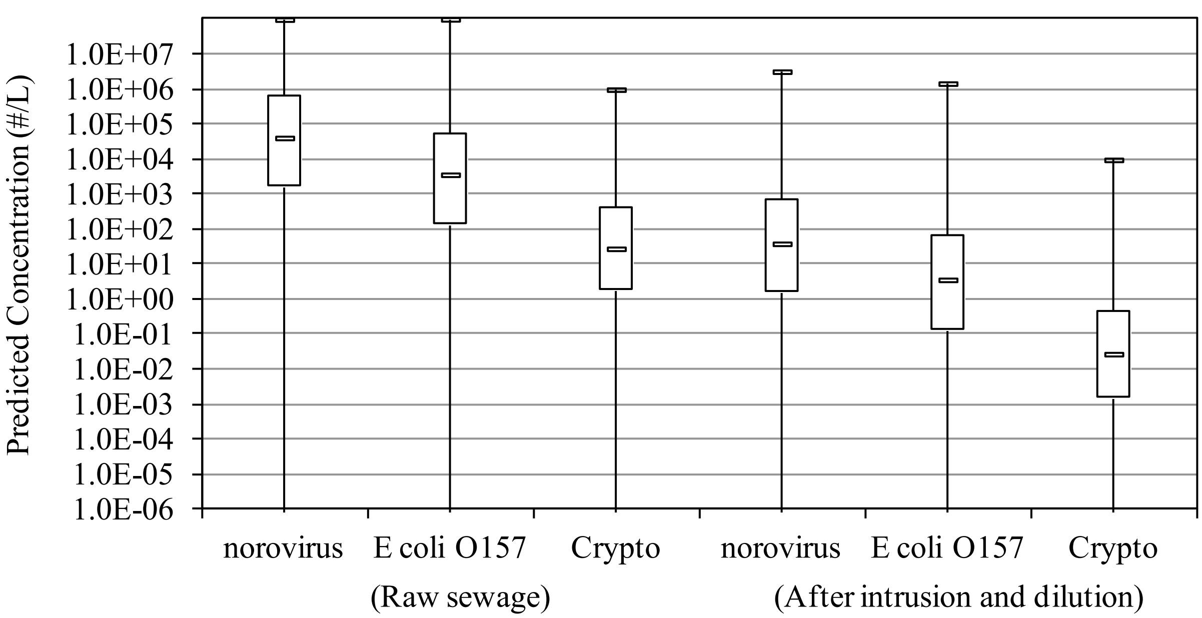


Figure D.4 Predicted pathogen concentrations after intrusion and dilution

Pathogen Levels after Main Break Repairs

To model the reduction of pathogen levels after main break repairs, three pieces of information need to be determined: the disinfectant demand, the inactivation kinetics of disinfection, and the effectiveness of flushing. Pathogens are either free-suspended or particle-attached. The percentage of suspended or particle-associated pathogens during intrusion may vary substantially due to different sizes, shapes, and surface charges of pathogens and particles. Winward et al. (2008) reported up to 91% of total coliforms in chlorinated grey water were particle-associated. Templeton et al. (2005) reported that the degree to which each MS2 phage became particle-associated varied substantially between replicate trials, e.g. ranged from 47% to 95% of particle-associated in the Kaolin Clay Floc samples. In this study, it was assumed normal distribution of 10-100% of pathogens attached to particles. For the purpose of the risk modeling, the experimental results on the reduction of pathogen levels by flushing and disinfection (detailed in later sections) were incorporated into the risk model as following.

a. Because all suspended pathogens should be removed by flushing (i.e., flushing would remove 0-1 log of the total pathogens), the risk modeling was based on the remaining soil-associated organisms. The removal of the remained soil-attached pathogens by flushing was modeled with normal distribution between 2-3 logs of removal.
b. Normal distribution between 4-5 logs of inactivation was modeled for disinfection of virus and bacteria.
c. Disinfection had no reduction on the *Cryptosporidium* levels.

Individual Water Intake

Infection risks are to be estimated for the first customer downstream of a main break. The USEPA generally employs a volume of 2 liters per person per day to estimate drinking water exposure for chemical risk assessment, however, only a fraction of which may be consumed unmodified (e.g., not boiled). In this study, the daily intake of unheated tap water was estimated from a population survey (Teunis et al. 1997) and approximated by a lognormal distribution with a median water consumption of 0.18 liter (Figure D.5).

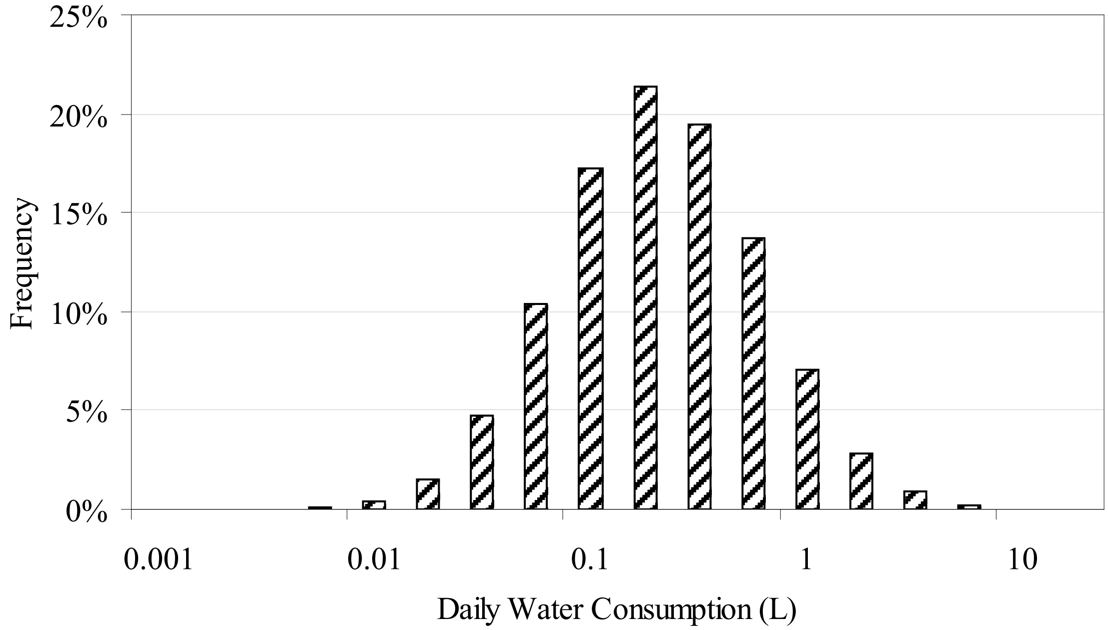


Figure D.5 Distribution of unheated tap water consumption

Dose Response Models

The dose response relationship of norovirus (Teunis et al., 2008a) is shown on Figure D.6a. The infectivity of norovirus (Norwalk virus) had been inferred from human challenge studies, and could be characterized by a (beta) probability distribution for the distribution of infectivity of a single Norwalk virus particle. A Monte Carlo sample of parameter pairs was used to characterize the uncertainty in infectivity (Teunis et al., 2008a). The model indicated high infectivity of the virus, e.g., exposure to a single norovirus could cause infection in about 30% of exposed population. The dose response relationship of *Cryptosporidium* (Messner et al., 2001) was used in the risk model, which included three different *Cryptosporidium* parvum isolates (IOWA, TAMU, and UCP). The maximum likely-hood dose-response curves are shown on Figure D.6b. Base on the meta-analysis, the risk of infection for a dose of one oocyst from the population of all *Cryptosporidium* strains was 0.028. A hierarchical Beta-Poisson dose response model of *E. coli O157:H7* developed from human outbreaks incorporating heterogeneity in exposure was used (Teunis et al., 2008b) and the sets of parameter pairs (α, β of the Beta-Poisson model) were obtained from the authors. The average infection risk for exposure to a single *E. coli O157:H7* was estimated to be 0.029 (the dose-response curves not shown).

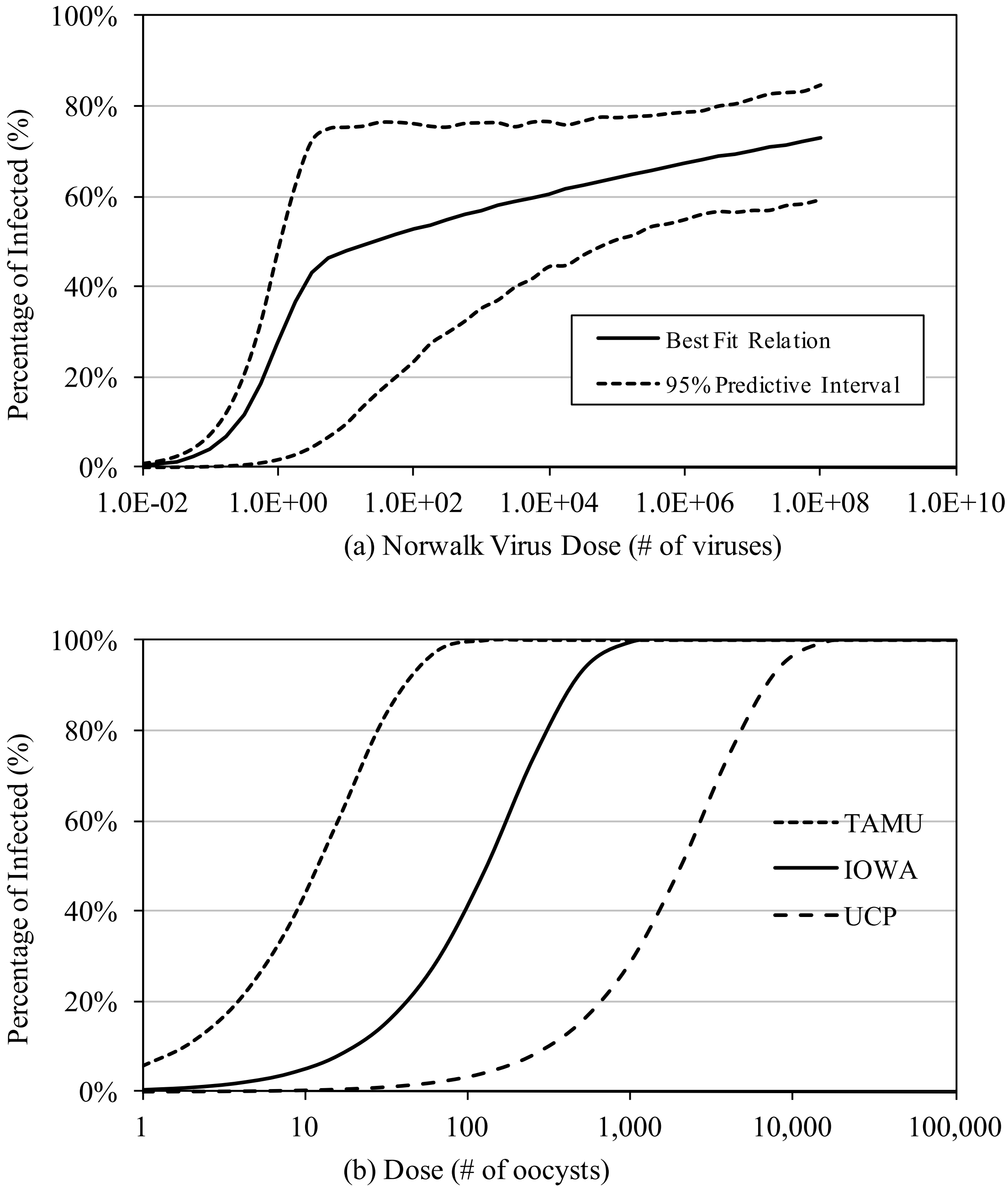


Figure D.6 Dose response relations of norovirus (a) and *Cryptosporidium* (b)

Risk Characterization

After exposure assessment, the dose response models were incorporated to estimate the infection risk of different pathogens at the first downstream customer. It was assumed that the first downstream customer would intake untreated tap water immediately after the broken main was repaired and back to service. The risk model was then developed using Monte Carlo simulation programmed in Mathematica 8.0 (Wolfram Research Inc., Champaign IL, USA). The Monte Carlo simulation was run with 10,000 repetitions or more. During each Monte Carlo repetition, the following random variables were generated or derived: external pathogen levels, reduction of pathogen levels after main break repair (dilution, flushing and/or disinfection), individual water intake volume, and pathogen infectivity. Figure D.7 summarizes the flow chart of the Monte Carlo simulations.

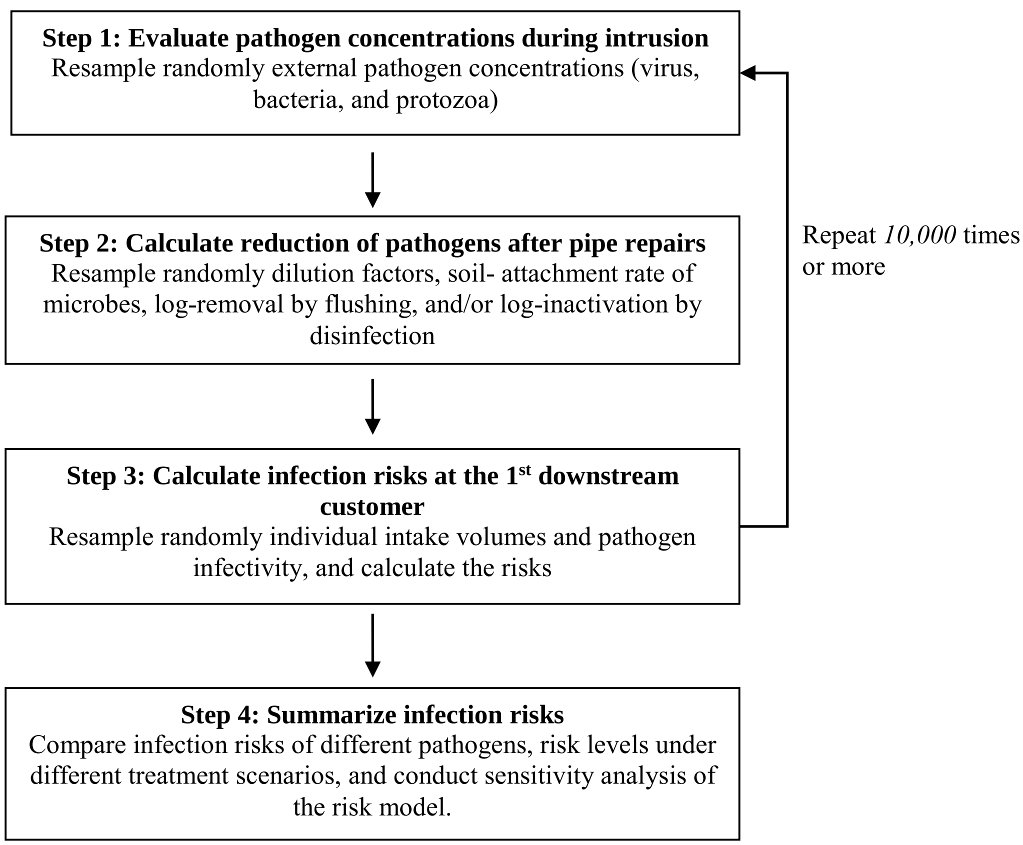


Figure D.7 Flow chart of Monte Carlo simulation of infection risks

The water industry has an average of 23-27 breaks/100 miles/year (AWWA, 2007). It is not uncommon that 1%-5% of main breaks are depressurized. The risk model predicted the following risk levels under different scenarios. For comparison, the USEPA has used an acceptable infection risk of 1 x 10^{-4} per person per year through drinking water contamination for regulatory purposes (NRC, 2006). Some previous risk study (Lambertini et al., 2012) has used median risk estimates of Monte Carlo simulations to compare with the 1 x 10^{-4} risk level. By definition 50% of the simulated risk levels would exceed the median level. In this study, arithmetic mean risk estimates were used as the control risk to compare with the 1 x 10^{-4} level, which was more conservative because the arithmetic mean risk levels were about 1-2 logs higher than the median values in this study (see results following).

Baseline Risk Levels (Dilution Only)

The baseline risk levels were estimated for the scenario that would have no flushing or disinfection during main break repairs. Figure D.8 shows the box and whisker plot of simulated infection risks for virus (norovirus), bacteria (*E coli O157*), and protozoa (*Cryptosporidium*) pathogens. This displays the entire risk distribution of the Monte-Carlo simulations. The center of the box represents the 50^{th} percentile or median risk value. The upper and lower edge of the box represent the 75^{th} and 25^{th} percentile risk values, respectively, and the whiskers extend to the maximum and minimum values of the Monte-Carlo simulations. Norovirus and *Cryptosporidium* had the highest and the lowest risks, respectively. These different risk levels were primarily due to different occurrence levels of the pathogens in sewage and different infectivity of each pathogen.

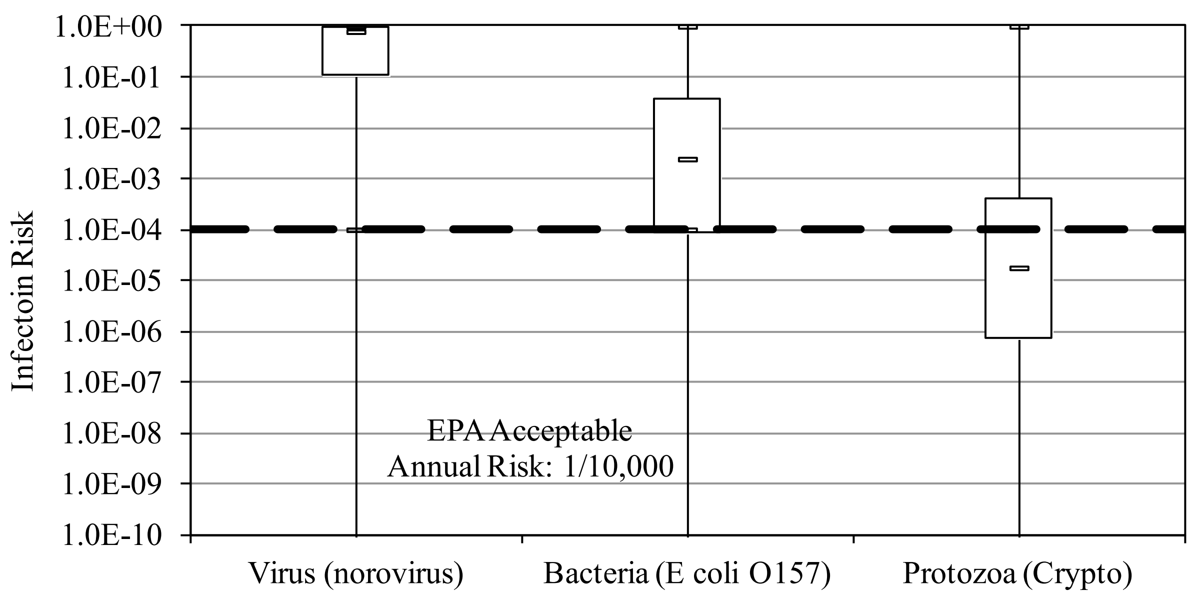


Figure D.8 Risks of infection after a main break and depressurization event (dilution only, no flushing or disinfection)

Figure D.9 shows the arithmetic mean risks of all three pathogens. As expected, there were significant risks from sewage intrusion if left untreated, especially from virus with an arithmetic mean risk of 0.59. The mean risks for bacteria and protozoa were also estimated at 0.095 and 0.017, respectively. These risk levels are comparable to the values reported in a cohort study of drinking water consumers in Norway (Nygård et al., 2007), which found that households exposed to water from a segment of distribution system where there had been a main break or maintenance had an increased risk of 0.047 (or 4.7%) to report gastrointestinal illness than households that were not exposed to such events.

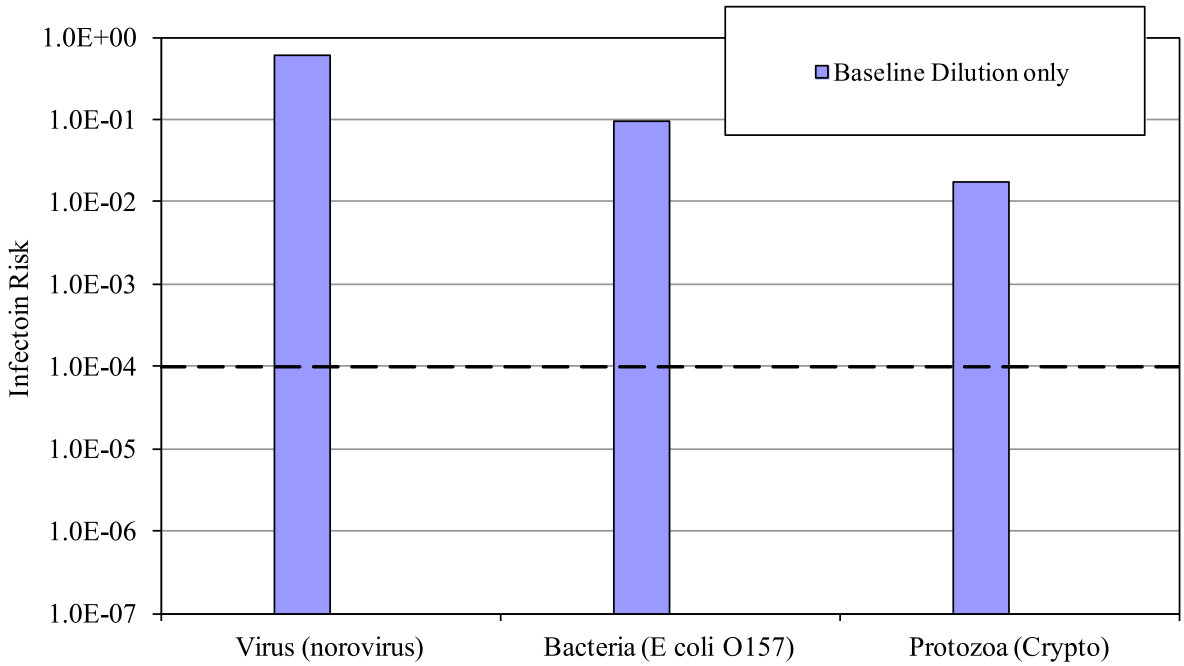


Figure D.9 Arithmetic mean infection risks of norovirus, *E coli O157*, and *Cyptosporadium* (dilution only)

Risk Levels after Flushing (Dilution + Flushing)

Pathogen levels would be further reduced by flushing assuming disinfection is not conducted. Figure D.10 shows the box plot of simulated infection risks after flushing. The infection risk levels of all three pathogens were reduced by 2-3 logs in general. As shown on Figure D.11, the arithmetic mean risk of *Cryptosporidium* was reduced below the USEPA acceptable level of 10^{-4}. However, the risks from virus and bacteria still remain high (the estimated arithmetic mean risk of 0.11 for norovirus).

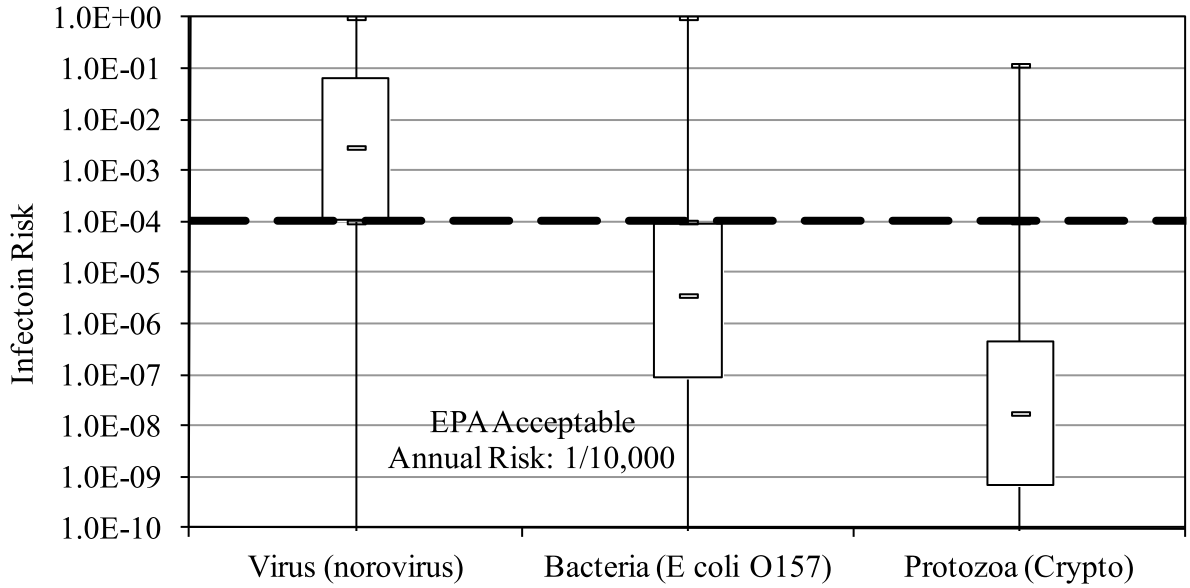


Figure D.10 Risks of infection after a main break and depressurization event (dilution and flushing)

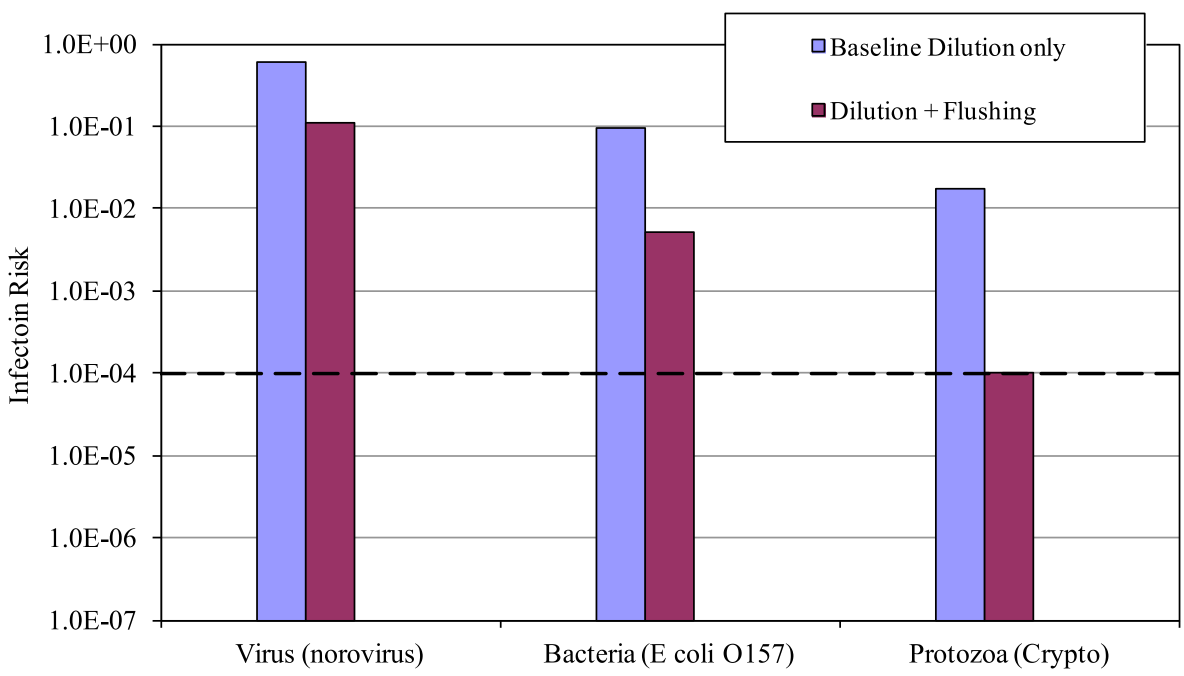


Figure D.11 Arithmetic mean infection risks of norovirus, *E coli O157*, and *Cyptosporadium* (dilution and flushing)

Risk Levels after Flushing and Disinfection (Dilution + Flushing + Disinfection)

The virus and bacteria levels need to be further reduced to lower the risks. The following assumptions were made to evaluate what levels of disinfection would be needed to control the risk below the acceptable level.

a. Normal distribution between 4-5 logs of inactivation was assumed for the reduction of virus and bacteria.
b. Disinfection had no reduction on the *Cryptosporidium* levels.

The simulated infection risks for norovirus and *E coli O157* were reduced by 4-5 logs, while the *Cryptosporidium* infection risk remained the same (Figure D.12).

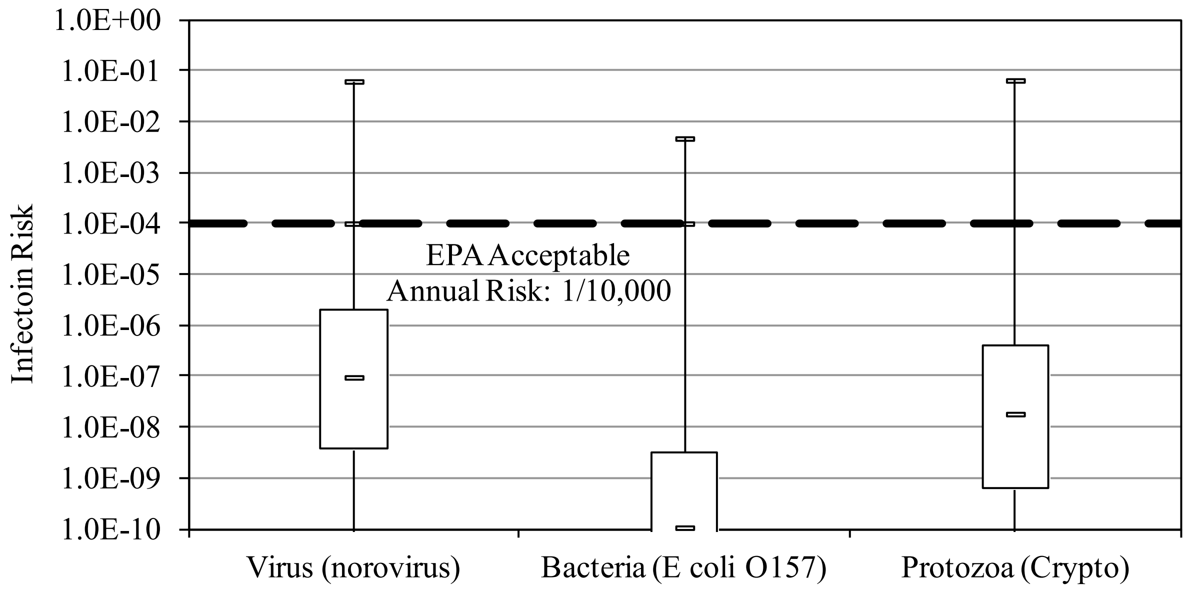


Figure D.12 Risks of infection after a main break and depressurization event (dilution, flushing, and disinfection)

The arithmetic mean risks of all three pathogens are reduced below the acceptable 10^{-4} level (Figure D.13). It suggested that a combination of effective flushing (2-3 logs of particle removal) and disinfection (4-5 log inactivation of virus) would be needed to achieve the acceptable risk levels.

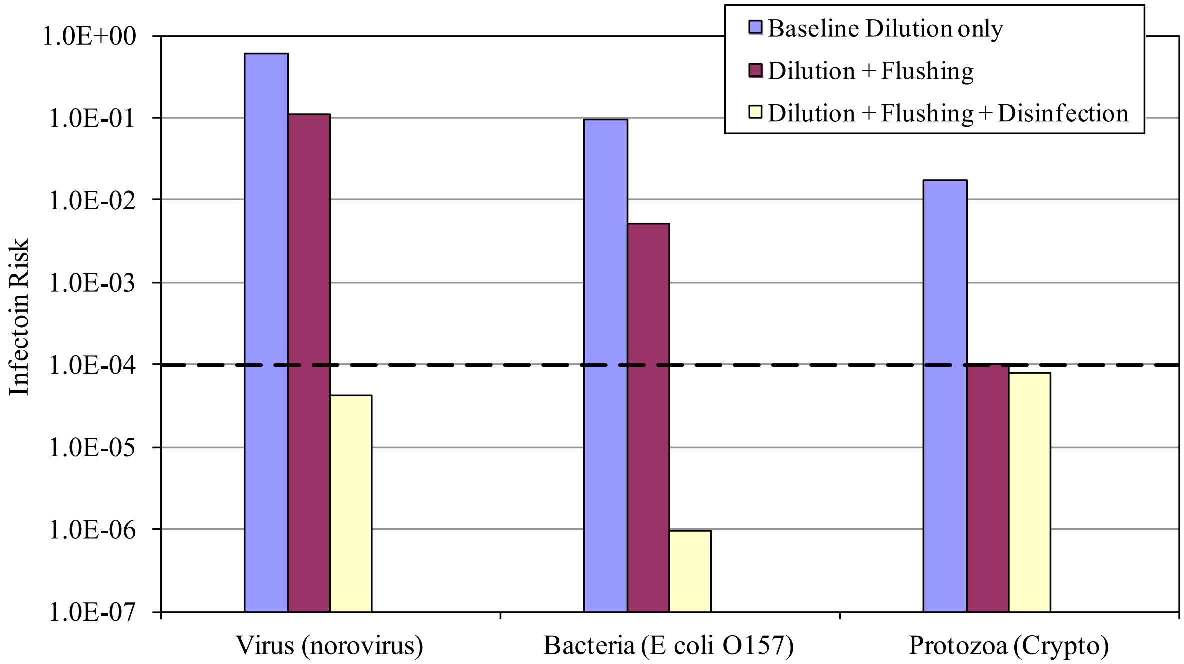


Figure D.13 Arithmetic mean infection risks of norovirus, *E coli O157*, and *Cyptosporadium* (dilution, flushing, and disinfection)

Sensitivity Analysis

In order to compare the contribution of individual random factors to the risk of infection, a sensitivity analysis was conducted for the infection risk of norovirus. The purpose of the analysis was to evaluate the variation of the modeled risk due to the randomness of the input random variables. The random factors included in the sensitivity analysis were:

- Virus concentration in sewage
- Pathogen reduction after main break repairs, dilution, flushing, and/or disinfection
- Water consumption at an intake event
- Infectivity of the virus

When all factors were kept fixed at their respective average values, the risk of infection would have no variation (see Figure D.14). The sensitivity of the infection risk to each contributing factor was evaluated by fixing the factor at the respective average value while keeping the other factors randomly distributed at their respective ranges. The strongest influence on the variation of the infection risk was shown to be from external virus concentrations, or the virus occurrence levels in raw sewage. In a previous QMRA study for intrusion caused by negative pressure transients (LeChevallier et al., 2011), external virus concentration was the third most sensitive factor. The coincidence and negative pressure duration were two most dominant sensitivity factors. In this study, risk was assessed at the first downstream customer. The first downstream customer was assumed to intake untreated tap water immediately after the broken main was repaired and resumed service (i.e. no coincidence factor). This significantly simplified the risk model and the risk estimates were conservative. All other factors contributed much less to the risk of infection and these factors could be ranked in a descending order as follows: virus reduction by repair, virus infectivity, and unheated tap water intake.

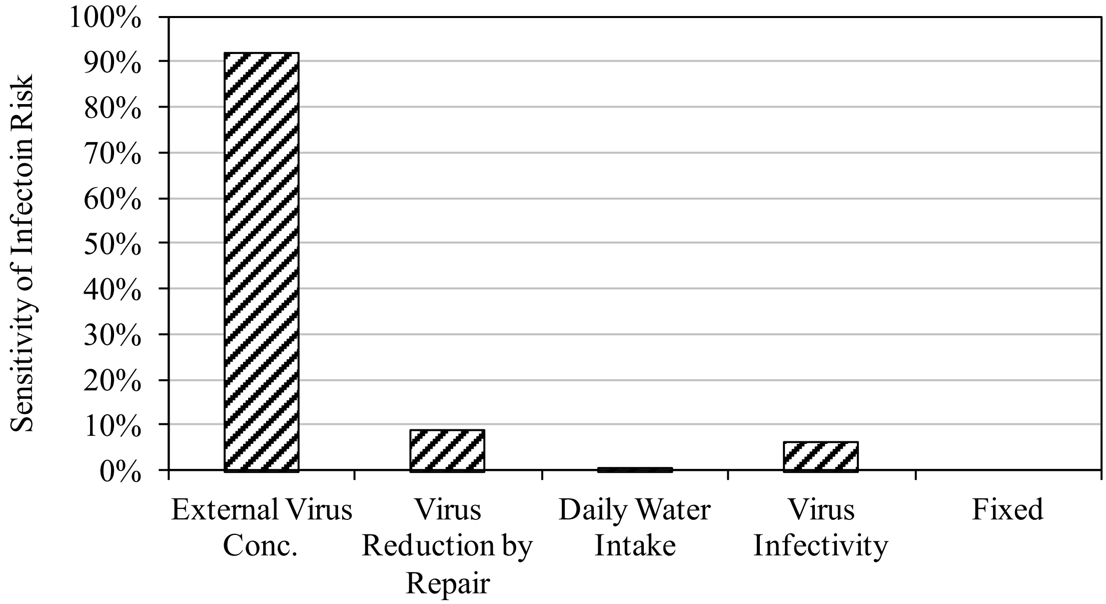


Figure D.14 Influence of single factors on the average risk of norovirus infection

Limitation and Applications

The developed risk model is overall conservative. The model assumes that pathogen levels of raw sewage existed external to the distribution system. A main break and depressurization event occurred where system physical and hydraulic integrity were breached. The risk was estimated at the first downstream customer assuming immediate water consumption after the main break repair. This creates a “worst case” scenario in that it combines all four elements necessary to create risk.

Another model assumption is the percentage of soil-attached pathogens ranged from 10% to 100%. Free suspended pathogens would be removed by flushing and hence pose no risk. The aggregation of microbes on particles is affected by the kinetic attachment and detachment processes. The equilibrium can be affected by many factors such as surface chemistry, water chemistry, flow regime, etc. This may explain that the percentage of suspended or particle-associated pathogens varied substantially due to different sizes, shapes, and surface charges of pathogens and particles. Templeton et al. (2005) reported that the degree to which each MS2 phage became particle-associated varied substantially between replicate trials, ranging from 47% to 95% of particle-associated in the Kaolin Clay Floc samples. For virus, because of their small sizes (i.e., 25-90 nm), low attachment to particles was reported at typical soil pH (Gupta et al. 2009), and large numbers could be shed in the stools of infected individuals with great potential to travel far (Borchardt et al., 2012). Besides microbial attachment and detachment, some settled particles may also re-suspend and pose potential health risks. Without modeling the kinetics of surface attachment/detachment, the risk model used all the particle-attached microbes to calculate the risk, which is a conservative assumption. Of course the exact soil-attachment rates of pathogens near the main break site are not known in real distribution systems, additional research on these parameters would help refine the risk assessments.

The developed risk model is also limited to address the properties that are unique to infectious disease transmission such as secondary transmission, acquired immunity and population dynamics (Haas and Eisenberg, 2001). Despite these limitations, the developed risk model is a valuable tool and provides a framework to organize existing science and knowledge related to health risks due to distribution system main breaks. It ties the regulatory risk goal of 1/10,000 with field practices, e.g., what levels of flushing and/or disinfection should be conducted in order to control the risks to the acceptable level. In this study, one direct application was to use the risk model to divide main breaks into categories based on their severity and develop corresponding procedures to mitigate the risks. It should be noted that the developed risk model is applied to assess risks at the main break and depressurization site locally. For main breaks causing system-wide loss of pressure, intrusion and microbial contamination could occur far away from the main break site. The risk model previously developed for intrusion due to negative pressure transients (LeChevallier et al., 2011) may be more applicable and additional research would help refine the risk assessment.

PILOT-SCALE FLUSHING EXPERIMENTS

One of the main components of the project was to determine the efficacy of pipe flushing. For this portion of the testing, rather than use a real system, it was decided to use a pilot scale pipe loop so that the materials and flow rates could be varied in a controlled fashion. Descriptions of the experimental set up and test conditions follows.

Experiment Setup and Test Conditions

Material Selection

Sand was chosen as the source of sediments for the flushing tests. This choice was a conservative decision as flushing velocities that can fluidize sand will exceed velocities required to fluidize other mineral components (silt and clay) of soils due to density differences.

Pipe loop

A pipe loop that had been previously built and described (Schneider et al., 2010) was modified to conduct the flushing experiments. The pipe loop, as built, consisted of 200 ft of 4-inch Schedule 80 PVC pipe along with a centrifugal pump, flow control valves, pressure gauges and a flow meter. The pipe had been coupled together using PVC couplings. For the flushing experiments, five 10-foot sections of the PVC pipe was removed and replaced with a single continuous segment of rubberized 4-inch fire hose. The fire hose was coupled to the main portion of the pipe loop using barb connections. A photograph of the pipe loop is shown below in Figure D.15. The use of the continuous piece of hose prevented material from getting caught in gaps between two individual pipe segments. Thus, it was thought that this would be a better representation of the ability of flushing water to move sediments through a piping system. The pipe loop also included a short (~2 foot) vertical section (also shown in Figure **D.15** below). This vertical section ensured that material could only be removed by water flowing above the fluidization velocity, when sediments become entrained in the water column and would not be removed by the water simply "pushing" the sediments along the bottom of the pipe. Thus, it is more representative of water distribution systems where the primary means of flushing is though fire hydrant risers.

Figure D.15 Pipe loop used for flushing experiments

Flow measurement

The flow rate through the pipe loop was set by manually adjusting a ball valve well upstream of the sand loading point and a butterfly valve well downstream of the loading point. The flow was measured using a paddle-wheel flow meter mount in-line downstream of the pump. Only after the valves were set and the desired flow rate was achieved was the sand loaded into the pipe loop. During the individual flushing experiments, the measured flow remained steady, with variations of less than 2 gpm (<0.05 ft/sec in a 4-inch diameter pipe). The flow rates used for the flushing experiments ranged from 78 to 180 gpm (2.0 – 4.6 ft/sec)

Sand preparation

Silica sand was sieved using NIST certified soil sieves. Three separate fractions were collected: 2-4 mm, 0.5-2.0 mm, and 0.25-0.5 mm. The sand in each of these fractions was washed using distilled water and then dried in a 103°C oven until ready for use.

Sand loading

Washed sand was weighed out into 1-kg portions for use in the flushing experiments. The hose clamps securing the rubberized fire hose to the first barb fitting were removed. This location (shown above in **Figure D.15**) was located downstream of the centrifugal pump and upstream of the initial rise and 50-ft section of hose. The sand was then placed inside of the hose and the hose reattached and secured to the pipe as shown in **Figure D.16**.

Figure D.16 Loading sand into pipeloop

Flushing Experiments

Filling loop. Following placement of the sand in the pipe loop, water was introduced slowly into the pipes through a ¾" garden hose connection downstream of the loading point. During the filling process, a second bleed valve at a high point in the loop was opened to allow air to escape.

Water flow. The water flow was started using a push button and simultaneously, a stop watch was started to measure the elapsed time. Periodically during each test run, the water flow rate was checked (see previous description of flow measurement) to ensure the desired flow was being achieved.

Stopping flow. After the desired time period had elapsed, the flow was stopped using a push button control. The sudden stop allowed for good control of the volume of water used for each experiment.

Draining pipe. Following the cessation of the flow, the pipe loop was allowed to drain by gravity to remove much of the water in the pipes. At this point the sand recovery operation was begun.

Sand Recovery

The recovery of the residual sand from the pipe loop was a multiple step process that involved moving any residual sand from the far end of the hose back through the system towards the loading point. These steps are described below:

1. Pipe washing

After the water was allowed to drain from the pipe loop, the fire hose was disconnected from the point farthest from the loading point. A 5-gallon bucket was used to collect any water left in the pipe loop. The fire hose was then allowed to drop onto the pipe supports and form “U” sections (shown in Figure D.17). Plant water was then used to wash the inside of the hose as each section was manually agitated. The water was then worked towards the loading point to ensure that any sand remaining in the hose would be collected. The same 5-gallon bucket used at the far end of the hose was used to collect the wash water and sand.

Figure D.17 Fire hose being prepared for sand recovery

The same washing procedure was used for the rigid vertical section of pipe as shown in Figure D.18.

Figure D.18 Vertical pipe section being prepared for sand recovery

2. Sand separation

Following the washing procedure for the hose and vertical sections of the pipe loop, the sand removed by the wash water was allowed to settle in the 5-gallon bucket. The majority of the water was then manually decanted (Figure D.19A) leaving just a small volume of water and sand (Figure D.19B). This water and sand was then poured into a 1-liter beaker (Figure D.19C) and any remaining sand manually removed from the bucket by washing down the bucket with a spray bottle into the beaker and then using tweezers to remove the last sand grains (Figure D.19D).

Figure D.19 Sand separation procedure

3. Sand drying

Following separation of the sand into a pre-weighed 1-liter beaker, the sand was dried in a 103°C oven and then weighed using a balance with an accuracy of 0.1 gram.

Other conditions

Most of the flushing tests were performed using the clean, smooth fire hose. In order to evaluate the impact of more "real-world" situations two alternative model situations were developed – the presence of biofilms and the presence of tubercles. These model systems are described below.

Biofilm establishment. Biofilms are present on most (if not all) distribution system piping systems. In order to evaluate if biofilms have an impact on flushing efficiency (either due to attachment of sediments to the biofilms or hydraulic impacts), a biofilm was established on the inside of the pipe loop system. This was carried out by cultivating bacterial growth inside the pipe loop system by filling the pipe with water containing 0.1% TSB nutrient broth and allowing the water to remain stagnant for two weeks. The biofilm density was determined prior to flushing runs by scraping a 10 cm^2 section of hose pipe and measuring the ATP and HPC levels in the scraped material.

Tubercles. Tubercles are commonly found in water pipes (especially unlined iron pipes) and can have an impact on flushing efficiency by restricting the volume of water that be used or by creating shielded regions and localized eddies that prevent solids from being carried away. In order to evaluate the impact of tuberculation, two separate model systems were established – one representing a highly tuberculated pipe (with ¼" to 1" gravel shown in Figure D.20), and one representing a low to moderately tuberculated pipe (with small aquarium gravel shown in Figure D.21). Because it was not feasible to use real pipes, the tubercles were created using gravel glued to the inside of 4-inch diameter 4-foot long sections of PVC pipe. This pipe section (shown in Figure D.22) was then inserted into the fire hose section of the pipe loop using barb connections.

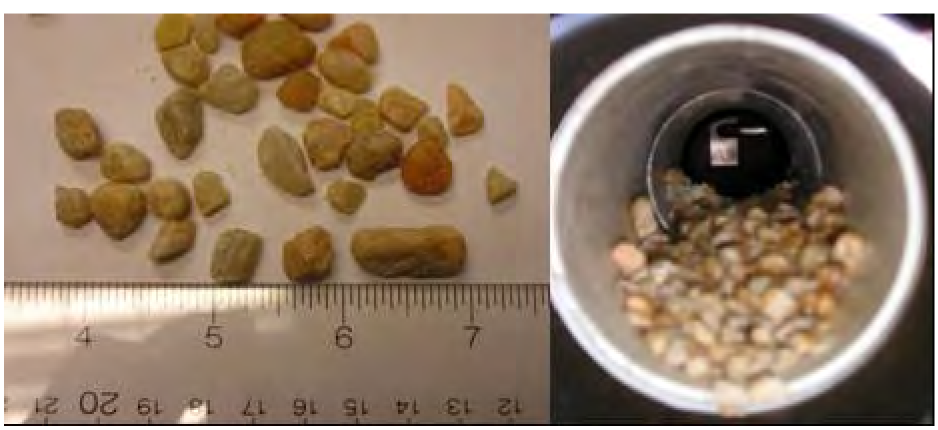


Figure D.20 Highly tuberculated pipe model

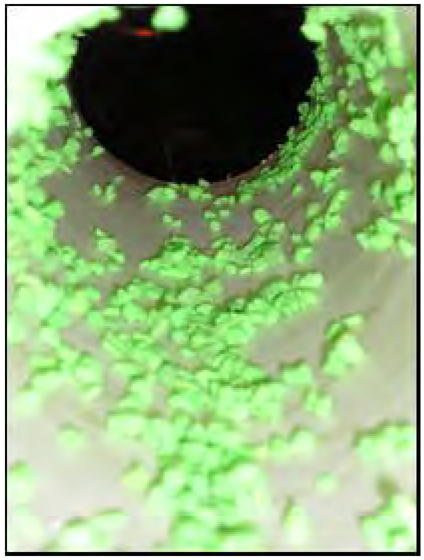


Figure D.21 Low to moderately tuberculated pipe model

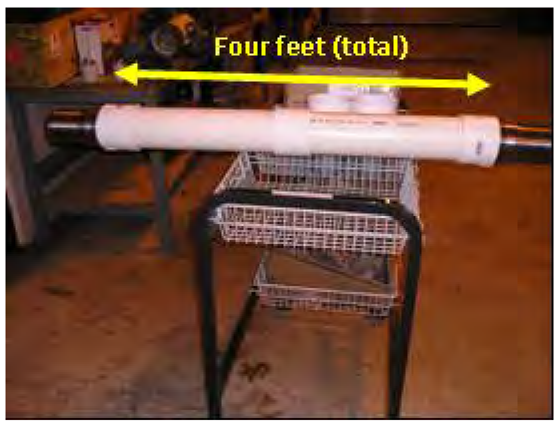


Figure D.22 Tuberculated pipe section waiting for insertion into pipe loop

Data Analysis

The flushing results were fitted with a Normal cumulative distribution function (CDF) model. The Normal CDF model was derived from the cumulative distribution function for a normal distribution. An initial test of the Normal CDF model showed an excellent fit to the data (R^2=0.93) and thus was used for all of the data analyses. The Normal CDF model can be expressed as the following equation.

Normal CDF $$R = \frac{k_1}{2}\left(1 + \mathrm{erf}\left(\frac{V - K_2}{\sqrt{2K_3^2}}\right)\right)$$ Equation 1

where *R* is the log removal, *erf* is the Gauss error function, *V* is the flushing velocity (feet/sec), and k_1, k_2, and k_3 are fitting parameters.

QA/QC for Sand Recovery

In order to determine the effectiveness of the flushing tests, it was first necessary to determine the precision of the sand recovery. For this process, varying amounts of sand were loaded into the far end of the pipe loop. The sand was then washed back to the loading point using the same washing procedure that had been developed. The sand was then washed, dried, and weighed. The weight of the recovered sand was then compared to the weight of the loaded sand. These results and a linear regression of the results are shown below in Figure D.23. These results show that the sand recovery, separation, and drying methods were highly effective – one kilogram of sand added resulted in 998.8 g recovered (99.88% recovery). At the lower end, 1.0 g of sand resulted in 1.0 g of sand recovered. These results indicate that the methodology used for sand recovery is valid over a wide range.

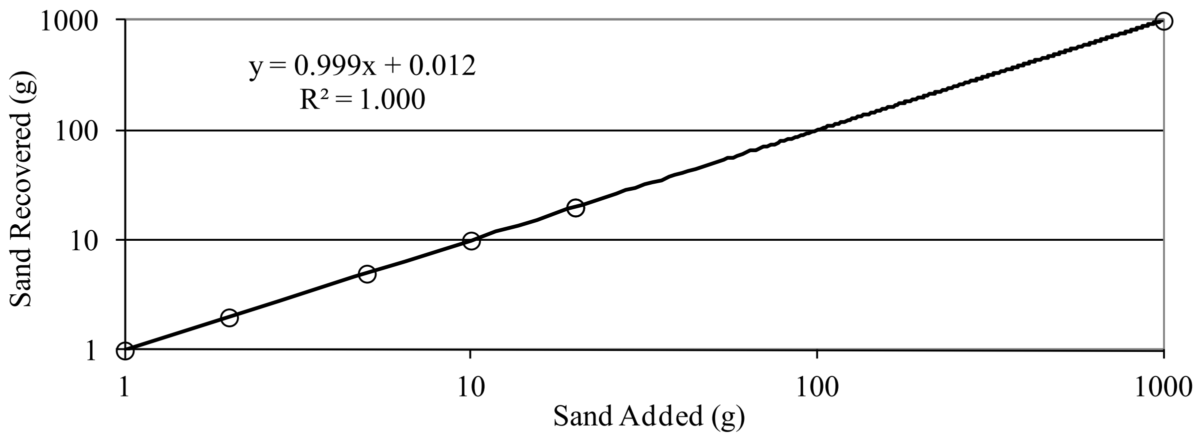


Figure D.23 QA/QC Results for sand recovery

Flushing Results

Clean Pipes

The majority of the flushing experiments focused on using clean pipes; smaller efforts were placed on using pipe with an established biofilm and smaller segments of pipes with model tubercles inside. All of the flushing experiments were performed using a set time of 5 minutes of flushing, representing at least 10 pipe volumes of flow through the 50-ft section of 4-inch fire hose. The results from these experiments are presented and discussed below.

The first set of flushing experiments was conducted using 2-4 mm sand. These results are shown below in Figure D.24.

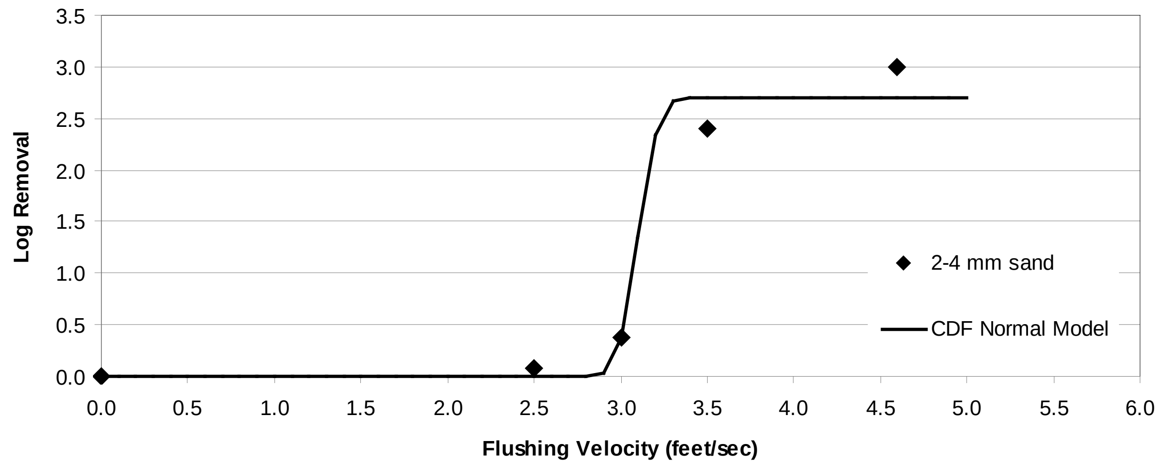


Figure D.24 Removal of 2-4 mm sand by flushing

As seen in this figure, the removal of sand becomes significant between 3.0 and 3.5 ft/sec, indicating the fluidization velocity is achieved. The removal achieved is 2.5-log (99.7%) representing only 3 g of sand recovered from the pipe after the flush.

The second set of flushing experiments used a smaller fraction of sand (0.5-2 mm) to evaluate removal. These results are shown in Figure D.25.

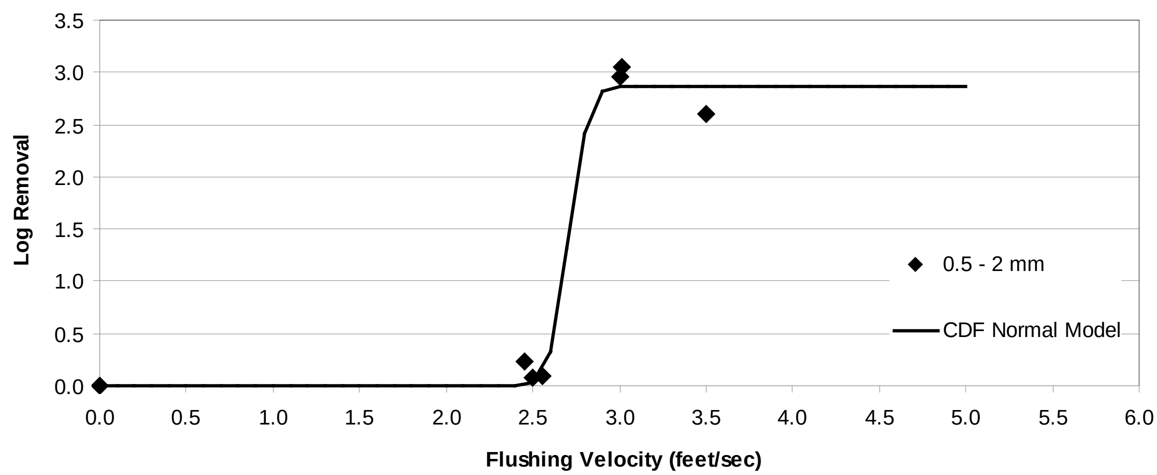


Figure D.25 Removal of 0.5-2 mm sand by flushing

As shown in this figure, the difference in removal between 2.5 ft/sec (almost no removal) and 3.0 ft/sec (nearly 3 log removal) is sudden, indicating fluidization velocity is achieved within this velocity range.

A third size of sand was also tested – 0.25-0.5 mm. Results are shown below in Figure D.26.

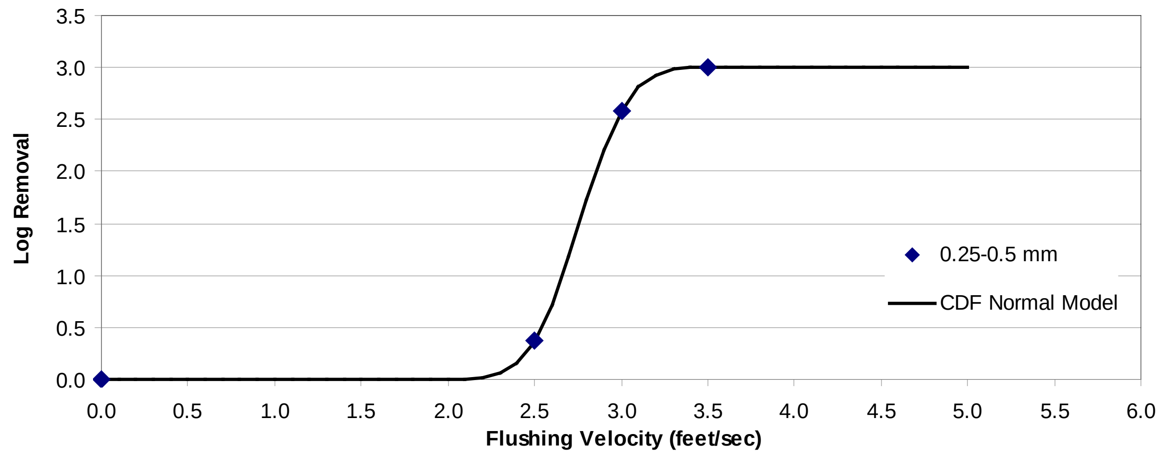


Figure D.26 Removal of 0.25-0.5 mm sand by flushing

As shown in this figure, the removal of sand greatly increases between 2.0 and 3.0 ft/sec, reaching 2.5-log (99.7%) removal at 3.0 ft/second 3-log (99.9%) at 3.5 ft/sec. The results for all three fractions of sand are shown below in Figure D.27.

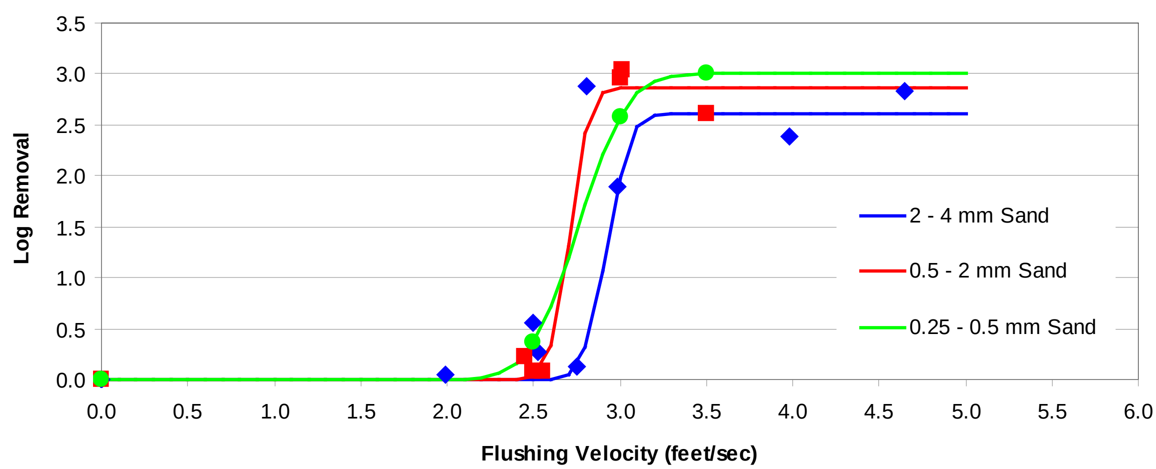


Figure D.27 Removal of all fractions of sand by flushing

As seen in this figure, the removal of 2-4 mm sand (shown in the blue line) is consistently lower than for the other two fractions (requiring higher flushing velocities and achieving a lower removal). Thus, using this size fraction as the basis for decision making is a conservative case.

Pipe with Biofilm

Results from the testing with a present biofilm are shown along side of results from the clean pipes in Figure D.28.

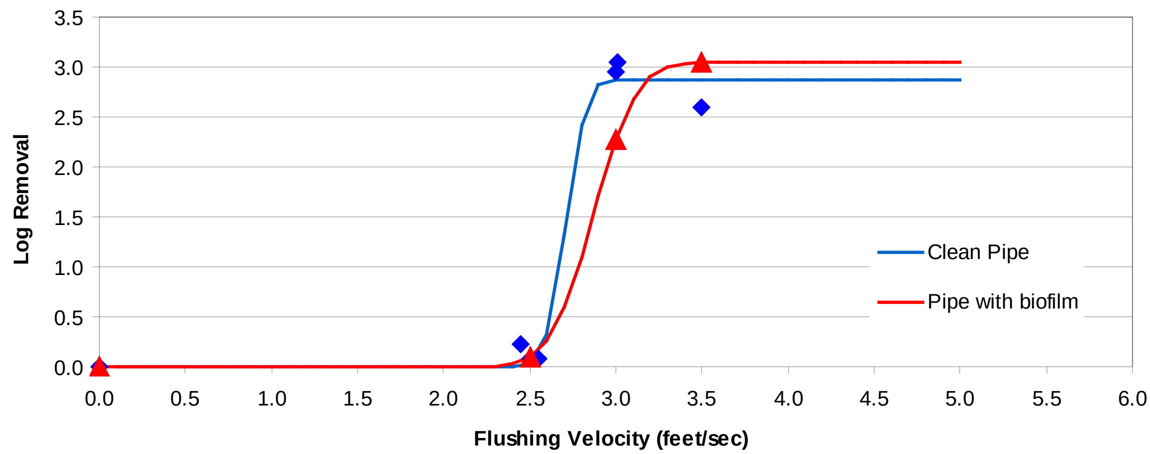


Figure D.28 Impact of biofilm on flushing efficiency

As shown in this figure, the biofilm results (shown by the red line), essentially mirrored the results without the biofilm (in blue), with virtually no removal below 2.5 ft/sec, and a sharp increase between 2.5 and 3.0 ft/sec, and almost complete (3-log) removal at 3.5 ft/sec.

Tuberculated Pipe

Two different sections of tuberculated pipe were used, one a heavily tuberculated pipe using a large amount of ¼" -1" gravel and the other with a smaller amount of smaller gravel. Both sets of experiments were run using the 2-4 mm sand. The results with heavily tuberculated pipe are shown in Figure D.29.

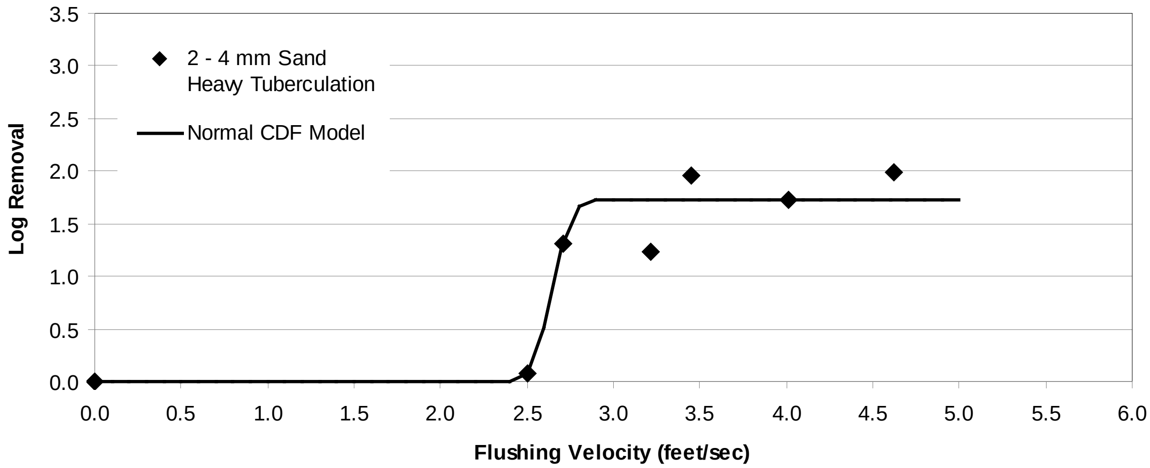


Figure D.29 Flushing results in a heavily tuberculated pipe with 2-4 mm sand

As seen in this figure, the general shape of the removal curve is similar to the experiments without tuberculation, i.e., almost no removal below 2.5 ft/sec and then a sudden increase in removal between 2.5 and 3.0 ft/sec.

Results from the experiment in the lightly tuberculated pipe are shown in Figure D.30.

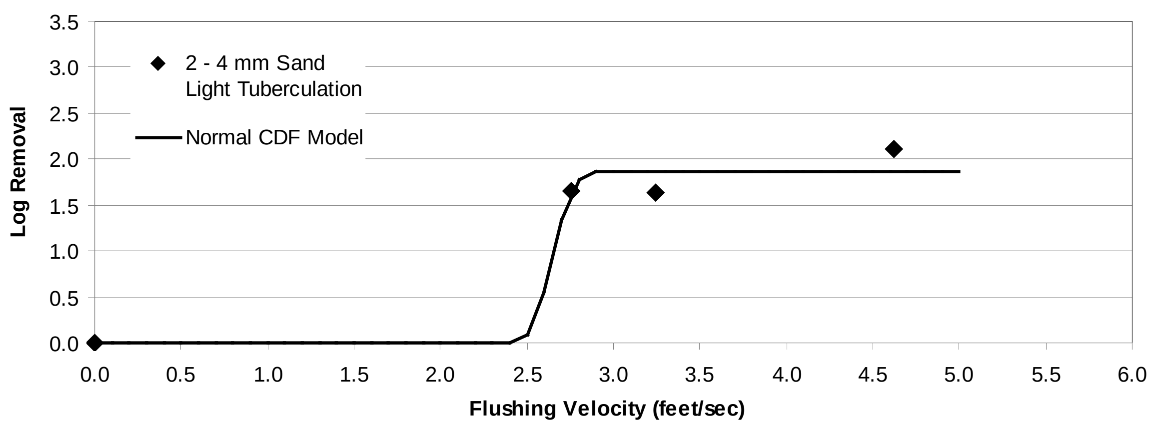


Figure D.30 Flushing results in a lightly tuberculated pipe with 2-4 mm sand

As with the results from the heavily tuberculated pipe, the results for the lightly tuberculated pipe are similar to the experiment without tuberculation, a sudden increase in removal once a fluidization velocity is achieved. When the results for the pipes with tuberculation are shown together with the results from the clean pipes (see Figure D.31), it become apparent that tuberculation had a deleterious impact on removal by flushing. While the tubercles may reduce the fluidization velocity (from approximately 2.7 ft/sec to 2.5 ft/sec), the presence of the tubercles greatly reduces the ultimate removal of sand, possibly by creating shielded areas that allow sand to escape fluidization. Without tuberculation (shown in blue), the ultimate removal of sand is approximately 2.7-log (99.8%). In pipes with tubercles (shown in green and red), the ultimate removal drops to approximately 1.7-log (98%). The results from the tests with the tuberculated pipe compare favorably to the results from theoretical modeling presented by Friedman et al (2003).

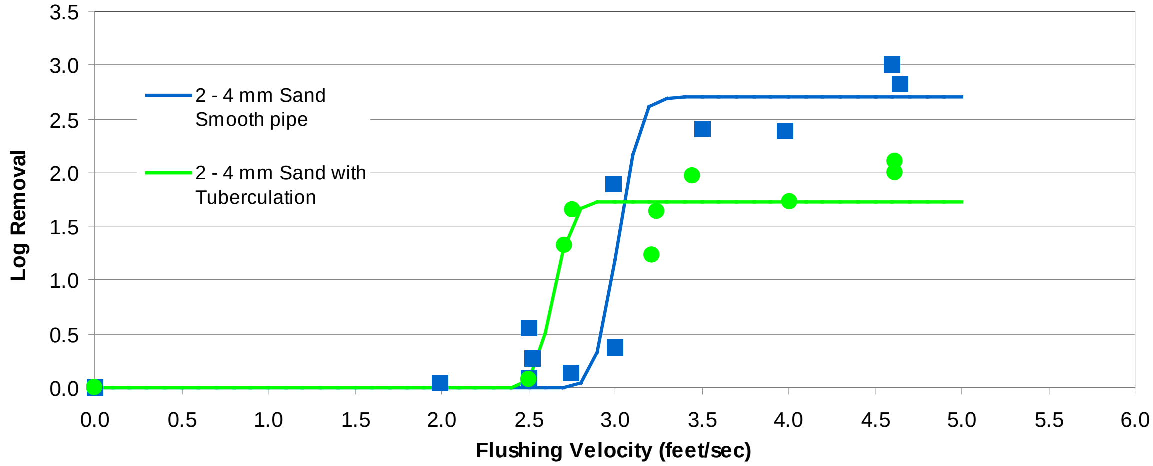


Figure D.31 Removal of sand in clean and tuberculated pipe by flushing

Summary of Flushing Experiments

Based on experiments with different size sand fractions, the use of large sand (2-4 mm) resulted in lower removal than medium-sized (0.5-2 mm) and small (0.25-0.5 mm) sand. The use of this larger fraction, therefore, represents a more conservative approach. Because of the high specific gravity of sand, it has been assumed that the other mineral fractions of soil (silt and clay) would be more easily removed by flushing due to their smaller size and lower specific gravity.

In clean pipes, once a fluidization velocity is achieved, removal of even large sand (2-4 mm) is almost complete (limited to 3-log by the weighing procedures). The presence of biofilms had a small, negative impact on the removal of the sand. The presence of tuberculation had a much more significant, negative impact on removal of sand by flushing. In clean pipes, the removal of large sand by flushing could reach 2.7-log (99.8%) once a flow velocity of 3 ft/sec was reached. In tuberculated pipe, the removal was reduced to approximately 2-log (99%). Based on these results and including a safety factor, it is reasonable to conclude that flushing with a linear velocity of 3.5 ft/sec (based on the maximum diameter in a given run of pipe) could achieve a 1.5-log (96.8%) removal of particles.

DISINFECTANT DECAY AND MICROBIAL INACTIVATION

As discussed earlier, to model the risk and the reduction of pathogen levels after main break and repairs, three pieces of information need to be determined: the disinfectant demand, the inactivation kinetics of disinfection, and the effectiveness of flushing. This information will provide answers to questions such as; will the background disinfectant residual persist and be adequate after contaminants intruded during main breaks? Or are additional flushing and/or disinfection treatment needed to control the risks? For this portion of the study, bench scale experiments were conducted to evaluate disinfectant decay, inactivation of free suspended microbes, and inactivation of soil-attached microbes. Descriptions of the experimental set up and test conditions follows.

Experiment Setup and Test Conditions

Disinfectant Decay and Inactivation of Suspended Microbes

Bench-scale experiments were conducted in the laboratory to investigate the disinfectant decay kinetics and inactivation of suspended microorganisms simultaneously. Four possible sources of contamination – (i) raw sewage (being the worst case scenario); (ii) standing water in valve boxes; (iii) water from metering chambers; and (iv) residual water from excavation pits were examined at three different levels of intrusion ranging from severe to mild (1%, 0.1%, and 0.01% by volume). MS2 bacteriophage (ATCC 15597-B1), *E. coli* (ATCC 15597), and *Bacillus subtilis* (ATCC 6051) were used as surrogate microorganisms to investigate the inactivation of virus, bacterial, and protozoan pathogens respectively. Stock cultures were used to propagate additional cultures in the lab that were enumerated and stored (-20°C) prior to these tests. These were used to spike the test reactors at approximate levels of 10^6 cfu/mL.

These studies were conducted for both free chlorine and monochloramine disinfectants and at least five environmental water samples for each contamination source were tested. A total of 23 environmental water samples were examined for their impact on disinfectant decay and/or microbial inactivation. The contaminating source water was analyzed for physical and chemical parameters (e.g. pH, TOC, NO_3, NH_3, etc) prior to their use in the batch tests. Median values and the ranges of the measured parameters are shown in Table D.4. While the conductivity, pH, and UV_{254} values were similar among the collected environmental water samples, the TOC and turbidity values were significantly different. As expected, the TOC, conductivity, and turbidity levels in the raw sewage samples were significantly higher. The turbidity levels in the excavation pit water samples were also significantly higher, probably due to the mixtures of water and soil particles.

Table D.4
Characteristics of collected environmental water samples

Characteristics	Raw Sewage	Standing Water in Valve Box	Water from Meter Chamber	Residual Water from Excavation Pit
Number of Samples	5	7	5	6
Conductivity (mS/cm)	970 (18 – 1,200)	220 (5.1 – 500)	290 (3.0 – 530)	290 (130 – 590)
pH	7.1 (6.7 – 7.9)	7.9 (7.5 – 8.1)	8.2 (6.9 – 9.1)	7.6 (7.4 – 9.8)
TOC (mg/L)	33 (3.5 - 150)	14 (1.0 - 42)	4.9 (3.7 – 9.9)	3.2 (2.7 – 4.1)
Turbidity (NTU)	61 (16 – 330)	20 (4.2 – 530)	25 (1.7 – 68)	8,300 (56 – 25,000)
UV_{254} (cm^{-1})	0.36 (0.042 – 0.96)	0.31 (0.012 – 1.8)	0.38 (0.084 – 0.67)	0.52 (0.11 – 1.4)

Each disinfectant decay test was conducted using two parallel reactors. If a microbial inactivation batch test was conducted at the same time with the disinfectant decay test, then three reactors were used as described below.

- Reactor 1 (R1) - microbial viability control; used to check the microbial decay in absence of disinfectant. This reactor contained 1L de-chlorinated tap water spiked with surrogate microorganisms plus the test environment water.
- Reactor 2 (R2) - disinfectant decay control; used to determine disinfectant decay in absence of microorganisms and the test environment water. This reactor contained 1L tap water and the disinfectant dose.
- Reactor 3 (R3) – microbial inactivation reactor; used to determine the disinfectant decay and microbial inactivation for the selected test condition. This reactor contained tap water contaminated with the test environment water, surrogate microorganisms, and the disinfectant dose.

Chlorine or chloramines of 1.0–10 mg/L was added as necessary, and all reactors were continuously mixed for 3 hours at 10°C during the test. Samples were withdrawn periodically during the test (0, 5, 15, 30, 60, 120, and 180 minutes) and were analyzed for chlorine (Hach method 8021) or chloramine residuals (Hach method 10200). Samples for microbial quantification were quenched with thiosulfate upon collection and refrigerated until plating studies were completed (<24 hours). The surrogates were enumerated according to the Standard Methods (APHA 2005): m-Endo Agar, nutrient agar, and EPA method 1602 for *E. coli*, *Bacillus*, and MS2, respectively.

Inactivation of Soil-Attached Microbes

Inactivation of particle-associated microbes is more complex because the nature of the particulate material (organic or inorganic) and the microbial interaction (simply attached or enmeshed in a biofilm). Contaminated soil particulates and water may enter distribution systems during main break and depressurization events. The most common engineering classification system for soils in North America is the Unified Soil Classification System (USCS), which has three major classification groups: (1) coarse-grained soils (e.g. sands and gravels); (2) fine-grained soils (e.g. silts and clays); and (3) highly organic soils (referred to as "peat").

For inactivation experiments of particle-associated organisms, sand, clay, and peat were evaluated for their shielding effects on protecting MS-2 virus and *E. coli* bacteria from chlorination or chloramination. The inactivation of particle-associated *Bacillus sp.* was not studied because disinfection was not effective for inactivating suspended *Bacillus sp. Bacillus* was used as a surrogate for protozoa *Cryptosporidium*, which is well known for its resistance to chlorine inactivation. For the same reason, chloramine inactivation of particle-associated MS-2 virus was not conducted. The experiment setup and approach follows.

Using the inactivation experiments of sand-attached organisms as an example, 10 grams of sand was combined with 100 mL of de-chlorinated filter effluent from the Delaware River WTP, Delran, NJ. The mixture was spiked with 1mL *E. coli* and 1 mL MS2 coliphage stocks. The mixture was incubated for microbial attachment overnight on a shaker (125 rpm) at room temperature (22±2°C). The densities of *E. coli* and MS2 coliphage cultures had been previously determined, which were frozen at -20°C prior to use. A total of 10 reactors were set up each time, including a control reactor (no disinfectant added) together with three sets of triplicate reactors (3x3) to be disinfected for 5, 15, and 60 minutes referred to as T_5, T_{15} and T_{60} reactors, respectively.

Some extra reactors were prepared and used to determine the disinfectant doses and these were not spiked with any organisms or incubated overnight. For each of these, 10 grams of sand was mixed with 100 mL phosphate buffer to determine the chlorine demand of the sand media. This was done by adding appropriate concentration of chlorine and measure chlorine residuals over time. The data was used to determine the dose of chlorine stock to meet a target of at least 1.0 mg/L free chlorine residual. Most chlorine demand was consumed instantaneously during the initial mixing (chlorine residuals measured after mixing for 10 seconds). Based on the trial run (initial chlorine demand of approximately 1.3 mg/L Cl_2 per 10 g sand), the disinfection dose was determined to be 2.5 mg/L to attain the target 1.0 mg/L Cl_2 during the test.

After incubation overnight, nine of the 10 reactors were processed for the disinfection process. For the control reactor, an aliquot of the supernatant was used to enumerate the *E. coli* and MS2 by plating on m-Endo LES agar (for *E. coli*) or using the single layer agar method (for MS2 with *E. coli* Famp host; USEPA, 2001). The rest of the supernatant was decanted. The sand was washed three times with 100 mL of phosphate buffer, and re-suspended in 100 mL of phosphate buffer before the disinfection process. After disinfection for 5, 15, or 60 minutes, aliquots were taken to determine the chlorine residuals. The rest of the mixture was quenched with sodium thiosulfate, centrifuged at 1120 rcf (4 minutes), and *E. coli* and MS2 in the supernatant were determined as described above. The sand pellet was re-suspended in 30 mL biofilm buffer comprised of Zwittergent 3-12 (10-6 M), ethylene glycol-bis(β-aminoethyl ether)-n,n,n',n'-tetraacetic acid (EGTA; Sigma-Aldrich, St. Louis, MO) (10-3 M), Tris (0.01 M), and 0.1% peptone (Camper et al., 1985). The suspension was homogenized at 13,000 rpm (Polytron PT1200; Kinematica, Littau-Lucerne, Switzerland) for 30 seconds (Jjemba et al., 2010). An aliquot was plated on m-Endo LES agar to enumerate *E. coli* and another aliquot used to enumerate MS2 by the single layer agar method. All plates were incubated overnight at 36°C and the *E. coli* colonies or MS2 phages were counted on the next day.

This experimental procedure was repeated using a 0.1% bentonite clay solution (i.e., 0.05g clay into 50 mL water) and 0.2% jiffy peat. During the inactivation experiments for peat-attached *E. coli* and MS2 virus, chlorine residuals in the reactors were increased to approximately 25 mg/L Cl_2 in order to overcome protection from peat particles and achieve significant inactivation. A similar set of experiments was also conducted to test the efficacy of chloramines on inactivation of particle-associated (i.e., sand, clay or peat) coliforms.

Disinfection Results and Discussions

In the study 26 runs were conducted when both disinfectant decay and inactivation of suspended microbes were tested in parallel (requires three reactors each run). The following Figures D.32 to D.35 show results of an example run: chlorine decay and microbial inactivation experiment with 1% wastewater contamination. Figure D.32 shows the initial chlorine concentration of 7.7 mg/L in Reactors 2 (chlorine decay control) and 3 (microbial inactivation reactor). After 10 mL of wastewater was added into Reactor 3, an initial chlorine demand of 4.3 mg/L was observed. After 180 minutes, chlorine residuals dropped to 2.7 mg/L in Reactor 3.

The initial concentrations of MS2 in Reactors 1 (microbial control) and 3 were approximately 10^7 cfu/mL (see Figure D.33). No significant die-off of MS2 was observed in Reactor 1. After 5 minutes, MS2 levels in Reactor 3 dropped below the detection limit (i.e. more than 7-log inactivation). The initial levels of *Bacillus* were about 8.6×10^4 cfu/mL and there was no significant die-off of *Bacillus* in the control reactor. After 180 minutes, *Bacillus* level in the test reactor (R3) was slightly reduced to 1.7×10^4 cfu/mL (less than 1-log, Figure D.34). The maintained chlorine residual of ~3.0 mg/L for the 180-minute run (i.e. a *CT* of 500 mg/L Cl_2•min) did not result in significant inactivation of *Bacillus* spores. The initial concentrations of *E. coli* in Reactors 1 and 3 were ~2.5×10^6 cfu/mL. While no significant die-off of *E. coli* was observed in control reactor, levels in the test reactor 3 dropped below the detection limit within 5 minutes (i.e. more than 6-log inactivation, Figure D.35). These observations are consistent with the *CT* values reported in the literature (USEPA 1989). Chlorine disinfection will likely be effective against contamination of enteric virus and bacteria, but not protozoa (not considering the presence of particles).

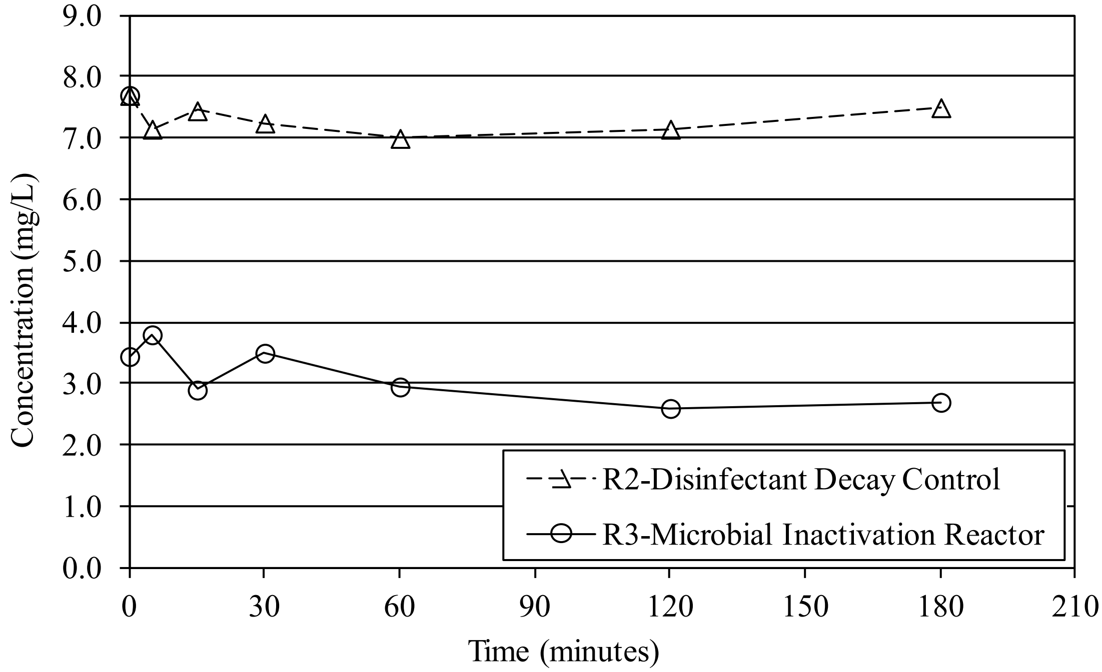


Figure D.32 Chlorine decay when contaminated with 1.0% of wastewater

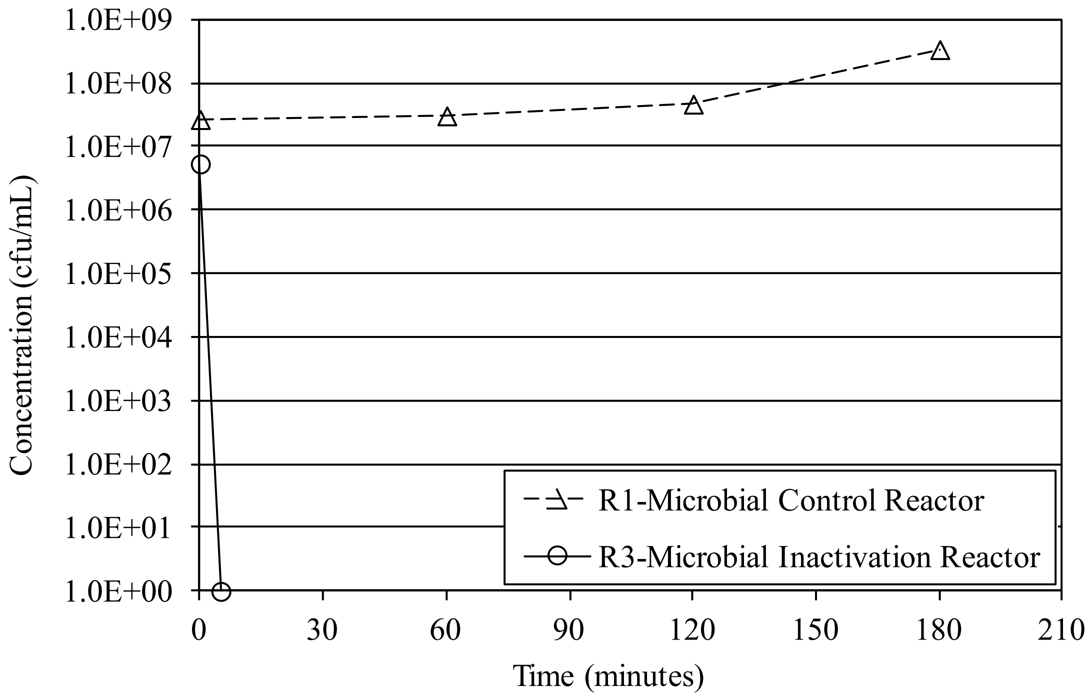


Figure D.33 Chlorine inactivation of MS2 when contaminated with 1.0% of wastewater

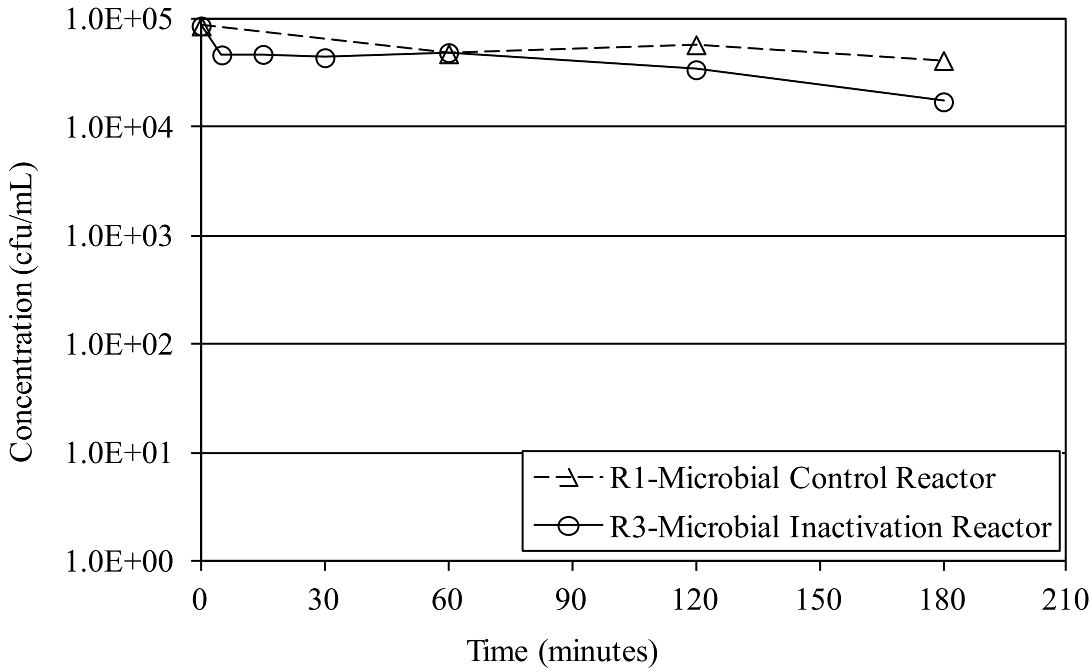


Figure D.34 Chlorine inactivation of *Bacillus* when contaminated with 1.0% of wastewater

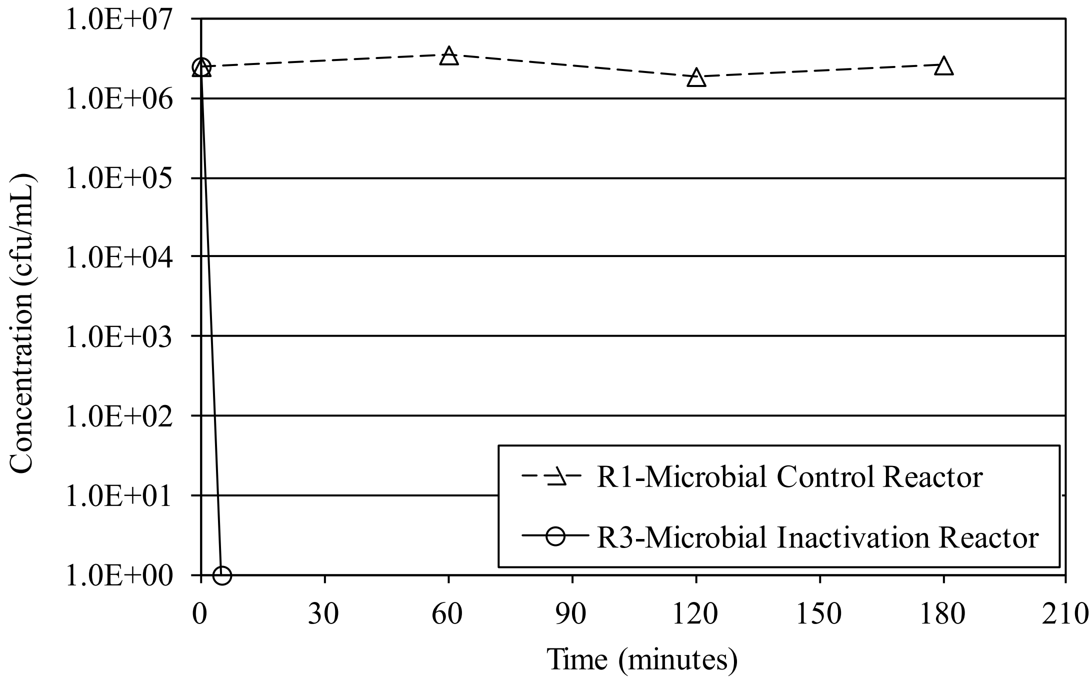


Figure D.35 Chlorine inactivatin of *E. coli* when contaminated with 1.0% of wastewater

Disinfectant Decay

In this study, a total of 105 disinfectant decay tests were conducted: 59 for chlorine and 46 for chloramines. As shown on Figure D.36, each test had a different combination of contamination volumes (0.01%, 0.1%, or 1%), free chlorine or chloramines, and sources of the environmental water samples (raw sewage, meter, pit, or valve box water). Most disinfectant decay or demand was consumed instantaneously during the initial mixing. The following shows the initial disinfectant demand versus contamination volume ratios and summarizes other significant findings. Figures D.37 and D.38 summarizes the histogram of initial chlorine and chloramine demands, respectively.

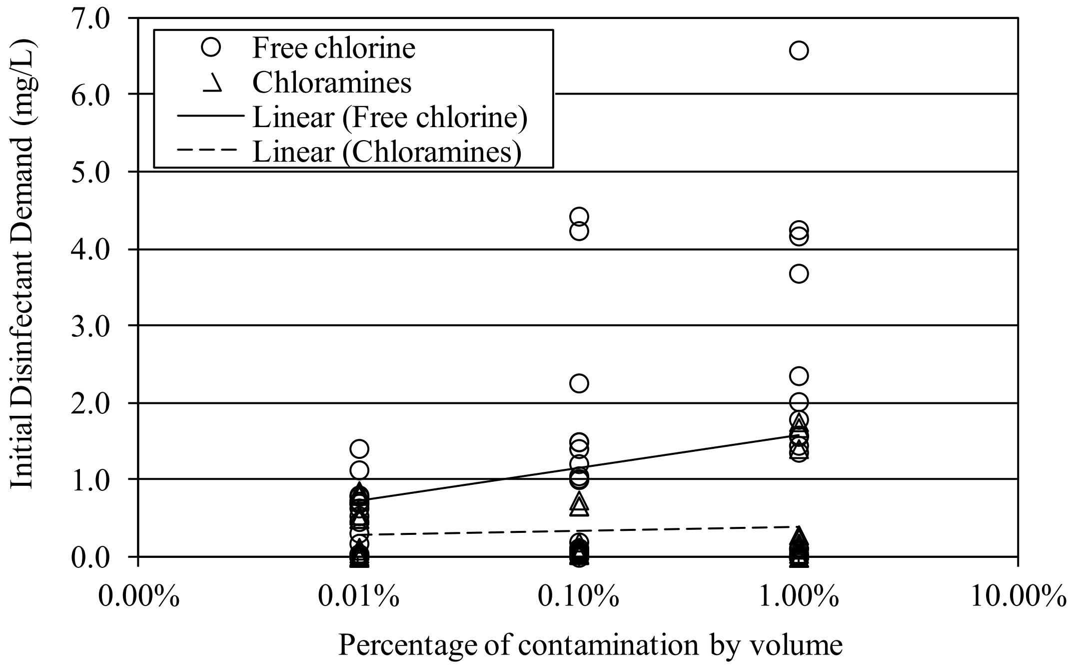


Figure D.36 Initial chlorine and chlormaine demands versus contamination volume ratios

1. The initial disinfectant demand was a function of disinfectant type, percentage of contamination introduced, and sources of environment water samples.
2. Wastewater contamination represents the worst scenario. Initial chlorine demands ranged mostly 0-2 mg/L and 1% wastewater water contamination resulted up to 6.6 mg/L of initial chlorine demand (Figure D.37).
3. Initial chloramine demands ranged mostly less than 1 mg/L (Figure D.38).
4. The disinfectant decay results suggests that in real distribution systems, initial chlorine residual could be overcome by water contamination after main break depressurization, while chloramine residual would remain largely unchanged. The initial disinfectant demand would be apparent within 10 seconds if a large amount of contamination intruded during main repair.

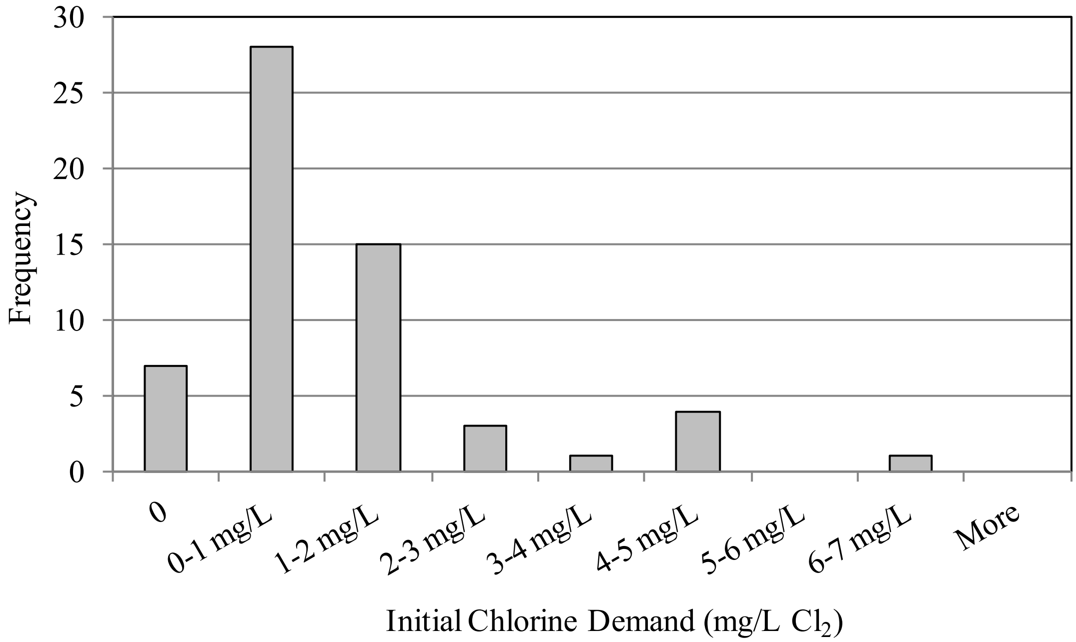


Figure D.37 Histogram of initial chlorine demand (n=59)

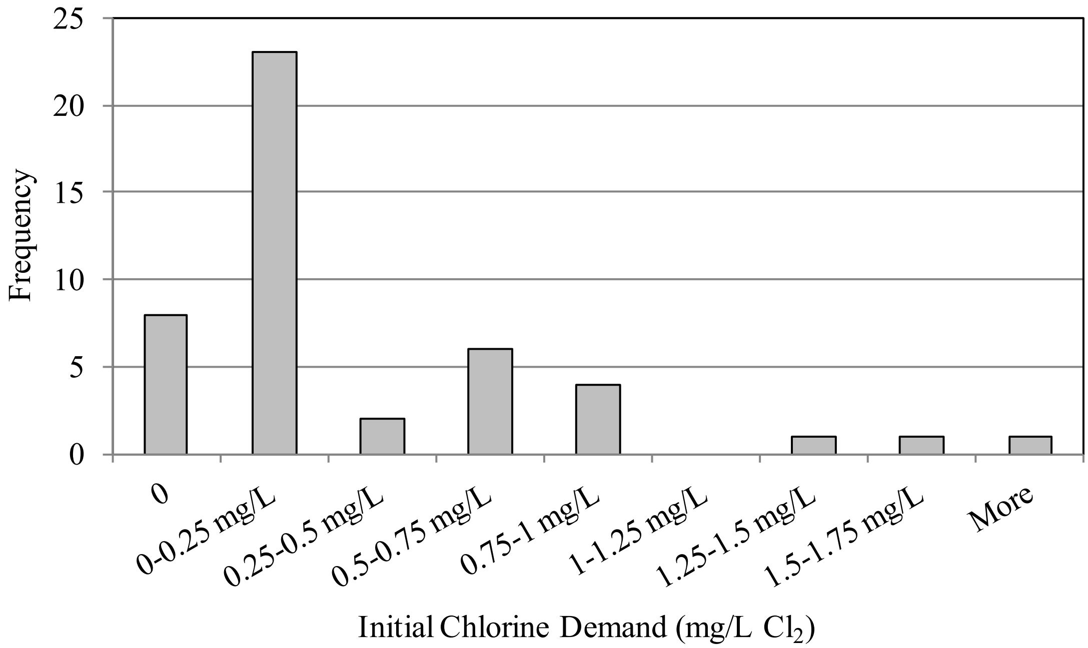


Figure D.38 Histogram of initial chloramine demand (n=46)

Inactivation of Suspended Microbes

After intrusion and main break repairs, all free suspended microbes should have been removed by flushing regardless if a scouring flushing velocity has been achieved, hence pose no risk. However, inactivation experiments for suspended microbes were still conducted to establish the baseline effectiveness of disinfection, to be compared with the later inactivation results of soil-attached microbes. A total of 25 kinetic inactivation experiments were conducted: 13 for chlorine and 12 for chloramines. The results of chlorine/chloramine inactivation for all three microbes are summarized as following.

MS-2 Inactivation. Chlorine could effectively inactivate MS-2 virus. As shown in Figure D.39, greater than 5-log inactivation was achieved with a *CT* of 15-20 mg/L Cl_2*min. This result was comparable with the *CT* values used in the Surface Water Treatment Rule (USEPA 1989). MS-2 was used as a surrogate for virus. Based on these *CT* values, it is likely that chlorine disinfection after main break repairs will be effective against contamination of virus (not considering the presence of particles).

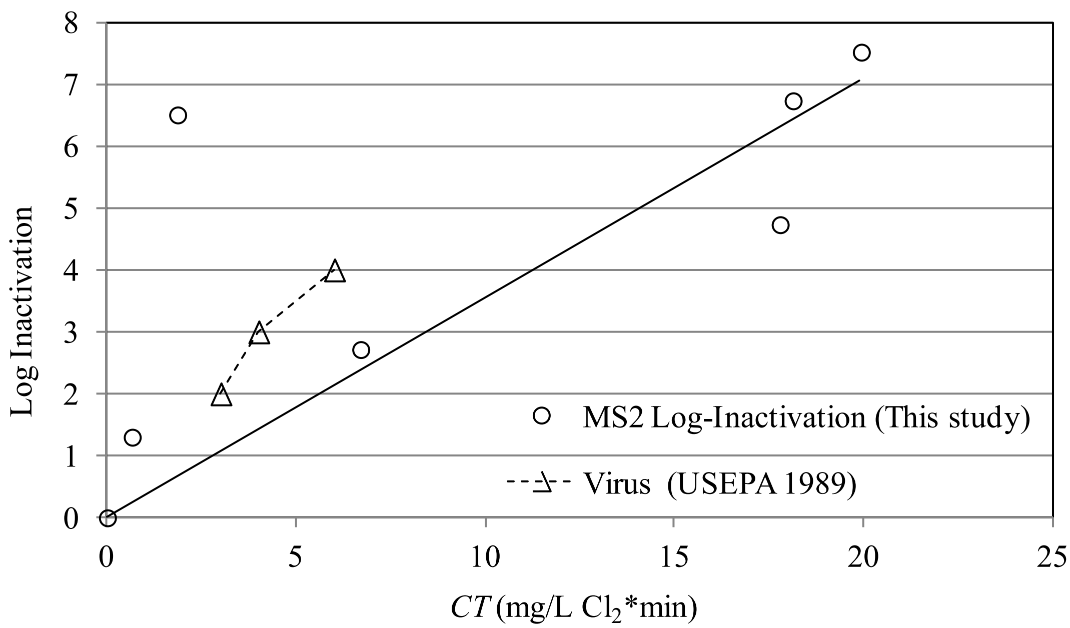


Figure D.39 Free chlorine inactivation of suspended MS2

MS2 appeared to be more resistant to chloramines that other virus, less than 1-log inactivation with a *CT* of 1,600 mg/L Cl_2*min (Figure D.40). This *CT* value should have about 4.0 log inactivation of virus (*CT* values based on Hepatitus A virus - HAV inactivation; USEPA, 1989). This suggests that MS2 might not be a good surrogate for chloramine disinfection of virus. Still, due to the magnitude of *CT* values needed for 2.5-log inactivation (>1,000 mg/L Cl_2*min) and high infectivity of virus, chloramines and their typical levels maintained in distribution systems might not be effective to reduce viral infection risks.

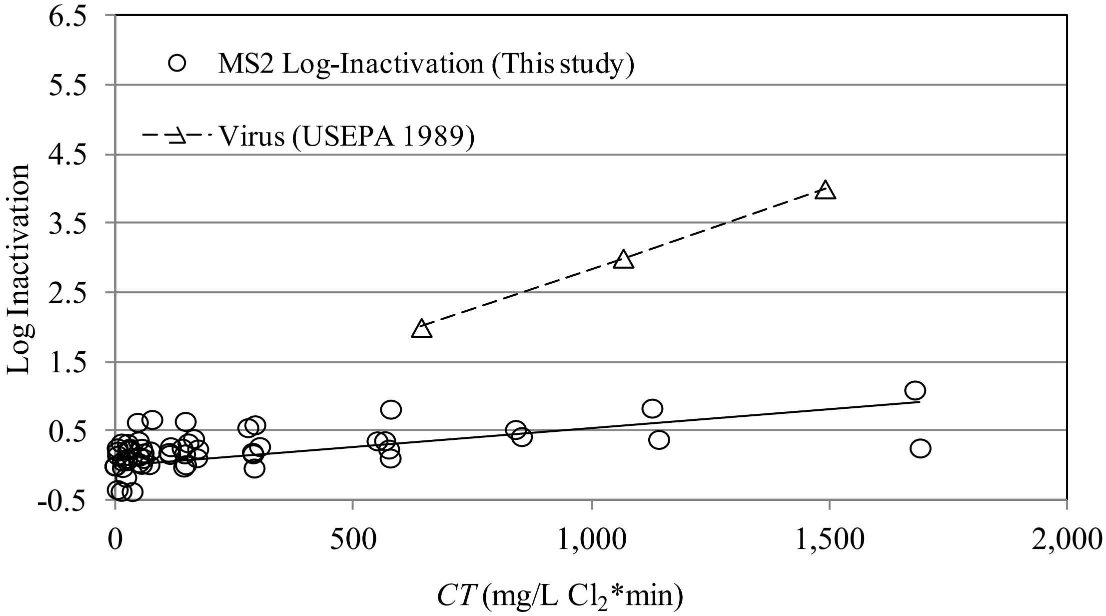


Figure D.40 Chloramine inactivation of suspended MS2

Baccillus Inactivation. As expected, *Bacillus* was highly resistant to chlorine and chloramines (Figure D.41). For chlorine inactivation, less than 1-log inactivation was observed with a *CT* up to 1,200 mg/L Cl_2*min. For chloramines, no significant inactivation was observed with a *CT* up to ~1,600 mg/L Cl_2*min. This result was consistent during all experiment runs, but somewhat lower than the values reported in the literature (Rose et al., 2005; Rice et al., 2005). Since *Baccillus* was used as a surrogate for protozoa, *Cryptosporidium* is well known for its resistance to chlorine inactivation. Chlorine disinfection after main break repairs would not be effective against contamination of protozoa like *Cryptosporidium*.

E. coli Inactivation. *E. coli* was found the least disinfection-resistant compared with the other two studied microbes. As shown in Figure D.42, chlorine achieved greater than 4-log inactivation with a *CT* less than 20 mg/L Cl_2*min. For chloramines, greater than 4-log inactivation was achieved with a *CT* 20-160 mg/L Cl_2*min. *E. coli* was used as a surrogate for pathogenic bacteria. It is likely that chlorine disinfection after main break repairs will be effective against contamination of enteric bacteria (not considering the presence of particles).

Summary Inactivation of Suspended Microbes. Chlorine was effective in inactivating MS2 (>5-log inactivation with a *CT* of 15-20 mg/L Cl_2*min), but chloramines were not effective for inactivation of the virus. No significant inactivation of *Bacillus* was observed with chlorine or chloramines within the tested *CT* ranges. Both chlorine and chloramines were effective in inactivating *E. coli* during the 180-minute experiment run (mostly greater than 5-6 log inactivation within 5 minutes).

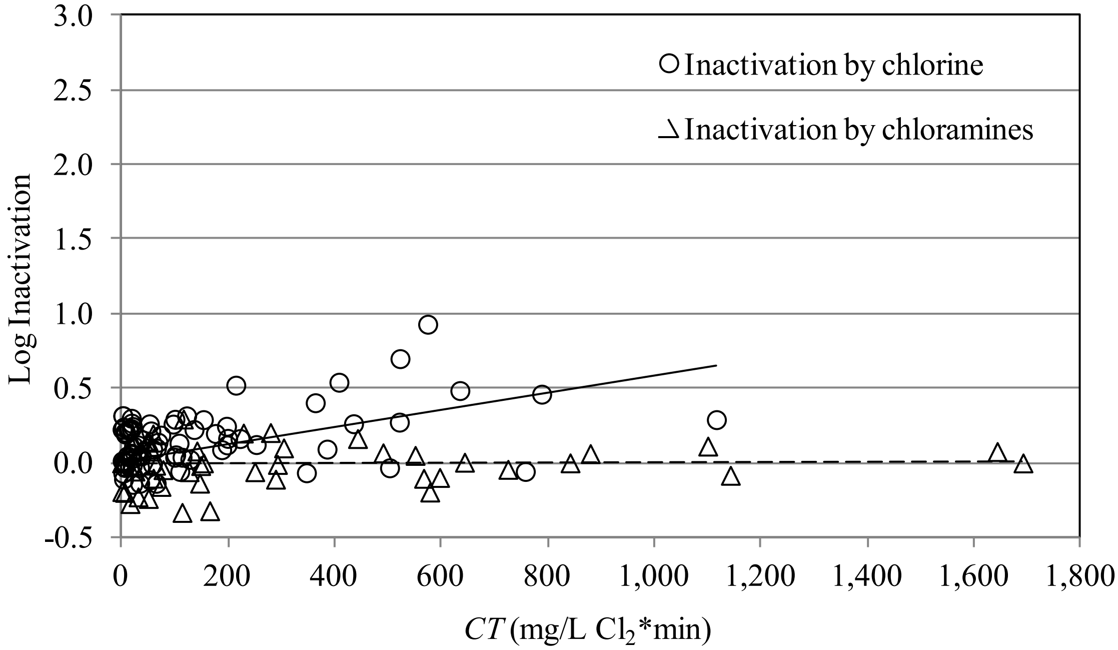


Figure D.41 Chlorine and chloramine inactivation of suspended *Bacillus*

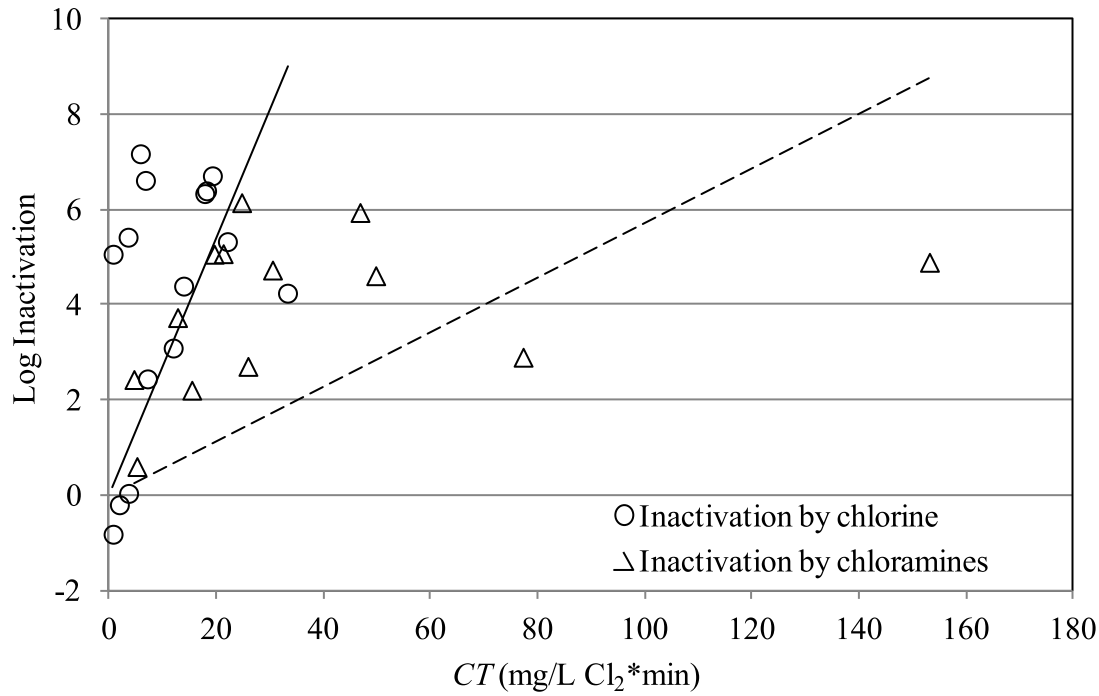


Figure D.42 Chlorine and chloramine inactivation of suspended *E. coli*

Inactivation of Soil-Attached Microbes

The following figures show inactivation of MS2 phage and *E. coli* associated with clay, sand, and peat particles. An envelope was drawn to derive the *CT* requirements needed to achieve a specific log-inactivation. All observed log-inactivation data points were either on or above the envelope. Disinfection requirements for specific textural classes are summarized below.

Clay-Associated Microbes. The following figure shows free chlorine inactivation of *E. coli* and MS2 coliphage associated with clay particles. Chlorine disinfection inactivated 2 to >9 log units of clay-associated MS2 with a *CT* of 8.0-115 mg/L Cl_2*min (Figure D.43). Clay appeared to provide some protection for the tested virus and bacteria from disinfection. As described early for suspended MS-2 virus and coliforms, free chlorine could effectively inactivate by >4-log reduction with a *CT* value of 15-20 mg/L Cl_2*min. The effectiveness of chlorine was somewhat reduced due to the shielding of clay. The 4-log inactivation of clay-associated MS-2 and *E. coli* needs a higher *CT* of 74 and 92 mg/L Cl_2*min, respectively.

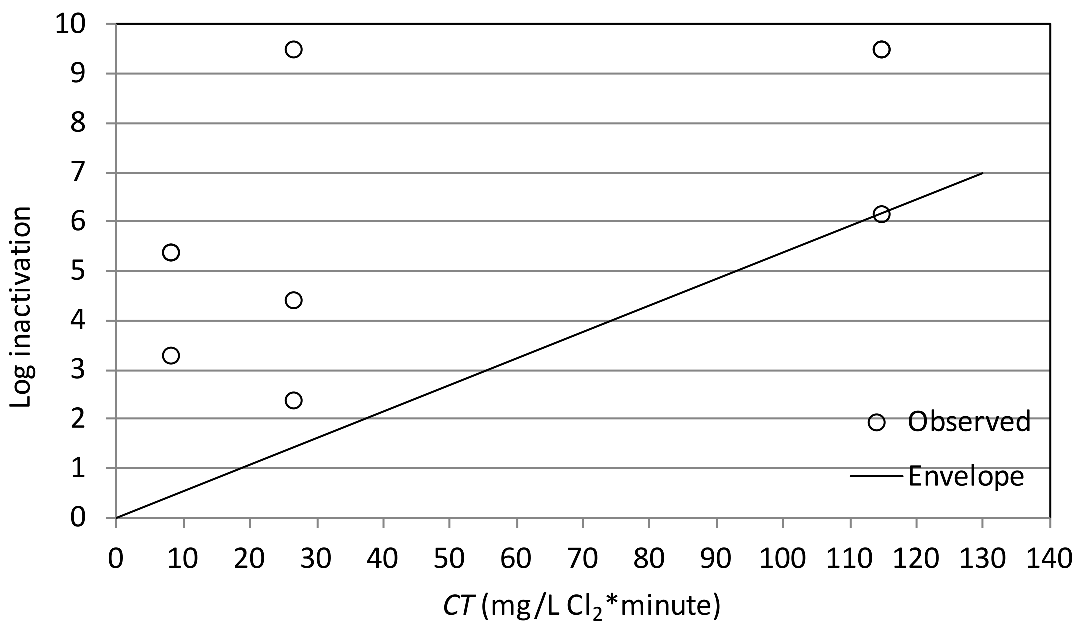


Figure D.43 Free chlorine inactivation of clay-associated MS2

Chlorine disinfection inactivated 1 to >9 log units of clay-associated coliform; with a *CT* of 8.0-103 mg/L Cl_2*min (Figure D.44). The inactivation of clay-associated *E. coli* with chloramines was also conducted. With chloramines, 4-log inactivation could be achieved with a *CT* of 85 mg/L Cl_2*min (Figure D.45). The chloramine inactivation of clay-associated MS2 virus was not conducted because chloramines could not effectively inactivate suspended MS2 virus.

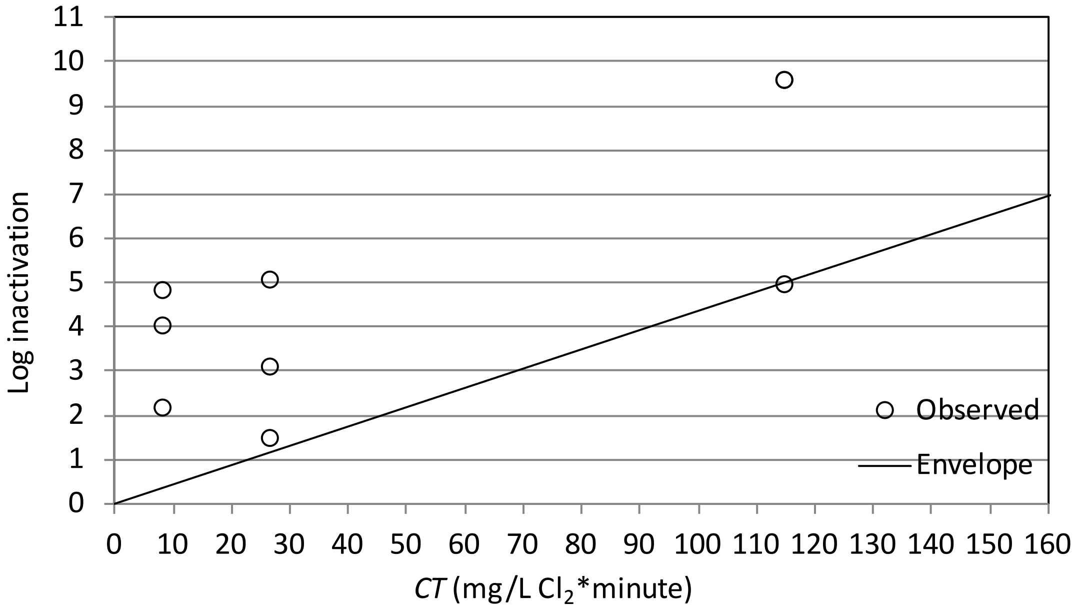


Figure D.44 Free chlorine inactivation of clay-associated coliform

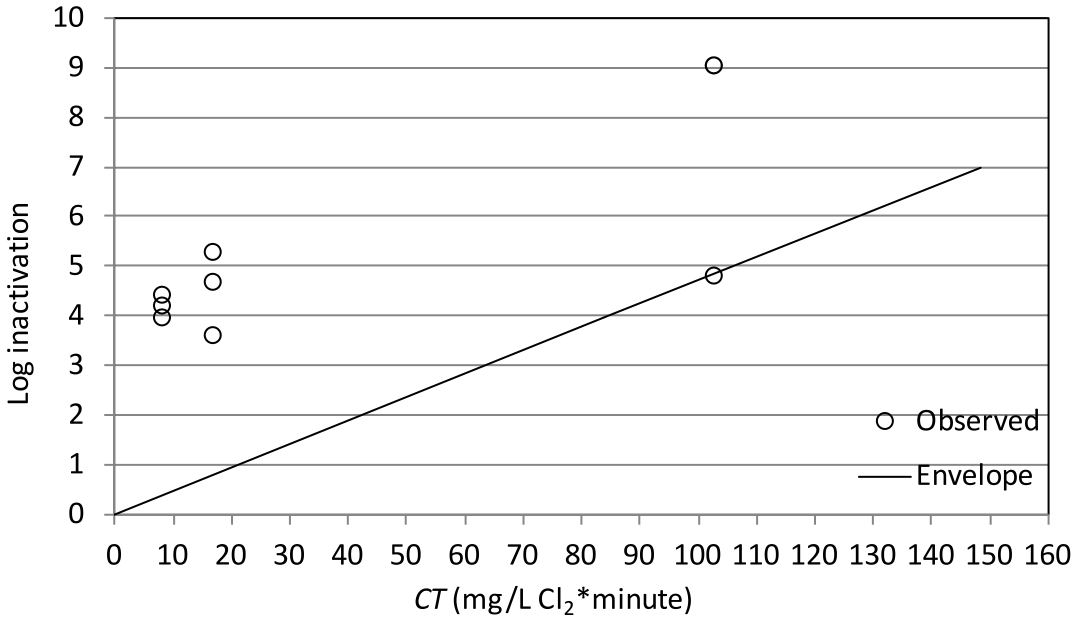


Figure D.45 Chloramine inactivation of clay-associated coliform

Sand-Associated Microbes. Sand also seemed to provide some protection from disinfection as clay. The following figures show chlorine inactivation of MS2 and *E. coli* associated with sand particles. Chlorine disinfection would need a *CT* of 69 and 45 mg/L Cl_2*min, respectively, to achieve 4-log inactivation of MS2 and *E. coli* (Figures D.46 and D.47). Similarly, 4-log inactivation of sand-associated *E. coli* by chloramines could be achieved with a *CT* of 49 mg/L Cl_2*min (figure not shown). Chloramine disinfection was still effective to inactivate the attached bacteria (from 3 to >5-log inactivation with a *CT* of 6.6-69 mg/L Cl_2*min).

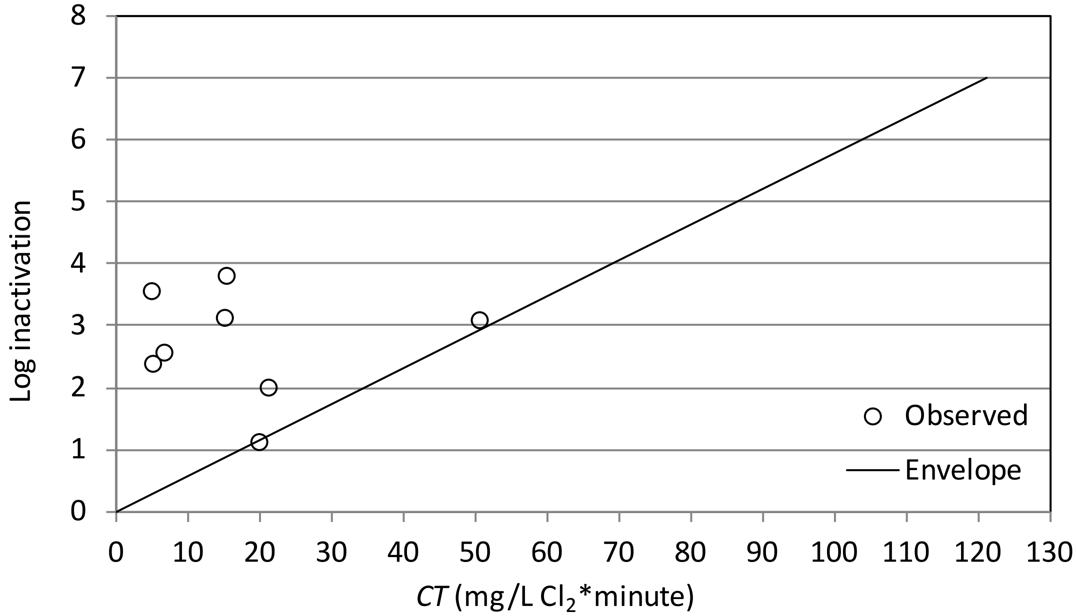


Figure D.46 Free chlorine inactivation of sand-associated MS2

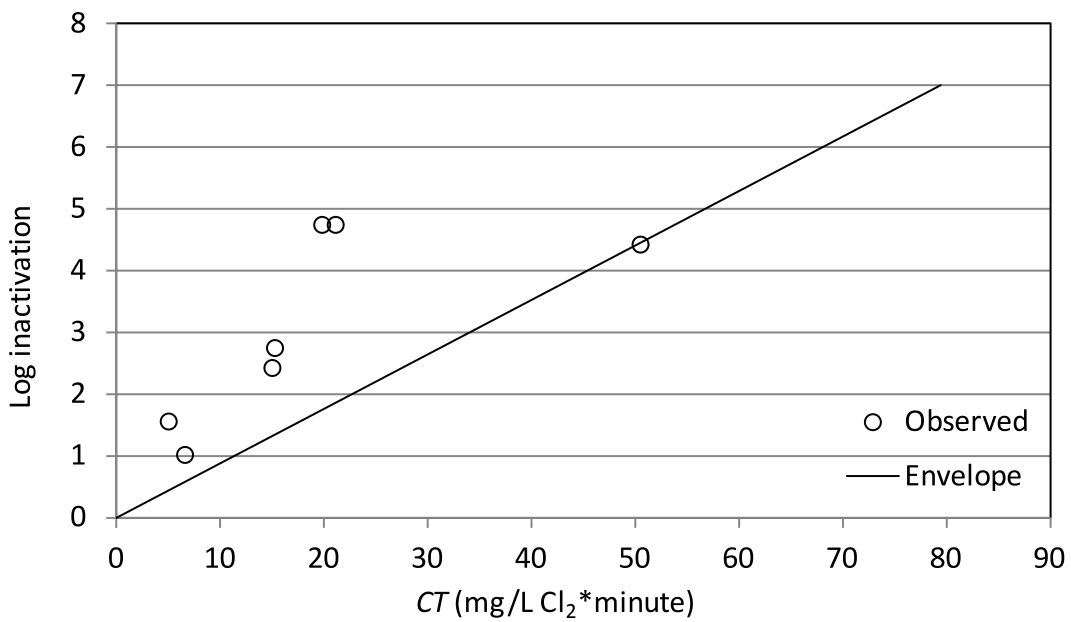


Figure D.47 Free chlorine inactivation of sand-associated coliform

Peat-Associated Microbes. Peat particles appeared to provide the most protection compared with clay and sand particles. To achieve 4-log inactivation of MS2 phage and *E. coli* needs a *CT* of 1,500 and 230 mg/L Cl_2*min, respectively (Figures D.48 and D.49). Similar trends were observed with inactivation using chloramines (results not shown).

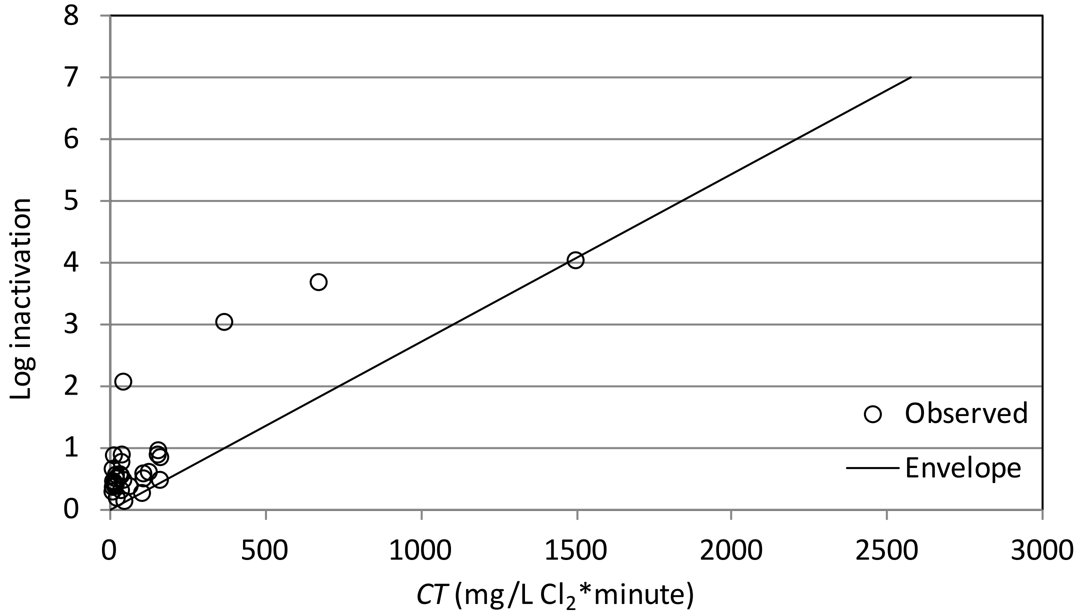


Figure D.48 Free chlorine inactivation of peat-associated MS2

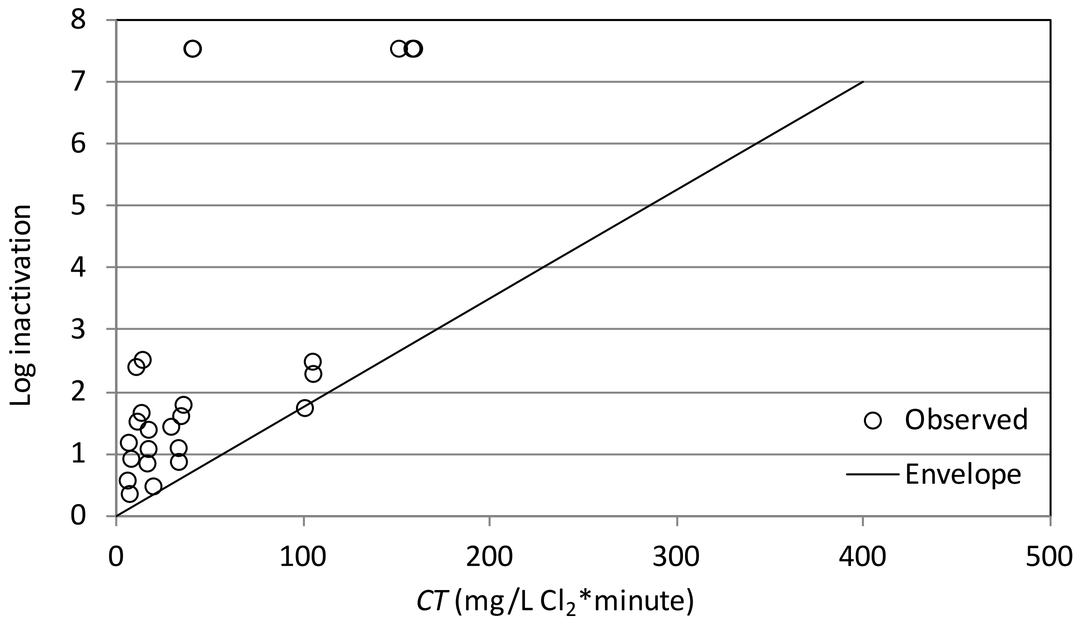


Figure D.49 Free chlorine inactivation of peat-associated coliform

Of the three tested soil particles, the risk controlling *CT* value is 1,500 mg/L Cl_2*min for 4-log inactivation of peat-associated virus (e.g., 25 mg/L Cl_2 for 60 minutes). This value is comparable to the values reported in the existing industry standard practices (AWWA 2005), however, difficult to implement in field due to concerns of elevated disinfectant residuals left in service lines and inadvertent intake by customers. Considering peat particles are much lighter than other soil particles and may be readily removed by flushing, a moderate *CT* value of 100 mg/L Cl_2*min (e.g., 5 mg/L Cl_2 for 20 minutes) is recommended to achieve 4-5 log inactivation of particle-associated virus (adequate for sand and clay particles).

SUMMARY

The risk modeling and lab studies suggest that infection risks from virus be the controlling risk (the highest risk) for intrusion during main breaks and depressurization. The risk model indicates that 7-log reduction of virus levels need to be achieved by using a combination of flushing, disinfection, and/or other risk management options. It also sheds light on alternative risk management options, specific field conditions, and potential improvements of the risk model itself.

1. Flushing, regardless of flushing velocity, should remove all suspended pathogens and some soil-associated pathogens. Effective flushing of >3 feet/sec should be targeted to remove particles.
2. During main breaks/depressurization of 16-inch or larger pipes, flushing might not be effective to remove particles (flushing velocity <3 feet/sec). Flushing at 3 feet/sec also may not be effective for heavily tuberculated pipes. Flushing at higher velocity (e.g. 5 feet/sec), other cleaning methods (e.g. ice pigging or pigging), or replacing new pipes should be considered. More disinfection may be necessary. The *Cryptosporidium* infection risk may become the controlling risk.
3. Disinfection is primarily aimed at inactivating the remaining soil-associated virus and bacteria (>4 log virus inactivation needed).
4. Free chlorine can effectively inactivate suspended MS-2 virus by >5-log inactivation with a *CT* value of 15-20 mg/L Cl_2*min. However, to account for the shielding effect of soil particles, higher *CT* values of 100 mg/L Cl_2*min (e.g., 5 mg/L Cl_2 for 20 minutes) are recommended to achieve 4-5 log inactivation of particle-associated virus.
5. For chloraminated distribution system, background chloramine disinfection may not be adequate to reduce the microbial risks from intrusion after main breaks and depressurization. Additional free chlorination may be needed to lower the risks.
6. The combination of using sand as a surrogate for particle removal by flushing and the assumption of direct sewage contamination might result in a conservative risk model in this study.

APPENDIX E:
REGULATORY AGENCY GUIDANCE

CONTENTS

- Pennsylvania Department of Environmental Protection: Policy for Determining When Loss of Positive Pressure Situations in the Distribution System Require One-Hour Reporting to the Department and Issuing Tier I Public Notification
- Instructions for BWA Due to a Loss of Positive Pressure
- Water UK Technical Guidance Note No.3 Distribution System (Repairing Mains)

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Water Standards and Facility Regulation

DOCUMENT NUMBER:	383-2129-004
TITLE:	Policy for Determining When Loss of Positive Pressure Situations in the Distribution System Require One-Hour Reporting to the Department and Issuing Tier 1 Public Notification
EFFECTIVE DATE:	October 3, 2009
AUTHORITY:	Pennsylvania's Safe Drinking Water Act (35 P.S. §721.1 *et seq*.) and regulations at Title 25 Pa. Code Chapter 109
POLICY:	Public water suppliers and Department of Environmental Protection (DEP) staff should follow the guidance and procedures presented in this document to respond to loss of positive pressure situations in the distribution system.
PURPOSE:	The purpose of this document is to establish uniform instructions and protocol for responding to loss of positive pressure situations in the distribution system to ensure the protection of public health.
APPLICABILITY:	This guidance will apply to all public water systems.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
PAGE LENGTH:	9 pages
LOCATION:	Volume 22, Tab 16
DEFINITIONS:	See Title 25 Pa. Code Chapter 109

POLICY FOR DETERMINING WHEN LOSS OF POSITIVE PRESSURE SITUATIONS IN THE DISTRIBUTION SYSTEM REQUIRE ONE-HOUR REPORTING TO THE DEPARTMENT AND ISSUING TIER 1 PUBLIC NOTIFICATION

I. PURPOSE:

This document is intended to provide a policy to public water suppliers and Department of Environmental Protection (DEP) staff for evaluating and responding to possible contamination of water distribution systems during loss of positive pressure situations caused by a physical disruption (i.e., line breaks, valve repairs, new construction, etc.) or an operational disruption (i.e., pump failure, power outage, telemetry failure, extreme fire flows, source outage, depletion of storage, etc.). This policy provides uniform procedures to ensure water supplies are safe for potable use during a loss of positive pressure situation and after pressure is restored.

II. BACKGROUND:

Any disruption of a water distribution system that results in a loss of positive pressure may allow contaminants to enter the distribution system. Water suppliers can minimize contamination by implementing acceptable department and water industry standards and practices. Pursuant to Chapter 109 of the Department's regulations and *Part II of the Department's Public Water Supply Manual*, water suppliers shall adhere to the American Water Works Association (AWWA) Standard C-651-05 – Disinfecting Water Mains when repairing or replacing water mains to ensure that water quality is not compromised or degraded. Standard C-651-05 includes procedures for adequate flushing, disinfection and microbiological testing. Refer to Section V for more information about Standard C-651-05.

In certain situations, additional measures may be necessary in order to protect public health. This guidance will discuss when one-hour reporting to DEP and issuance of Tier 1 public notification (PN) may be warranted.

III. APPLICABLE REGULATIONS OF TITLE 25 PA CODE CHAPTER 109 (SAFE DRINKING WATER):

A. **§ 109.4.** Requirement to effectively operate and maintain public water system facilities and to take whatever investigative or corrective action is necessary to assure that safe and potable water is continuously supplied to users.

B. **§ 109.408.** Tier 1 public notice.

C. **§ 109.602(a) - (c).** Acceptable design.

D. **§ 109.606.** Chemicals, materials and equipment.

E. **§ 109.607.** Pressures.

F. **§ 109.701(a)(3).** One-hour reporting requirements.

G. **§ 109.702.** Operation and maintenance plan. The operation and maintenance plan must generally conform to the guidelines contained in the Department's *Public Water Supply*

Manual and contain at least the following information: … Procedures for repairing and replacing water mains that conform to the Department and water industry standards.

H. **§ 109.709.** Cross-connection control program.

I. **§ 109.710.** Disinfectant residual in the distribution system.

J. **§ 109.711.** Disinfection of facilities prior to placing them into service. After repairing a facility or performing other activities which place the facility out of service, and before returning the facility to service, the public water supplier shall disinfect the facilities in accordance with the most recent procedures established by the American Water Works Association.

IV. OTHER APPLICABLE REFERENCES:

A. "Public Water Supply Manual, Part II: Community System Design Standards", DEP #383-2125-108, May 6, 2006. All DEP publications are available on DEP's Web site at www.depweb.state.pa.us, keyword: eLibrary.

B. "Policy for Issuing and Removing Water Supply Warnings", DEP #383-2129-005, 2009.

C. Latest standards issued by the American Water Works Association (AWWA) and the American National Standards Institute (ANSI), including ANSI/AWWA Standard C651-05 - Disinfecting Water Mains.

AWWA Standards are copyrighted materials. To place an order, please call AWWA Customer Service at 800-926-7337. Or, you can download a Bookstore Order Form from AWWA's Web site at http://www.awwa.org/, complete it, and mail or fax it to:

Customer Service
AWWA
6666 West Quincy Avenue
Denver, CO 80235-3098
FAX 303-347-0804

Individual AWWA Standards may also be ordered online.

D. "Disinfection of Pipelines and Storage Facilities Field Guide", AWWA, 2006.

E. "Recommended Standards for Water Works", Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, 2007 edition. These Standards are otherwise known as 10 State Standards and are available from Health Research Inc., Heath Education Services Division at http://www.hes.org/.

V. POLICY:

A. One-Hour Reporting Requirements for Loss of Positive Pressure Situations.

Under 109.701(a)(3), a public water supplier shall report the circumstances to the Department within 1 hour of discovery when circumstances exist which may adversely affect the quantity or quality of drinking water including, but not limited to, a situation that causes a loss of positive water pressure in any portion of the distribution system where there is evidence of contamination or a water supplier suspects a high risk of contamination.

To further clarify this requirement, a water supplier shall notify DEP within 1 hour when:

1. A loss of positive pressure within the distribution system is caused by a situation other than a main break, such as a power outage, pump failure, source outage, or depletion of storage.

2. A loss of positive pressure within the distribution system is caused by a main break, repair or replacement **AND**:

   - There is evidence of contamination **OR**,
   - A high risk of contamination.

   Some examples of evidence of contamination may include:

   - Changes to the physical characteristics, such as unusual discoloration, taste or odor.
   - Changes to the water chemistry as evidenced by field test results.

   Some examples of situations with a high risk of contamination include:

   - A flooded trench that cannot be properly dewatered or remedied by best management practices where the water level is at or above the level of the pipe being repaired.
   - Evidence of contamination caused by leaking sewer lines near the site of the main break.
   - Evidence of contamination caused by nearby failing on-lot septic systems near the site of the main break.
   - Evidence of contamination caused by back flow or a cross connection entering the main in the area of the main break or other impacted area.
   - High system unaccounted for water loss (> 20%) due to leaks in the distribution system near the site of the main break.
   - Low system water storage which results in loss of service to customers.
   - Evidence of contamination caused by a stream or river crossing near the site of the main break.
   - Any condition that allows contaminated water to enter the distribution system.

3. Repairs to a main break associated with a loss of positive pressure cannot be completed as per the requirements under Standard C-651-05 and this policy.

4. Special bacteriological samples collected as per Standard C-651-05 and this policy are positive for fecal coliform or *E. coli*.

B. Tier 1 PN Requirements for Loss of Positive Pressure Situations.

For any of the situations listed above, a water supplier shall also consult with DEP regarding the need for and issuance of Tier 1 PN in the form of a Boil Water Advisory (BWA) or some other water supply warning. Tier 1 PN will generally be required for situations meeting the criteria in 2, 3 or 4 above. Situations meeting the criteria in 1 above may require a Tier 1 PN.

Refer to the *Department's Policy for Issuing and Removing Water Supply Warnings* for more information about PN and additional follow-up actions. For example, additional follow-up actions for a BWA may include: repairing/replacing water lines, establishing and maintaining higher chlorine residuals, flushing lines, collecting check samples, etc.

C. Best Management Practices for Main Breaks Which Result in a Loss of Positive Pressure (ANSI/AWWA Standard C-651-05).

Pursuant to Chapter 109 and *Part II of the Department's Public Water Supply Manual*, water suppliers shall adhere to department and water industry standards and practices when repairing or replacing water mains to ensure that water quality is not compromised or degraded. Industry standards and practices include procedures for adequate flushing, disinfection, and microbiological testing. Practical application procedures based on the standard may also be found in AWWA's field guide entitled, "Disinfection of Pipelines and Storage Facilities."

The following check list summarizes the best management practices. Please refer to the AWWA standard for more details.

D. Best Management Practices Check List for Main Breaks Which Result in a Loss of Positive Pressure (ANSI/AWWA Standard C-651-05).

1. Minimize entry of contaminants:

- ☐ Isolate the affected main segment.
- ☐ Shut off all affected service connections that lack adequate backflow prevention, where practical.
- ☐ Dewater excavation trenches prior to repairs. Disinfect wet trenches where practical or where evidence of contamination exists.

2. Disinfect the pipe:

- ☐ Swab or spray pipe interiors and associated fittings with a 1% solution of hypochlorite prior to installation.

- ☐ Where practical or where evidence of contamination exists, disinfect the entire affected main segment using the slug chlorination method. Refer to Standard C-651 for detailed disinfection procedures.

Note: Leaks or breaks that are repaired with clamping devices while the main remains full of pressurized water may present little danger of contamination and therefore may not require disinfection.

3. Remove contaminants and dechlorinate chlorinated-waste discharge:

- ☐ Flush the affected main segment until discolored water is eliminated and the disinfectant residual concentration in the water exiting the main is no higher than the residual disinfectant concentration in the distribution system.

- ☐ Dechlorinate the chlorinated-waste discharge by applying an adequate amount of reducing agent to thoroughly neutralize the chlorine residual remaining in the water. Refer to Standard C-651 for information about dechlorination procedures.

4. Determine effectiveness of procedures:

- ☐ Measure the disinfectant residual concentration to verify establishment of an acceptable residual.

- ☐ As per Standard C-651, collect special follow-up total coliform bacteriological samples to confirm that contamination did not occur during repair or replacement activities. Refer to Table 1 for the minimum number of required samples. Samples must be analyzed by an accredited environmental laboratory. Representative sampling locations must be downstream of the main break or repair. If the direction of flow is unknown, samples must be taken both up and downstream.

Table 1: Minimum # Daily Samples Required for Line Repair	
Population Affected[1]	Minimum # of Samples
1 – 500	1
501 – 1,000	2
1,001 – 2,000	3
2,001 – 3,000	4
3,001 – 4,000	5
4,001 – 5,000	6
5,001 – 7,500	7
7,501 – 10,000	8
10,001 – 25,000	9
25,001 – 50,000	10
> 50,000	11

[1]Population affected = # service connections x 2.7 people

☐ Sampling shall be continued until **two consecutive days of negative samples** are obtained.

☐ If follow-up total coliform sample results are negative for two consecutive days, go to the last check list item and record the details in your Repair Log.

☐ If any follow-up total coliform samples are positive, ensure that the lab is also analyzing the samples for fecal coliform or *E. coli*.

- ☐ **If results are total coliform-positive only**, continue flushing, disinfecting and collecting follow-up samples until such time as samples are negative for total coliform bacteria.

- ☐ **If results are positive for fecal coliform or *E. coli***, notify DEP within 1 hour and issue a BWA as soon as possible, but no later than 24 hours. Refer to the *Department's Policy for Issuing and Removing Water Supply Warnings* for additional information about follow-up actions.

Where practical or where evidence of contamination exists, repaired or replaced water mains must be completely installed, flushed, disinfected and satisfactory bacteriological sample results received prior to returning the main to service.

As per Standard C-651, and as per the water supplier's best professional judgment, after the appropriate disinfection and flushing procedures have been completed, the existing main may be returned to service prior to the completion of bacteriological testing in order to minimize the time customers are without water.

In certain situations, and as per the water supplier's best professional judgment, the collection of bacteriological samples may be avoided. In order to avoid collecting bacteriological samples, **all of the following criteria must be met**:

- There is no evidence of contamination or a high risk of contamination.
- All repair parts are disinfected as per Standard C-651, or if service connections are shut off, the main is disinfected utilizing the slug chlorination method.
- Any area of repair is flushed thoroughly and background chlorine residual levels of at least 0.2 mg/L (as free chlorine or its equivalent) are re-established.
- The water supplier has had no coliform MCL violations in the last year.
- The water supplier is in compliance with the requirements of The Water and Wastewater Systems Operators' Certification Act and associated regulations. Specifically, an available operator with the appropriate level of certification must make all process control decisions related to repairing or replacing the water main.
- The crew must utilize written standard operating procedures that are in conformance with Standard C-651 and this policy.

If a water supplier cannot comply with Standard C-651 and this policy for responding to a loss of positive pressure situation, water quality may be compromised. The water supplier shall notify DEP within 1 hour to discuss whether Tier 1 PN is necessary.

5. Complete recordkeeping:

☐ Record details of the main break in a Repair Log, including all follow-up coliform sample results, or an indication that all criteria were met to avoid bacteriological sampling. Retain the Repair Log on-site, and make it available to DEP upon request.

E. Maintain a Repair Log for Loss of Positive Pressure Situations:

Water suppliers should record the main break event in their repair log. This log should include:

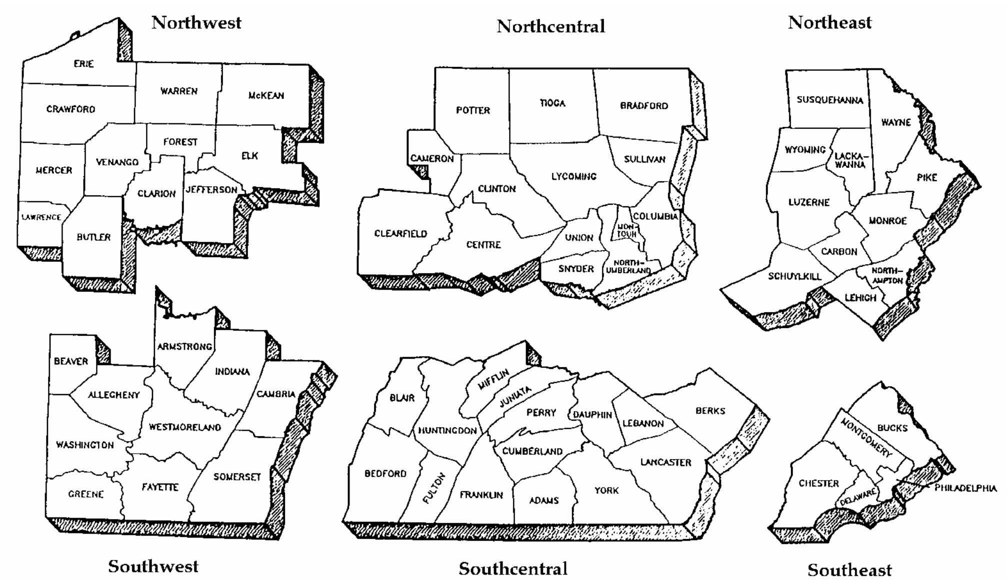
- Date, location and type of repair needed to correct the break.
- Time it was discovered.
- Population affected.
- Length of time required to repair.
- Type of disinfection method used.
- Date and time disinfectant residuals were detected.
- Date and time coliform bacteria samples were collected, or an indication that appropriate criteria were met to avoid bacteriological sampling.
- Results of the coliform bacteria samples and the date results were obtained.

The log should be made available to DEP upon request.

VI. DEP FIELD OPERATIONS REGIONAL OFFICES:

For more information,
call the DEP regional office in your area or contact:

Department of Environmental Protection
Bureau of Water Standards and Facility Regulation
P.O. Box 8467
Harrisburg, PA 17105-8467
717-787-5017



DEP Regional Offices

Northwest Region
230 Chestnut St.
Meadville, PA 16335-3481
Main Telephone: 814-332-6945
24-Hour Emergency: 1-800-373-3398

Counties: *Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Venango and Warren*

Northcentral Region
208 W. Third St., Suite 101
Williamsport, PA 17701
Main Telephone: 570-327-3636
24-Hour Emergency: 570-327-3636

Counties: *Bradford, Cameron, Clearfield, Centre, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga and Union*

Northeast Region
2 Public Square
Wilkes-Barre, PA 18711-0790
Main Telephone: 570-826-2511
24-Hour Emergency: 570-826-2511

Counties: *Carbon, Lackawanna, Lehigh, Luzerne, Monroe, Northampton, Pike, Schuylkill, Susquehanna, Wayne and Wyoming*

Southwest Region
400 Waterfront Drive
Pittsburgh, PA 15222-4745
Main Telephone: 412-442-4000
24-Hour Emergency: 412-442-4000

Counties: *Allegheny, Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington and Westmoreland*

Southcentral Region
909 Elmerton Ave.
Harrisburg, PA 17110
Main Telephone: 717-705-4700
24-Hour Emergency: 1-877-333-1904

Counties: *Adams, Bedford, Berks, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry and York*

Southeast Region
2 E. Main St.
Norristown, PA 19401
Main Telephone: 484-250-5900
24-Hour Emergency: 484-250-5900

Counties: *Bucks, Chester, Delaware, Montgomery and Philadelphia*

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Instructions for BWA Due to a Loss of Positive Pressure:

A situation that causes a loss of positive pressure in any portion of the distribution system where there is evidence of contamination or a water supplier suspects a high risk of contamination has the potential to cause adverse health effects. Public notice, in the form of a boil water advisory, shall be provided to persons impacted by the loss of positive pressure as soon as possible, but no later than 24 hours after you learn of the violation or situation. The form and manner shall fit the specific situation and shall be designed to reach residential, transient, and non-transient users of the water system. In order to reach all persons served, you shall use, at a minimum, one or more of the following forms of delivery:

- Appropriate broadcast media such as radio or television.
- Posting of the notice in conspicuous locations throughout the area served by the water system.
- Hand delivery of the notice to persons served by the water system.
- Another delivery method approved in writing by the Department.

In addition, you shall:

- Report the circumstances to the Department within 1 hour of discovery of the violation or situation.
- Initiate consultation with the Department as soon as possible, but no later than 24 hours after the violation or situation, to determine initial and any additional public notice requirements.
- Comply with initial and any additional public notification requirements that are established as a result of the consultation with the Department.

Description of the Violation/Situation:

If you know why the loss of distribution system pressure occurred, explain it in your notice.

Potential Health Effects

Use the mandatory health effects language indicated in ***italics*** on the following template.

Population at Risk

Some people can be affected more severely than others, as described on the following template. The specific language on the following template is not mandatory, but you must provide information on the population at risk. In addition, make sure it is clear who is served by your water system—you may need to list the areas you serve.

Corrective Action

In your notice, describe the corrective actions you are taking. Listed below are some steps commonly taken by water systems that experience a loss of pressure in the distribution system. Use one or more of the following actions, if appropriate, or develop your own:

- We are sampling/we sampled the finished water for the presence of coliform bacteria.
- We are sampling/we sampled disinfectant levels and will adjust/adjusted the amount of disinfectant added as necessary to maintain adequate levels.
- We are repairing/replacing water lines.
- We are flushing the system thoroughly to re-establish disinfectant residuals.

DRINKING WATER WARNING

BOIL YOUR WATER BEFORE USING

HIERVAN EL AGUA ANTES DE USARLA.
ESTE INFORME CONTIENE INFORMACIÓN IMPORTANTE ACERCA DE SU AGUA POTABLE. HAGA QUE ALGUIEN LO TRADUZCA PARA USTED, O HABLE CON ALGUIEN QUE LO ENTIENDA.

______________________________ May Be At Increased Risk From Microbial Contamination.

We routinely monitor the conditions in the distribution system. On __________________, we experienced a loss of positive water pressure due to ________. A loss of positive water pressure is a signal of the existence of conditions that could allow contamination to enter the distribution system through back-flow by back-pressure or back-siphonage. As a result, there is an increased chance that the water may contain disease-causing organisms.

What should I do?

DO NOT DRINK THE WATER WITHOUT BOILING IT FIRST. Bring all water to a rolling boil, let it boil for one minute, and let it cool before using; or use bottled water. You should use boiled or bottled water for drinking, making ice, washing dishes, brushing teeth, and food preparation until further notice.

Inadequately treated water may contain disease-causing organisms. These organisms include bacteria, viruses, and parasites, which can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

These symptoms, however, are not caused only by organisms in drinking water, but also by other factors. If you experience any of these symptoms and they persist, you may want to seek medical advice.

People with severely compromised immune systems, infants, and some elderly may be at increased risk. These people should seek advice about drinking water from their health care providers. General guidelines on ways to lessen the risk of infection by microbes are available from EPA's Safe Drinking Water Hotline at 1 (800) 426-4791.

What happened? What is being done?

____

____

____

____

____

We will inform you when all corrective actions have been completed and when you no longer need to boil your water.

For more information, please contact: ______________________________

____

____

at ______________________________

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

This notice is being sent to you by ____.

PWS ID#: _________________________ Date distributed: ____________________

Technical Guidance Note No.3

DISTRIBUTION SYSTEM (REPAIRING MAINS)

Introduction

A burst or damaged main and the process of its repair are potential opportunities for contamination to enter the distribution system. A risk assessment should be carried out immediately prior to all repair activity; this should be dynamic and respond to any new developments during the repair process. Precautions are necessary to prevent contamination and minimise the risk to public health when responding to these circumstances and during subsequent repair work.

Good Practice

1. Repair activities on all water mains are restricted operations. All personnel undertaking repairs must be registered under the National Water Hygiene Scheme administered by EU Skills and carry the card that provides evidence of registration.

2. The risk of contamination is greatest when the main is depressurised, whether from the burst or damage itself, or during subsequent isolation for repair when contaminated water or other material can enter the main directly or from backflow through service pipe connections.

3. An on-site assessment should be performed in each case to establish whether there is a risk of contamination and if so its nature and severity. The risk assessment should take account of the possibility that the surrounding soil may be contaminated with chemical or biological materials (for example, petrol or sewage).

4. Where the main is leaking, but still under pressure, for example from a crack around the circumference of the main, a simple repair can be effected with a collar. The excavation should be drained below pipe level (at least 150mm below the invert of the pipe), and the water should remain under a positive, but if necessary reduced, pressure while the repair is made.

5. Where possible, the excavation should be made and pumped so that the water is below pipe level prior to the main being depressurised. For more serious bursts (where there is risk of flooding to properties, danger to the public or significant loss of downstream pressure) the main should be isolated as soon as possible at the nearest downstream valve first. Under these circumstances it is likely that a cut-out repair or pipe length replacement will be necessary.

6. Where the main has to be replaced or cut out for repair, the excavation should extend to a sump well to at least 150mm below the invert of the pipe. The water level should be kept below the bottom of the pipe throughout the repair process, when necessary by suitable pumping.

7. Fittings and pipes should be inspected prior to installation to ensure they are clean and free of defect. Replacement pipes and pieces of pipes together with all fittings and

cut ends should be spray disinfected with a fresh solution of 1000mg/L of free available chlorine.

8. After completing any repair on a depressurised main, including installations of new sections or components, the main should be flushed at the nearest downstream hydrant to remove any debris and excess chlorine. Where practicable, flushing should ideally achieve three volume changes. Due consideration must be given to the potential for contamination of watercourses. Sufficient neutralising agent (eg: sodium thiosulphate) should be added to de-chlorinate the water where this is necessary.

9. Measurement of the downstream chlorine residual should be carried out in order to determine whether sufficient flushing of the repaired section has been completed and the residual has returned to background concentration.

10. Where depressurisation occurs during the repair, the precautions necessary prior to return-to-service should be documented. Where the repair requires a cut-out, but the risk assessment indicates no reason to suspect contamination and the appearance and smell of the water is satisfactory, a sample should be taken for chlorine residual, taste and odour properties, physicochemical and bacteriological analysis from the nearest available downstream hydrant or property. The main may be returned to service pending the results. In the event of a failing sample, the main should be re-sampled and additional samples taken in the adjacent distribution system. Further actions proportionate to the circumstances should be considered to protect public health including disinfection or the issuing of protective advice as necessary.

11. If it is known or suspected that groundwater or other material has entered the pipe, on completion of the repair the main should be flushed (and where necessary swabbed), disinfected and sampled. Dependant on the nature and extent of the contamination, the main may be returned to service prior to receipt of analytical results. Where the risk assessment suggests significant contamination may have occurred (eg: from sewerage) the main should remain out of service until results are known, or if it is critical to restore the supply immediately after repair precautionary advice (such as Boil Water Advice or Do Not Drink Advice) should be issued.

12. Where the on-site risk assessment has determined the necessity for disinfection of the isolated section of main this should be carried out with a minimum of 50mg/L of free available chlorine for 30 minutes (or equivalent method). During this time all service connections should be closed. If this is not possible, steps should be taken to protect any customers who may be affected. After disinfection the main should be flushed as in 8 above.

13. Where "Thermopipe" is used as a repair material it should be treated as an epoxy or polyurethane spray lining. Sterilisation by steam is not acceptable. For further information refer to the codes of practice for In-situ Lining of Water Mains[1].

14. Repairs requiring more than 3 pipe lengths or more than approximately 20 metres long should be disinfected as new mains.

[1] IGN 4-02-02 Code of Practice for In-situ Resin Lining of Water Mains, and WIS-4-02-01 Operational requirements: in situ resin lining of water mains

15. The table below is designed to provide a summary of the operational requirements for various types of mains repair and circumstances.

Job	Risk Assess	Hand Spray Disinfect	Flush	Charge & Disinfect	Sample	Water Quality clearance required
Repair on pressurised main	√	√				
Repair on depressurised main (eg: cut-out repair or piece-up).	√	√	√		√	
Repair on depressurised main - risk of contamination*	√	√	√	√	√	√

*Note: This includes possible foul contamination for example due to the proximity of a damaged sewer.

APPENDIX F: WORK SHOP MINUTES AND FIELD BETA TESTING RESULTS

PROJECT WORKSHOP

The project team conducted a Risk Management Workshop with the utility and regulatory agency partners from April 18-19, 2012. Approximately 30 participants were in attendance and pre-read materials covering the laboratory and questionnaire results were provided in advance of the event.

The objectives of the workshop were:

1) Confirm the applicability of the risk model to be presented at the workshop;

2) Confirm the risk model input parameters (e.g., disinfectant concentration, flushing velocity);

3) Identify field activities for the next phase of the study; and

4) Discuss the applicability of this study as the technical basis for revision of AWWA Standard C651-05

Day 1 Highlights

The workshop opened with presentations that covered the project overview and the results of the baseline of practice survey. The survey results are included with this project report as Appendix C. Points of discussion during this part of the workshop are summarized as follows:

- A discussion of whether utilities use outside contractors for repairing main breaks:
  - Many utilities use outside contractors for main break repair.
  - The survey did not identify the percentage of utilities that use outside contractors.
  - Whether repairs are conducted in-house or by contractors, the consensus was that the practices shall be the same.
  - Some utilities use contractors for work above a specified diameter (e.g 16-inches).
  - Utility representatives inspect the contractor's work for quality control.
  - The contractors can be general contractor or Job Order Contractors, depending on the utility.

The workshop continued with a presentation and discussion of main breaks in general. Points of discussion during this part of the workshop are summarized as follows:

- A question was raised about what level of water loss (from a few gals/min to thousands of gals/min) should an event be considered a "break."

- Rather than setting an arbitrary flow rate limit, a break or leak that compromises the integrity of the pipe shall be considered a "break."

- Discussions on common practices during breaks included:
  - Are break repairs performed at night – the utilities will perform night repairs if there is significant pressure loss or significant water coming to the surface.
  - Depending on the circumstances, participating utilities attempt to minimize the water pressure at damaged areas and maintain service to customers before excavation and repair.
  - Regarding repair clamp sizing relative to the break size, it is sufficient as long as the clamp covers the entire break area. For longitudinal breaks, a stick of pipe is used for main repair or a new valve is commonly installed at the break.
  - All fittings that come into contact with water are disinfected.
  - When a stick of pipe is installed during repair, the stick of pipe is swabbed with hypochlorite solution on site before installation.
  - Customer communications during breaks was discussed ranging from door-to-door contact for small breaks to the use of media in large events.
  - New Jersey American Water demonstrated an interactive website map showing main break locations which is updated every two hours. They also maintain a Facebook page for notifications.

The workshop continued with a presentation and discussion of the risk model. Points of discussion during this part of the workshop are summarized as follows:

- One Norwalk virus can cause 30% chance of illness.
- Disinfection removes 4-5 logs of virus risk, but cannot reduce risks associated with Cryptosporidium.
- Flushing of 3 pipe volumes can remove Cryptosporidium and associated risk by 2-3 logs.
- A question was raised whether cold weather or temperature needs to be considered for CT values for 4-5 log removal.
  - A factor of 2 can be considered for every 10 degrees of temperature for CT values. Cold temperature requires higher CT.
- A question was raised of what minimum pressure shall be maintained in the pipe during repair to avoid intrusion of contaminants.
  - Any indication of positive pressure in the main is sufficient (even bubbling of water out of the pipe), there is no minimum psi.
- Chloramine decay was less in the sewage intrusion experiments as chloramines do not react as readily with organics.
- Currently, utilities are spending a lot of emphasis and time on microbial testing such as: bacteriological test requirements, where to take samples, how to decide what is a representative sample, etc. There is a need to develop a protocol that will ensure good and proper sanitation during main break repairs and that will reduce the dependency on bacteriological tests.
- Small utilities collect coliform samples once per month versus large utilities that collect coliform samples every day. Therefore, it is easier for large utilities to track potential problems in their system.

- Good documentation and a better protocol for main break repair will help the smaller utilities to better protect public heath.

- Chlorine residual monitoring is very important during disinfection. It is the most important measurement that needs to be maintained in the affected area for proper disinfection and inactivation. How to maintain chlorine residual in a chloraminated system is a big challenge.

Following the full-group presentations and discussions above, the study team divided the participants into three technical discussion groups. Points of discussion during this part of the workshop are summarized as follows:

Technical Group Discussion on Repair Procedures

1. General Repair Procedures.

   - Find the problem
   - Identify other utilities in the vicinity
   - Identify critical facilities
   - Assess and minimize damage
   - Shutdown procedure – valve isolation/throttling
   - Hydrant flushing plan – pressure relief; disposal
   - Traffic control; road safety; job site control
   - Fire department and other external clients
   - Excavation plan, approach, and dewatering water disposal
   - Right crew to do the job – right tools available
   - Temporary service to affected customers
   - Assess procedures and repairs
   - Notification
   - Documentation of repair
   - Training – formal; informal

   The above activities were divided into 5 classifications:

   A. Communication:

      - Required throughout the repair process from start to end.
      - Internal: within utility; call center; supervisors – chain of command.
      - External: depending on geographic location.
        - Notify other utilities that there would be excavation/repair in close proximity to their services.
        - Critical customers, health department, regulatory agency, etc.

   B. Site Assessment:

      - Survey to define or identify the problem.

- Assess the damage and potential damage that could occur to others.
- Identify location; address traffic control.
- Operate valves to control flow and shutdown.

C. Operation/ Repair:

- May or may not have any record on type/ size of pipe at break site.
- Mobilize repair crew.
    - May not have enough tools to deal with very large diameter main breaks.
- Excavation considerations:
    - Ground water table
    - Traffic conditions
    - Other utility locations
    - Site contamination, superfund site, etc.
- Whether it is easy to throttle/shutdown valve operation.
- Length of repair; whether temporary service would be required.
- Fix and repair breaks.

D. Return to Normal:

- As soon as possible – zero tolerance for errors.
- Flush and dechlorinate.
- Types of testing that may be necessary.

E. Debrief and After Action:

- Lessons learned – share with others/team for training purposes.
- Proper documentation.

2. Best Practices.

A. Maintain positive pressure

- Use hydrant to maintain positive pressure and flow.
- For elevation variation, pressure shall be such that no backflow is allowed.
- Trench security and safety.
- Good inventory of materials.
- Monitor pressure away from site.
    - SCADA, storage tanks
    - Customer with no water or low pressure

B. Shutdown – cut pipe

- Maintain water level 1-ft below the pipe invert.
- Flushing, swabbing, and disinfection.
- Chlorine residual, bacteriological sample, public notification, temporary water service, boil water advisory (BWA), if necessary.

3. Boil Water Advisory.

- Zero or negative pressure.
  - Zero or negative pressure can be either controlled or uncontrolled. Usually the uncontrolled situations trigger the BWA.
- Procedural errors can cause pipe to become submerged.
- Proximity of sewer or surface/storm water.
- Backflow condition.
- Inability to flush, presence of chemical toxics, etc.

Technical Group Discussion on Disinfection

Per the workshop discussions, the following main break scenarios were identified:

1. Repair Under Pressure: Three conditions.

- Positive pressure from break (no minimum psi)
- Verify flow at close proximity – fire hydrant tap is an option
- No widespread water or pressure loss.

2. Controlled Shutdown – General.

- Clean surfaces
- Swab and spray fittings and pipes with 1% bleach
- Safety tools – personal safety – gloves, goggles, etc.

2a. Controlled Shutdown – Excavate Break under Pressure.

- Excavate area under break.
- Dewater excavation pit and maintain water level below the pipe invert. Per the Repair Procedures group, the separation should be minimum 1 foot.
- Physically clean surfaces.
- Swab and spray fittings and pipes with 1% bleach.
  - Up to 18 feet length of pipe. Anything longer than 18 feet of pipe will be classified under an Uncontrolled Shutdown (see below).
- Flush at lower velocity (less than 3 feet per second) – three pipe volumes.
- Measure disinfectant residual and compare with ambient.
- Advise customers to flush service lines (premise plumbing guideline).

2b. Controlled Shutdown with Downstream Section with Loss of Pressure.

- If the downstream area has no other source of supply, there will be depressurization.
- For the section of break, follow procedures under 2a.
- For depressurized downstream section

- Issue BWA.
- Measure disinfectant residual and perform bacteriological test(s).

3. Uncontrolled Shutdown.

- Valved off before excavation.
- Flooding after excavation.
- Replace more than one pipe section (18 feet).
- Clean, swab, flush and disinfect.
- Achieve proper CT requirements for disinfection and slug chlorination
  - 100 mg/L Cl2 for 15 minutes @ 20 °C; CT = 1,500 mg/L Cl2*min (pH 6-9).
  - 200 mg/L Cl2 for 15 minutes @ 10 °C; CT = 3,000 mg/L Cl2*min (pH 6-9).
  - 300 mg/L Cl2 for 15 minutes @ 5 °C; CT = 4,500 mg/L Cl2*min (pH 6-9).
  - A table will be developed by varying temperature, Cl2 concentration, and time for CT requirements.
  - Need to develop guidance for CT requirements for pH>9.0.
  - UK guideline specifies 1,500 CT requirement.

3a. Uncontrolled Shutdown – Service connections turned-off

- Need to shut down service lines.
- Clean, swab, flush, and disinfect.
- Advise customers to flush service lines (premise plumbing guideline).

3b. Uncontrolled Shutdown – No service connections turned-off

- BWA and bacteriological test.
- Clean, swab, flush (at 3 feet per second), and disinfect.
- Many utilities do not prefer to use more than 4 mg/L of Cl2 concentration for slug chlorination if the service lines are open. Prefer to have BWA rather than using high Cl2 concentration for slug chlorination.

4. Catastrophic Break.

- Widespread pressure loss.
- BWA.
- Repair.
- Measure and verify disinfectant residual.
- Bacteriological tests.

Technical Group Discussion on Flushing:

1. Flushing at 3 feet per second (fps) is reasonable to achieve except at dead ends, in tuberculated pipes, and in >16-inch diameter pipes.

- Dechlorination is an issue.
- Flush all affected areas.
- Velocity of 3 fps to be measured at maximum pipe diameter.
  - A table should be developed for 3 fps velocity for different diameter pipes based on flow to be used in the field.
  - Up to 16-inch diameter pipe, 3 fps velocity can be achieved.
  - For pipes >16-inch diameter, 3 fps velocity is very difficult to achieve because of volume of water to be disposed.
- Will achieve less log credit if 3 fps velocity is not attained and more disinfection log credit will be required to achieve a total of 7 log removal.

2. Flushing should be continued until all the dirt, rust, cloudy/milky water is removed.

   - 3 pipe volumes is reasonable.

3. Pitot gauge or equivalent alternatives can be used for velocity measurements at the hydrants.

   - A flow test may not be helpful if the hydrants are located very far from the break point.

4. If flushing causes a backflow condition, it may not be an option.

5. Consequences of flushing:
   - Environmental impact
   - Physical/property damage

6. A question was raised on the sequence of flushing and disinfection. Which one shall be performed first, flushing or disinfection?

   - Disinfection group commented that the sequence does not matter so long as 7 log removal credit is achieved.
   - Flushing group commented that proper sequencing can take advantage of synergies between the two procedures. If flushing by 3 fps cannot be achieved, a higher level of disinfection will be required to achieve a total 7 log removal credit. Therefore, flushing first will determine if standard disinfection is sufficient or if an increased CT will be required.

7. A question was raised if flushing at 3 fps cannot be achieved; 2-3 log removal credit by flushing cannot be attained. Therefore, the risk from Cryptosporidium prevails and how should this be handled?

   - Depending on the nature of the break as discussed in the disinfection section, if it appears that 3 fps scour velocity is required for flushing and that velocity cannot be attained, BWA shall be issued to reduce the risk of contaminants and Cryptosporidium. However, materials associated with Cryptosporidium are retained in the pipe and need to be removed from the pipe at some point in the repair process.

Full Group Debrief after Technical Group Discussions:

1. Currently, there is an overuse of BWA and many utilities think that BWA followed by bacteriological test will ensure public safety. In reality, many people ignore frequent BWA advisories and the risk may remain. A goal of the current project is to develop a good practice for main repair which will ensure public heath safety and will help alleviate the dependency on BWA.
2. Too much flushing may cause aesthetic problems. Many older pipes are associated with rust and biological growths (biofilms). Flushing may cause the rust and biofilms to mobilize and in many cases they end up at the customer tap.

Day 2 Highlights

The workshop continued into Day 2 with a summation of the results of Day 1. The primary outcome of Day 1 was the development of the four classifications of main breaks. This classification system will be useful in categorizing main breaks based upon the level of associated risk. This in turn helps to determine the appropriate response measures that should be taken to reduce risk. The categories and criteria presented on Day 2 of the workshop were refined over the remainder of the project and are presented in this report in Section 5 in their final form.

To gauge the potential usefulness of developing response measures tied to the four main break categories, the attendees were informally asked to estimate the percentage of the main breaks they experience in their systems that would fall into each category. The presumption was that most main breaks fall into the first two categories (repair under pressure and controlled shutdown); therefore, the issuance of a BWA may be an unnecessary step on many breaks. This presumption was verbally confirmed at the workshop, although not definitive without further work.

Discussion of CT Requirements for Types of Main Breaks:

- For Type I – no CT is required.
- For Type II – no CT is required.
  - Swab/spray repair items with 1% bleach.
  - For pipe replacement under this type, there might be seepage of pit or ground water and suspended microbes can intrude.
    - Flush three pipe volumes, but scour velocity of 3 fps is not required to remove heavy particles from pipe.
    - After flushing, free Cl2 residual should be measured to ensure it is adequate for disinfection.
    - No slug chlorination is required. Under current practice, the utilities do not do any slug chlorination for this type of break.
- For Type III – use 5 mg/L of Cl2 for 20 minutes (CT of 100) for disinfection/slug chlorination.
- For Type IV – 1500 CT; may be using Cl2 concentration at lower level for longer period of time. [Note that this procedure was the subject of much debate during the workshop and the protocols for disinfection were refined over the remainder of the project.]

- A question was raised regarding how repair crews would decide what type of break they are encountering while in the field
  - A risk triage decision flowchart will be developed for field use to determine the type of break.
  - A checklist will help for documentation of the main repair.

Discussion on Field Risk Assessment:

- None of the workshop participating utilities are currently using a chart or table for risk assessment.
- The project will develop a risk assessment table or chart to be used in the field by the utilities.
- Utilities and regulators prefer a flow chart rather than a table for risk assessment.
- The risk assessment flow chart will help for the documentation of the risk assessment procedure.

Discussion on Field Beta Testing:

The workshop participants established several objectives to be achieved during the next phase of the project during field beta testing.

- Maintain Pressure during Repair
  - Many utilities have practices to shut down the line for main break repairs, even when a repair under pressure is possible. The research team will develop a protocol for main break repair under pressure and wants to hear from those utilities of their opinions on switching to pressure repair from non-pressure (shutdown) repair.
  - Repair under pressure does not require flushing and disinfection of the main, unlike shutdown repairs. The cost savings for performing a pressure repair versus a shutdown repair may drive utilities to repair under pressure whenever possible.
  - Repair under pressure does not require maintaining a specific minimal pressure in the main. As long as water is flowing out of the pipe during the repair, positive pressure is present.
- Conduct and Verify Scour Flush
  - Flow shall be measured during repair and verification of whether a flushing velocity of 3 fps or higher is achieved shall be documented.
  - A comment was made that most of the repair crews do not know how to measure the flow. Therefore, the protocol will include sufficient information for training.
  - Field crews should document the flow during flushing to ensure that scour flushing velocity was achieved.
  - The protocol should have a table for flushing velocities for different diameters of pipes.
- Perform Slug Chlorination
  - Slug chlorination at CT of 100 will be tested.
  - Dechlorination of chlorinated water (during slug chlorination) is required by regulation before discharge to the environment.

- Pennsylvania DEP prefers to include the pollution prevention as an integral part of the field testing protocol.

- Measure Chlorine Residual in the Field
  - Some utilities measure Cl2 and turbidity before releasing a main to service after repair.
  - Utilities debated whether turbidity should be a part of the protocol, as this does not indicate the sanitary condition of the water.
  - A sanitized cast iron pipe may have water with >1 NTU because of rust.
  - Customer complaints are expected with highly turbid water and require further flushing. A visual inspection of water for turbidity may be sufficient as turbidity is not a health issue.
- Use Risk Triage Flowchart and Repair Checklist

Discussion on Updating the Field Pocket Guide:

- If authorized by Water Research Foundation, the research team will use the results of the project and field testing to update the existing field pocket guide to aid field crews performing break repairs.
- Note that this request was subsequently approved and funded by the Foundation and the pocket guide update is in progress.

Discussion of AWWA Standard C-651:

- The standard was first developed for new pipe installation and the requirements for main repair were added later on.
- Trained repair crews, good standard operating procedures (SOP), good workmanship, and proper supervision are the key components for main break repair and risk management.
- Many of the participating utilities have their own SOP for main break repair based on AWWA Standard C-651.
- Repair of main breaks requires more attention and caution compared to installation of new mains.
  - Main break repair is time sensitive.
- How to verify whether the written protocol for main break repair has been properly followed in the field when contractors are used?
  - Documentation is very important for verification.
- If the time of shutdown is long for a main repair, temporary water service is required. The current standard does not specify any requirements for the type of pipe to be used, disinfection, Cl2 residual, or sampling of the temporary service line.
  - Proper disinfection and some Cl2 residual in the temporary line are required for risk minimization.
  - Some utilities have specifications for the type of pipe that needs to be used for a temporary service line. It needs to be NSF certified.
- Coliform testing provides only presence or absence results and does not provide any quantification.

- Access to AWWA standards.
  - Many small utilities are not members of AWWA and do not have access to AWWA standards.
  - Regulatory agencies have limited budget and mentioned an inability to afford to buy the standards.
- Small utilities do not have in-house capability for microbial testing.
- Dechlorination vs. Dechloramination.
  - This issue is not discussed in the current standard.
  - Instant dechloramination of monochloramines is not feasible. It requires much longer contact time to achieve complete dechloramination.
- A question was raised whether the research team has investigated the CT requirements for trench treatment for disinfection. If a sewer or storm drain is present next to a broken pipe, does it add any value to add Cl2 to trench water?
  - Most of the utilities do not follow the AWWA standard for trench treatment using hypochlorite solution.
  - Trench treatment is required mainly for the safety of the repair crews, may not be critical for public safety.
  - Conversely, airborne Cl2 gas can be an issue for the safety of the workers in the trench.
- A question was raised whether any biodegradable mat shall be used in the trench for the safety of the workers.
  - Many utilities are using rocks in the trench over the wet soil.
- Swabbing with hypochlorite solution and flushing is a good practice for main repair for public safety.
  - A question was raised whether all the utilities know what swabbing is and what type of material shall be used for swabbing? This needs to be clearly specified in the standard.
  - The standard shall include the procedure of swabbing.
- The standard shall specify that separate sets of tools shall be used for water and wastewater main repairs.
- A question was raised whether a new terminology, i.e., “scour flush” shall be used in the standard instead of flushing.
  - The term “scour flush” may not be necessary to be included in the standard.
  - For flushing the mains following a repair, a velocity of 3 fps or higher needs to be achieved for getting log credit. The current standard specifies for 2.5 fps velocity. This needs to be updated with a minimum of 3 fps velocity requirement.
  - The standard should include a section on how to flush customer taps or plumbing.
- The slug chlorination requirement in the current standard is not practical. This needs to be updated with a realistic protocol.
- Bacteriological samples can provide a false positive or false negative. The results are received 24 hours after the test and after the mains are released to service. Therefore, more emphasis should be given to disinfection, flushing, and repair procedures.
- A question was raised “If we were to start developing the standard C-651 from scratch, what should be the layout/format of the standard for better understanding?”
  - The updated standard shall have two separate sections; one for new pipe and the other for main repairs.

  - The main repair section may have subsections for each of the four break types identified in this study.
- The current standard describes two procedures; disinfection and flushing. A question was raised on decision making whether to use flushing or disinfection or both.
  - If pressure is maintained during repair, disinfection of the main is not required. Flushing is adequate.
- The current standard specifies that all new pipes shall be disinfected and this should stay in the updated version.
- A question was raised that if a section of pipe is replaced due to main break; do we need to follow all the sanitation requirements of new pipe installation?
  - For small sections, spray disinfection of the pipe from both ends may be sufficient.
  - For longer pipe sections, all the protocols for new pipe installation requirements need to be followed.

FIELD INVESTIGATION

The field investigation included field beta testing of procedures and monitoring the results at the break or repair sites or in the distribution system. The requirements and objectives of each field test were developed during the course of the project through literature review and utility survey of the existing practices; laboratory and pilot research; risk modeling; and direct inputs from the participating utilities during the project workshop. The intent for the field investigation was to demonstrate how well the laboratory/pilot results translate to the field and beta-testing the recommended risk mitigation procedures in a field setting to identify if the procedures are effective, practical, and economical. Based on all these specifications, and the inputs from the participating utilities, detailed protocols and checklists have been developed for the field beta testing. The documents developed for field investigation fall under three broad categories:

- Decision making: Documents that have been developed for deciding the types of breaks and measures to be taken for proper sanitation.

- Guideline and documentation: Documents that provide detailed documentation of steps/ procedures that were followed during the main break repair.

- Field protocols: Documents that were developed to be tested in the field to ensure that proposed procedures are effective, practical, and economical.

Decision Making Documents

Two types of documents were developed to categorize the types of main breaks, guide the utilities to decide the types of main break in the field, and measures to be initiated for repair and protection of public health.

- Main break triage table: This table categorizes main breaks into four categories and lists the measures for each category that will be required for main break repair and proper sanitation. The four main break categories (as they existed at the time of beta testing) are listed below. The triage table is provided in the main report body.

- Type I – Controlled repair: For this category, repair is possible with maintaining positive pressure in the main at break area. No contamination intrusion is expected for this type of breaks. The repair crews need to disinfect the repair parts, and check for residual disinfectant level in the distribution system. Neither boil water advisory (BWA) nor bacteriological tests are required.
- Type II – Controlled shutdown: For this category, pressure is maintained during excavation at break area and the repair is performed after controlled shut down of the main. No contamination intrusion is expected for this type of breaks. The repair crews need to disinfect the repair parts, conduct low velocity flushing of the main, and check for residual disinfectant level in the distribution system. Neither BWA nor bacteriological tests are required.
- Type III – Uncontrolled shutdown: For this category, pressure cannot be maintained during the excavation of the break area. All excavation and repair is performed after shutting down the main and may cause local depressurization adjacent to the break. Possible contamination intrusion is expected for this type of breaks. The repair crews need to disinfect the repair parts, conduct scour flushing of the main at 3 ft/sec, conduct slug chlorination with a minimum CT of 100 and check for residual disinfectant level in the distribution system. BWA and bacteriological tests may be required based on the extent of the depressurization.
- Type IV – Catastrophic failure: For this category, a widespread depressurization is observed in the distribution system due to the main break and controlled shutdown is not possible. Actual contamination intrusion is expected for this type of breaks. The repair crews need to disinfect the repair parts, conduct scour flushing of the main at 3 ft/sec, conduct slug chlorination with a minimum CT of 100 mg-min/L and check for residual disinfectant level in the distribution system. BWA and bacteriological tests will be required for public safety.

- Main break risk triage flowchart: A flowchart that guides the utilities/ repair crews to decide the type of main break occurred in the field. This flowchart is provided in the main report body.

Guideline and Documentation

Utilities need to keep track and records of all the main break repairs for internal use and compliance requirements. A master checklist has been developed that can be used as a complete guideline for main break repairs and for documenting of steps that were followed in the field. This checklist documents the break site conditions, causes of breaks, types of main breaks, affected customers, types of notifications, and types of responses level required for the main repair. The checklist also demonstrates the detailed steps to be followed for each category of main break repair, safety and earth work tools that are required at the jobsite. The checklist is adapted in this appendix as Attachment 1.

Field Protocols

Based on laboratory/pilot investigation and risk modeling, four types of field protocols have been developed to demonstrate how well the modeling and research results translate to the field and whether the procedures are effective, practical, and economical. The protocols that were developed for field beta testing include the following:

- Pressure maintenance and verification: The procedure demonstrates that in a small, controlled main break circumstance (Type I), it is practical and feasible to maintain a positive pressure in the pipe at the main break site during the repair. The protocol also confirms and documents that positive pressure is continuously maintained throughout the main repair by visually monitoring a flow of water from the break or a nearby hydrant/tap. The detailed field procedure, related assumptions and field evaluation form is adapted in this appendix as **Attachment 2**.
- Field monitoring for chlorine residuals: The procedure demonstrates that following a repair, it is practical and feasible to achieve and measure appropriate disinfectant residuals to confirm ambient water has been brought back into the system prior to returning to normal service. The detailed field procedure, related assumptions and field evaluation form is adapted in this appendix as **Attachment 3**.
- Scour flushing: The procedure demonstrates that scour flushing, following a main break repair that involves loss of pressure at the break site or elsewhere in the system resulting in possible or actual contamination intrusion, is practical and feasible to remove and dispose of debris and contaminants from the pipe. The protocol also confirms and documents that a minimum of 3.0 ft/sec velocity (in the largest diameter pipe) can be achieved during flushing following a water main break repair. The detailed field procedure, related assumptions and field evaluation form is adapted in this appendix as **Attachment 4**.
- Disinfection slug: The procedure demonstrates that slug chlorination (CT of 100 mg-min/L), following a main break repair that involves loss of pressure at the break site can be reasonably implemented to achieve adequate disinfection and better protect public health. The detailed field procedure, related assumptions and field evaluation form is adapted in this appendix as **Attachment 5**.

All the above field investigation documents were sent to the participating utilities for their review, demonstrating the repair crews on how to implement the protocols in the field setting, practicing the procedures/protocols three times in the field and providing the research team with the feedback and the results of the field investigation.

FIELD BETA TESTING RESULTS

City of Bellevue

The City of Bellevue has very strong procedures for protecting sanitary conditions of pipe and fittings. The City was requested to practice the following procedures/protocols three times in the field.

- Using main break Triage Table (**Table 5.1 – main body report**) and risk triage Flowchart (**Figure 5.1 – main body report**) to decide the type of break and use the Checklist (**Attachment 1**) for documentation and steps to be followed for repair.
- Using Pressure Maintenance and Verification procedure (**Attachment 2**) to ensure that the repair crews are able to maintain pressure in the pipe during repair of Type I breaks.
- Using Field Monitoring for Chlorine Residuals procedure (**Attachment 3**) to ensure that the repair crews are able to measure chlorine residuals following main break repair.
- Using Scour Flushing procedure (**Attachment 4**) to ensure that the repair crews know how to scour flush the main for repair of Type III and Type IV breaks.
- Using Disinfection Slug procedure (**Attachment 5**) to ensure that the repair crews know how to disinfect the main as a part of Type III and Type IV break repairs.

However, the timeframe between the official start date and the deadline for sending back the outcomes of the field investigation was not long enough for the City to allow for proper field staff training. As a result, the City decided to distribute limited information to the crews to avoid confusion. The City documented the information after the repair was made.

The City of Bellevue did not experience enough main breaks during the field investigation timeframe to practice all the protocols three times in the field. The City experienced two Type III main break events on 09/7/2012 and 09/26/2012 and one Type II main break on 09/20/2012; and conducted the field beta testing on three protocols, i.e., pressure maintenance, Cl_2 monitoring and scour flushing. Historically, the City of Bellevue has very good chorine residuals throughout most of the distribution system and slug chlorination is not currently practiced by the City during water main repairs, and therefore, “Disinfection Slug” protocol was not field tested. “Pressure Maintenance and Verification” could not be conducted for Type I breaks, however, the City applied this protocol for the Type II break repair on 09/20/2012 and pressure was monitored. The City crews were able to maintain positive pressure in pipe throughout the repair. The City was able to monitor for chlorine residuals on 09/7/2012 and 09/26/2012 break events. The City conducted “Scour Flushing” successfully during the Type III break repairs on 09/7/2012 and 09/26/2012 to achieve a 3 ft/sec velocity and conducted a low velocity flushing during the Type II break repair on 9/20/2012.

The City of Bellevue had a few concerns on bacteriological testing for Types III and IV breaks, aesthetics of water, etc.; and suggests that future standards should consider these concerns strongly:

- In many situations, the area impacted by the repair comfortably be left out of service for 24-48 hours (or longer if overlapping a weekend) while waiting for lab results to be returned. Further, if a sample is collected and the main is put back online, what should be the action if the sample came back unsatisfactory with fecal or E-coli.
    - Work with local health department(s) to determine the timing of mains being put back into service.
    - An unsatisfactory sample could be used to trigger a “repeat” sample be collected for confirmation of actual contamination similar to the Total Coliform Rule.
    - Sampling could be identified as a tool to verify the effectiveness of the response.
    - Some customers will require higher levels of notification and response when service is restored. Customers like hospitals, medical facilities, large buildings, assisted care, and food services may require more detailed notification or support

to restore water quality in the premises after a significant main break, especially if samples are found to be unsatisfactory.

- Scour flushing performed right in the middle of a water distribution system without using directional flushing procedures can create significant aesthetic concerns in areas outside the one being impacted by the break, and can force crews to remain onsite for several hours after the main is repaired trying to improve the water's aesthetics.
  - Impacts will be limited depending on the velocities achieved during the break itself and depending on when the last time the area was directionally flushed as part of an O&M program.
- The paperwork documentation should include backflow and cross connection control information and questions.
  - Field crews to identify if "residential" or "commercial" customer services were affected by pressure loss during the break/response. Commercial areas may increase the risk of hazardous backflows if pressure loss occurred prior to service isolations and backflow assemblies are either not installed or not operational, or if there are unknown/illegal connections to the distribution system.
  - Repair crews to document if they notice any suspicious water coming out of the main after isolation; hot, colored, smelly water, etc which would immediately prompt a higher level of response.

City of Boulder

The City of Boulder is one of the utilities that do not follow the AWWA C651 standards for main repairs but do flushing of mains as a criterion for release-to-service after repairing a water main break. The repair crews have been maintaining and protecting both water and sewer very successfully over the years. The City of Boulder was requested to practice the following procedures/protocols three times in the field.

- Using main break Triage Table (**Table 5.1** – **main body report**) and risk triage Flowchart (**Figure 5.1 – main body report**) to decide the type of break and use the Checklist (**Attachment 1**) for documentation and steps to be followed for repair.
- Using Pressure Maintenance and Verification procedure (**Attachment 2**) to ensure that the repair crews are able to maintain pressure in the pipe during repair of Type I breaks.
- Using Field Monitoring for Chlorine Residuals procedure (**Attachment 3**) to ensure that the repair crews are able to measure chlorine residuals following main break repair.
- Using Scour Flushing procedure (**Attachment 4**) to ensure that the repair crews know how to scour flush the main for repair of Type III and Type IV breaks.
- Using Disinfection Slug procedure (**Attachment 5**) to ensure that the repair crews know how to disinfect the main as a part of Type III and Type IV break repairs.

Historically, the City of Boulder experiences only 71 breaks on average per year and the timeframe between the official start date and the deadline for sending back the outcomes of the field investigation was not long enough for the City to have many breaks in the field and practice the protocols. The City personnel demonstrated the field crews on the protocols and documented the information after the repair was made.

The City recognizes the protocols as very thorough and complete sets that will cover many conditions that may be encountered in responding to a main break or maintenance, whether scheduled or not and expects it to be a valuable planning and training tool. However, the City felt that the Field Checklist is much too detailed to be used routinely by maintenance crews in the field without proper training, especially when responding to an emergency in the system.

Under City's current practice, some aspects of responding to main breaks in the protocols pose special challenges. Most City responders will not have time (or enough information) to calculate a flow rate/ volume/ time for flushing after a repair. The City does not have any current practice for slug disinfection/chlorination. The City also do not routinely collect bacterial samples and leaving a main isolated (and customers without service) long enough to get results.

The City is planning to use the Field checklist as a basis to develop a condensed (e.g. one-page) checklist by that can be used by any of their crew that may be called out to respond to a main break.

The City of Boulder experienced one broken valve which required to be replaced within field investigation time frame. The City categorized the repair as Type II using the Triage Table and risk triage Flowchart and replaced the valve on 10/16/2012 following the Field Checklist. The City also conducted Cl_2 monitoring and low velocity flushing (instead of scour flushing) following the field protocols during the repair.

Charlotte-Mecklenburg Utility (CMUD)

The number of main breaks per year for CMUD is relatively high, 2,145 main breaks per year. CMUD has developed a comprehensive training and certification program for the repair crews to maintain the sanitary conditions of pipe and fittings during repairs. CMUD was requested to practice the following procedures/protocols three times in the field.

- Using main break Triage Table (**Table 5.1 – main body report**) and risk triage Flowchart (**Figure 5.1 – main body report**) to decide the type of break and use the Checklist (**Attachment 1**) for documentation and steps to be followed for repair.
- Using Pressure Maintenance and Verification procedure (**Attachment 2**) to ensure that the repair crews are able to maintain pressure in the pipe during repair of Type I breaks.
- Using Field Monitoring for Chlorine Residuals procedure (**Attachment 3**) to ensure that the repair crews are able to measure chlorine residuals following main break repair.
- Using Scour Flushing procedure (**Attachment 4**) to ensure that the repair crews know how to scour flush the main for repair of Type III and Type IV breaks.
- Using Disinfection Slug procedure (**Attachment 5**) to ensure that the repair crews know how to disinfect the main as a part of Type III and Type IV break repairs.

Due to limited manpower and time, CMUD was able to collect field data for one break which includes the field beta testing results on chlorine monitoring and scour flushing. CMUD was able to monitor for chlorine residuals and conducted "Scour Flushing" successfully as a part of the main repair on 10/10/2012 to achieve a 3 ft/sec velocity.

City of Fort Worth

The City of Fort Worth experiences an average of 1,146 main breaks per year and has adopted a comprehensive main break repair program. The City of Fort Worth was requested to practice the following procedures/protocols three times in the field.

- Using main break Triage Table (**Table 5.1 – main body report**) and risk triage Flowchart (**Figure 5.1 – main body report**) to decide the type of break and use the Checklist (**Attachment 1**) for documentation and steps to be followed for repair.
- Using Pressure Maintenance and Verification procedure (**Attachment 2**) to ensure that the repair crews are able to maintain pressure in the pipe during repair of Type I breaks.
- Using Field Monitoring for Chlorine Residuals procedure (**Attachment 3**) to ensure that the repair crews are able to measure chlorine residuals following main break repair.
- Using Scour Flushing procedure (**Attachment 4**) to ensure that the repair crews know how to scour flush the main for repair of Type III and Type IV breaks.
- Using Disinfection Slug procedure (**Attachment 5**) to ensure that the repair crews know how to disinfect the main as a part of Type III and Type IV break repairs.

The timeframe between the official start date and the deadline for sending back the outcomes of the field investigation, the City experienced six main breaks. The City classified three breaks to be Type I and three breaks to be Type II using Triage Table and risk triage Flowchart.

The City recognizes the Field Checklist as very thorough and helpful to be used routinely by maintenance crews in the field and documenting steps to be followed to repair the breaks. For all six breaks, the City used the Field Checklist to document background information, repair procedures followed in the field, notification, safety protocols followed in the field, break site control and site excavation/trench work. It is to be noted that the City of Fort Worth conducts bacteriological testing regardless of types of break under their current practice.

The City conducted monitoring of chlorine residuals for all six main breaks and pressure maintenance and verification for two of the three Type I main breaks. The City could not conduct scour flushing or slug disinfection as they did not experience any Type III or Type IV main breaks during the field investigation period. However, the City conducted low velocity flushing for all Type II breaks.

ATTACHMENT 1

Field Checklist for Main Break Evaluation

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

Field Checklist for Main Break Evaluation

Date of Break: ________________________ Time:_____________ ❑ A.M. ❑ P.M.

1. **Site Assessment and Identification:** By site survey, first responder, GIS, as-built drawings and/or communication. Please check all that apply:

❑ Identify main break/leak location

- Location: ____

❑ Identify pipe size and pipe material (if possible)

- Pipe Diameter: ___________ Inches
- Pipe Material: ____________________________

❑ Identify nature of break: Please check all that apply:

❑ Circumferential ❑ Longitudinal ❑ Blowout ❑ Joint

❑ Sleeve ❑ Split at Corporation ❑ Hole

❑ Other:_______________________________________

❑ Identify the cause of break: Please check all that apply:

❑ Water Hammer (Surge) ❑ Defective Pipe ❑ Deterioration

❑ Corrosion ❑ Improper Bedding ❑ Operating Pressure

❑ Temperature Change ❑ Differential Settlement ❑ Contractor

❑ Unknown ❑ Other: ____

❑ Degree of tuberculation on interior of pipe:

❑ Negligible (0%-20%) ❑ Light (20%-50%)

❑ Moderate (50%-80%) ❑ Severe (>80%)]

❑ Assess damage and/or potential damage (public hazard) that could occur to others: __________

❑ Assess expected traffic disruptions: ____

❑ Identify affected customers: ____

❑ Identify critical customers: ____

- ❑ Existing utilities in close proximity of the repair site

❑ Water	❑ Gas	❑ Power
❑ Sanitary Sewer	❑ Phone	❑ Fiber Optics
❑ Storm	❑ Cable	❑ Others: ________________________

- ❑ Locate and mark nearby water grid isolation valves to control flow and shutdown.
- ❑ Locate and mark nearby water hydrants for flushing plans.
- ❑ Determine location of dewatering and runoff, and avoid or mitigate erosion and property damage.
- ❑ Determine whether temporary service would be required: _________________________ ______
- ❑ Comments: ____

____

Types of Repair and Response Level:

Based on the following parameters, use the attached "**Main Break Risk Triage Flowchart**" to classify the type of break, and conduct subsequent repairs per Table 1:

Sanitary/Regulatory Parameters

- Valve condition and location
- Critical customers affected
- Size of area affected
- Depressurization potential
- Sanitary condition
- Regulatory requirements

Other parameters

- Volume of water
- Potential for damage
- Public and employee safety

Table 1: Types of Main Breaks and Response Level

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/ 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 break exposed	• Partially or un-controlled shutdown	• Catastrophic event/failure
• No signs of contamination intrusion	• No signs of contamination intrusion	• Possible contamination intrusion	• Possible/ actual contamination intrusion
Repair Procedures	Repair Procedures	Repair Procedures	Repair 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 min)	• Disinfect repair parts
• Check residual disinfectant level in distribution system	• Conduct low velocity flush (flush three pipe volume)	• Conduct slug chlorination (CT of 100)	• Conduct scour flush (3 ft/sec min)
• No Boil Water Advisory (BWA)	• Check residual disinfectant level in distribution system	• Check residual disinfectant level in distribution system	• Conduct slug chlorination (CT of 100)
• 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
• See page 4 for details	• No bacteriological samples	• BWA – TBD; based on depressurization extent	• Check residual disinfectant level in distribution system
	• See page 5 for details	• Bacteriological samples - TBD; based on depressurization extent	• Issue BWA/ Boil Water Order
		• See page 6 for details	• Bacteriological sampling required
			• See page 7 for details

Pipe Flushing Velocity Based on Flow

In order to achieve a 3.0 ft/sec flushing velocity in pipe (largest diameter pipe section) in terms of flow (gpm), use the Table 2 below:

Table 2: Flow in Pipe (gpm) for a Flushing Velocity of 3.0 ft/sec

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

2. **Repair Activities:** Once the type of break has been determined, follow associated repair procedures:

   A. **Type I - Controlled Repair or Repair under Pressure:** When repair is possible with maintaining the pressure in the line. Please check all that apply:

   - ❑ Isolate the pipe section using valves and hydrants; and maintain positive pressure in the pipe to reduce backflow or runoff contamination.
   - ❑ No depressurization elsewhere in the water distribution system (minimum 20 psi elsewhere in the system).
   - ❑ Excavate to expose main break.
   - ❑ Throttle flow. Visually observe positive flow/spray at the break site until the hydrant/tap used for pressure verification is opened. Hydrant/tap elevation must be higher than break site.
   - ❑ Visually confirm three times during the repair (start/middle/completion) that water was flowing from the pressure verification hydrant/tap or at the break site, indicating that positive pressure was maintained continuously.
   - ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
   - ❑ Dispose of or dechlorinate water in accordance with local regulations.
   - ❑ Ensure that no obvious contamination such as sewage or chemical contamination present at site.
   - ❑ Determine the pipe material, its outside diameter (OD), and fittings (repair clamps) necessary to perform work:
     - ❑ Pipe material: ________________________________

- ❑ Pipe outside diameter: _________________ Inches
- ❑ Required fittings: ____

❑ Clean and spray disinfect (with 1% bleach) all tools and fittings (repair clamps) before installation.

❑ Complete repair.

❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.

❑ Measure disinfectant residual and compare with ambient. Level after repair shall be within +/- 10% of the pre-repair level.

❑ Following satisfactory disinfectant residuals, return to normal service.

B. Type II - Controlled Shutdown: Pressure is maintained during excavation and the repair is performed after controlled shut down of the line. Please check all that apply:

❑ Isolate the pipe section using valves and hydrants; and maintain positive pressure in the pipe to reduce backflow or runoff contamination.

❑ Maintain positive pressure (flow from pipe) until bottom of pipe is 12” above water in the trench.

❑ No depressurization elsewhere in the water distribution system (minimum 20 psi elsewhere in the system).

❑ Shutdown service lines within the break area.

❑ Excavate to expose main break.

❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.

❑ Dispose of or dechlorinate water in accordance with local regulations.

❑ Physically clean visible debris in the pipe and fittings – exterior and interior.

❑ Ensure that no obvious contamination such as sewage or chemical contamination present at site.

❑ Determine the pipe material and its outside diameter (OD), fittings, joints, gaskets, clamps, and other repair equipment necessary to perform work:

- ❑ Pipe material: ________________________________
- ❑ Pipe outside diameter: _________________ Inches
- ❑ Required pipe/fittings: ____

❑ Maintain pipe caps, plugs and other protective coverings until pipes are joined.

❑ Keep fittings, valves and appurtenances covered and protected until ready for installation.

❑ Keep gaskets clean all the time.

❑ Disinfect all repair tools.

❑ Swab pipe and fittings with 1% bleach.

❑ Spray disinfect pipe and fittings with 1% bleach.

❑ Complete repair.

❑ Fill the line slowly and use lower hydrants first to remove entrapped air.

- ❑ Flush hydrants to remove debris (three pipe volume). Note: Not required to achieve 3.0 ft/sec flushing velocity in the pipe.
- ❑ Dispose of or Dechlorinate chlorinated water in accordance with local regulation.
- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.
- ❑ Measure disinfectant residual and compare with ambient. Level after repair shall be within +/- 10% of the pre-repair level.
- ❑ Advise customers to flush service lines (premise guideline).
- ❑ Following satisfactory disinfectant residuals, return to normal service.

C. Type III - Uncontrolled Shutdown: Pressure not maintained during excavation; controlled shut down not possible. Please check all that apply:

- ❑ Isolate the pipe section using valves.
- ❑ Shutdown service lines within the affected area.
- ❑ Excavate to expose main break.
- ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Physically clean visible debris in the pipe and fittings – exterior and interior.
- ❑ Possible contamination such as sewage or chemical contamination intrusion at break site.
- ❑ Determine the pipe material and its outside diameter (OD), fittings, joints, gaskets, clamps, and other repair equipment necessary to perform work:
  - ❑ Pipe material: ________________________________
  - ❑ Pipe outside diameter: __________________ Inches
  - ❑ Required pipe/fittings: ____
- ❑ Maintain pipe caps, plugs and other protective coverings until pipes are joined.
- ❑ Keep fittings, valves and appurtenances covered and protected until ready for installation.
- ❑ Keep gaskets clean all the time.
- ❑ Disinfect all repair tools.
- ❑ Swab pipe and fittings with 1% bleach.
- ❑ Spray disinfect pipe and fittings with 1% bleach.
- ❑ Complete repair.
- ❑ Fill the line slowly and use lower hydrants first to remove entrapped air.
- ❑ Flush hydrants (achieve 3 fps velocity in the largest diameter pipe section) to remove debris (three pipe volume). See Table 2.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Slug chlorination of the repaired section using a CT of 100 mg-min/L (5 mg/L of residual Cl_2 for 20 minutes of contact time) for proper disinfection.
- ❑ After the appropriate chlorination contact time, flush slug of chlorinated water from the main until the chlorine concentration in the water is within +/- 10% of the ambient chlorine

concentration, meeting minimum regulatory standards. Dispose of or Dechlorinate water in accordance with local regulations.

- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.
- ❑ Measure additional disinfectant residual in the system (if required) and compare with ambient. Level after repair shall be within +/- 10% of the pre-repair level.
- ❑ Any local depressurization in the water distribution system?
  - ❑ If, No
    - ❑ No Boil Water Advisory (BWA) Necessary.
    - ❑ No Bacteriological Test Necessary.
  - ❑ If, Yes – to be determined
    - ❑ Issue Boil Water Advisory (BWA) based on extent of local depressurization.
    - ❑ Conduct Bacteriological Test based on extent of local depressurization.
- ❑ Advise customers to flush service lines (premise guideline).
- ❑ Following satisfactory disinfectant residual and bacteriological sample results (if required), return to normal service.

D. <u>Type IV – Catastrophic Failure:</u> Widespread depressurization in the water distribution system. Please check all that apply:

- ❑ Shutdown the line using valves.
- ❑ Shutdown service lines within the affected area.
- ❑ Excavate to expose main break.
- ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Physically clean visible debris in the pipe and fittings – exterior and interior.
- ❑ Possible/actual contamination such as sewage or chemical contamination intrusion at break site and/or elsewhere in the distribution system.
- ❑ Determine the pipe material and its outside diameter (OD), fittings, joints, gaskets, clamps, and other repair equipment necessary to perform work:
  - ❑ Pipe material: ________________________________
  - ❑ Pipe outside diameter: __________________ Inches
  - ❑ Required pipe/fittings: ____
- ❑ Maintain pipe caps, plugs and other protective coverings until pipes are joined.
- ❑ Keep fittings, valves and appurtenances covered and protected until ready for installation.
- ❑ Cover or cap (water tight) all open ends of new pipes and fittings in the trench at the end of each workday.
- ❑ Keep gaskets clean all the time.
- ❑ Disinfect all repair tools.

- ❑ Swab pipe and fittings with 1% bleach.
- ❑ Spray disinfect pipe and fittings with 1% bleach.
- ❑ Complete repair.
- ❑ Fill the line slowly and use lower hydrants first to remove entrapped air.
- ❑ Flush hydrants (achieve 3 fps velocity in the largest diameter pipe section) to remove debris (three pipe volume). See Table 2.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Slug chlorination of the repaired section using a CT of 100 mg-min/L (5 mg/L of residual Cl_2 for 20 minutes of contact time) for proper disinfection.
- ❑ After the appropriate chlorination contact time, flush slug of chlorinated water from the main until the chlorine concentration in the water is within +/- 10% of the ambient chlorine concentration, meeting minimum regulatory standards. Dispose of or Dechlorinate water in accordance with local regulations.
- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.
- ❑ Measure additional disinfectant residual in the system (if required) and compare with ambient. Level after repair shall be within +/- 10% of the pre-repair level.
- ❑ Conduct Bacteriological Test.
- ❑ Issue Boil Water Advisory (BWA).
- ❑ Advise customers to flush service lines (premise guideline).
- ❑ Return to service upon approval from regulatory agencies.

3. **Notification:** Distribute notification in advance on main break problem, interruption of service, scheduled period of work, potential traffic disruption and other public hazard. Please check all that apply:

- ❑ Affected and critical customers.
- ❑ Department of Public Works.
- ❑ Department of Transportation.
- ❑ Local law enforcement.
- ❑ State Department of Health.
- ❑ Regulatory agencies.
- ❑ Media in the form of a press release.
- ❑ Affected customers.
- ❑ Other Utilities: ____

4. **Safety Equipments, Fittings and Repair Tools:** Please check all that apply:

- ❑ Personnel protective equipment (PPE) such as protective gloves, reflective vests, hard hats, protective goggles, etc.
- ❑ Flow and pressure measurement gauges or devices.
- ❑ Disinfection and dechlorination chemicals and equipment.
- ❑ Repair and excavation tools (saws, wrenches, buckets, shovels, pick axes, ladders, flashlights, night work lights, etc.).
- ❑ Pipes, fittings/repair clamps etc.:____
- ❑ Flow and surface runoff diversionary equipment like, sandbags, trench covers, etc.
- ❑ Dewatering pump.
- ❑ Tapping equipment.
- ❑ Biological sampling bottles, gloves, transport cooler, ice packs, and laboratory chain-of-custody sheets: ____

5. **Site Control:** Please check all that apply:

- ❑ Public warning and road hazard signs, traffic cones, and barriers.
- ❑ Provide measures for dust control.
- ❑ Provide site access routes that will minimize airborne contamination of material and equipments.
- ❑ Locate and mark all existing utilities in the vicinity of the main repair/excavation including water, sewer, storm, phone cable, gas, power lines, fiber optics etc.: _____________________________
- ❑ Provide measures for protection against storm water, agricultural and industrial runoff.
- ❑ Assess how groundwater levels, inclement weather, and other factors may affect the repair, and determine compensatory methods.

6. **Excavation and Trench Work:** Please check all that apply:

- ❑ Install temporary diversion devices to control surface water runoff into trench.
- ❑ Dewater the excavated trench.
- ❑ Provide adequate shoring and use ladders for safety.
- ❑ Keep pipes, fittings, and valves away from excavated soil or backfill materials.
- ❑ Call “underground utility notification center” if necessary.
- ❑ Expose, thoroughly scrape and clean the area around the pipe section for inspecting the break.

ATTACHMENT 2

Field Protocol - Pressure Maintenance and Verification

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.
2. Confirm through SCADA, monitoring, modeling, or other means that depressurization did not occur elsewhere in the pressure zone as a result of the break or during the following repair procedures. Minimum threshold is 20 psi away from the break site.

3. Excavate to expose the main break.
4. Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired. Dispose of or dechlorinate water in accordance with local regulations.
5. Determine the pipe material, the outside diameter (OD), and fittings (repair clamps) necessary to perform work. Keep tools, fittings, gaskets, valves and appurtenances covered and protected until ready for installation.
6. Throttle flow. Visually observe positive flow/spray at the break site until the hydrant/tap used for pressure verification is opened. Hydrant/tap elevation must be higher than break site.
7. Open hydrant/tap. Confirm positive pressure is achieved through visual observation of flow at the selected hydrant nozzle/tap. Dispose of or dechlorinate water in accordance with local regulations.
8. Start repair.
9. Clean and spray disinfect (with 1% bleach) all tools and fittings (repair clamps) before installation, or other disinfection measures that may be required.
10. At the mid point of the repair, reconfirm that positive pressure is achieved through visual observation of flow at the selected hydrant nozzle/tap or at the break site.
11. Complete repair.
12. Following repair completion, reconfirm that positive pressure is achieved through visual observation of flow at the selected hydrant nozzle/tap.
13. If flow is observed, collect water sample from the repaired main and measure disinfectant residual.
14. Close hydrant/tap.
15. Backfill and compact per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.
16. Following satisfactory chlorine residuals, return to normal service.

MONITORING DATA:

1. Break site: Visually confirm 3 times during the repair (start/middle/completion) that water was flowing from the pressure verification hydrant/tap or at the break site, indicating that positive pressure was maintained continuously.
2. Other Areas in Pressure Zone: Confirm through SCADA, monitoring, modeling, or other means that depressurization did not occur elsewhere in pressure zone as a result of the break or repair procedures. Minimum threshold is 20 psi elsewhere in the system.

DOCUMENTATION AND CLOSE OUT:

1. Complete the attached Documentation and Evaluation Form to demonstrate and affirm that procedures were followed.
2. Close-out the work order per the specific utility procedures.

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD VERIFICATION STUDIES BY UTILITY PARTNERS

Documentation & Evaluation Form		
Field Study Procedure: *Pressure Maintenance and Verification*		
Name of Utility: ______________________	Crew Chief Name: ______________________	
Date of Break: ______________________	Time:____________	❑ A.M. ❑ P.M.

GENERAL:

Pipe Diameter: __________ Inches Pipe Material: ______________________

Identify nature of break (Please check all that apply):

❑ Circumferential ❑ Longitudinal ❑ Blowout ❑ Joint

❑ Sleeve ❑ Split at Corporation ❑ Hole

❑ Other:____

Identify the cause of break: Please check all that apply:

❑ Water Hammer (Surge) ❑ Defective Pipe ❑ Deterioration

❑ Corrosion ❑ Improper Bedding ❑ Operating Pressure

❑ Temperature Change ❑ Differential Settlement ❑ Contractor

❑ Unknown ❑ Other: ____

FIELD PROCEDURE VERIFICATION & MONITORING DATA

Was the repair completed while maintaining positive pressure in the pipe? Yes ___ No ___

Was flow throttled to help facilitate repair procedures? Yes ___ No ___

Was water in the excavation pit kept at least 12 inches below the bottom of the exposed pipe under repair? Yes ___ No ___

Was obvious sewage or chemical contamination observed in the excavation? Yes ___ No ___

Was a hydrant/tap used to visually observe flow for positive pressure verification? Yes ___ No ___
If actual pressure reading was obtained at hydrant, please document below (not required for this field study procedure).

How far was the hydrant/tap selected for pressure verification from the break site?

____

Was the hydrant/tap located uphill, downhill, or at the same elevation as the break site?

____

Was positive flow/spray at the break site observed until the hydrant/tap used for pressure verification was opened? Yes ___ No ___

Was pressure maintained during the entire repair procedure (please document below)?

Yes ___ No ___

Start of Repair:	*Time:*	________ A.M or P.M
	Flow observed at hydrant/tap:	Yes ___ No ___
	Pressure (if known):	______________ PSI
Middle of Repair:	*Time:*	________ A.M or P.M
	Flow observed at hydrant/tap:	Yes ___ No ___
	Pressure (if known):	______________ PSI
Completion of Repair:	*Time:*	________ A.M or P.M
	Flow observed at hydrant/tap:	Yes ___ No ___
	Pressure (if known):	______________ PSI

At any time during the repair, was a “no flow” condition observed at the break site or hydrant?

Yes ___ No ___

Document disinfectant residual: ___________________ mg/L free chlorine residual

Was 20 psi maintained elsewhere in the pressure zone? Yes ___ No ___
Was it monitored through SCADA, modeling, or other means during the repair? Yes ___ No ___
What monitoring method was used? _________________

Please document comments, concerns, observations, and/or feedback regarding this field study procedure below:

ATTACHMENT 3

Field Protocol - Field Monitoring for Chlorine Residuals

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

TITLE OF FIELD STUDY: Field Monitoring for Chlorine Residuals during Main Break Repair

PURPOSE OF FIELD STUDY:

1. To demonstrate that following a repair, it is practical and feasible to achieve and measure appropriate disinfectant residuals to confirm ambient water has been brought back into the system prior to returning to normal service.

ASSUMPTIONS:

1. This Field Study Procedure can be applied to a Type I, II, III, or IV water main break.
2. Water in the excavation pit is maintained at least 12 inches below the bottom of the exposed pipe being repaired.
3. All other good sanitary repair practices are followed (e.g. repair parts are sanitized with bleach).
4. Procedures are applicable for both free and combined chlorine residuals.

FIELD PROCEDURES:

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 flow (Type I) or isolate the main break (Type II, III, IV), depending on the type of main break.
   e. Identify appropriate hydrants to facilitate flushing from both directions, if possible, and required for the type of main break.
2. Confirm through SCADA, monitoring, modeling, or other means whether or not depressurization has occurred elsewhere in the pressure zone as a result of the break or during the following repair procedures. Minimum threshold is 20 psi away from the break site.
3. Throttle flow or close valves to isolate the section of main break and selected hydrants from the water distribution system, depending on the type of main break.
4. Excavate to expose the main break.
5. Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired. Dispose of or dechlorinate water in accordance with local regulations.
6. Determine the pipe material, the outside diameter (OD), and fittings (repair clamps) necessary to perform work. Keep tools, fittings, gaskets, valves and appurtenances covered and protected until ready for installation.

7. Test and document the ambient free and total chlorine residual in the water distribution system.
8. Complete repair. Clean and spray disinfect (with 1% bleach) all tools and fittings (repair clamps) before installation, or other disinfection measures that may be required.
9. Following repair completion, conduct low velocity flush (Type II) or scour flush (Type III, IV) as required depending on the type of main break.
10. Following the flushing activities, fill the system with water from the distribution system.
11. Collect water sample from the repaired main and measure disinfectant residual (free and total chlorine). Ensure sample collected is representative of the water quality in the main, not from a service line.
12. Compare residual with the ambient residual collected in Step 7 to confirm that ambient levels of disinfectant are present in the pipe following flushing and prior to placing system back in service. Level after repair shall be within +/- 10% of the pre-repair level.
13. Backfill and compact per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.
14. Following satisfactory chlorine residuals, return to normal service.

ANALYTICAL MONITORING PROCEDURES:

1. Calibration and testing procedures are specific to the analytical equipment/test kits used by each respective utility. Analytical equipment/test kits shall be approved for use by the USEPA and/or state regulatory agency.
2. Prior to using analytical equipment/test kits, personnel shall read User Manual and receive training for proper use.
3. Consult the User Manual for step-by-step procedures for calibration and testing.
4. Preparation of calibration standards should span the full concentration range of the test you are using.
5. Be certain to use the correct sample cell and reagent set for the test conducted and the concentration range (high versus low).

MONITORING DATA:

1. Break site: Monitor free chlorine or chloramine residual and compare to ambient system levels following break repair and prior to placing system back into service. Level after repair shall be within +/- 10% of the pre-repair level.
2. Other Areas in Pressure Zone: Confirm through SCADA, monitoring, modeling, or other means whether or not depressurization has occurred elsewhere in pressure zone as a result of the break or repair procedures. Minimum threshold is 20 psi elsewhere in the system.

DOCUMENTATION AND CLOSE OUT:

1. Complete the attached Documentation and Evaluation Form to demonstrate and affirm that Procedures were followed.
2. Close out the work order per the specific utility procedures.

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD VERIFICATION STUDIES BY UTILITY PARTNERS

Documentation & Evaluation Form		
Field Study Procedure: *Field Monitoring for Chlorine Residuals*		
Name of Utility: ______________________	Crew Chief Name: ______________________	
Date of Break: ______________________	Time:____________	❑ A.M. ❑ P.M.

GENERAL:

Pipe Diameter: __________ Inches Pipe Material: _______________________

Identify nature of break (Please check all that apply):

❑ Circumferential ❑ Longitudinal ❑ Blowout ❑ Joint

❑ Sleeve ❑ Split at Corporation ❑ Hole

❑ Other:____

Identify the cause of break: Please check all that apply:

❑ Water Hammer (Surge) ❑ Defective Pipe ❑ Deterioration

❑ Corrosion ❑ Improper Bedding ❑ Operating Pressure

❑ Temperature Change ❑ Differential Settlement ❑ Contractor

❑ Unknown ❑ Other: ____

FIELD PROCEDURE VERIFICATION & MONITORING DATA

What type of main break was this Field Study Procedure conducted on (Type I, II, III, or IV)? ______________

Was water in the excavation pit kept at least 12 inches below the bottom of the exposed pipe under repair? Yes ___ No ___

Was obvious sewage or chemical contamination observed in the excavation? Yes ___ No ___

Were two hydrants available to allow flushing the pipe in both directions? Yes ___ No ___

What is the measured ambient free and total chlorine residual in the water distribution system?
_____________ mg/L free chlorine
_____________ mg/L total chlorine

What is the measured free and total chlorine residual at the break site following repair and prior to returning to normal service?
_____________ mg/L free chlorine
_____________ mg/L total chlorine

Was the post-repair level within +/- 10% of the pre-repair level prior to returning to normal service?
Yes ___ No ___

If the measured residual at the break site following repair was too high or too low, what measures were implemented to bring the residual within +/- 10% of ambient levels? ____

____

Was 20 psi maintained elsewhere in the pressure zone? Yes ___ No ___
Was it monitored through SCADA, modeling, or other means during the repair? Yes ___ No ___
What monitoring method was used? __________________

Please document comments, concerns, observations, and/or feedback regarding this field study procedure below:

ATTACHMENT 4

Field Protocol - Scour Flushing

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

TITLE OF FIELD STUDY: Scour Flushing following Main Break Repair

PURPOSE OF FIELD STUDY:

1. To demonstrate that scour flushing, following a main break repair that involves loss of pressure at the break site or elsewhere in the system resulting in possible or actual contamination intrusion, is practical and feasible to remove and dispose of debris and contaminants from the pipe.
2. To confirm and document that a minimum of 3.0 ft/sec velocity (in the largest diameter pipe) can be achieved during flushing following a water main break repair.

ASSUMPTIONS:

1. Depressurization occurs at the break site and immediately adjacent to the site.
2. No depressurization results at other locations in the water distribution system (minimum 20 psi elsewhere in the system).
3. Only a partial or uncontrolled shutdown can be achieved.
4. Contamination such as sewage or chemical contamination may be present 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:

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, locate, and close nearest valves to main break location to isolate the area affected by depressurization to the greatest extent possible. Properly notify all customers and shut off service connections within the affected area.
   e. Identify appropriate hydrants to facilitate flushing from both directions, if possible.
2. Confirm through SCADA, monitoring, modeling, or other means that depressurization did not occur elsewhere in the pressure zone as a result of the break or during the following repair procedures. Minimum threshold is 20 psi outside the isolated area.
3. Excavate to expose the main break.

4. Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired. Dispose of or dechlorinate water in accordance with local regulations.
5. Determine the pipe material, the outside diameter (OD), and fittings necessary to perform work. Keep tools, fittings, gaskets, valves and appurtenances covered and protected until ready for installation.
6. Complete repair. Clean and spray disinfect (with 1% bleach) all tools and fittings before installation, or other disinfection measures that may be required.
7. Following repair completion, fill the line slowly to remove entrapped air. Start scour flushing and continue until three pipe volumes have been flushed. If valve and hydrant locations permit, flush pipe in both directions.
8. During flushing activities, determine and maintain appropriate flow at the flushing hydrants to ensure a minimum velocity of 3.0 ft/sec is maintained in the largest diameter pipe section.
9. Following completion of scour flushing, collect water sample from the repaired main and measure disinfectant residual.
10. If the disinfectant residual is within +/- 10% of the ambient residual level, proceed to Step 13. If the disinfectant residual is greater than + 10% of the ambient residual level, continue scour flushing until the disinfectant residual is with +/- 10% of the ambient residual level.
11. Close hydrants.
12. Backfill and compact per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.

MONITORING DATA:

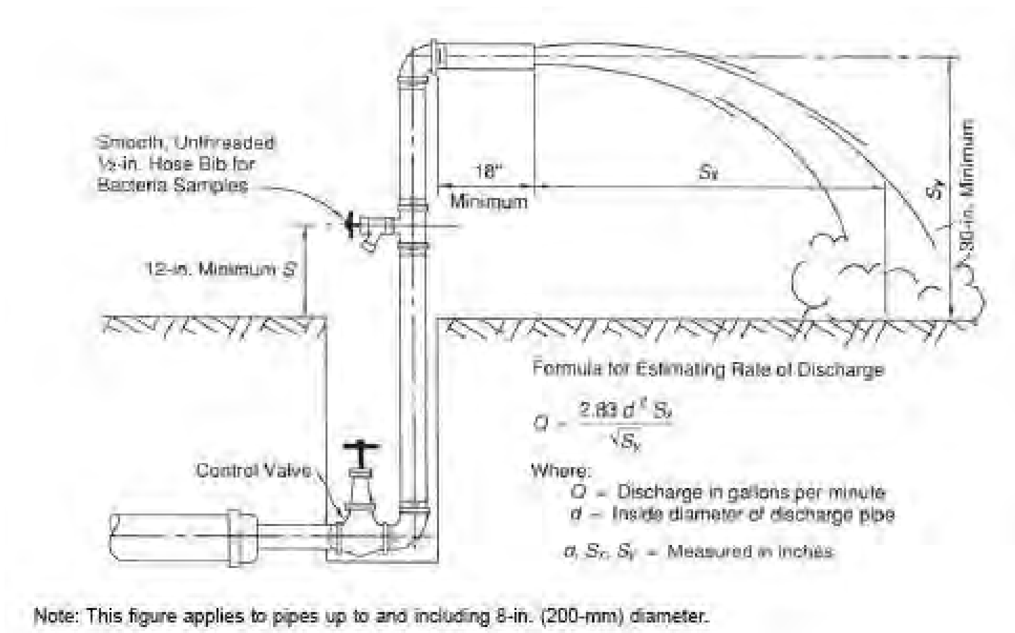
1. Break site: Confirm that a scour velocity of 3.0 ft/sec was obtained in the largest diameter pipe section during flushing. In order to achieve 3.0 ft/sec flushing velocity in the pipe, the flows in the following Table shall be achieved, maintained during flushing, and measured at the hydrant location.

Flow in Pipe (gpm) for a Flushing Velocity of 3.0 ft/sec

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

Flow at the hydrant shall be determined by one of the following methods:

a. Use of a flow measuring device at hydrant
b. Measuring the trajectory of the discharge and estimating flow per the below Figure 1



Source: AWWA Standard C-651; Figure 2

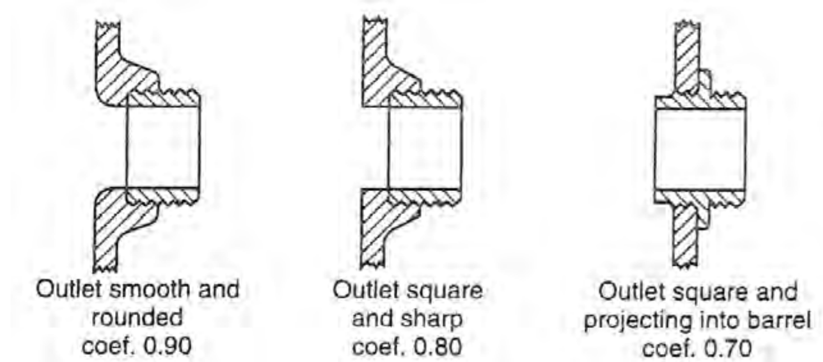
Figure 1: Measuring flow using the trajectory of discharge

c. Flow calculation based on the following equation derived by expressing flow Q (gpm) as a function of pitot pressure P (psi) and hydrant nozzle diameter D (in):

$$Q = c * 29.83 * \sqrt{P} * D^2$$

The discharge coefficient c varies with the type of outlet on the hydrant; the transition between the vertical barrel of the hydrant and the horizontal outlet. The operator must feel the inside contour of the hydrant outlet and compare it to the following three types of outlets to estimate a discharge coefficient:

Outlet Type	**Coefficient**
Smooth and rounded	0.90
Square and sharp	0.80
Square and projecting into barrel	0.70



2. Other Areas in Pressure Zone: Confirm through SCADA, monitoring, modeling, or other means that depressurization did not occur elsewhere in pressure zone as a result of the break or repair procedures. Minimum threshold is 20 psi outside the isolated area.

DOCUMENTATION AND CLOSE OUT:

1. Complete the attached Documentation and Evaluation Form to demonstrate and affirm that Procedures were followed.
2. Close out the work order per the specific utility procedures.

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD VERIFICATION STUDIES BY UTILITY PARTNERS

Documentation & Evaluation Form			
Field Study Procedure: *Scour Flushing*			
Name of Utility: ______________________	Crew Chief Name: ______________________		
Date of Break: ______________________	Time:____________	❑ A.M.	❑ P.M.

GENERAL:

Pipe Diameter: __________ Inches   Pipe Material: ______________________

Identify nature of break (Please check all that apply):

❑ Circumferential ❑ Longitudinal ❑ Blowout ❑ Joint

❑ Sleeve ❑ Split at Corporation ❑ Hole

❑ Other:____

Identify the cause of break: Please check all that apply:

❑ Water Hammer (Surge) ❑ Defective Pipe ❑ Deterioration

❑ Corrosion ❑ Improper Bedding ❑ Operating Pressure

❑ Temperature Change ❑ Differential Settlement ❑ Contractor

❑ Unknown ❑ Other: ____

FIELD PROCEDURE VERIFICATION & MONITORING DATA

Was water in the excavation pit kept at least 12 inches below the bottom of the exposed pipe under repair? Yes ___ No ___

Was obvious sewage or chemical contamination observed in the excavation? Yes ___ No ___

Were two hydrants available to allow flushing the pipe in both directions? Yes ___ No ___

What is the largest diameter pipe between the break and the hydrants that was used during flushing (Note: 3.0 ft/sec should be maintained on this pipe)? _____________ inches

What average flow was maintained at the hydrant during the scour flush? __________________ gpm

What length of pipe is being flushed? ________________ feet

How long was the pipe flushed for? _______________minutes

Were three pipe volumes flushed at the average flowrate?   Yes ___ No ___

What method was used to determine flow to verify that 3.0 ft/sec velocity in the largest diameter pipe was achieved during scour flushing? (circle one and provide requested information)

a. Flow measuring device,

   Flow at hydrant (gpm): _____________________

b. Measurement of discharge trajectory (see Field Procedure), or

   S_x (in): _____________________

   S_y (in): _____________________

   d (in): _____________________

   Estimated Flow at hydrant, Q (gpm): _____________________

c. Calculated flow based on pitot pressure and hydrant nozzle diameter (see Field Procedure)

   Pitot Pressure Gauge Reading, P (psi): _____________________

   Hydrant Nozzle Diameter, D (in): _____________________

   Hydrant Coefficient, c: _____________________

   Calculated Flow at hydrant, Q (gpm): _____________________

Document disinfectant residual at the time the system is placed back in service:

___________________mg/L free chlorine residual

Was 20 psi maintained elsewhere in the pressure zone?   Yes ___ No ___

Was it monitored through SCADA, modeling, or other means during the repair?   Yes ___ No ___

What monitoring method was used? __________________

Please document comments, concerns, observations, and/or feedback regarding this field study procedure below:

ATTACHMENT 5

Field Protocol – Slug Disinfection

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

TITLE OF FIELD STUDY: Disinfection Slug during Main Break Repair

PURPOSE OF FIELD STUDY:

1. 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 can be reasonably implemented to achieve adequate disinfection.

ASSUMPTIONS:

1. Depressurization occurs at the break site and immediately adjacent to the site.
2. No depressurization results at other locations in the water distribution system (minimum 20 psi elsewhere in the system).
3. Only a partial or uncontrolled shutdown can be achieved.
4. Contamination such as sewage or chemical contamination may be present 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:

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, locate, and close nearest valves to main break location to isolate the area affected by depressurization to the greatest extent possible. Properly notify all customers and shut off service connections within the affected area.
    e. Identify appropriate hydrants to facilitate flushing from both directions, if possible.
2. Confirm through SCADA, monitoring, modeling, or other means that depressurization did not occur elsewhere in the pressure zone as a result of the break or during the following repair procedures. Minimum threshold is 20 psi outside the isolated area.
3. Excavate to expose the main break.
4. Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired. Dispose of or dechlorinate water in accordance with local regulations.

5. Determine the pipe material, the outside diameter (OD), and fittings necessary to perform work. Keep tools, fittings, gaskets, valves and appurtenances covered and protected until ready for installation.
6. Complete repair. Clean and spray disinfect (with 1% bleach) all tools and fittings before installation, or other disinfection measures that may be required.
7. Following repair completion, fill the line slowly to remove entrapped air. Perform scour flush (minimum velocity of 3 ft/sec) per separate Field Study Procedure. Dispose of or dechlorinate water in accordance with local regulations.
8. Following completion of scour flushing, start slug disinfection.
9. Expose the main to a free chlorine CT of 100 mg-min/L (this requirement is for both chlorinated and chloraminated systems). The slug of chlorinated water should be monitored at regular intervals for chlorine residual. If the concentration decreases over time as a result of chlorine consumption, either the time duration for the slug chlorination shall be increased or the concentration shall be restored to ensure a CT of 100 mg-min/L is achieved.
10. After the appropriate chlorination contact time, the slug of chlorinated water shall be flushed from the main until the chlorine concentration in the water is within +/- 10% of the ambient chlorine concentration, meeting minimum regulatory standards. Dispose of or dechlorinate water in accordance with local regulations.
11. Collect water sample from the repaired main, measure disinfectant residual, and conduct bacteriological testing per existing Local and/or State requirements.(1)
12. Close hydrants.
13. Backfill and compact per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to at least original condition.
14. Following satisfactory bacteriological sample results, return to normal service. Advise customers to flush service lines (premise guideline). If the system must be returned to service prior to receiving satisfactory bacteriological results in order to minimize the time customers are without water, a precautionary boil water advisory to the affected customers shall be provided until the sample results are available, in compliance with applicable Local and State requirements.

    Footnotes:

    (1) While bacteriological testing is not directly a part of this specific Field Procedure, compliance with current regulatory standards must be maintained during conduct of the research program.

MONITORING DATA:

1. Break site: The slug of chlorinated water should be measured at regular time intervals to ensure a free chlorine CT of 100 mg-min/L is achieved.
2. Break site: Samples shall be taken for bacteriological tests to determine the effectiveness of the disinfection procedure.
3. Other Areas in Pressure Zone: Confirm through SCADA, monitoring, modeling, or other means that depressurization did not occur elsewhere in pressure zone as a result of the break or repair procedures. Minimum threshold is 20 psi outside the isolated area.

Footnotes:

(1) While bacteriological testing is not directly a part of this specific Field Procedure, compliance with current regulatory standards must be maintained during conduct of the research program.

DOCUMENTATION AND CLOSE OUT:

1. Complete the attached Documentation and Evaluation Form to demonstrate and affirm that Procedures were followed.
2. Close out the work order per the specific utility procedures.

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD VERIFICATION STUDIES BY UTILITY PARTNERS

Documentation & Evaluation Form			
Field Study Procedure: *Disinfection Slug*			
Name of Utility: ______________________	Crew Chief Name: ______________________		
Date of Break: ______________________	Time:____________	❑ A.M.	❑ P.M.

GENERAL:

Pipe Diameter: __________ Inches   Pipe Material: ______________________

Identify nature of break (Please check all that apply):

❑ Circumferential   ❑ Longitudinal   ❑ Blowout   ❑ Joint

❑ Sleeve   ❑ Split at Corporation   ❑ Hole

❑ Other:____

Identify the cause of break: Please check all that apply:

❑ Water Hammer (Surge)   ❑ Defective Pipe   ❑ Deterioration

❑ Corrosion   ❑ Improper Bedding   ❑ Operating Pressure

❑ Temperature Change   ❑ Differential Settlement   ❑ Contractor

❑ Unknown   ❑ Other: ____

FIELD PROCEDURE VERIFICATION & MONITORING DATA

Was water in the excavation pit kept at least 12 inches below the bottom of the exposed pipe under repair?   Yes ___   No ___

Was obvious sewage or chemical contamination observed in the excavation?   Yes ___   No ___

Were two hydrants available to allow flushing the pipe in both directions?   Yes ___   No ___

Was a minimum velocity of 3 ft/sec in the pipe achieved during scour flushing and documented per separate Field Study Procedure?   Yes ___   No ___

Were three pipeline volumes evacuated during the scour flush?   Yes ___   No ___

What method was used to disinfect the pipe? ______________________________

Was a free chlorine CT of 100 mg-min/L achieved during disinfection? Yes ___ No ___
What was the time duration of the slug disinfection? _________________ minutes
What was the free chlorine concentration used for slug disinfection? ____________ mg/L

At what time intervals was the free chlorine concentration measured throughout the duration of the slug chlorination procedure? ______________________

Document measurements in the below Table:

Time of Measurement	**Cumulative Duration of Slug Disinfection (minutes)**	**Free Chlorine Concentration (mg/L)**	**CT (mg-min/L)**

If due to chlorine consumption, the concentration of the slug decreased over time, was the time duration increased or the concentration restored to ensure a CT of 100 mg-min/L is achieved? Yes ___ No ___

Document disinfectant residual at the time the system is placed back in service:
___________________ mg/L free chlorine residual

Were satisfactory bacteriological test results obtained following slug disinfection? Yes ___ No ___

Was 20 psi maintained elsewhere in the pressure zone? Yes ___ No ___
Was it monitored through SCADA, modeling, or other means during the repair? Yes ___ No ___
What monitoring method was used? __________________

Please document comments, concerns, observations, and/or feedback regarding this field study procedure below:

APPENDIX G:
FIELD GUIDANCE SUGGESTIONS

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

Potentially Useful Information - Field Checklist for Main Break Evaluation

Date of Break: ______________________ Time:____________ ❑ A.M. ❑ P.M.

1. **Site Assessment and Identification:** By site survey, first responder, GIS, as-built drawings and/or communication.

❑ Identify main break/leak location (address, nearest crossing street, system)
- Location: ____

❑ Identify pipe size and pipe material (if possible)
- Pipe Diameter: __________ Inches
- Pipe Material: _________________________

❑ Identify nature of break: Please check all that apply:

❑ Circumferential ❑ Longitudinal Split ❑ Blowout ❑ Joint

❑ Sleeve ❑ Split at Corporation ❑ Hole(s)

❑ Other:____

❑ Identify the probable cause of break: Please check all that may apply:

❑ Water Hammer (Surge) ❑ Defective Pipe ❑ External Deterioration

❑ Internal Corrosion ❑ Improper Bedding ❑ Operating Pressure

❑ Temperature Change ❑ Differential Settlement ❑ Contractor

❑ Unknown ❑ Other: ____

❑ Degree of tuberculation on interior of pipe

❑ No significant encrustation

❑ Pipe approximately 20% blocked by encrustation

❑ Pipe approximately 60% blocked by encrustation

❑ Slight tuberculation which may give a rough surface, but does not substantially reduce the cross-sectional area of the pipe

❑ Pipe approximately 40% blocked by encrustation

❑ Pipe approximately 80% blocked by encrustation

❑ Assess damage and/or potential damage (public hazard) that could occur to others: ____________

❑ Assess expected traffic disruptions: ____

❑ Identify affected customers: ____

❑ Identify critical customers: ____

❑ Existing utilities in close proximity of the repair site, if known

❑ Water	❑ Gas	❑ Power
❑ Sanitary Sewer	❑ Phone	❑ Fiber Optics
❑ Storm	❑ Cable	❑ Others: ______________________

- ❑ Locate and mark nearby water grid isolation valves to control flow and shutdown.
- ❑ Locate and mark nearby water hydrants for flushing plans.
- ❑ Determine location of dewatering and runoff, and avoid or mitigate erosion and property damage.
- ❑ Determine whether temporary water service would be required: _________________________
- ❑ Comments: ____

  ____

<u>Types of Repair and Response Level:</u>

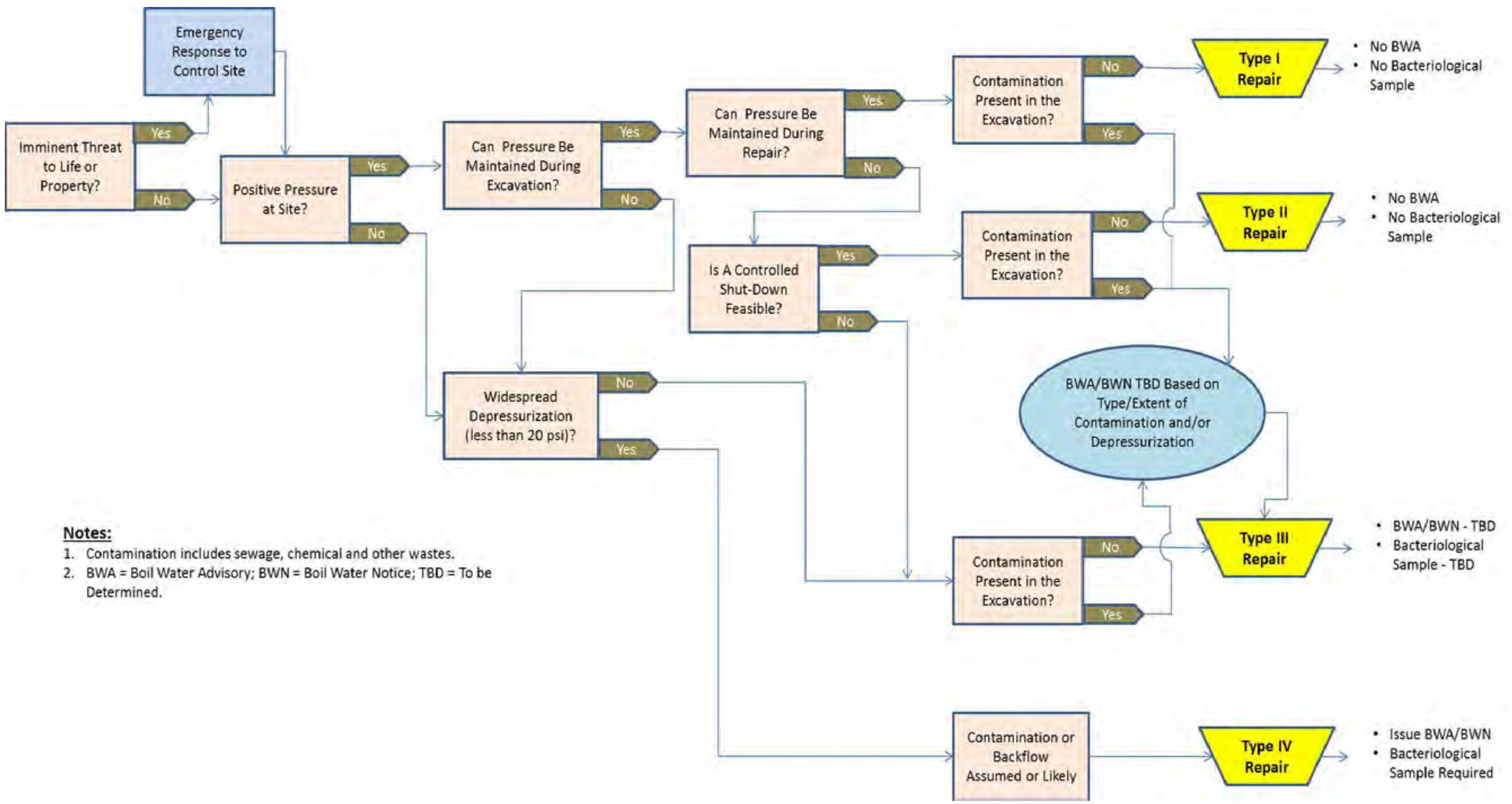
Based on the following parameters, use "**Main Break Risk Triage Flowchart**" in **Figure G-1** to classify the type of break, and conduct subsequent repairs per Table G-1:

<u>Field/Regulatory Parameters</u>

- Valve condition and location
- Critical customers affected
- Size of area affected
- Depressurization potential & extent
- Sanitary condition
- Regulatory requirements
- Contamination type and extent

<u>Other parameters</u>

- Volume of water (flow rate and duration)
- Potential for damage
- Traffic and commerce issues
- Public and employee safety



Notes:
1. Contamination includes sewage, chemical and other wastes.
2. BWA = Boil Water Advisory; BWN = Boil Water Notice; TBD = To be Determined.

Figure G-1 Main break risk triage flowchart

Table G-1 Main Break Types and Responses

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/ 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 break exposed	Partially 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)	Disinfect repair parts
Check residual disinfectant level in distribution system	Conduct low velocity flush (flush three pipe volume)	Conduct slug chlorination (CT of 100 mg/L-min)	Conduct scour flush (3 ft/sec)
No Boil Water Advisory (BWA)	Check residual disinfectant level in distribution system	Check residual disinfectant level in distribution system	Conduct slug chlorination (CT of 100 mg/L-min)
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	[1, 2]BWA – TBD; based on depressurization extent and presence of contamination	Check residual disinfectant level in distribution system
		[1, 2]Bacteriological samples - TBD; based on depressurization extent and prescence of contamination	Issue BWA/ Boil Water Notice
			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 is 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.

Pipe Flushing Velocity Based on Flow

In order to achieve a minimum 3.0 ft/sec flushing velocity in pipe (largest diameter pipe section) in terms of flow (gpm), use the Table G-2 below:

Table G-2: Flow in Pipe (gpm) for a Flushing Velocity of 3.0 ft/sec

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

2. **Repair Activities:** Once the type of break has been determined, implement applicable repair guidelines:

   A. **Type I - Controlled Repair or Repair under Pressure:** When repair is possible with maintaining the pressure in the line.

   - ❑ Throttle flow in the pipe section using valves and hydrants; and maintain positive pressure in the pipe to reduce backflow or runoff contamination and pinpoint location of leak.
   - ❑ Identify if there is depressurization elsewhere in the water distribution system (minimum 20 psi elsewhere in the system) based on topographic or other factors.
   - ❑ Excavate to expose main break and control water level in the working repair pit.
   - ❑ Throttle flow as needed, maintaining positive pressure. Visually observe positive flow/spray at the break site or use nearby hydrant/tap that must be at higher elevation than break site.
   - ❑ Visually confirm during the repair (start through completion) that water was flowing full pipe from the pressure verification hydrant/tap or at the break site, indicating that positive pressure was maintained continuously during repair.
   - ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
   - ❑ Dispose of or dechlorinate water in accordance with local regulations.
   - ❑ Ensure that no obvious contamination such as sewage or chemical contamination is present at site.
   - ❑ Determine the pipe material, its outside diameter (OD), and repair fittings (repair clamps, sleeves, pipe) necessary to perform work:
     - ❑ Pipe material: ______________________ Pipe outside diameter: ________Inches

- ❑ Required repair fittings:

  ____

  ____

- ❑ Clean and spray disinfect (with 1% bleach) all tools and fittings (repair clamps) before installation.
- ❑ Complete repair.
- ❑ Open valves and flush pipe from nearby hydrant or blowoff as needed.
- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to withstand any traffic loading.
- ❑ Measure disinfectant residual and compare with ambient. Level after repair should be minimum of 90% of the pre-repair level and no greater than 4.0 mg/L.
- ❑ Following satisfactory disinfectant residuals, return to normal service.

B. **<u>Type II - Controlled Shutdown:</u>** Pressure is maintained during excavation and the repair is performed after controlled shut down of the line.

- ❑ Identify how to isolate the pipe section using valves and hydrants; and maintain positive pressure in the pipe to reduce backflow or runoff contamination and pinpoint location of leak.
- ❑ Excavate to expose main break.
- ❑ Maintain positive pressure (flow/spray from pipe) until bottom of pipe is 12" above water in the pit.
- ❑ Determine if there may be depressurization elsewhere in the water distribution system (minimum 20 psi elsewhere in the system).
- ❑ Shutdown affected service lines within the immediate break area and notify customers affected.
- ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Physically clean visible debris in the pipe and fittings – exterior and interior.
- ❑ Ensure that no obvious contamination such as sewage or chemical contamination is present at site.
- ❑ Determine the pipe material and its outside diameter (OD), fittings, joints, gaskets, clamps, and other repair equipment necessary to perform work:
  - ❑ Pipe material: ____
  - ❑ Pipe outside diameter: __________________ Inches
  - ❑ Required pipe/fittings: ____
- ❑ Keep repair materials clean as practical as they are installed
- ❑ Maintain pipe caps, plugs and other protective coverings until pipes are joined.
- ❑ Keep fittings, valves and appurtenances covered and protected until ready for installation.
- ❑ Keep gaskets clean all the time.
- ❑ Disinfect all repair tools.
- ❑ Swab/spray pipe and fittings with 1% bleach.
- ❑ Complete repair.
- ❑ Fill the line slowly and use lower hydrants first to remove entrapped air.

- ❑ Flush hydrants to remove air and debris (minimum three pipe volume). Note: Not required to achieve 3.0 ft/sec flushing velocity in the pipe for Type 2 break.
- ❑ Dispose of or dechlorinate chlorinated water in accordance with local regulation.
- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to withstand any traffic loading.
- ❑ Measure disinfectant residual and compare with ambient. Level after repair should be minimum of 90% of the pre-repair level and no greater than 4.0 mg/L.
- ❑ Open closed service lines and advise customers to flush service lines (premise guideline).
- ❑ Following satisfactory disinfectant residuals, return to normal service.

C. Type III - Uncontrolled Shutdown: Pressure not maintained during excavation; controlled shut down not possible.

- ❑ Isolate the pipe section using valves
- ❑ Notify apprpropriate authorities of hazardous conditions.
- ❑ Shutdown service lines within the affected area.
- ❑ Excavate to expose main break.
- ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Physically clean visible debris in the pipe and fittings – exterior and interior.
- ❑ Note any possible contamination such as sewage or chemical contamination intrusion at break site.
- ❑ Determine the pipe material and its outside diameter (OD), fittings, joints, gaskets, clamps, and other repair equipment necessary to perform work:
  - ❑ Pipe material: ____
  - ❑ Pipe outside diameter: _________________ Inches
  - ❑ Required pipe/fittings: ____
- ❑ Keep repair materials clean as practical as they are installed
- ❑ Maintain pipe caps, plugs and other protective coverings until pipes are joined.
- ❑ Keep fittings, valves and appurtenances covered and protected until ready for installation.
- ❑ Keep gaskets clean all the time.
- ❑ Disinfect all repair tools.
- ❑ Swab or spray pipe and fittings with 1% bleach.
- ❑ Complete repair.
- ❑ Fill the line slowly and use lower hydrants first to remove entrapped air.
- ❑ Flush hydrants (achieve 3 fps velocity in the largest diameter pipe section) to remove air and debris (at least three pipe volume). See Table G-2.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Slug chlorination of the repaired section using a CT of 100 mg-min/L (e.g. 5 mg/L of residual Cl_2 for 20 minutes of contact time) for proper disinfection.
- ❑ After the appropriate chlorination contact time, flush slug of chlorinated water from the main.
- ❑ Dispose of and dechlorinate the water per applicable regulations.

- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to withstand any traffic loading.
- ❑ Measure disinfectant residual in the system and compare with ambient. Level after repair should be minimum of 90 % of the pre-repair level and no greater than 4.0 mg/L.
- ❑ Any local depressurization in the water distribution system?
    - ❑ If depressurization is limited to the pipe section, or area flushed, then
        - ❑ No Boil Water Advisory (BWA) Necessary.
        - ❑ No Bacteriological Test Necessary.
    - ❑ If area of depressurization is larger than the treated area then
        - ❑ Issue Boil Water Advisory (BWA) based on extent of local depressurization and on presence of any contamination.
        - ❑ Conduct Bacteriological Test based on extent of local depressurization.
- ❑ Advise customers to flush service lines (premise guideline).
- ❑ Following satisfactory disinfectant residual and bacteriological sample results (if required), return to normal service.

D. <u>Type IV– Catastrophic Failure:</u> Widespread depressurizationin the water distribution system.

- ❑ Shutdown the line using valves.
- ❑ Shutdown service lines within the affected area as practical.
- ❑ Excavate to expose main break.
- ❑ Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.
- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Physically clean visible debris in the pipe and fittings – exterior and interior.
- ❑ Note any possible/actual contamination such as sewage or chemical contamination intrusion at break site and/or elsewhere in the distribution system.
- ❑ Determine the pipe material and its outside diameter (OD), fittings, joints, gaskets, clamps, and other repair equipment necessary to perform work:
    - ❑ Pipe material: ________________Pipe outside diameter: ___________ Inches
    - ❑ Required pipe/fittings:

      ____

      ____
- ❑ Maintain pipe caps, plugs and other protective coverings until pipes are joined.
- ❑ Keep fittings, valves and appurtenances covered and protected until ready for installation.
- ❑ Cover or cap (water tight) all open ends of new pipes and fittings in the trench at the end of each workday.
- ❑ Keep gaskets clean all the time.
- ❑ Disinfect all repair tools.
- ❑ Swab/spray pipe and fittings with 1% bleach.
- ❑ Complete repair.
- ❑ Fill the line slowly and use lowest elevation hydrants first to remove entrapped air.
- ❑ Flush hydrants (achieve 3 fps velocity in the largest diameter pipe section) to remove remaining air and debris (three pipe volume). See Table G-2.

- ❑ Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Slug chlorination of the repaired section using a CT of 100 mg-min/L (e.g. 5 mg/L of residual Cl_2 for 20 minutes of contact time) for proper disinfection.
- ❑ After the appropriate chlorination contact time, flush slug of chlorinated water from the main until the chlorine concentration in the water is at least 90% of the ambient chlorine concentration but no greater than 4.0 mg/L, meeting minimum regulatory standards. Dispose of or dechlorinate water in accordance with local regulations.
- ❑ Backfill and compact pipe bedding per applicable AWWA pipe installation standard and/or local requirements; repair ground surface to withstand any traffic loading.
- ❑ Measure disinfectant residual in the system (if required) and compare with ambient. Level after repair should be at least 90% of the pre-repair level and no greater than 4.0 mg/L.
- ❑ Conduct Bacteriological Testing.
- ❑ Issue Boil Water Advisory (BWA) or Boil Water Notice as required by Health Department.
- ❑ Advise customers to flush service lines (premise guideline).
- ❑ Return to service upon approval from regulatory agencies who may require satisfactory bacteriological testing results.

3. **<u>Notification:</u>** If feasible, distribute notification in advance of main break problem, interruption of service, scheduled period of work, potential traffic disruption and other public hazard.

- ❑ Affected and critical customers.
- ❑ Department of Public Works.
- ❑ Department of Transportation.
- ❑ Local law enforcement.
- ❑ State Department of Health.
- ❑ Regulatory agencies.
- ❑ Media in the form of a press release.
- ❑ Affected customers.
- ❑ Other Utilities:

____

4. **<u>Safety Equipments, Fittings and Repair Tools:</u>**

- ❑ Personnel protective equipment (PPE) such as protective gloves, reflective vests, hard hats, protective goggles, etc.
- ❑ Flow and pressure measurement gauges or devices.
- ❑ Disinfection and dechlorination chemicals and equipment.
- ❑ Repair and excavation tools (saws, wrenches, buckets, shovels, pick axes, ladders, flashlights, night work lights, etc.).
- ❑ Pipes, fittings/repair clamps etc.:____
- ❑ Flow and surface runoff diversionary equipment like, sandbags, trench covers, etc.
- ❑ Dewatering pumps
- ❑ Emergency generators if work performed at night.
- ❑ Tapping equipment.

- ❑ Biological sampling bottles, gloves, transport cooler, ice packs, and laboratory chain-of-custody sheets.

5. **Site Control:**

- ❑ Public warning and road hazard signs, traffic cones, and barriers.
- ❑ Provide measures for sediment/dust control.
- ❑ Provide site access routes that will minimize sediment/airborne contamination of material and equipments.
- ❑ Locate and mark all existing utilities in the vicinity of the main repair/excavation including water, sewer, storm, phone cable, gas, power lines, fiber optics etc.: ______________________________
- ❑ Provide measures for protection against storm water, agricultural and industrial runoff.
- ❑ Assess how groundwater levels, inclement weather, and other factors may affect the repair, and determine compensatory methods.

6. **Excavation and Trench Work:**

- ❑ Install temporary diversion devices to control surface water runoff into trench.
- ❑ Dewater the excavated trench.
- ❑ Provide adequate shoring and use ladders for safety.
- ❑ Keep pipes, fittings, and valves away from excavated soil or backfill materials.
- ❑ Call “underground utility notification center” if necessary.
- ❑ Expose, thoroughly scrape and clean the area around the pipe section for inspecting the break.

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD IMPLEMENTATION GUIDELINES

FIELD ACTIVITY: Pressure Maintenance and Verification during Main Break Repair

PURPOSE OF ACTIVITY:

1. 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).
7. This field procedure is most applicable for a Type 1 Break but many features also apply to a Type 2 Break as well.

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:
    1. Survey the site to identify and define the problem. Initiate and maintain appropriate communications, per utility and regulatory agency protocol.
    2. Assess actual and potential damage that could occur.
    3. Identify location and address traffic control, if necessary.
    4. Identify valves to control/throttle flow.
    5. Identify appropriate hydrant/tap to observe flow for pressure verification throughout the duration of the main break repair.
    6. Notify other utilities of intent to excavate and secure street opening permission as required.
2. Confirm through SCADA, monitoring, customer contact, or other means that depressurization did not occur elsewhere in the pressure zone as a result of the break or during the following repair procedures. Minimum threshold is 20 psi away from the break area.
3. Excavate to expose the main break.
4. Dewater as necessary to maintain water in the excavation pit at least 12 inches below the bottom of the exposed pipe being repaired.

5. Determine the pipe material, the outside diameter (OD), and fittings (repair clamps) necessary to perform work. Keep tools, fittings, gaskets, valves and appurtenances covered and protected until ready for installation.
6. Throttle flow. Visually observe positive flow/spray at the break site until the hydrant/tap used for pressure verification is opened. Hydrant/tap elevation must be higher than break site.
7. Open hydrant/tap. Confirm positive pressure is achieved through visual observation of flow at the selected hydrant nozzle/tap. Dispose of or dechlorinate water in accordance with local regulations.
8. Start repair.
9. Clean and spray disinfect (with 1% bleach) all tools and fittings (repair clamps) before installation, or other disinfection measures that may be required.
10. Complete repair.
11. Following repair completion, reconfirm that positive pressure is achieved through visual observation of flow at the selected hydrant nozzle/tap.
12. If flow is observed, collect water sample from the repaired main and measure disinfectant residual.
13. Operate hydrant/tap.
14. Backfill and compact per applicable AWWA pipe installation standard and/or local requirements; repair ground surface per local requirements.
15. Following satisfactory chlorine residuals, return to normal service.

MONITORING DATA:

1. Break site: Visually confirm start to completion that water was flowing from the pressure verification hydrant/tap or at the break site, indicating that positive pressure was maintained continuously.
2. Other Areas in Pressure Zone: Confirm through SCADA, monitoring, modeling, customer contact, or other means that depressurization did not occur elsewhere in pressure zone as a result of the break or repair procedures. Minimum threshold is 20 psi elsewhere in the system.

DOCUMENTATION AND CLOSE OUT:

1. Complete the required documentation and evaluation to demonstrate and affirm that procedures were followed.
2. Close-out the work order per the specific utility procedures.

Example Documentation Form			
Field Activity: *Pressure Maintenance and Verification*			
Name of Utility: ______________________	Crew Chief Name: ______________________		
Date of Break: ______________________	Time:____________	❑ A.M.	❑ P.M.

FIELD PROCEDURE VERIFICATION & MONITORING DATA

Was the repair completed while maintaining positive pressure in the pipe? Yes ___ No ___

Was flow throttled to help facilitate repair procedures? Yes ___ No ___

Was water in the excavation pit kept at least 12 inches below the bottom of the exposed pipe under repair? Yes ___ No ___

Was a hydrant/tap used to visually observe flow for positive pressure verification? Yes ___ No ___

How far was the hydrant/tap selected for pressure verification from the break site?

____

Was the hydrant/tap located uphill, downhill, or at the same elevation as the break site?

____

Was positive flow/spray at the break site observed until the hydrant/tap used for pressure verification was opened? Yes ___ No ___

Was pressure maintained during the entire repair procedure from start to completion? Yes ___ No ___

At any time during the repair, was a "no flow" condition observed at the break site or hydrant? Yes ___No ___

Was 20 psi maintained elsewhere in the pressure zone? Yes ___ No ___

Was it monitored through SCADA, modeling, or other means during the repair? Yes ___ No ___

What monitoring method was used? ____

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD IMPLEMENTATION GUIDELINES

FIELD ACTIVITY: Field Monitoring for Chlorine Residuals during Main Break Repair

PURPOSE OF ACTIVITY:

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

ASSUMPTIONS:

1. This Guideline can be applied to a Type I, II, III, or IV water main break.
2. Water in the excavation pit is maintained at least 12 inches below the bottom of the exposed pipe being repaired.
3. All other good sanitary repair practices are followed (e.g. repair parts are sanitized with bleach).
4. Procedures are applicable for both free and combined chlorine residuals.

FIELD PROCEDURES:

1. Test and document the ambient free and total chlorine residual in the water distribution system.
2. Collect water sample from the repaired main and measure disinfectant residual (free and total chlorine). Ensure sample collected is representative of the water quality in the main, not from a service line.
3. Compare residual with the ambient residual collected in Step 2 to confirm that ambient levels of disinfectant are present in the pipe following flushing and prior to placing system back in service. Level after repair should be minimum of 90% of the pre-repair level and no more than 4.0 mg/L.

ANALYTICAL MONITORING PROCEDURES:

1. Calibration and testing procedures are specific to the analytical equipment/test kits used by each respective utility. Analytical equipment/test kits shall be approved for use by the USEPA and/or state regulatory agency.
2. Prior to using analytical equipment/test kits, personnel shall read User Manual and receive training for proper use.
3. Consult the User Manual for step-by-step procedures for calibration and testing.
4. Preparation of calibration standards should span the full concentration range of the test you are using.
5. Be certain to use the correct sample cell and reagent set for the test conducted and the concentration range (high versus low).

MONITORING DATA:

1. Break site: Monitor free chlorine or chloramine residual and compare to ambient system levels following break repair and prior to placing system back into service.

DOCUMENTATION AND CLOSE OUT:

1. Complete Documentation Form to demonstrate and affirm that procedures were followed.
2. Close out the work order per the specific utility procedures.

Example Documentation Form			
Field Activity: *Field Monitoring for Chlorine Residuals*			
Name of Utility: ______________________	Crew Chief Name: ______________________		
Date of Break: ______________________	Time:____________	❑ A.M.	❑ P.M.

FIELD PROCEDURE VERIFICATION & MONITORING DATA

What is the measured ambient free and total chlorine residual in the water distribution system?
mg/L free chlorine ____
mg/L total chlorine ____

What is the measured free and total chlorine residual at the break site following repair and prior to returning to normal service?
mg/L free chlorine ____
mg/L total chlorine ____

Was the post-repair chlorine level at least 90% of the pre-repair level and not more than 4.0 mg/L prior to returning to normal service? Yes ___ No ___

If the measured residual at the break site following repair was too high or too low, what measures were implemented to bring the residual within acceptable levels?

____

____

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EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD IMPLEMENTATION GUIDELINES

FIELD ACTIVITY: Scour Flushing following Main Break Repair

PURPOSE OF ACTIVITY:

1. To confirm and document that a minimum of 3.0 ft/sec velocity (in the largest diameter pipe) was achieved during flushing following a water main break repair.

ASSUMPTIONS:

1. This Guideline applies to Type 3 and 4 breaks.

FIELD PROCEDURES:

1. Identify appropriate hydrants to facilitate flushing from both directions, if possible.
2. Following repair completion, fill the line slowly to remove entrapped air. Start scour flushing and continue until three pipe volumes have been flushed. If valve and hydrant locations permit, flush pipe in both directions. Dechlorinate as required by applicable regulatory agency.
3. During flushing activities, determine and maintain appropriate flow at the flushing hydrants to ensure a minimum velocity of 3.0 ft/sec is maintained in the largest diameter pipe section.
4. Following completion of scour flushing, collect water sample from the repaired main and measure disinfectant residual.
5. Close hydrants.

MONITORING DATA:

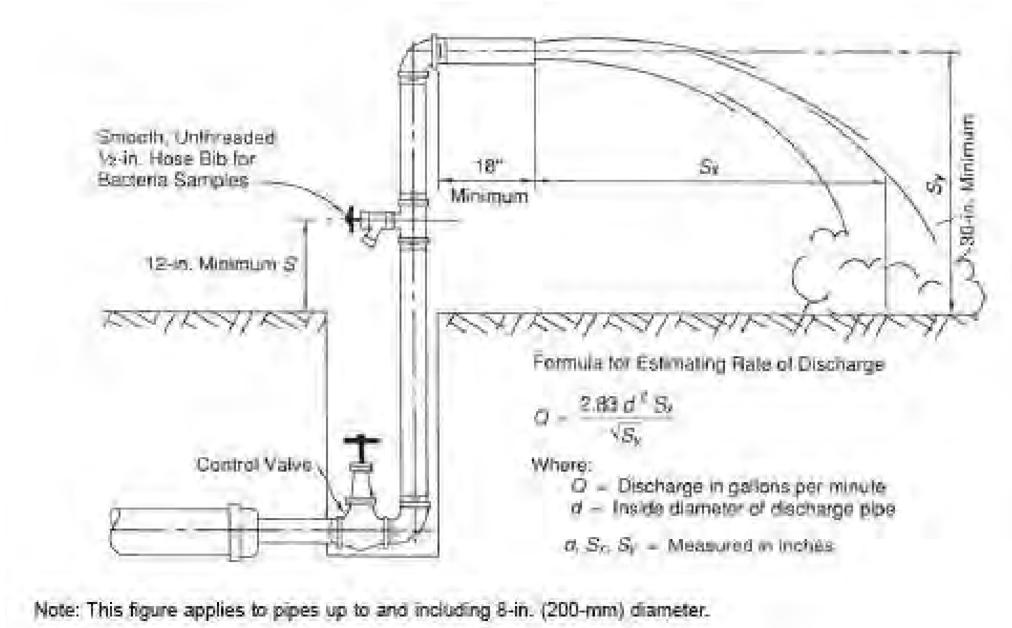
1. Break site: Confirm that a minimum scour velocity of 3.0 ft/sec was obtained in the largest diameter pipe section during flushing. In order to achieve 3.0 ft/sec flushing velocity in the pipe, the flows in the following Table G-3 should be achieved, maintained during flushing, and measured at the hydrant location.

Table G-3 Flow in Pipe (gpm) for a Flushing Velocity of 3.0 ft/sec

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

Flow at the hydrant may be determined by one of the following methods:

a. Use of a flow measuring device at hydrant
b. Measuring the trajectory of the discharge and estimating flow per the below (Figure G-2).



$$Q = \frac{2.83\, d^2\, S_x}{\sqrt{S_y}}$$

Source: AWWA Standard C-651; Figure 2

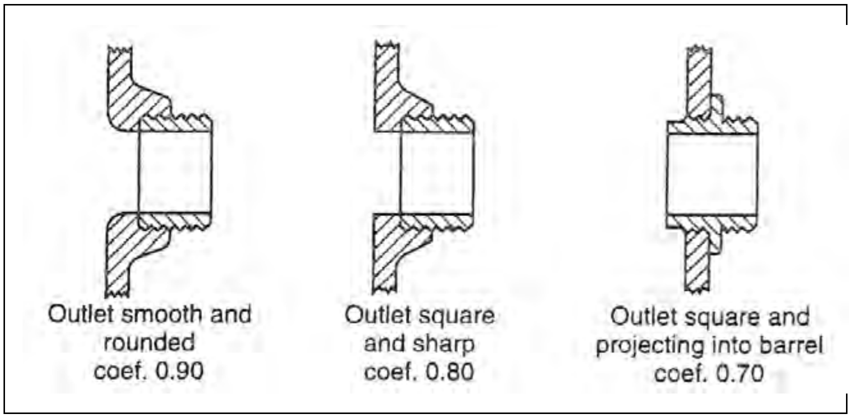
Figure G-2: Measuring flow using the trajectory of discharge

c. Flow calculation based on the following equation derived by expressing flow Q (gpm) as a function of pitot pressure P (psi) and hydrant nozzle diameter D (in):

$Q = c * 29.83 * \sqrt{P} * D^2$

The discharge coefficient c varies with the type of outlet on the hydrant; the transition between the vertical barrel of the hydrant and the horizontal outlet. The operator must feel the inside contour of the hydrant outlet and compare it to the following three types of outlets to estimate a discharge coefficient:

Outlet Type	Coefficient
Smooth and rounded	0.90
Square and sharp	0.80
Square and projecting into barrel	0.70



DOCUMENTATION AND CLOSE OUT:

1. Complete documentation to demonstrate and affirm that guidelines were followed.
2. Close out the work order per the specific utility procedures.

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

Example Documentation Form		
Field Activity: *Scour Flushing*		
Name of Utility: ______________________	Crew Chief Name: ______________________	
Date of Break: ______________________	Time:____________	❑ A.M. ❑ P.M.

FIELD PROCEDURE VERIFICATION & MONITORING DATA

Were two hydrants available to allow flushing the pipe in both directions? Yes ___ No ___

What is the largest diameter pipe between the break and the hydrants that was used during flushing (Note: 3.0 ft/sec should be maintained on this pipe)? _________ inches

What average flow was maintained at the hydrant during the scour flush? ________ gpm

What length of pipe is being flushed? _________ feet

How long was the pipe flushed for? _________ minutes

Were three pipe volumes flushed at the average flowrate? Yes ___ No ___

What method was used to determine flow to verify that minimum 3.0 ft/sec velocity in the largest diameter pipe was achieved during scour flushing? (circle one and provide requested information)

a. Flow measuring device,
   Flow at hydrant (gpm): ____________________

b. Measurement of discharge trajectory (see Field Procedure), or
   S_x (in): ____________________
   S_y (in): ____________________
   d (in): ____________________
   Estimated Flow at hydrant, Q (gpm): ____________________

c. Calculated flow based on pitot pressure and hydrant nozzle diameter (see Field Procedure)
   Pitot Pressure Gauge Reading, P (psi): ____________________
   Hydrant Nozzle Diameter, D (in): ____________________
   Hydrant Coefficient, c: ____________________
   Calculated Flow at hydrant, Q (gpm): ____________________

Water Research Foundation Project 4307

EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS

FIELD IMPLEMENTATION GUIDELINES

FIELD ACTIVITY: Disinfection Slug during Main Break Repair

PURPOSE OF FIELD STUDY:

1. 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.

ASSUMPTIONS:

1. Slug disinfection is applicable to Type 3 and 4 breaks.

FIELD PROCEDURES:

1. Following completion of scour flushing, start slug disinfection.
2. Expose the main to a free chlorine CT of 100 mg-min/L (this requirement is for both chlorinated and chloraminated systems). The slug of chlorinated water should be monitored at regular intervals for chlorine residual. If the concentration decreases over time as a result of chlorine consumption, either the time duration for the slug chlorination shall be increased or the concentration shall be restored to ensure a CT of 100 mg-min/L is achieved.
3. After the appropriate chlorination contact time, the slug of chlorinated water shall be flushed from the main until the chlorine concentration in the water is at least 90% of the ambient chlorine concentration but not greater than 4.0 mg/L, meeting minimum regulatory standards. Dispose of or dechlorinate water in accordance with local regulations.
4. If required, collect water sample from the repaired main, measure disinfectant residual, and conduct bacteriological testing per existing Local and/or State requirements.

MONITORING DATA:

1. Break site: The slug of chlorinated water should be measured at regular time intervals to ensure a free chlorine CT of 100 mg-min/L is achieved.

DOCUMENTATION AND CLOSE OUT:

1. Complete the documentation to demonstrate and affirm that guidelines were followed.
2. Close out the work order per the specific utility procedures.

Example Documentation Form

Field Activity: *Disinfection Slug*

Name of Utility: ______________________ Crew Chief Name: ______________________

Date of Break: ______________________ Time:____________ ❑ A.M. ❑ P.M.

FIELD PROCEDURE VERIFICATION & MONITORING DATA

What method was used to disinfect the pipe? ____

Was a free chlorine CT of 100 mg-min/L achieved during disinfection? Yes ___ No ___

What was the time duration of the slug disinfection? ____________ Minutes

What was the free chlorine concentration used for slug disinfection? ____________ mg/L

At what time intervals was the free chlorine concentration measured throughout the duration of the slug chlorination procedure? ____

Document measurements in the below Table G-4:

Table G-4 Slug Disinfection Data

Time of Measurement	Cumulative Duration of Slug Disinfection (minutes)	Free Chlorine Concentration (mg/L)	CT(mg-min/L)

If due to chlorine consumption, the concentration of the slug decreased over time, was the time duration increased or the concentration restored to ensure a CT of 100 mg-min/L is achieved? Yes ___ No ___

Document disinfectant residual at the time the system is placed back in service: ______________________