Comprehensive Approach to Increase Effectiveness & Efficiency of Flushing Programs Using Latest Hydraulic & Water Quality Monitoring Tools

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Utilities are constantly striving to maintain a high standard of cost-effective service to potable water customers. Minimizing flush water is vital to water providers, given the cost of finished water and the limited source of supply. This article will discuss ways to:

- Identify potential water-quality problem areas.
- Optimize flows throughout the distribution system to reduce water age.
- Develop a flushing program to clean the piping in the distribution system.
- Reduce flush-water volumes.

Monitoring the System

Before initiating any system flushing program, a utility should establish a monitoring program to collect and evaluate data at the point of entry and throughout the distribution system. Monitoring is not a simple task, but it will aid in identifying existing and potential water-quality problem areas. Several system monitoring tools are discussed in the following sections.

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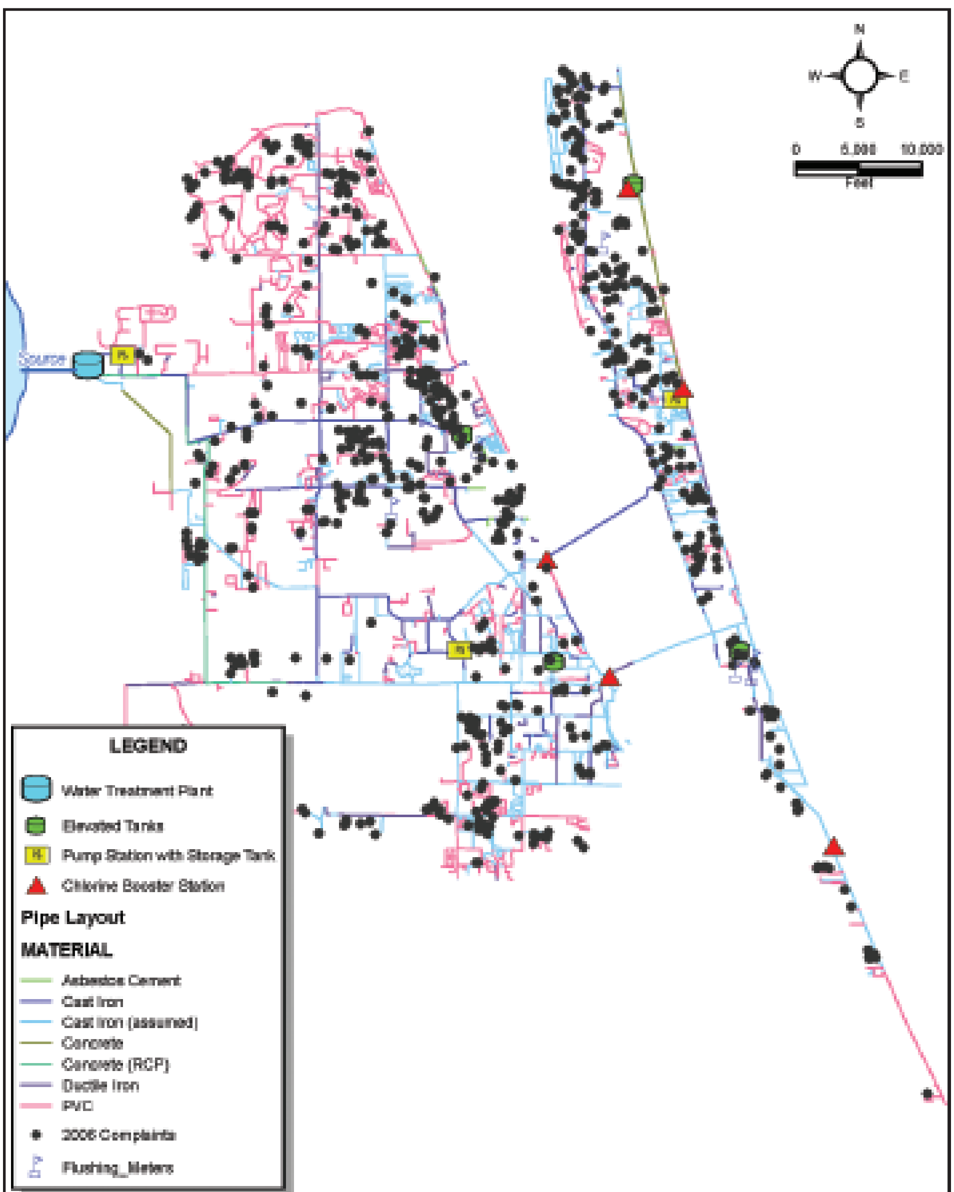

Figure 1. Collected Customer Complaint Information

Form a Distribution Water-Quality Team

In order to measure the success of any flushing program, distribution system water-quality data must be collected and interpreted. A distribution water-quality team should be formed to accurately interpret the data.

This team should have representatives from all divisions of the utility and any contracted entities that guide the decision making of the utility. Team members should set specific goals for tracking and maintaining the distribution system while achieving water-quality goals and customer satisfaction.

Distribution system data can include customer complaint locations, complaint water color, complaint water quality, regular flushing locations, flushing flows, flushing location water quality, location pipe material, and entry-point water quality. This information can be used to identify potential water-quality problem areas in the distribution system.

Figure 1 illustrates typical data collected by a utility. Immediate access to customer complaints and distribution water-quality data is necessary to evaluate effectiveness and change objectives during any flushing program.

Locate & Track Customer Complaints

Investigation of Figure 1 shows that minimal information is provided about the complaint. Valuable information is presented, such as complaint location and pipe material, but without specific complaint water characteristic information such as water color, presence of particles, pressure change, frequency of occurrence, and other properties, it is very difficult to assess the system effectively. The utility customer complaint database may need to be improved or constructed to collect the information need-

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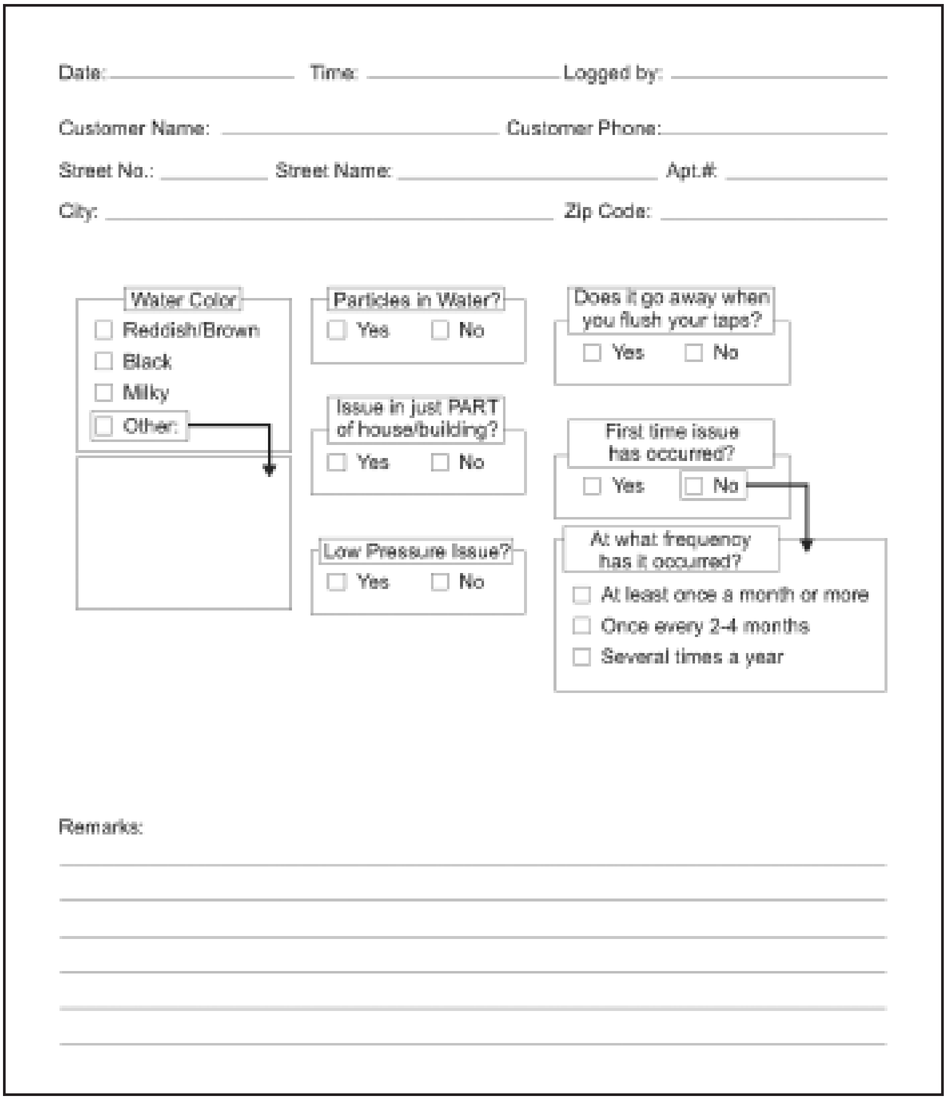
Date: ______ Time: ______ Logged by: ______

Customer Name: ______ Customer Phone: ______

Street No.: ______ Street Name: ______ Apt.#: ______

City: ______ Zip Code: ______

Water Color
- ☐ Reddish/Brown
- ☐ Black
- ☐ Milky
- ☐ Other:

Particles in Water?
☐ Yes ☐ No

Issue in just PART of house/building?
☐ Yes ☐ No

Low Pressure Issue?
☐ Yes ☐ No

Does it go away when you flush your taps?
☐ Yes ☐ No

First time issue has occurred?
☐ Yes ☐ No

At what frequency has it occurred?
- ☐ At least once a month or more
- ☐ Once every 2-4 months
- ☐ Several times a year

Remarks:

Figure 2. Water Quality Complaint Call Log

Continued from page 31

ed, as illustrated by Figure 2.

Monitor Distribution Water Quality

In addition to collecting the information in Figure 2, it is also important to collect the water-quality data such as chlorine residuals, turbidity (field and lab), pH, HPC, color, total iron, and other water-quality properties that may provide information specific to the utility. Data should be collected throughout the distribution system near or at the location that corresponds to the customer complaints database entries. The collection of this data in a database will enable the utility to have immediate access (via Web access, hardcopy map, and/or tables) to customer complaints.

Monitor Source Water Quality

Some customer complaints may be attributed to the quality of the water entering the distribution system. Various issues such as finished water buffering capacity, pH, total iron, hardness, and other water-quality properties should be investigated, but specific issues with the source water quality maybe not be known, in part because of minimal information regarding customers' complaints.

Any action taken to improve the quality of the source water should be performed based on an understanding of what type of water-quality issue customers are experiencing. The implementation of a customer complaint database would provide essential information which will benefit the utility decision-making process.

Interpret Collected Data

The water-quality team should implement specific ways to view and interpret all data collected through system monitoring. Easy-to-access output maps, charts, and/or tables should be developed and updated on a regular basis. Mapping the information collected from distribution-system monitoring tools with an overlay of pipe material and diameter can aid the interpretation of the data being collected. This interactive output review will aid the utility in developing an enhanced flushing program.

Define your Enhanced Flushing Program

An enhanced flushing program is made up of routine flushing and unidirectional flushing programs. The development of any flushing program can be simplified be using a water-quality hydraulic model. The following section provides basic program development information for a routine flushing program and a unidirectional flushing program and also the methodology to simulate a structurally and operationally current hydraulic model to accurately represent hydraulic and

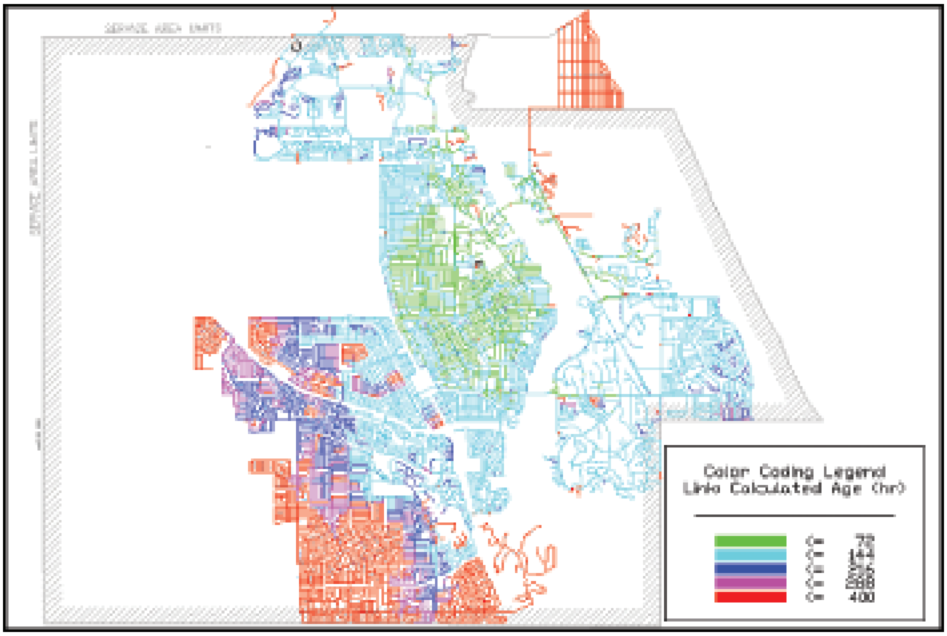

Figure 3. Water Age at Average Daily Flow with No Flushing

water-quality conditions.

Routine Flushing Program

A routine flushing program is used to improve water quality in the distribution system by reducing the retention time (water age) of water. This program involves regular flushing of the system at a fixed rate to decrease water age.

Routine flushing is optimized by using water-quality modeling to pinpoint the best locations and flows. Considerable volumes of non-revenue water can potentially be saved with this technique. With the widespread use of automatic water-distribution flushing devices, such as HydroGuard™, locating the flushing devices and setting flows with water quality-modeling will enhance results.

Unidirectional Flushing Program

A unidirectional flushing (UDF) program is used to achieve water flow in one direction and high velocities in targeted pipes to properly scour and remove deposits and debris. This program involves flushing the system in sequences from a clean source, achieving velocities typically ≥5 feet per second. UDF is a very structured flushing program which has to be designed to achieve specific goals using step-by-step instructions for each pipe less than 12 inches in diameter within the distribution system. Generally, flushing maps and technical data sheets are required for each sequence.

Water-Quality Model

- *Structural*–The hydraulic model structure includes pipes, pumps, nodes, and supply sources. Because the hydraulic model will be used for water-quality modeling, the structure includes only six-inch diameter and larger pipes and crucial four-inch loops. The structural model components were created from Utility Division Mapping Department electronic files, construction plans, and as-built drawings. The hydraulic model was cre-

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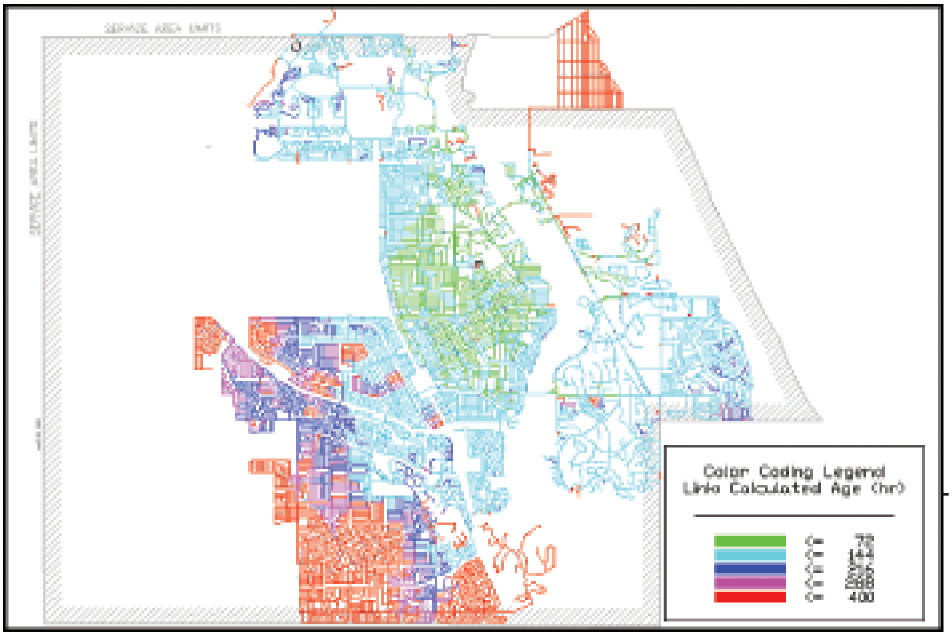

Figure 4. Water Age at Average Daily Flow with Recommended Flushing

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ated on a computer-aided design (CAD) platform with state-of-the-art hydraulic modeling software. (WaterCAD version 6.0 by Haestad Methods)

- ***Demand Allocation***–The demand allocation method has a profound effect on the hydraulic model accuracy, especially with regard to water-quality simulations. These projects used the most accurate demand allocation procedure currently available. Water-meter data was geo-located using the city and county geographical information system (GIS) databases and maps. The geo-located water meters can then be assigned to hydraulic model nodes using either GIS spatial overlay or the MWH Soft Demand AllocatorTM module nearest pipe-junction demand allocation method. These methods create a permanent link from the city's water-meter database to the hydraulic model node demand database.
- ***Scenario Development***–Scenarios are a unique set of operational conditions selected to simulate the water distribution system. Conditions include pumps and pipes toggled on or off, demand peaking factors, and tanks filling or discharging. Treatment plant operational personnel provided input to develop the hydraulic model scenarios, including average annual flow, maximum daily flow, peak hourly flow, and two remote tank filling scenarios.
- ***Extended Period Simulations (EPS)***–EPS are required to model water age and quality. EPS were developed to model diurnal (24-hour) variations in one-hour increments. Remote tank fill and draw operations were adjusted using logical controls to mimic field conditions. EPS were run for 400 hours to establish equilibrium for water age in the system.
- ***Calibration***–The hydraulic model calibration is an event used to capture flows and pressures throughout the system using remote pressure monitoring locations, pump station flow and pressure SCADA information. Calibration data is then used to adjust pipe friction to achieve hydraulic model results within ten percent of field measurements.
- ***Future Updates***–To avoid having an outdated hydraulic model, a system of updates should be implemented. A Hydraulic Model Strategic Plan should be prepared with a list of action items, a schedule, and a determination of manpower necessary to maintain and use the hydraulic model.

Develop your Enhanced Flushing Program

Compare Distribution Water Age

Developing a routine flushing program can be completed using the hydraulic model based on minimizing the "age" of the water in the distribution system. Figure 3 depicts a distribution system water age without flushing. High water age is observed in the southwest and northeast areas of recent construction.

Nineteen flushing locations were introduced to the system at a combined rate of 381 gallons per minute (gpm), which is equivalent to a total flow of 550,000 gallons per day (gpd), distributed throughout the southwest and northeast areas. Figure 4 shows the water age with flushing at indicated locations. In comparing the varying water ages that occur in the system without and with flushing implementation, it is observed that flushing reduced the water age significantly in the southwest and northeast areas.

Determine Water Savings

The recommended flushing flow of 550,000 gpd resulted in a decrease in total waters, based on current flushing practices, and could save the utility up to 50,000 gpd of production water. The flushing recommendations provided are simplistic and are based on the system behavior following flushing optimization.

Unidirectional Flushing Program

The typical requirements to structure a successful UDF program include determining the size and the make-up of the zone to be flushed within a typical work week (five days) utilizing eight to 10 hours per day, test preparation and precautions, zone maps and data collection, and manpower and flushing flow. These topics are discussed in the following section.

Zone Structure

Since a UDF program targets distribution pipes less than 12 inches in diameter, transmission piping is typically not included in a UDF program. Larger transmission piping can be evaluated using the hydraulic model to determine the maximum velocity seen in a typical day. Based on that assessment, the utility can determine if other cleaning methods such as pigging or multiple hydrant flush would be required.

Default Description	Units	UDF Program Default*	User Default
Minimum Flush Velocity	feet/second	3	5**
Maximum Flush Volume	gallons	5,000	—
Maximum Flush Length	feet	5,000	—
Minimum Residual Pressure	psi	20	20
Minimum System Pressure	psi	20	20
Desired No. of Turnovers	—	3	2
Desired Flush Time	minutes	30	—
Orifice Flow Coefficient	—	0.9	0.9
Hydrant Nozzle to Operate	—	2.5	2.5

* Defaults from MWH Soft InfoWater Software UDF Module, ** if achievable.

Table 1. Typical UDF Program and User Defaults

Distribution pipes less than 12 inches in diameter are then dissected into zones. A UDF zone should be structured so that the minimum of two operators (one crew) can complete the zone within a typical work week (five days) utilizing eight to 10 hours per day. Even though the flushing time per zone is typically one to two hours, time is required to locate hydrants and valves, make any necessary repairs and replacements within the zone, and make preparations for the actual flushing event.

This type of flushing is optimized with the use of hydraulic modeling and geographical information systems (GIS) to pinpoint the best hydrant locations, valve manipulation, flows, and sequence (the flushing of each pipe within the zone) velocities that make up a zone. UDF program software is currently available to ensure that specific sequence requirements such as default or alternative user-defined requirements are met throughout the system and in each specific zone. Table 1 lists typical program defaults and an example of alternative user defaults.

<u>UDF Preparation & Precautions</u>

A successful UDF program has several important aspects that must be accomplished by the operators conducting the flushing event. Operators should inspect zones for adequate drainage, collect water-quality data, and adhere to specific precautions. The operators should

Continued on page 38

- ❖ Review zone location and sequence elements maps
  - o Inspect area for adequate drainage
  - o Locate hydrants and valves
  - o Conduct repairs/replacements as needed
- ❖ Prepare sample bottles
  - o Two sets of bottles for each sequence
  - o Test for selected water quality items *(Pre- and Post-Flush)*
  - o Send sample bottles to laboratory *(Post-Flush Only)*
- ❖ Notify customers in zone area
- ❖ Notify water department official of test location and time
  - o Water plant(s)
  - o Utilities (field and customer complaint call center personnel)
- ❖ Be sure local water service personnel are not working in immediate vicinity

Table 2 – Pre- and Post-Flush Preparation Summary

- ❖ Minimize property damage from a flowing water stream. Damage control measures include:
  - o Notwashing out driveways and sodded areas
  - o Directing water streams away from traffic or at people
  - o Opening and closing all hydrants slowly to avoid water hammering
- ❖ Control pedestrian and automobile traffic during flush
- ❖ Make sure that all unused hydrant caps are properly tightened
- ❖ Avoid standing in front of closed caps
- ❖ Avoid leaning over the top of the hydrant while in operation
- ❖ Avoid flowing hydrants where adequate drainage is not provided
- ❖ Hydrant pressure should never drop below 20 psi during flushing
- ❖ When in doubt, do not flow, read directions again or call the project manager for assistance

Table 3 - Test Precautions Examples

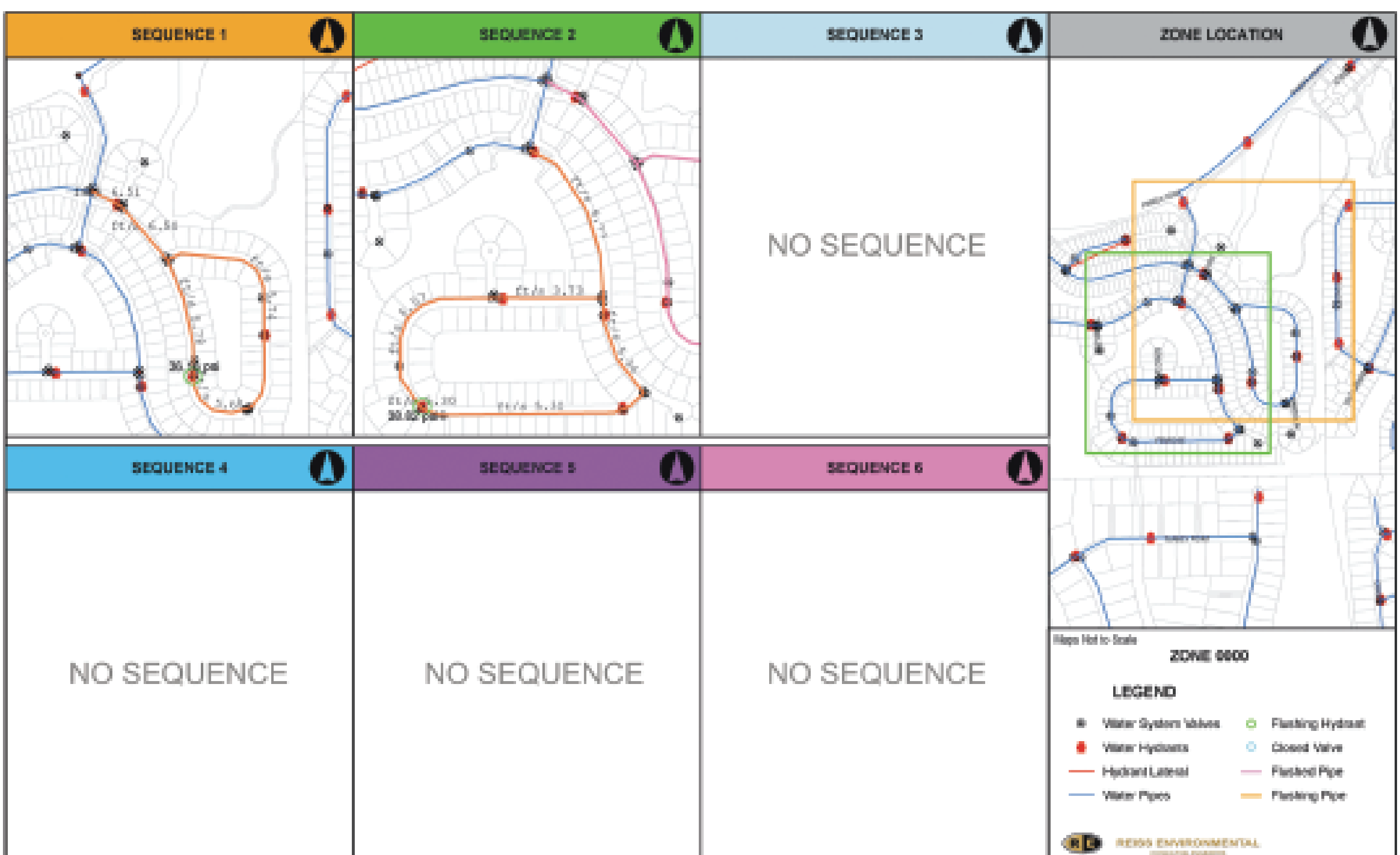

Figure 5. Example Zone Location and Sequence Map

Table 4. Zone Location and Sequence Map

- ❖ Zone ID map
  - o Road names
  - o Pipe sizes
- ❖ Sequence map
  - o Pipe ID
  - o Valve ID
  - o Hydrant ID
  - o UDF model output
    - ▪ Pipe velocity (ft/s)
    - ▪ Hydrant pressure (psi)
  - o Target OPEN hydrant (enclosed in "GREEN" circle)
  - o Target CLOSED valves (enclosed in "CYAN" circle)

Continued from page 37

conduct specific activities, such as review UDF location zone and sequence elements maps to locate hydrants and valves, make necessary repairs and replacements within the flushing zone, issue public and internal notification, and complete sampling preparations. These items are summarized in Table 2.

Test precautions should be developed by the utility for operator safety and damage control. Some examples of test precautions are listed in Table 3.

Zone Maps & Data Sheets

The most efficient representation of zone location, target sequence, and data would be through maps and data sheets. Table 4 shows the basic information that should be included on the maps to create an effective and easy-to-understand tool.

Figure 5 shows an example of a zone location and sequence map. Model results and field data are represented in the data sheets that should be constructed for each zone. The field data that should be collected are static pressure (psi), residual pressure (psi), discharge flow (gpm), and water-quality readings. Figure 6 shows an example data sheet.

Manpower & Flushing Flow Estimates

A utility which has 700 miles of pipe would require approximately 350 zones. The average flushing time per zone is approximately 1.5 hours, but the average time to flush and prepare a zone is approximately 40 hours per week, which yields approximately 14,000 hours (6.5 years) to unidirectional flush the entire system.

An average of seven sequences per zone yields about 2,500 sequences for the distribution system. The total flushing volume based on 11,000 gallons per sequence is estimated at 27.5 million gallons (MG), or 4.2 MG per year utilizing one crew for the entire distribution system.

The amount of time required to completely unidirectionally flush the entire system can be reduced by dividing the system into several sections to allow additional crews to work on the system. When utilizing multiple crews, a detailed flushing schedule should be developed to ensure that crews are not flushing at the same time and that the amount of flow needed is available while maintaining average flow and minimum pressures within the distribution system.

This article was presented at the FSAWWA Fall Conference in November. ◊

Zone 0	Date:	Start Time:		End Time:	
Sequence.	**Description**	**Valve/Hydrant ID**	**Parameters**	**Model Results**	**Field Data Collecti**
1	Flush pipe(s) P-3575,P-3578,P-3569,P-3583 using hydrant 1496.				
	Open Hydrant	1496	Static Pressure (psi)	52.1	
			Residual Pressure (psi)	36.2	
			Discharge Flow (gpm)	1010.	
			Available Flow (gpm)	1523.6	---
			Total Flushing Pipe Length (ft)	2110.	---
			Min. Flushing Volume (ft*3)	797.4	---
			Min. Flushing Time (min.)	5.9	---
			Desired Flushing Volume (ft*3)	1594.8	---
			Desired Flushing Time (min.)	11.8	---
2	Flush pipe(s) P-3558,P-3580,P-3582,P-3581,P11 using hydrant 1498.				
	Open Hydrant	1498	Static Pressure (psi)	45.5	
			Residual Pressure (psi)	30.6	
			Discharge Flow (gpm)	928.7	
			Available Flow (gpm)	1288.2	---
			Total Flushing Pipe Length (ft)	2673.8	---
			Min. Flushing Volume (ft*3)	1594.9	---
			Min. Flushing Time (min.)	12.8	---
			Desired Flushing Volume (ft*3)	3189.9	---
			Desired Flushing Time (min.)	25.7	---

Sequence 1 - Water Quality Collection Data				Sequence 2 - Water Quality Collection Data			
WQ Parameters	**Value**	**WQ Parameters**	**Value**	**WQ Parameters**	**Value**	**WQ Parameters**	**Value**
Turbidity (NTU)		Iron (mg/L)		Turbidity (NTU)		Iron (mg/L)	
Initial Turbidity		Initial Value		Initial Turbidity		Initial Value	
Final Turbidity		Final Value		Final Turbidity		Final Value	
Residual Chlorine (mg/L)		Odor (TON)		Residual Chlorine (mg/L)		Odor (TON)	
Initial Value		Initial Value		Initial Value		Initial Value	
Final Value		Final Value		Final Value		Final Value	
Field Residual Chlorine (mg/L)		HPC (per 100 mL)		Field Residual Chlorine (mg/L)		HPC (per 100 mL)	
Initial Value		Initial Value		Initial Value		Initial Value	
Final Value		Final Value		Final Value		Final Value	
pH (std. units)		Color (cpu)		pH (std. units)		Color (cpu)	
Initial Value		Initial Value		Initial Value		Initial Value	
Final Value		Final Value		Final Value		Final Value	
Notes:							

Figure 6. Example Data Sheet