UNIDIRECTIONAL FLUSHING SOP

SOP #432

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SOP VERSION CONTROL

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STAFF ACKNOWLEDGEMENT

I certify that the requirements of this SOP have been communicated to me and that I am trained in its use. A copy of this page will be distributed to the employee training record file.

Name	Date

APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. & Confluence Engineering Group LLC Date: 01/31/2018

Approved by: ____ Date: ____________

1 DEFINITIONS AND ACRONYMS

CF	conventional flushing
CWI	clean water interface
FPS	feet per second
GIS	geographic information system
GPM	gallons per minute
GPS	global positioning system
PPE	personal protective equipment
PSI	pounds per square inch
PV	pipe volume
UDF	unidirectional flushing

2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Superintendent:
  - Maintain schedule and generate work orders (based on objectives listed in scope/purpose section) for flushing areas and events.
  - Identify additional planning/scheduling activities and resources for each flush (such as establishing additional traffic control measures, coordinating pre-flush hydrant and valve inspection, performing customer notification, assessing the hydraulic impact and water quality impact, equipment organization and other planning steps).
  - Maintain records of flush events, including hydrants used, nearest Clean Water Interface (CWI), general direction of water movement, water used, start and finish water quality (including chlorine residuals and turbidity measurements).
  - Ensure all problem hydrants and valves, map discrepancies, water quality issues, and other issues are properly communicated to the responsible parties and ensure identified repairs/replacements, and/or further remediation steps are executed within a timely manner.
- GIS Specialist or other support staff:
  - Assist in developing flush area delineations working with modeling and GIS support staff.
  - Once flush areas are described, construct specific flushing run descriptions to be detailed in the flush loop book. Coordinate with modeling and GIS to confirm acceptable flows and pressures can be maintained with planned runs.

  - Interface with Water Distribution Operator to set up and review valve sequences, pipe diameters and types, run descriptions, water disposal constraints, traffic logistics, and other field related logistics.
- Water Distribution Operator (3):
  - Perform flushing pre-inspection, assemble required flushing and traffic control equipment, and perform flushing efforts as generated by work orders.
  - Prepare records of flushing efforts, issues or maintenance concerns for each hydrant, record all water quality data on standardized forms, and enter into the flushing GIS database.

3 SCOPE/PURPOSE

The purpose of this SOP is to ensure proper goals and objectives are realized for regular and consistent execution of a system-wide or area-wide unidirectional flushing (UDF) program. The Water Distribution Superintendent should consider the following five steps necessary for developing a successful UDF program:

1. Flush Area Delineation
2. Flushing Run Development
3. Preliminary Inspection
4. Customer Notification
5. Implementation of UDF field effort (this is discussed in Section 5 - Procedure)

Unlike conventional flushing (CF), UDF is a tool that the Water Distribution Superintendent can use over the long term as a periodic preventative maintenance practice to limit deposit buildup and remove readily mobilized solids. The purpose of UDF is to remove loose and destabilized deposits from pipe wall surfaces in a controlled, organized manner. With proper planning, UDF provides control over the origin, direction, and velocity of flow. UDF is not intended to removal all deposits from pipe walls; rather, it is focused on application of an optimal flushing velocity to remove hydraulically-mobile deposits without damaging pipe scales. Although higher velocities are used compared to CF, flushing velocities should be kept low enough to avoid destabilizing pipe corrosion scales/tubercles on unlined iron pipe. A well-managed UDF program has been shown to reduce incidents of water quality upsets and customer complaints, improve system water quality stability, while assisting in asset management and upkeep.

The following SOP is intended to assist the Water Distribution Superintendent in all stages of the development and implementation of a successful UDF program. The 5 steps mentioned above should be addressed consecutively and will be used as a roadmap for this SOP. The Water Distribution Superintendent should consider each of the steps below and assign the appropriate individual or set of individuals to handle each task. Overlap is not essential, but may assist in the success of the program. Steps 3-5 should be assigned to the crews intended to complete the actual field work.

1) Flush Area Delineation

UDF is typically employed on an area-wide basis, not on a spot basis. Development of a UDF plan requires breaking a large system or pressure zone into smaller flush areas. Flush areas are user-defined portions of the system that can be flushed independent of and without adverse hydraulic or water quality impacts to other nearby portions of the system. Flush areas consist of a set of sequestered flushing runs that provide coverage of all mains in the area along with one or more nearby CWIs. Flush areas should be defined using the following criteria:

- Located entirely within a single pressure zone. UDF is not performed across booster pump stations or zone valves, and is only performed across pressure-reducing valves in cases where the down-gradient zone is pressure-regulated and does not “float” on storage (even in such cases, the down-gradient area is typically defined as a separate flush area).
- Directly served by at least one clean water source that interfaces with the flush area. This can either be an original clean water source or an extension of a previous clean water source. Collectively these are referred to herein as clean water interfaces or CWIs.
  - A CWI is defined as a source that will provide sufficient flow of “fresh” (e.g., good chlorine residual), low-turbidity water when flowed at the maximum flow rate anticipated for the area it serves. Typical CWIs include: finished water storage reservoirs (if adequately turned-over and cleaned), system or zone entry-points (e.g., treatment plants, interties, pump stations), and most commonly, large diameter transmission lines (typically 12-in. or larger).
  - If a large-diameter transmission main is intended for use as a CWI, at the time of field work, flushing should first be conducted to assess whether it is suitably clean. In some cases, these mains may need to be pre-flushed (starting back at an established original clean water source) in order to extend the CWI up to the target flush area. This process typically involves UDF at the maximum flow rate (gpm) anticipated for the flush area. When flushing large diameter mains, flow should always proceed in the direction of normal system flow.
- Small enough to enable the area to be flushed with a reasonably short and uninterrupted effort. Typical flush areas are less than 10 pipe-miles, although they can be larger as needed or desired.

2) Flushing Run Development

Flushing runs are defined segments or stretches of pipe that are flushed in a highly-organized sequence through strategic valve operations. Flushing runs are typically developed for all mains ≤ 12-inch diameter within a given flush area (as well as larger mains for the purpose of extending the CWI, as discussed in the previous section). Flushing run development is part science, part art, and part iteration. Specific criteria and guidelines for flushing loop development are as follows:

1. Identify the primary source(s) of water serving the flush area to be designated as the CWI(s). These should conform to routine flow directions for mains ≥ 12-inch diameter.
2. Identify opportunities to extend the CWI along 12-inch lines to create multiple interfaces with the flush area. The presence of multiple interfaces to the flush area facilitates a “surround-and-conquer” or a “divide-and-conquer” approach, while also helping to ensure that service is maintained to all customers at all times. The process of extending the CWI should follow routine flow directions in mains ≥ 12-inch diameter.
3. Associate the extended CWI with smaller areas of piping to be flushed, as follows:
   - Sub-divide the flush area based on the concept of working from larger diameter mains to smaller ones, so that flow rates also proceed from larger to smaller.
   - “Center” the flush area extremities between the CWIs to promote the desired “source-to-extremity” flushing approach.
4. Create sequential flushing runs that meet the following requirements and preferences:
   - Service must be maintained to all customers at all times. Valves should not be closed in such a way that they completely isolate customer(s) from water supply.
   - Residual pressure should be maintained above 20 psi at all times throughout the flush area.[1]
   - Inspect the flush area to assist with optimal run development. Identify areas that may present challenges with disposal, traffic, topography, etc. and plan accordingly.
   - Each loop should end with a hydrant (or blowoff) and line valve that can be used to isolate downstream sources of supply. It is preferable to terminate runs at hydrants that have a large port as opposed to only two small ports.
   - All adjacent, non-dead-end mains should be isolated by valving, to ensure flow originates solely from a previously cleaned upstream pipe segment or CWI.
   - To improve efficiency, maximize the loop length subject to other constraints and criteria herein. Typical loop lengths are 500–2,000 feet.
   - Identify opportunities to stay mobilized at a given hydrant and simply adjust valving to clean multiple loops in sequence.
   - Downstream loops must have a nominal diameter that is either the same or smaller than the current loop.
   - Each loop must have a constant pipe diameter throughout its length to ensure a uniform flushing velocity. Avoid spanning lengths of unlined iron and “non-scale-forming” pipe within a single loop since scale buildup on unlined iron pipe can reduce its effective diameter.
   - Ensure adequate water disposal capability at the discharge hydrant. Runs can be shortened to reduce flush time and thus discharge volume in locations with

[1] Residual pressure is often lowest at the flowing hydrant. However, the minimum pressure criterion should be based on the line pressure prior to flow throttling, which may not be readily-measured if either the auxiliary or main stem valve is used to throttle. Alternate approaches include field-measurement of residual pressure at the nearest upstream hydrant and/or the hydrant of maximum elevation, as well as hydraulic modeling of residual pressure throughout the area.

disposal limitations. Alternately, runs can be lengthened to “skip over” localized areas of disposal challenges.

Hydraulic modeling should be used to: (a) identify routine flow directions; and (b) verify that acceptable residual pressures can be maintained at target flushing rates and with valves appropriately positioned. For instances where modeling indicates that target flow rates and/or pressures cannot be achieved, alternate flushing run arrangements should be explored and evaluated with modeling in an attempt to meet these targets.

Flushing runs should be documented to provide an easy-to-follow plan for field crews, and to ensure that the significant time needed to develop them is made to be a “one-time” planning activity. Flushing run documentation should include the following:

- System map that depicts flushing run sequence, individual run start and endpoints, asset locations, and disposal locations. System maps should be complete, up-to-date, and include all relevant assets, pipe sizes/types, and asset IDs for reference.
- Flushing Book narrative that contains all pertinent pipe details and valve operations information for each individual run.
    - Targeted main to be cleaned, including key characteristics (length, diameter, and material)
    - Hydrant ID to mobilize at
    - Discharge disposal location
    - Pre- and post-flush valve instructions
- Valve sequencing master tracking chart. This allows crew members to easily track valve positioning for each run of the area. In cases where completion of a given flush area requires multiple days or shifts, it enables crew to quickly identify valves that need to be opened at the end of each shift and the specific valves that need to be closed to resume flushing at the start of the next shift.

3) Preliminary Inspection

The City should conduct a field walk-through pre-inspection of each flush area prior to flushing. This reconnaissance is especially critical for the first time that UDF is performed in a given area to identify potential flushing run issues and revision needs. Typical pre-inspection activities and objectives are:

- Verify the location, accessibility, and operability of valves, hydrants, and blow-off assemblies. It should not be assumed that all assets listed on system maps exist or are located as depicted. The pre-inspection should ideally include all assets, not simply those targeted for use in the UDF plan. Crews should perform maintenance as needed and update GIS records and system maps based on field findings.
- Identify the preferred water disposal option for each flushing run. Crews should also clean sewer inlets/lines as needed to ensure they are free of leaves or other clogging debris.
- Identify and document site-specific challenges that will require special measures and/or impact feasibility of specific flushing runs. Examples include: traffic control needs, steep slopes, water disposal challenges, sensitive environments, map errors, assets that cannot

be found or are not operable, etc. Crews should identify potential solutions to address feasibility issues where they are encountered.

- Pre-inspection should be performed several weeks in advance of scheduled flushing to allow ample time for asset maintenance and loop refinement, if necessary.

4) Customer Notification

Customer notification prior to each scheduled flushing event is important because of the highly visible nature of flushing and the potential for undesirable and unanticipated impacts. The most effective means of customer notification are direct mailings and door tags, while other potential methods include notices in City/utility newsletters, water bills, and on the City's website. For sensitive customers such as hospitals and schools, direct phone contact should be provided. Notification should include a description of the reason for flushing, steps that customers can take to address discoloration at the tap, the anticipated timeframe that crews will be in their neighborhood, frequently-asked questions (FAQs) and answers, and a phone number that customers can call with questions or to report issues.

During flushing, the crew should post large signs on-site indicating their activities, and have on-hand copies of the mailed/posted notification materials to give to inquiring public or customers.

4 HEALTH, SAFETY, AND PUBLIC AWARENESS

See section above for customer notification procedures.

One of the most significant health and safety risks during UDF is vehicle traffic. The field service team should use trucks, temporary signs, and traffic cones to prevent automotive accidents and injury to staff. In addition, a flag crew may be needed to direct traffic in some locations. Trucks should be parked between oncoming traffic and the work area to provide a barrier. In addition, the following personal protective equipment (PPE) should be worn during maintenance activities:

- Hard hat
- High visibility safety vest
- Knee pads (as needed)
- Safety glasses
- Steel-toed boots
- Work gloves

5 PROCEDURE

Equipment Required (per flushing crew of 3):

- Flushing Book with run narratives and valve sequencing chart (with clear labels for pipe diameter, street names, parcel addresses, critical water users, and all hydrant/appurtenance identification numbers)

- Valve status master tracking reference
- Flush area system map
- Hydraulic Conversion Chart, showing relationship between flow rate and flushing velocity for various pipe diameters
- Traffic cones
- Temporary signs/arrow boards (warning lights, strobe lights, arrow boards, traffic maintenance signs)
- Valve keys
- Hydrant wrench
- Various lengths of 2.5” hose
- Various lengths of 4.5” hose with appropriate adapters to diffusers
- 1 Pollard LPD-250 diffuser
- 1 Hose Monster BigBoy diffuser with pitot-less nozzle
- Dechlor pucks for Pollard LPD-250 diffuser
- Dechlor mats for use with Hose Monster
- One (1) Hach colorimeter II for free & total chlorine
- One (1) Hach 2100q turbidimeter
- Data collection forms
- GPS unit (optional)
- Digital camera (optional)

Procedure:

1. Once a work order is received from the Water Distribution Superintendent, the Water Distribution Supervisor will identify the 3-person maintenance crew to perform the UDF work.
2. Prior to travel to the site, perform the necessary pre-planning activities. This includes reviewing system maps, GIS, and asset history to identify hydrants that are in busy intersections, neighborhood of sensitive customers, or may result in a potential hydraulic impact. Review Flushing Books and associated run narratives and valve status sheets. Notify the Water Distribution Superintendent if additional planning/coordination is needed.
3. Locate and access the fire hydrant identified as the starting point for the work order. Identify the unique identification number for the hydrant on the appropriate water system map and confirm the actual field location is a correct match. Identify the valving sequence for the first run and send two team members out to close or open valves according to the valve sequencing chart. Verify the following information in the field and document it on the appropriate UDF data collection form:
    - Hydrant ID number
    - Area-run number
    - Pipe material, or unlined iron versus “non-scale-forming”
    - Nominal pipe diameter and assumed effective pipe diameter
    - Run length, in feet
    - Target velocity, in fps. Unless site-specific determination has been made, a target flushing velocity of 4 to 5 fps should be applied.

- Target flowrate, in gpm, based on the Hydraulic Conversion Chart
- Map discrepancies (if applicable)

4. Determine the appropriate diffuser and hose connection setup based on the target flushing rate and site constraints. For flushing of mains that are 8-in. nominal diameter or smaller, the City should attempt to use the large hydrant port with matching-size fire hose and an adapter down to the Pollard directional diffuser. If the 5 fps target flushing velocity cannot be attained with this setup, the BigBoy Hose Monster diffuser should be used per the setup described below (assuming the non-directional nature of discharge can be tolerated). If the hydrant does not have a large port and/or if directional discharge is required, an alternate setup involving the use of the two smaller hydrant ports leading to parallel Pollard diffusers should be implemented. For mains larger than 8-in. diameter, the BigBoy Hose Monster diffuser should be used with the large hydrant port and matching hose to improve the likelihood of achieving the target flushing velocity. When flushing from blowoffs, if possible, the City should avoid using a diffuser altogether to maximize the attainable flow rate (since blowoffs are typically flow-limited).
5. Identify the intended location for water disposal and direct the hose and diffuser assembly accordingly. Stabilize the diffuser. Avoid crossing private property and areas of vehicle traffic with hose, or if needed, use a hose ramp.
6. If discharging to a storm drain catch basin or drainage ditch, remove leaves and other debris from the flow path to improve drainage. Lay down dechlor mats as necessary.
7. If discharging to a sanitary sewer, maintain an air gap to eliminate the risk of cross-connection.
8. When using the Pollard LPD diffuser, place dechlor tablets within diffuser cell. When using the Hose Monster, lay down a dechlor mat in front of the intended disposal location.
9. Plumb a sidestream sample tap assembly into a spare 2½" hydrant port, to be used for sample collection.
10. Control flow with the hydrant foot valve (also known as auxiliary valve). To prepare for the flush, slowly close the hydrant foot valve and fully open the main stem hydrant valve.
11. Crack the foot valve to produce a low flow rate (< 20 gpm) for 3 to 5 minutes to allow the hydrant barrel and lateral to clear. Once the barrel and lateral have cleared, collect a baseline sample for turbidity and chlorine residual.
12. Determine the target flow rate (in gpm) based on the effective pipe diameter and the target flushing velocity.
13. Slowly open the hydrant foot valve to achieve the target flow rate reading on the diffuser gauge. If the target cannot be attained and there is an opportunity to modify the hydrant setup to improve flow, discontinue the flush and change the hydrant setup to improve flow (as described in step 5 above). In some cases, the maximum attainable flow rate may be lower than target, in which case the flow should be maxed out.
14. Record the flow rate achieved and calculate/record the corresponding flushing velocity.

15. Determine the time (in seconds) per pipe volume (PV) turnover based on the flushing velocity achieved. The time per PV turnover should be calculated as the length of the run (in feet) divided by the actual flushing velocity (in FPS).
16. Start a timer and continue flushing until “flush-terminating” criteria have been met, as described below.
17. Collect water samples from the discharge (using the sidestream sample tap assembly) and analyze immediately onsite, when possible, to assess flushing effectiveness and water quality restoration. Basic parameters to be monitored for all runs include visual clarity, turbidity, and chlorine residual. Regarding timing of sample collection, once high-rate flushing has begun, turbidity samples should be collected to correspond with discrete pipe volume (PV) turnovers, starting at time zero (zero PV) and at each PV turnover, i.e., at one PV, two PV, and so on, until the flush-terminating criteria provided below have been met. In cases where each PV turnover time is less than two minutes, it is recommended to sample for turbidity every two minutes. Prior to terminating the flush, a final chlorine residual and turbidity measurement should be obtained to confirm that background chlorine residual conditions have been restored.
18. Collect samples for any other analyses that are desired, as well as photographs. Record visual observations of discharge water.
19. Data collection and management are important to assess flushing effectiveness. A new data collection form should be used for each run, and all pertinent hydraulic data and water quality results should be documented on the form.
20. Water quality results and disposal constraints should be used to determine when to terminate a flush. In the absence of disposal constraints, flushing should be continued until all of the following “flush-terminating criteria” have been met:
    - At least two PV have been turned over.
    - Discharge chlorine residual is similar to that of the CWI.
    - Discharge turbidity is low and stable for at least 2 consecutive measurements. For unlined iron pipe, an appropriate end-of-flush turbidity criterion is less than 10 ntu. For “non-scale-forming” pipe, an appropriate end-of-flush turbidity is less than 5 ntu.
    - The water is visually clear.
21. As flushing proceeds, check downstream flows to ensure that water is being drained properly and that there are no major water backups. If water accumulation is an issue, slowly reduce or shut off flow. Use flow start/stop cycles as needed to dissipate discharge and complete flushing.
22. Measure the chlorine residual of the discharge prior to its disposal to ensure that chlorine is fully neutralized.
23. Prior to discontinuing the flush, conduct any sampling desired, including chlorine residual. Note the elapsed flush time at the end of flush.
24. To terminate the flush: (a) slowly close the hydrant foot valve; (b) close the main stem hydrant valve; and (c) slowly open the hydrant foot valve to fully open.

25. Complete the data collection form. Document any issues confronted and follow-up action needed.
26. Disconnect and remove equipment. Gather equipment, signs, and field notes.
27. Restore the site to its original condition.
28. Conduct the designated “post-flush” valve operations.
29. At the end of each shift, re-open all line isolation valves in the area. Refer to the valve status master tracking reference for the area.

6 DATA RECORDING AND MANAGEMENT

Following completion of a UDF area work order, enter all necessary information into the flushing GIS database, including the area/runs flushed, date of flushing, water volume used, and personnel completing the work order. Enter the baseline and end-of-flush water quality results in the flushing GIS database. All notes pertaining to each run should be stored in the Flushing Book to be readily available for future staff and efforts.

The Water Distribution Superintendent should be notified of any hydrant found to be inoperable, whether expected flow rates were achievable, and any customer complaints or unexpected water quality upsets. The Water Distribution Superintendent shall assign work orders for any follow-up items and coordinate updates to the asset management plan.

7 REFERENCES

None.