TECHNICAL MEMORANDUM

Primary and Contributing Causes of the Loss of Primary Function of the Jones Ferry Road Water Treatment Plant

PREPARED FOR:	Ed Kerwin, Executive Director Orange Water and Sewer Authority
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DATE:	February 10, 2017

Executive Summary

At 3:22 PM on February 2, 2017, Orange Water and Sewer Authority (OWASA) management decided to shut down the Jones Ferry Road Water Treatment Plant (WTP) due to an excessive amount of fluoride present upstream of the clearwell. Following the WTP shut down, the fluoridated water was removed and the WTP was returned to service on February 5, 2017, with fluoride addition suspended until further notice.

On February 6, OWASA requested that CH2M HILL North Carolina, Inc (CH2M) review the events of February 2, conduct a root cause analysis (RCA) of the WTP shut down and provide a report by Friday, February 10, 2017.

The RCA was developed using data and input collected from OWASA staff interviews, systems data review, and on-site physical system inspection and testing. The RCA identified both primary and secondary causes: the primary cause initiated the event, and the secondary cause extended the duration of the event that ultimately led to the decision to shut down the WTP. The causal factors are as follows:

- **Primary Cause:** An unintentional WTP operator key stroke at 11:43 AM sent a command to the fluoride feed pump to increase its chemical feed rate to 80% of its total design speed (normal operating range is 8-12% of design speed). A subsequent command was sent to the pump approximately 12 seconds after the initial key stroke to readjust the pumping rate back down to the normal range, but the pump did not respond to the command. The pump appears to have operated at a rate significantly greater than the subsequent commanded speed for approximately 3.25 hours, resulting in a fluoride overfeed condition.
- **Secondary Cause:** At 12:54 PM, the Lead Operator observed an abnormally high estimated fluoride dose, but did not take corrective action**,** leading to the issue not being resolved until after 2:40 PM.

In addition to the primary and secondary causes, a number of other contributing factors to the fluoride overfeed were also identified. This RCA was developed using information collected from the staff interviews, systems data and on-site field-testing completed over the course of four days.

Background

OWASA feeds hydrofluorosilicic acid to the WTP's filtered water prior to entering the clearwell to maintain a fluoride ion level (fluoride) of 0.7 milligrams per liter (mg/L). On February 2, 2017, OWASA staff at the Jones Ferry Road Water Treatment Plant (WTP) observed a fluoride level of 5.90 mg/L (parts per million or ppm) upstream of the WTP's clearwell. The level exceeded the state and federal primary drinking water standards of 4.0 mg/L, thereby leading to the decision to take the plant offline. Production was ceased and ultimately the clearwell was drained to remove excess fluoride. Investigations by OWASA staff indicated a significantly higher draw down of the fluoride solution day tank, leading them to conclude that fluoride had indeed been added to the system at a higher rate than desired. An analysis by OWASA's state certified laboratory showed distribution system fluoride levels of 0.68 mg/L, within desired values. See Appendix A for sampling location schematic.

On February 2, at least five outside contractors were on site, with two of them requiring direct interaction with the operator to adjust plant processes and/or controls. In an effort to assist contractors in their efforts, the operator was pulled away from his/her primary duties, including the monitoring of SCADA and conducting operational rounds (i.e. direct physical inspection) every 2 hours as required by standard operating procedures (SOPs).

Key events related to the occurrence of elevated fluoride levels are summarized below and will be discussed in further detail within this report; refer to Appendix B for a more detailed timeline:

- 10:42 AM - Raw water flow testing begins with varying raw water flows to WTP
- 11:34 AM - Fluoride system pump adjustments made by Supervisor in response to varying flow rate, fluoride day tank drawdown rate significantly increases
- 2:40 PM - Potential fluoride overfeed identified by Lead Operator
- 3:10 PM - Laboratory sampling and test results from OWASA's certified laboratory confirm elevated fluoride levels
- 3:22 PM - WTP shut down

After the incident, OWASA directed their staff to document, to the best of their recollection, the events of the day and engaged CH2M to conduct a further analysis of the occurrence. CH2M was directed to conduct a root cause analysis (RCA) and provide a report by Friday, February 10, 2017. CH2M staff spent February 7 and 8, 2017, on-site at the WTP interviewing staff, observing equipment condition and operation, and recreating events of February 2 in an effort to determine the cause(s) of the high fluoride values.

Problem Statement

On February 2, 2017, the Jones Ferry Road WTP was shut down by OWASA staff with complete loss of the facility's intended function to deliver potable water to OWASA's service area, until February 5, 2017.

Methodology

The formal methods used for this RCA were the "Five Whys," Casual Factor Charting, and Failure Modes and Effects Analysis (FMEA). The "Five Whys" is a basic methodology that uses five levels of questions to provide an indication of the root cause. Each fact or statement is followed up with a "why?" question and a minimum of five questions must be asked before a cause can be eliminated or left on the table for further consideration. Refer to Appendix C for a summary of the "Five Whys."

In addition to the Five Whys approach, CH2M staff constructed an approximate event time line (in Appendix B) based on SCADA logs; operator's written and verbal accounts; and laboratory, on-line and operator analysis data (i.e. pH readings, fluoride values, etc.). An FMEA was used to evaluate the primary modes of failure of the fluoride pump system, and specifically to help determine which modes of failure would cause the pump to over-supply fluoride and the level of possible detectability.

The basic components of a formal RCA include:

1. Define problem
2. Initiate investigation
3. Collect data
4. Analyze data
5. Identify root cause
6. Develop recommendations
7. Implement recommendations
8. Follow up, modify and improve

Of the above steps, the RCA summarized herein consists of steps 1 through 5, with recommendations to complete the remaining steps following OWASA's review of this report.

The review of compiled information led to the identification of several suspected and/or root causes. To confirm or eliminate suspected causes, CH2M observed the operation of the fluoride system (using water as a replacement for the fluoride solution). This effort, discussed further in the report, provided additional information to further refine the potential root causes of the excess fluoride levels.

OWASA requested assistance from their on-call third party Supervisory Control and Data Acquisition (SCADA) and instrumentation contractor (CITI) for a review of SCADA operation. CH2M observed CITI testing control inputs registering correctly to the programmable logic controller (PLC), conducting "loop tests" to verify the equipment receives proper control signals and to retrieve data logged on the system to assist in recreating the event timeline. CH2M staff interviewed CITI staff as they were working on site during the events in question to determine if they had any knowledge of the problem (i.e. observed or otherwise noticed unusual circumstances) or if any of their actions caused and/or contributed to the event.

CH2M conducted a FMEA of the fluoride feed pumps to determine if any factors within the pumping system could cause or exacerbate the over-addition of fluoride when in operation. Appendix D contains the results of this analysis.

Upon completing the above analysis, CH2M determined the primary and secondary causal factors and associated contributing factors to the fluoride levels that led to the WTP shut down.

Primary and Secondary Causes

Upon completing the initial RCA review, two primary causes of the high fluoride levels surfaced.

- **Primary Cause:** An unintentional WTP operator key stroke at 11:43 AM sent a command to the fluoride feed pump to increase its rate to 80% of its total design speed (typical operating range is 8-12%). Even though a subsequent command was sent to the pump approximately 12 seconds after the initial key stroke to readjust the pumping rate back down to the normal range, the pump continued to operate at a rate significantly greater than the subsequent commanded speed for an extended duration resulting in a fluoride overfeed condition.
- **Secondary Cause:** At 12:54 PM, the Lead Operator observed an abnormally high estimated fluoride dose, but did not take corrective action**,** leading to the issue not being resolved until after 2:40 PM.

Discussion

In order to confirm the initial review and analysis of the sequence of events from February 2, 2017 through field-testing and simulations, CH2M staff attempted to re-create and closely monitor the sequences during the afternoon of February 7, 2017. In reviewing the events and situation of the day, CH2M confirmed that excess fluoride was added to the plant between 11:34 AM and 2:40 PM on February 2. Coinciding with this timeframe, OWASA staff reported mis-entering the fluoride dose setpoint in the SCADA system at 8% to 80% and then immediately correcting (SCADA log shows a passage of 12 seconds) it to 4.0%. On its own, this corrected mis-entry would not be expected to cause an excess fluoride dose.

The Lead Operator on site was without assistance from 8 AM to 10:30 AM while assisting outside contractors in completing assigned tasks. Specifically, the operator was on their own when contractors began work simultaneously, thereby diverting the operator's attention from the WTP processes. Due to the activities of the day, operator attention to plant processes was insufficient. In addition, ancillary support personnel, who after the fact reporting hearing unusual noise from equipment, did not know this should be reported to operations staff.

During the aforementioned February 7, 2017 event simulation, using OWASA staff's verbal accounts, SCADA logs and simulated operating conditions, CH2M observed an abnormal operation of the fluoride feed pump. Specifically, fluoride feed pump #2 (right side pump as facing it in fluoride feed room) was observed to run at an approximate 30 revolutions per minute (RPM) condition (approx. 10 gal/hr) despite the SCADA command indicating the pump should operate at an approximate 4 RPM setpoint (<1 gal/hr). CH2M replicated this condition on multiple test runs. Additionally, CH2M observed that, upon changing SCADA setpoints, as documented from the logs using actual values from February 2 (i.e. 11% to 8.0% to 80% to 4%), the pump would register the new flow setpoint on its output screen and the pump speed would increase instead of decrease and maintain the new undesired increased speed. Ultimately, this resulted in a fluoride overfeed at approximately 10 times the expected feed rate. As part of the investigation, fluoride feed pump #1 (left side pump as facing it in fluoride feed room) was tested in the same manner and exhibited a speed increase as well, albeit pump #1 would return to the set value within 10-15 seconds without maintaining the undesired speed.

In discussions with the chemical pump manufacturer's authorized repair center representative, the observed condition of pumps ramping up to a higher speed after receiving a new lower flow set point (e.g. 4% after being at 80%) "…is not a normal operation." The representative's theory is that this condition "would likely be caused by a control board (internal to the pump) problem." Since pump #2 (the in-service pump), and pump #1, (the standby pump) both exhibited tendencies to ramp to higher speeds after receiving the lower flow set point, this may indicate potential problems with continued use of pump #1 as well.

The mis-key and subsequent equipment malfunction (i.e. pump overspeed condition) on their own directly caused the fluoride overdose. However, the length of time the pump remained in an overspeed condition is the result of distracted staff. Normally the WTP is staffed with two operators per shift, Monday through Friday for 24 hours per day. Additionally, Monday through Friday, typically daytime hours, the Supervisor is also onsite. On February 2, the Lead Operator was the only staff member engaged in plant operations from approximately 8:00-10:30 AM due to training and a dental appointment by the Back-up Operator. On the day in question, at least five outside contractors were on site, with two of them requiring direct interaction with the operator to adjust plant processes and/or controls. In an effort to assist contractors in their efforts, the operator was pulled away from his/her primary duties, including the monitoring of SCADA and conducting operational rounds (i.e. direct physical inspection) every 2 hours as required by standard operating procedures (SOPs). Contributing to

this situation, ancillary staff present in the plant recounted hearing pumps running at high speed yet did not report the observations, or understand the need to report this as an abnormal condition.

Contributing Conditions

Several contributing conditions prolonged the chemical overfeed situation or may have allowed for prevention of the event in the first place. They are broken down into two categories: (1) Equipment and Controls and (2) Situational Factors Related to Operations and Maintenance.

Equipment and Controls

Several factors related to SCADA set up, equipment and monitoring aspects did not create the fluoride overfeed condition, rather could have mitigated the duration of the overfeed.

Rate of Change Alarm – The SCADA system is programmed to alert the operator if tank levels fall faster than expected conditions; however, this feature was not set up with an alarm value and did not function as it potentially could. This is indicated as being functional within the Fluoride SOP.

Malfunctioning Analog Output Card – The programmable logic controller (PLC) output card sending signals to the fluoride pump in question was observed sending a 7 milli Amp (mA) signal at the off or 0% command from SCADA rather than the expected 4 mA. While field testing did not indicate any difference in the pump malfunction once the card was replaced, it remains a potential source or indication of the pump control issue (i.e. a short in pump or card causes damage to opposite unit).

Situational Factors Related to Operations and Maintenance

Historically, the WTP has operated in full compliance with required drinking water standards and meets the state rules for operational requirements. However, on February 2, a number of situational factors occurred in an unusual sequence, and in retrospect should have been avoided.

Operator(s) Distraction(s) – Several situations led to the operator being distracted during the day on February 2, 2017:

1. While assisting the flow meter contractor by manipulating raw water flow rates from a remote location (i.e. outside of control room) he/she was unaware of the changes inside the plant. Several low flow and low-level alarms were indicated and acknowledged by the Supervisor who arrived on site during the testing.

2. In response to the varying flow rates, the Supervisor made adjustments to the fluoride feed pumps to reduce setpoints from 11% to 8% and eventually 4%. The Supervisor initially mis-entered an 80% setpoint (approximately 10 gal/hr) and upon realizing the mistake, immediately re-entered a 4% setpoint (approximately 1 gal/hr) and then a 4.0%. At some point, the Supervisor instructed the Lead Operator to continue working with the flow meter contractor, as they were going to oversee the WTP. The Supervisor also alerted the Lead Operator to the lack of flow in the plant. It is unclear what, if any, specific information was exchanged between the Supervisor and the Lead Operator about how the WTP was operating during the flow testing.

3. Additionally, some of the aforementioned contractor work required attention in other areas of the facility (Solids Press Room) by operations personnel that distracted staff from WTP process monitoring duties.

4. During the normally scheduled “12:00 PM rounds”, which were delayed until 12:25 PM by the flow testing work, the Lead Operator noticed a higher than normal calculated fluoride dose on the Datawell PDA system. The Lead Operator reported that he/she wanted to recheck the

calculations from SCADA; however, he/she became otherwise engaged in additional discussions about the flow testing and stated he/she forgot to get back to reviewing the data.

Work Scheduling/Communication – On February 2, 2017, five outside contractors arrived to work at the plant, one of which required significant operator assistance and manipulation of raw water sources and flow rates. Compounding the situation:

1. Lack of notice for work – On the day in question, operations staff were informed that a new raw water flow meter was scheduled for installation; however, the testing of the meter requiring raw water flow rate manipulation and was scheduled for the following week (February 6). Instead, without prior knowledge of the operations staff, the outside contractor wanted to manipulate flows to test functionality of meter without a defined testing plan.

2. Lack of Staff on site – Due to training and a subsequent dental appointment, one operator was excused from plant operational duties throughout most of the morning, from approximately 7:00 AM to 11:30 AM. This left one operator to run the plant and work with at least two of the contractors and more importantly focus significant effort on flow changes for the flow meter contractor.

3. Normalcy of Additional Work Assignments – It is normal for management to expect full engagement of staff during the work day; however, given the reduction of operators on the site on this day, having additional duties contributed to a lack of concentrated focus when the event occurred.

Contractor Interference with Normal Operations – on February 2, 2017, in conducting their work, contractors interfered with the normal process of the facility. While this effort would normally be routine for the contractor, under the facility conditions it was not routine work for the operators.

1. As indicated earlier, to accommodate the flow meter contractor, the operator had to leave the control room unattended and manipulate flows, which is an abnormal situation requiring additional “eyes on” the process to ensure proper treatment is maintained at all times.

2. The SCADA contractor was conducting instrumentation maintenance and calibration. This is a normal work effort and is necessary for accurate data and process measurement/control. However, in conducting this work, it is routine to set the SCADA in a “hold” condition. In the “hold” condition, while working on a set of probes, and conducting calibration and other tests, the SCADA system displays the last value read from the probe. This prevents erroneous data from being recorded while servicing, cleaning or calibration is being conducted. For example, a pH probe that normally reads 7.5 standard units (S.U.) will be held at 7.5 S.U. while the contractor calibrates using a 4.01 S.U., 7.00 S.U. and 10.01 S.U. buffer solutions. This prevents chemical feed pumps that are in automatic control from needlessly ramping up or down to adjust for incorrect data. This also would give the operator a false sense of security or hide potential problems when reviewing plant SCADA data.

In this case, a low pH value was noted after the values were restored, one potential sign of an acid overfeed (fluoride is dosed as hydrofluorosilicic acid) or caustic soda under feed and operators began investigating an under dose (leak) on the caustic soda system. During this investigation, the Backup Operator found the instrumentation contractor (CITI) calibrating a pH probe which s/he attributed to seeing a low pH value and concluded his/her investigation. This situation distracted operations staff from looking for other causes (i.e. fluoride overfeed) as the cause of pH depression.

Standard Operating Procedures (SOPs) – several issues related to SOPs were indicated.

1. Not followed – In at least two instances, SOPs were not strictly followed during this situation. Specifically, rounds are required every two hours and additional staffing is required while manually operating (i.e. raw water flows in this case) the facility. While other factors may have led to SOPs being ignored or bypassed on the day in question, it does go back to a training issue for management to reinforce the importance of SOPs to be followed at all times. This requires frequent review, update and training on the SOPs to reinforce the need to follow at all times in all conditions.

2. Out of Date – Most SOPs provided for this review were at least four years old and included inaccurate or out of date discussions on expected operational practices. Additionally, the last recorded training on the SOPs coincided with the SOP initial roll out.

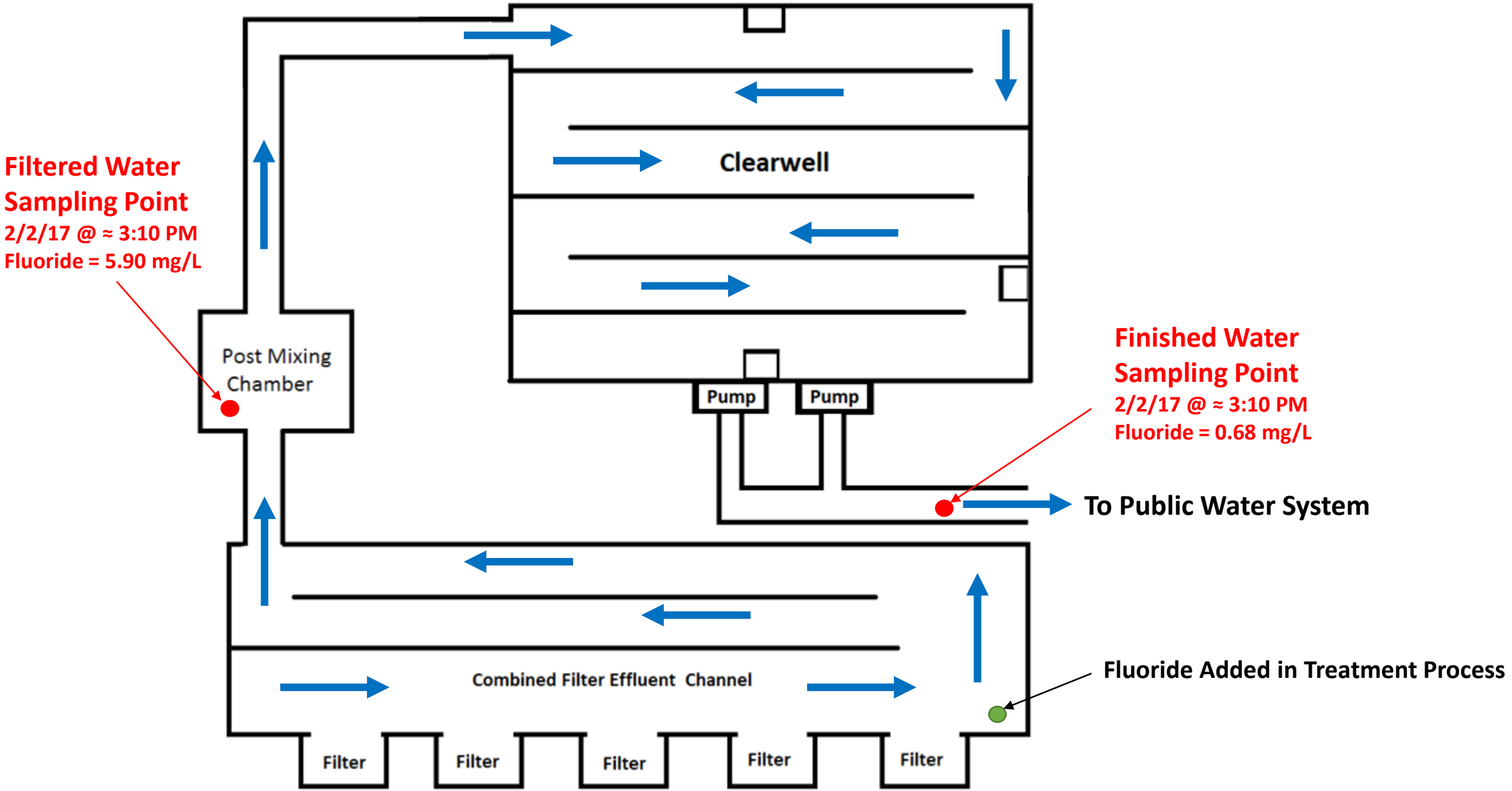
3. Incorrect information – Some SOPs (including the Fluoride SOP) refer to conditions that do not exist or are not applicable to the equipment installed.

Follow-On Action Item

Review the RCA, define, and implement corrective actions as part of a continuous improvement process.

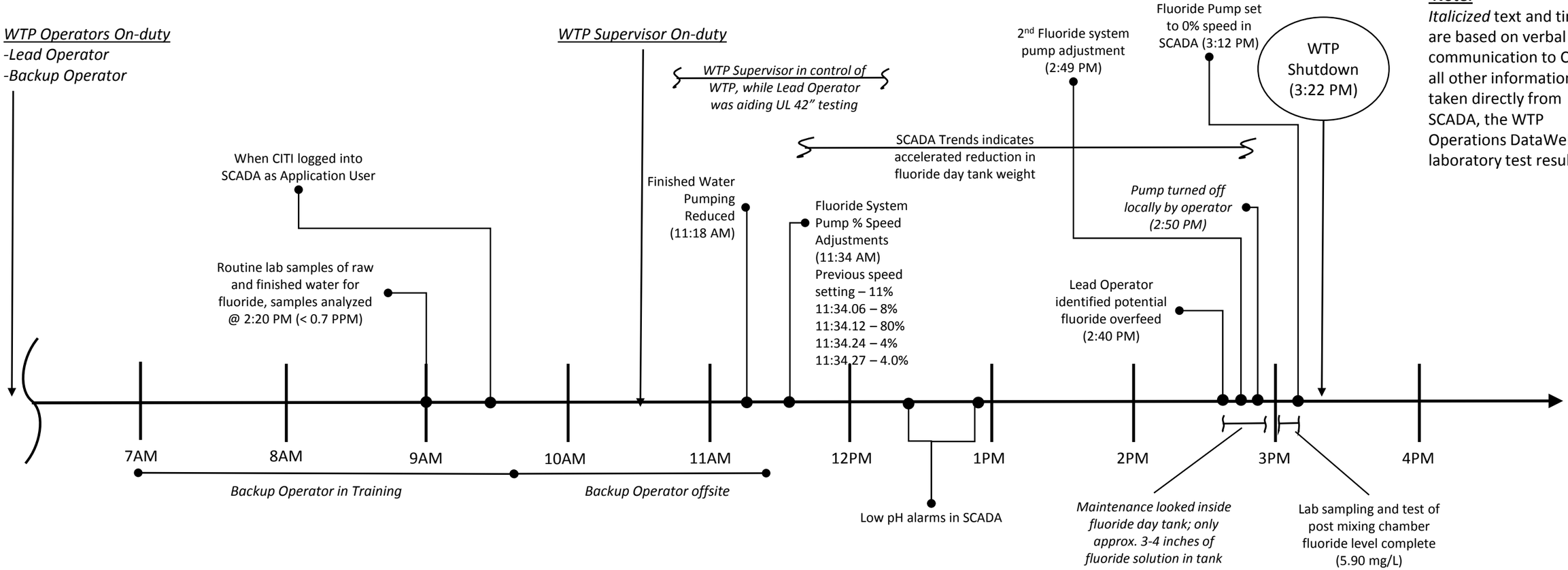
Appendix A

Sampling Location Schematic


Filtered Water
Sampling Point
2/2/17 @ ≈ 3:10 PM
Fluoride = 5.90 mg/L
Clearwell
Post Mixing
Chamber
Pump
Pump
Finished Water
Sampling Point
2/2/17 @ ≈ 3:10 PM
Fluoride = 0.68 mg/L
To Public Water System
Combined Filter Effluent Channel
Fluoride Added in Treatment Process
Filter
Filter
Filter
Filter
Filter

Appendix B
Event Timeline

Jones Ferry Road WTP Shutdown – February 2, 2017 Timeline



Note:
Italicized text and times are based on verbal communication to CH2M; all other information is taken directly from SCADA, the WTP Operations DataWell and laboratory test results.

Lead Operator Rounds

- 8:25AM – 8:56AM: (8 AM Round) *Fluoride concentration reading in Data Well - 0.9 mg/L
- 9:47AM – 9:52AM: (10 AM Round) *Fluoride concentration reading in Data Well - 0.8 mg/L
- 12:25PM – 1:15PM: (12 PM Round) *Operator records calculated fluoride dosage = 4.8 mg/L
- 2:34PM – 2:59PM: (2 PM Round) *Operator records calculated fluoride dosage = 8.1 mg/L

University Lake 42" Raw Water Main testing

- 10:42AM – 11:18AM: UL 42" Testing (Run #1)
- 12:34AM: UL 42" Testing (Run #2)

Contractors Onsite

- CITI
- McKim & Creed
- Advanced Energy

- 8:50AM – 1:00PM
- 10:30AM – 1:00PM
- 10:30AM – 3:00PM

Note:
2 other contractors onsite during 2/2/2017:
YES Solar and OWASA's security system contractor.

Appendix C
“5 Why’s”

Root Cause Analysis

"5 Whys"

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Problem Statement: On February 2, 2017 the Jones Ferry Road WTP was shut down by OWASA staff and no potable water could be delivered from the WTP until February 5th.

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1. Why did OWASA decide to shut down the WTP?

A fluoride level of 5.90 mg/L was detected in the filtered water at location upstream of the clearwell.

2. Why was there such a high level of fluoride in the post mixing chamber?

The fluoride day tank was almost completely empty at 3:00PM, indicating an overfeed of fluoride.

3. Why was the day tank nearly empty at 3:00PM?

The fluoride feed system had malfunctioned sending fluoride to the WTP's post mixing chamber at a volume approximately 9 times greater than normal operations (90 lbs/hr).

4. Why did the fluoride feed system malfunction?

The fluoride feed pump was pumping outside its typical operating range; feeding fluoride at a rate 9 times greater than the normal feed rate for approximately 3.25 hours.

5. Why was the fluoride feed pump pumping outside its normal operating range?

An unintentional key stroke sent a command to the pump to increase its rate to 80% of its total design speed (typical operating range 8-12%) and even though a corrective command was sent to the pump less than 12 seconds after to readjust the pumping rate back down to the normal range, the pump continued to pump at a rate of approximately 80%.

Appendix D

Failure Modes and Effects Analysis

	By **CH2M**											
	Date **2/9/2017**			**FMEA**								
	Plant **Jones Ferry Road WTP**		Equip No.	**Fluoride Feed Pump No. 2**					**Location: Fluoride Room**			
	Mfgr **Blue-White**		Description	**Flex-Pro Peristaltic Metering Pumps - Series A3V - Series A3V14-SNH**					**Function: To deliver fluoride to the filter effluent flume at a 0.7 mg/L dose over a 24-hour period at a rated plant capacity of 20 MGD.**			
	Unit		**Failure**							**Pre-Failure Warning**		**Maint**
System	**Component**	**Notes**	**Mode**	**Effect**	**Criticality**	**Cause**	**Likelihood**	**Detectability**	**Risk Priority Number**	**Characteristics**	**Evident / Hidden**	**Option**
Chemical Metering Pump (Peristaltic)	Tube		Tube bursts	Product not pumped/reduced capacity. Spill in in feed room.	5	Age related wear	4	5	100	Track estimated useful life by pump tube timer (hours)	Evident	PM
					5	Chemical degradation of hose	3	5	75	Track estimated useful life by pump tube timer (hours)	Evident	PM
					5	Tubing misalignment	2	5	50	Track estimated useful life by pump tube timer (hours)	Evident	PM
					5	Accidental damage or puncture	3	5	75	Track estimated useful life by pump tube timer (hours)	Evident	PM
			Discharge Tube loosens/disconnects from pump discharge	Product not pumped/reduced capacity. Spill in in feed room.	5	Tube nut fails	2	5	50	Leaking around the tube connection	Evident	CM
					5	Age related wear	2	5	50	Leaking around the tube connection	Evident	CM
					5	Stainless clamp breaks	2	5	50	Leaking around the tube connection	Evident	CM
					5	Incorrect size tube	2	5	50	Check tube size prior to installation	Evident	DES
	Suction Header		Suction strainer clogged	Product not pumped/reduced capacity.	1	Debris/particles build up on strainer	2	5	10	None	Evident	PM
			Suction Tube loosens/disconnects from pump discharge	Air intrusion into piping reducing quantity of fluoride delivered to system. Spill in feed room	5	Loose connection	3	5	75	None	Evident	PM
	Rotor		Rotor seizes	Product not pumped/reduced capacity.	1	Misalignment	1	5	5	Loss of efficiency, high amp draw	Evident	PM
					1	Age related wear	2	5	10	Loss of efficiency, high amp draw	Evident	PM
			Rotor Shoes wear	Product not pumped/reduced capacity/or leak-by.	5	Age related wear	3	5	75	Track estimated useful life by pump tube timer (hours)	Hidden	PM
	Motor	Motor has sealed bearings	Shaft breaks	Product not pumped	1	Shaft fatigue	2	5	10	Vibration/Noise	Evident	PM
					1	Defect in shaft	2	5	10	Vibration/Noise	Evident	PM
					1	Foreign object	1	5	5	Vibration/Noise	Evident	PM
			Bearings seize	Product not pumped	1	Age related wear	3	5	15	Vibration/Noise	Evident	PM
			Replaced with different RPM motor and settings not adjusted in pump (pump will not run according to manual)	Product not pumped	1	Lack of reprograming controls	2	5	10	None	Evident	CM
			Windings Open	Product not pumped	1	Age related wear	2	5	10	None	Hidden	CM
	Motor Controller (VFD)		Defective signal transmission	Product is overfed	5	Internal component failure	2	1	10	None	Hidden	CM
			Defective conversion of input speed command to motor output (Internal to pump controller)		5	Internal component failure	1	1	5	None	Hidden	CM
			Defective signal transmission	Product is underfed	1	Internal component failure	2	1	2	None	Hidden	CM
			Defective conversion of input speed command to motor output (Internal to pump controller)		1	Internal component failure	1	1	1	None	Hidden	CM
			Loss of signal or interpretation	Product not pumped	1	Internal component failure	3	5	15	None	Hidden	CM
			Loss of power	Product not pumped	1	Internal component failure	3	5	15	None	Evident	CM
			Signal not present	Product not pumped	1	Internal component failure	3	5	15	None	Evident	CM
	Pump Head		Pump Head cover bearing seizes	Product not pumped	1	Lack of lubrication	3	5	15	None	Evident	PM
					1	Age related wear	3	5	15	None	Evident	PM
			Pump Head Cover cracks	Product is not delivered at intended rate, Product spill.	5	Misalignment	3	5	75	None	Evident	PM
					5	Loose screws	3	2	30	None	Evident	PM
	Flow Verification Sensor system	This is an available option from the manufacturer with an additional sensor installation									N/A	N/A
	Tube Failure Detection System	Does not provide output alarm but will stop pump operation in remote mode	Tube Detection Sensor fails	Pump continues to operate with broken tube; Spill in feed room	5	Chemical degradation	2	5	50	None	Hidden	PM
					5	Age related wear	2	5	50	None	Hidden	PM
Injection Device	Injection device		Injection points plugged	Pump pressure increases and injection of adequate chemical is not possible.	3	Chemistry of the water is reacting with the chemical and causing it to clog on the injection device	3	3	27	The pump pressure slowly increases as the tip becomes plugged	Hidden	PM