EPA Fire Hydrant Flushing and Chlorination Experiments at Idaho National Laboratory

Introduction

The U.S. Environmental Protection Agency's (EPA's) Center for Environmental Solutions and Emergency Response (CESER) performs field studies to demonstrate drinking water distribution system decontamination methods at the Water Security Test Bed (WSTB) located at the Idaho National Laboratory (INL). EPA researchers from the Wide Area and Infrastructure Branch performed this research to demonstrate field decontamination methods in response to a contamination event within a water distribution system. Flushing contaminated water out of the distribution system using the existing network of fire hydrants is considered the most probable first action in response to a drinking water system contamination incident. These experiments were designed to determine the efficacy of removing contaminated water from the water distribution system by flushing the water through fire hydrants. Additional experiments also tested the ability of a custom-made chlorination diffuser (diffusers are a device used to reduce pressure and discharge flow from a fire hydrant) to add chlorine to the water discharged from the fire hydrant and disinfect biologically contaminated water before it was released to the environment. Several operational best practices were identified by these experiments. In general, hydrant flushing under the right operating conditions was found to be effective at removing contaminated water from a water distribution system. In addition, the hydrant diffuser was able to add chlorine to water discharged from the fire hydrant.

Background

EPA's Homeland Security Research Program has partnered with INL to build the WSTB near Idaho Falls, Idaho. The centerpiece of the WSTB is a 450-foot long, 8-inch diameter cement-mortar lined ductile iron drinking water pipe that had been taken out of service. The pipe was exhumed from the INL grounds and then oriented in the shape of a small drinking water distribution system. The WSTB has been fitted with service connections, fire hydrants, and removable coupons (excised sample materials) to collect samples from the pipe interiors (US EPA, 2016). The WSTB was an ideal location to test the effectiveness of flushing and chlorination of fire hydrant discharge because it contains a 450-foot pipe run, between two standard fire hydrants on either end (upstream and downstream), with pressurized tap water (40 psi) flowing through it. The Hydrants are installed to the main 8-inch pipeline by hydrant tees, which is representative of current installation practice. The downstream hydrant is equipped with a two-inch Mueller Hydro-Guard® HG-6 automated flusher (Mueller Co., Chattanooga, TN). A 28,000-gallon lagoon at the end of the 8-inch pipe collects the water from the experiments. Hydrant flushers are typically used by utilities to manage water quality conditions, especially water age and/or low residual issues. Several experiments were conducted at the WSTB to explore the additional functionality of using hydrants for contaminant removal and chlorination.

EPA/600/S-20/337
July 2020

Part 1: Flushing Experiments

Flushing Experimental Design

The WSTB pipe is supplied with pressurized (40 psi), chlorinated (0.2 to 0.5 mg/l free chlorine) ground water from a treatment pump house near the site. Figure 1 shows a schematic of the WSTB pipe with the experimental setup. Briefly, a solution of sodium thiosulfate, which represented a contaminant traveling through the pipeline, was injected for 15 minutes upstream from the fire hydrant, which completely dechlorinated (0.0 mg/l free chlorine) the water flowing in the pipeline. This dechlorinated slug of water was used as an indicator to track the sodium thiosulfate traveling through the pipeline. The automated fire hydrant flusher was connected to an online chlorine sensor, which was located approximately 50 feet upstream from the hydrant and automated flusher. When the chlorine sensor indicated that the slug of dechlorinated water was approaching the hydrant, the automated flusher was triggered (Figure 2) and samples were collected at 1 to 2 minute intervals at the samples ports before and after the hydrant. The automated flusher could also be opened manually with the chlorine sensor disconnected. Samples were collected and enumerated using the Hach® DPD method with a Hach® DR 900 colorimeter with Hach® DPD free chlorine reagent Accuvac® ampules (Hach Corp., Loveland, CO) to determine if chlorine was present before or after the hydrant (Figure 3). The water downstream of the hydrant and automated flusher should maintain a chlorine residual if the sodium thiosulfate solution is completely flushed out of the pipe by the flushing operation. The downstream water would become dechlorinated if the sodium thiosulphate flowed past the hydrant. The range of the Accuvac ampules used was 0.02 to 2.00 mg/l. Readings of 0.02 or lower were reported as 0 in Figures 4 and 5.

The automated flusher was tested in two ways, with downstream pipe flow (test 1 and 2) and with downstream pipe flow shut off (test 3 and 4). For tests 1 and 2, the pipe flow was maintained at 15 gallons per minute (gpm) for the duration of the two experiments. Before the thiosulfate reached the hydrant, the online chlorine sensor connected to the hydrant (Figure 1), the automated flusher was allowed to be opened to either the ½ open (test 1) or full open position (test 2). The automated flusher provided an estimated 45 gpm at the ½ open position and 90 gpm at the full open position. The flows from the flusher (45 or 90 gpm) were significantly higher than the downstream flow demand (15 gpm). Flushing tests 1 and 2 allowed the water in the system to exit the pipe through the hydrant flusher or through the ball valve at the end of the pipe (downstream from the hydrant and flusher). The objective of these tests were to determine if some of the thiosulfate would be able to flow past the flushing hydrant outlet and the dechlorinate the water downstream of the hydrant.

Tests 3 and 4 were conducted with the downstream pipe flow shut off (0 gpm) once the contaminant arrived at or was close to the hydrant and automated flusher. In test 3, the downstream pipe flow was shut off (0 gpm) after the thiosulfate passed the hydrant, and then the hydrant was turned on manually. The goal was to see if the automated flusher would remove the thiosufalte from the downstream section no demand present. Test 4 was conducted with the downstream pipe flow shut off (0 gpm) before the contaminant reached the hydrant and automated flusher. Flushing tests 3 and 4 only allowed the water in the system to exit the pipe through the flusher.

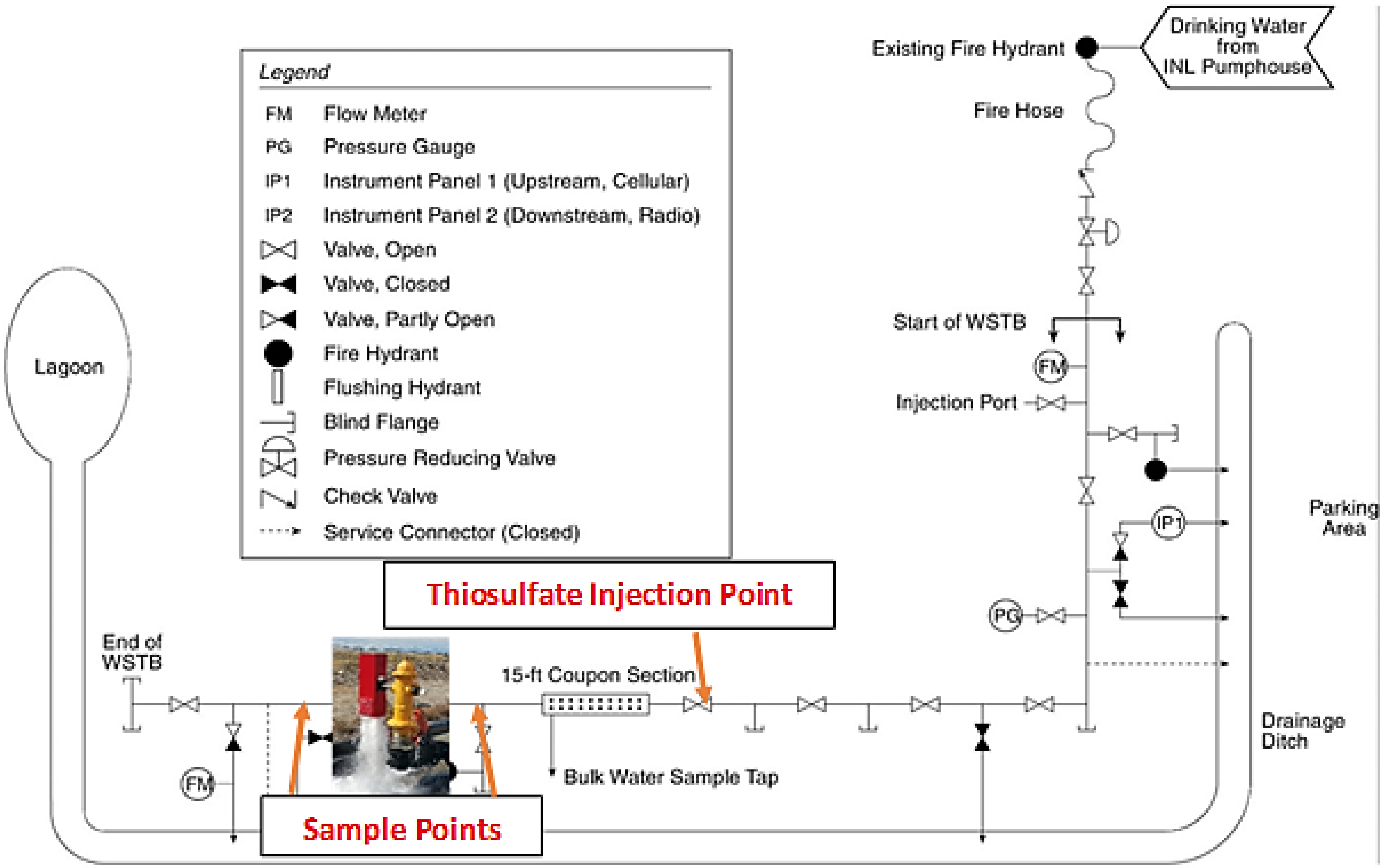

Figure 1: Diagram of the WSTB and the locations of the thiosulfate injection point and sampling points.

Figure 2: Fire hydrant with automatic flusher flushing water.

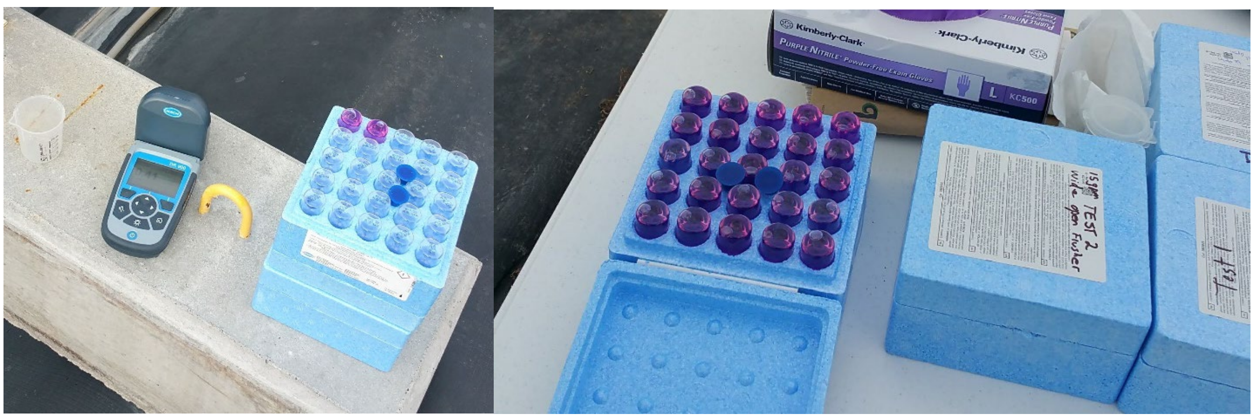

Figure 3: Free chlorine samples upstream showing that sodium thiosulfate had removed the chlorine (left) and downstream showing that there was still a chlorine residual (right) downstream from the flushing hydrant. These ampules are from the experiment that shut off the downstream flow before the thiosulfate arrived at the flushing hydrant.

Flushing Experiments Results and Discussion

The results of the first two flushing experiments, flushing tests 1 (1/2 open) and 2 (full open), are shown in Figure 4a and 4b, respectively. Sodium thiosulfate was able to flow past the fire hydrant and automated flusher and reach the downstream sample port in both flusher experiments with a continuous downstream flow of 15 gpm, as shown in tests 1 and 2. This was indicated by the chlorine levels dropping to zero in the downstream portion of the pipe past the hydrant in both experiments. Test 1 only took 1 minute for the chlorine level past the hydrant to go to 0 mg/l. Test 2 took 4 minutes for the chlorine level past the hydrant to reach 0 mg/l. In both cases, chlorine was not detected in the automated flusher effluent, which indicates that some (but not all) thiosulfate was being flushed. Figure 4 also shows that the chlorine levels rebounded after the slug of thiosulfate was discharged from the flusher and was replaced by chlorinated water.

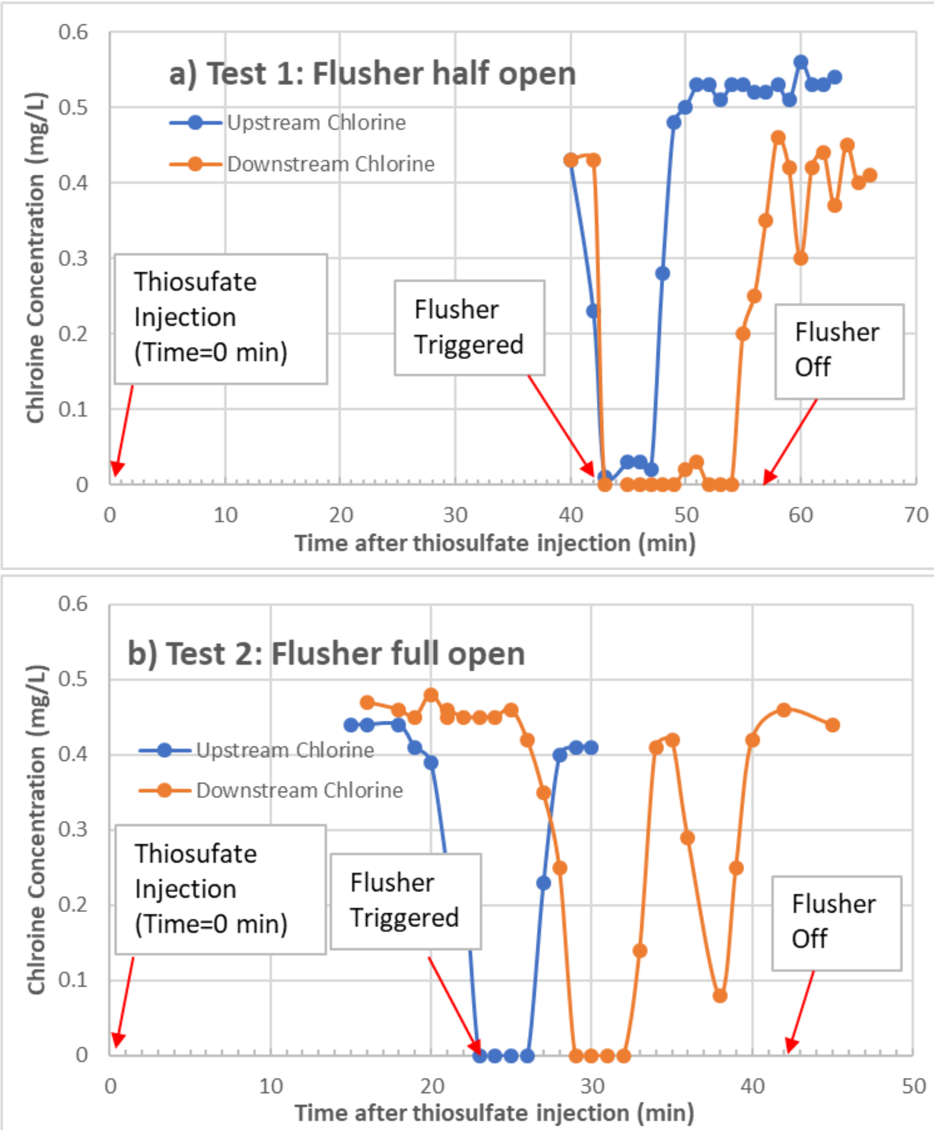

Figure 4: Flushing hydrant test results with flow (15 gpm) present (a) is when automated flusher is half open and (b) is when the automated flusher is fully open.

Figure 5 shows data from tests 3 and 4, where the flow downstream from the hydrant was shut off (0 gpm). Test 3, shown in Figure 5a, thiosulfate was allowed to pass the hydrant with flow at 15 gpm and the automated flusher on. Once thiosulfate was detected downstream, the pipe flow was stopped. The downstream chlorine levels remained at zero with the flusher on, which suggested that for these flow conditions the hydrant flusher would not pull contaminated water back upstream, even with no downstream demand. Test 4, shown in Figure 5b, the downstream flow was shut off before the thiosulfate made it to the hydrant, and the hydrant flusher was turned on. In this case, thiosulfate was not detected downstream of the hydrant.

The results from these tests showed how contamination in a pipe behaves when one is trying to remove it via flushing. Data from tests 1 and 2 (Figure 4) showed that the automated hydrant flusher can remove contamination, but that some of the contamination would continue downstream if demand (flow) was present. Tests 3 and 4 (Figure 5) showed that the automated hydrant flusher cannot pull contamination back upstream, even if the downstream demand is reduced to zero. Most importantly, the automated hydrant flusher could remove all contamination from a pipe if downstream demand was reduced to zero before the contaminant reached the hydrant. In conjunction with hydraulic modeling, a utility responder could use this information to plan a flushing strategy if a contamination incident occurred.

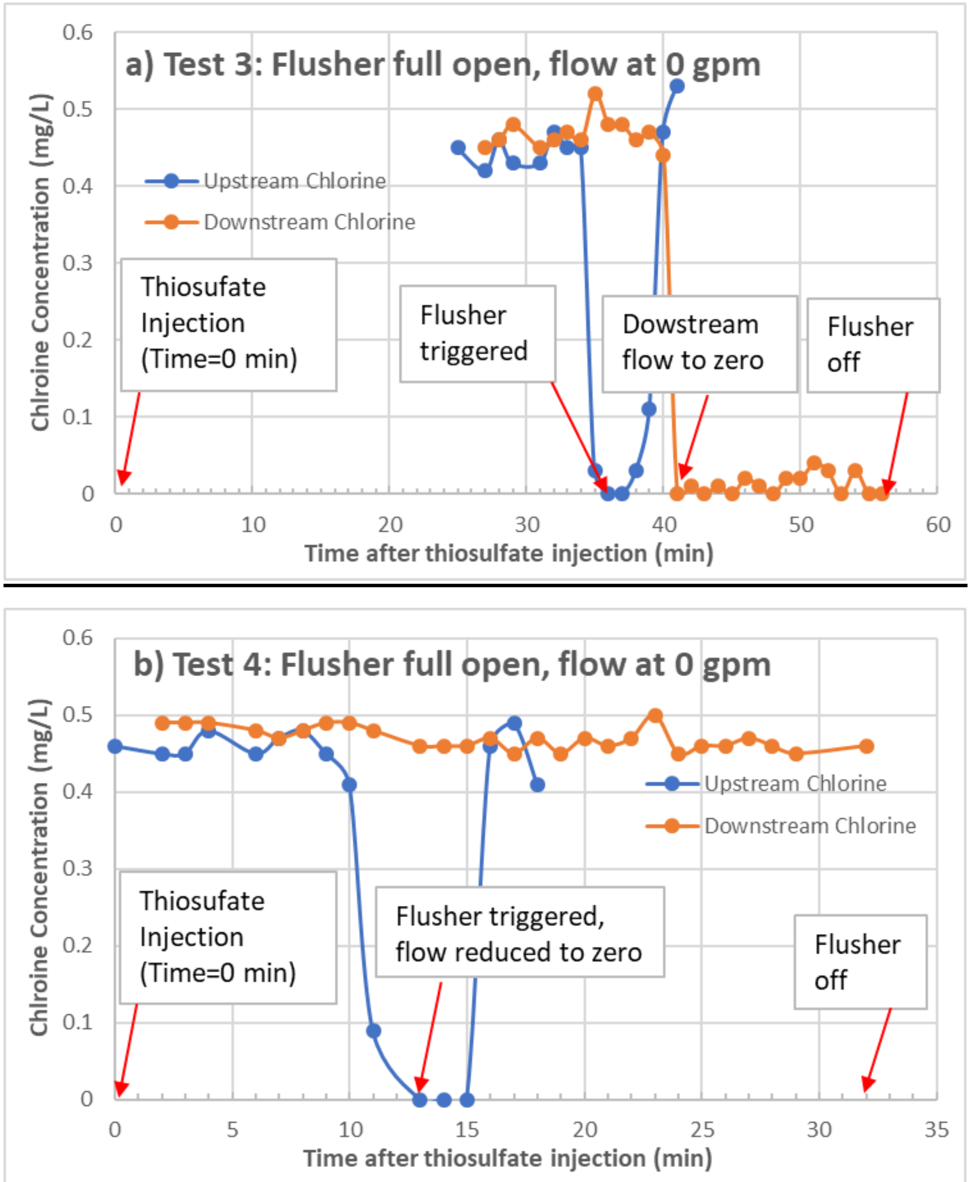

Figure 5: Test 3 allows the sodium thiosulfate to flow past the hydrant tee before triggering the flusher and closing off the downstream flow. This test indicates that some of the sodium thiosulfate made it past the flusher to dechlorinate the water downstream of the hydrant tee. Test 4 triggers the flusher and closes off the downstream flow before the sodium thiosulfate reaches the hydrant. In this case, the sodium thiosulfate was not able to make it past the flusher and dechlorinate the water past the hydrant tee.

Part II: Chlorination Enhancement Experiment

Chlorination Experimental Design

Hydrant diffusers are made with optional metal sleeves to hold dechlorinating tablets so that the water being discharged from the hydrant can be dechlorinated as it exits the diffuser. This prevents chlorinated water from harming aquatic or plant life near the point of discharge. However, in response to a biological water contamination incident, it is likely that additional chlorine would need to be added to the water prior to discharge to prevent the spread of biological contamination to the environment or downstream treatment works. Therefore for this experiment, two Pollard 250 hydrant aluminum diffusers (LPD-Chlor™ FNST 2-1/2 in. aluminum dechlorinator, Pollardwater, New Hyde Park, NY) were welded together to make a custom chlorination diffuser (Figure 6). One diffuser connected directly to the fire hydrant and the other diffuser redirected the flow into a fire hose. This setup also allowed the two metal sleeves to be used for the addition of the Clorox® Pool and Spa™ chlorine tablets for small pools (Clorox Company, Oakland CA). Using the hose allowed the flow to be more directly discharged into a manhole or storm sewer while creating less airborne splash. Additional chlorine contact time prior to discharge could be added by lengthening the hose. The chlorine levels in the WSTB were maintained around 0.2 mg/l for the chlorination experiment. The flush rate was established at approximately 100 gpm. Twenty one-inch diameter chlorine tablets (99% trichloro-s-triazinetrione and 1% other) were added to one of the sleeves. The hydrant was discharged through the Pollard assembly for 45 minutes and the chlorine levels were measured at 5-minute intervals from the discharge hose. Figure 7 shows the location of the diffuser in connection to the WSTB pipe and lagoon, and Figure 8 shows the diffuser hose discharge entering the lagoon.

Figure 6: The prototype hydrant diffuser with hoses attached (top), Twenty one-inch diameter chlorine tablets in the diffuser (bottom, left), and a regular hydrant flow diffuser before modification (bottom, right).

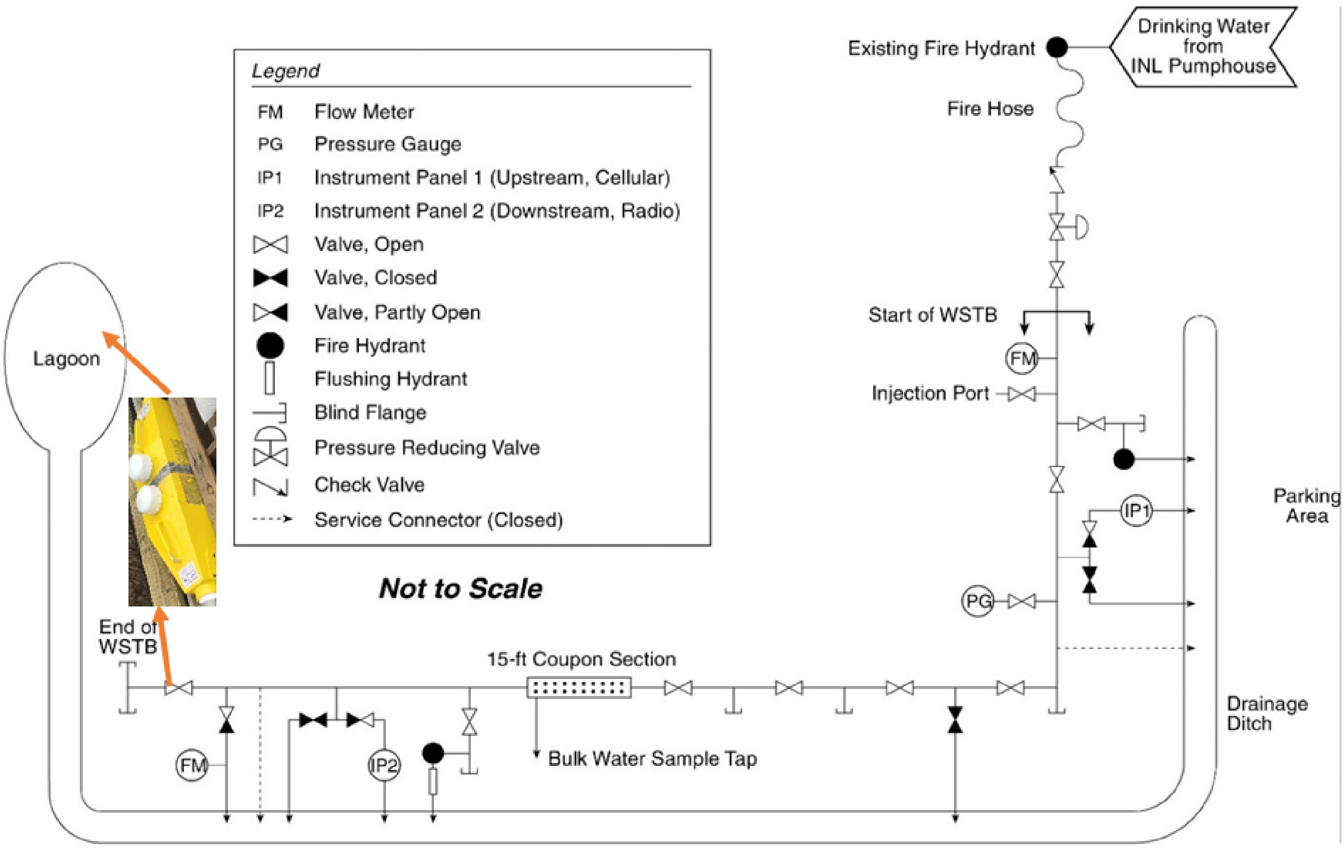

Figure 7: Location of the diffuser on the WSTB site, and how hoses (represented by arrows) were plumbed.

Figure 8: Diffuser discharge into the WSTB lagoon.

Chlorination Experiment Results and Discussion

Table 1 shows the chlorination data from the diffuser test. The 20 chlorine tablets were able to increase the chlorine levels for the entire 40 minutes of the test. The elevated chlorine level immediately after the flush began (1.49 mg/L at 11:12 am) was due to a concentrated slug of water that had been sitting in the chlorine tablet chamber exiting the diffuser. The water entering the diffuser assembly was approximately 0.2 mg/l and it consistently left the diffuser hose at approximately 0.7 mg/l. The chlorine tablets after the test appeared to be unchanged, which suggested that chlorine could have been produced for days.

Table 1: Diffuser Effluent Chlorine Levels

Time	Elapsed Time (min)	Effluent Chlorine Level (mg/L)
11:09 AM	Baseline	0.19
11:10 AM	0	Begin Flush
11:12 AM	2	1.49
11:15 AM	5	0.68
11:20 AM	10	0.70
11:25 AM	15	0.69
11:30 AM	20	0.74
11:35 AM	25	0.67
11:40 AM	30	0.64
11:45 AM	35	0.64
11:50 AM	40	0.75
11:55 AM	45	0.66
11:55 AM	50	End Flush

Conclusions

Flushers and diffusers can be used as tools to respond to contamination incidents in a drinking water distribution system. EPA developed a drinking water distribution system modeling and simulation tool, the Water Security Toolkit (WST), which uses a calibrated hydraulic model to determine the best hydrants in a city's distribution system to flush in response to a contamination event (US EPA, 2014). The intent of this research is to pave the way for more automated flushing systems to be employed as an approach to respond to contamination events detected within the distribution system. The information obtained from WST could help identify the best locations to install the automated flushing systems.

The growing availability of remote-disconnect water meters and automatic control valves on hydrant flushers linked with real-time monitoring creates the feasibility of automatically responding to contamination within a distribution system and to prevent contaminants from reaching consumer taps. Further research is needed to fully develop and demonstrate automated water security systems.

This research indicates that automated hydrant flushers can be used effectively to remove or reduce contaminants from a water distribution system. However, contamination can bypass a flushing hydrant and reach downstream water consumers, especially if there is downstream flow during the flushing. Utilities should limit downstream demand when conducting flushing activities to remove distribution system contamination. This data also indicates that hydrant diffusers can be used to boost chlorine levels in the field prior to discharge of water from a fire hydrant.

References

U.S. Environmental Protection Agency (US EPA). 2016. Testing large-volume water treatment and crude oil contamination using the EPA water security test bed experiments at the Idaho National Laboratory. Cincinnati, Ohio: U.S. Environmental Protection Agency. EPA/600/R-161/126

U.S. EPA. 2014. Water Security Toolkit User Manual: Version 1.3. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/338.

Contact Information

For more information, visit the HSRP Web site at www.epa.gov/homeland-security-research

Technical Contact: John Hall (hall.john@epa.gov)

General Feedback/Questions: Kathy Nickel (Nickel.kathy@epa.gov)

U.S. EPA's Homeland Security Research Program (HSRP) develops products based on scientific research and technology evaluations. Our products and expertise are widely used in preventing, preparing for, and recovering from public health and environmental emergencies that arise from terrorist attacks or natural disasters. Our research and products address biological, radiological, or chemical contaminants that could affect indoor areas, outdoor areas, or water infrastructure. HSRP provides these products, technical assistance, and expertise to support EPA's roles and responsibilities under the National Response Framework, statutory requirements, and Homeland Security Presidential Directives.