



DBP Reduction and SCADA Improvements at the SGWASA Water Treatment Plant

see page 22 for high HAA5 levels statement; page 32 for many "non functional statements and p 35 for summary and comments on "80 years old" and "lack of master plan"



Final Report
Hazen No. 31313-000
December 8, 2017



December 8, 2017

To: South Granville Water and Sewer Authority
Lindsay Mize, Executive Director
Fred Dancy, Utilities Director

From: David Briley, PE
Gary Iversen, PE
Alana Loughlin, PE
Dan Edwards, PE

DBP Reduction and SCADA Improvements at the SGWASA Water Treatment Plant

FINAL

Table of Contents

- 1. Background..... 3
- 1.1 Introduction 3
- 1.2 Stage 2 Disinfectants/Disinfection Byproducts Rule 3
- 1.3 Recent SGWASA Actions to Enhance DBP Control 7
- 1.4 Study Objectives 8
- 2. Bench-Scale Testing..... 8
- 2.1 Process Testing..... 8
 - 2.1.1 Jar Test Calibration 10
 - 2.1.2 Coagulant Comparison 12
 - 2.1.2.1 Polymer Testing 14
 - 2.1.2.2 Pre-Oxidant Testing 16
 - 2.1.2.3 Potassium Permanganate and Powdered Activated Carbon (PAC) Testing..... 18
 - 2.1.3 DBP Testing..... 20

Job no

- 2.1.4 Evaluation of SGWASA WTP DBP Formation 21
- 2.1.5 Bench Testing Summary..... 24
- 3. Chemical System Evaluation 26
 - 3.1 Existing Chemical Facilities..... 26
 - 3.2 Evaluation of Chemical Systems 27
 - 3.2.1 Potassium Permanganate 28
 - 3.2.2 Powdered Activated Carbon 28
 - 3.2.3 Ferric Sulfate..... 29
 - 3.2.4 Coagulant-Aid Polymer 29
 - 3.2.5 Sodium Hydroxide..... 29
 - 3.2.6 Sodium Hypochlorite..... 30
 - 3.2.7 Anhydrous Ammonia..... 31
- 4. SCADA System Evaluation..... 32
 - 4.1 Existing Instrumentation and Controls..... 32
 - 4.2 Butner WWTP Control System..... 32
 - 4.3 SGWASA WTP Control System Recommendations..... 33
 - 4.3.1 Hardware and Software Recommendations 33
 - 4.3.2 Control Strategies 34
 - 4.3.3 Field Instruments 34
- 5. Summary and Recommendations..... 35
 - 5.1 Summary..... 35
 - 5.2 Recommendations for DBP Compliance..... 35
 - 5.3 Estimated Implementation Costs..... 37

1. Background

1.1 Introduction

The South Granville Water and Sewer Authority (SGWASA) has owned and operated the SGWASA Water Treatment Plant (WTP) since 2006. The plant, originally constructed in the 1940's serves Butner, Creedmoor, Stem, and unincorporated areas of southern Granville County.

The SGWASA WTP is a conventional treatment plant with a permitted capacity of 7.5 mgd. The current average day demand is 3 mgd, and max demands are approximately 4.4 mgd. The WTP draws raw water from a terminal reservoir supplied from Lake Holt. The plant is provided with rapid mix, flocculators, sedimentation basins with inclined plates, dual-media filters, a chlorine contact chamber, a 2-million-gallon clearwell, and finished water pump station. The plant typically feeds the following chemicals:

- Potassium permanganate (KMnO₄) for pre-oxidation
- Powdered activated carbon (PAC) to remove TOC and taste and odor compounds
- Ferric sulfate (recently converted from aluminum sulfate) for coagulation
- Sodium hydroxide (caustic) for pH adjustment
- Sodium hypochlorite for primary disinfection
- Anhydrous ammonia for monochloramine formation
- Hydrofluosilicic acid for fluoride addition
- Phosphate corrosion inhibitor.

A process flow schematic of the plant is shown in Figure 1-1. Raw water entering the plant has a relatively high TOC of 5 to 15 mg/L, which has contributed to the production of disinfection byproducts (DBPs) within the treatment process.

1.2 Stage 2 Disinfectants/Disinfection Byproducts Rule

The maximum contaminant levels (MCL) for total trihalomethanes (TTHM) is 80 ppb and 60 ppb for the sum of five haloacetic acids (HAA5). Stage 2 DBPR established that compliance is on a Locational Running Annual Average (LRAA) basis. The LRAA approach uses the annual average at each sampling location to determine compliance, addressing concerns of spatial variation in DBP exposure throughout the distribution system. The number of system monitoring locations depends on the size of the population served by the given water system. As of October 1, 2017, SGWASA monitors DBP concentrations at six (6) locations in the distribution system.

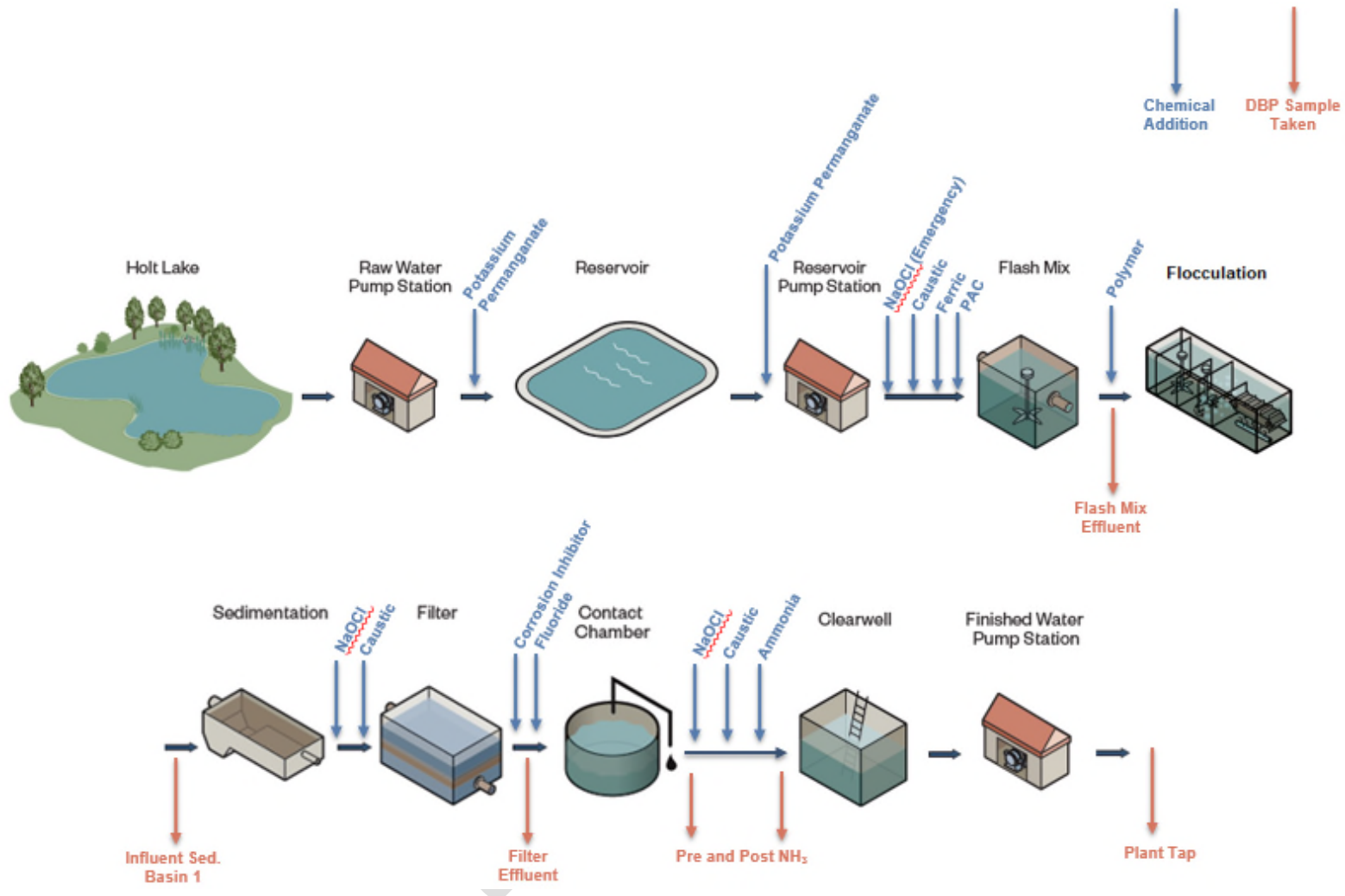


FIGURE 1-1: SGWASA WTP Process Schematic

Job no

The Stage 2 DBPR requires systems that exceed “operational evaluation levels” to evaluate system operational practices and identify opportunities to reduce DBP concentrations in the distribution system. The operational evaluation levels for each monitoring location are determined by the following equation:

Operational Evaluation Level = $(Q1 + Q2 + 2Q3) / 4$, where:

Q1 = quarter before previous quarter measurement

Q2 = previous quarter measurement

Q3 = current quarter measurement

If the operation evaluation level exceeds the MCL value (80 TTHM, 60 HAA5), then the system must conduct an operational evaluation. The operational evaluation involves an examination of system treatment and distribution operational practices, including changes in sources or source water quality, storage tank operations, and excess storage capacity, which may contribute to high TTHM and HAA5 formation. Systems must also identify what steps could be considered to minimize exceeding operational evaluation levels in the future.

The SGWASA system has been challenged with compliance with the Stage 2 Disinfectants/Disinfection Byproducts Rule (Stage 2 DBPR), particularly since the end of 2016. Beginning in November 2016, HAA levels have exceeded the MCL as presented in Figure 1-2. Three of the four monitor sites have exceeded the MCL in the past year. Since May 2017, TTHM levels have exceeded the MCL at all four sampling sites as shown in Figure 1-3. On January 5, 2017, SGWASA was given 30 days to present a compliance plan to the Public Water Supply Section of NC Department of Environmental Quality (PWS). As the MCL violation continued and conversion of coagulant from alum to ferric sulfate was not completed in the first quarter of 2017, PWS issued a \$15,500 penalty to SGWASA on March 24, 2017. MCL violations continued with the second quarter disinfection byproducts sampling, and PWS notified SGWASA on July 28, 2017, of their intent to issue another penalty. SGWASA received a second penalty of \$17,500 on August 15, 2017. How many monitor sites are there? 6 in figure 1:1; 6 in paragraph 1:2 and 4 in this paragraph? Monitor versus Sample?

Figure 1-4 and 1-5 illustrate the quarterly DBP concentrations at the monitoring sites for HAA5 and TTHM, respectively. Historically, SGWASA has experienced high HAA5 levels in August and November. The HAA5 data shows some variability in the concentrations, which is not uncommon and could possibly be due to some biodegradation of HAA in the distribution system where chloride residuals are lower. The TTHM concentrations are fairly consistent between the monitoring sites. TTHM concentrations show a strong seasonal pattern with higher concentrations in the warmer months, typically exceeding 100 ppb.

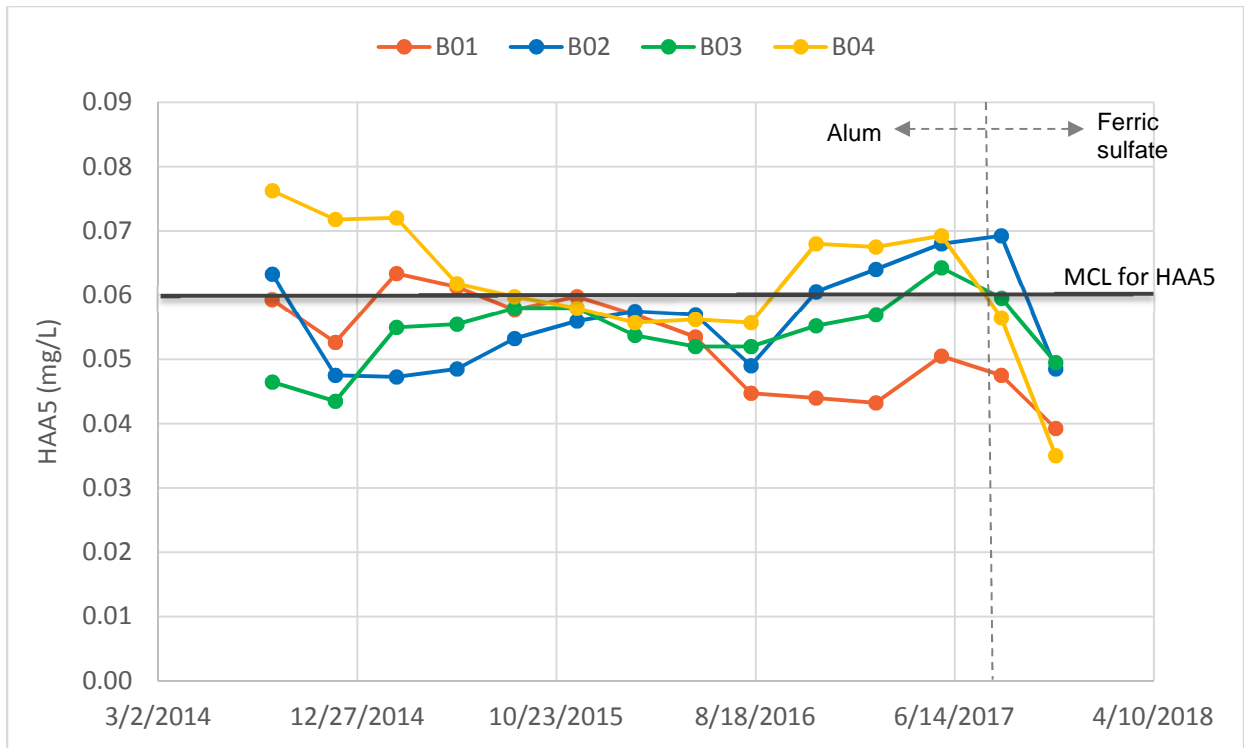


FIGURE 1-2: Locational Running Annual Average (LRAA) for HAA5

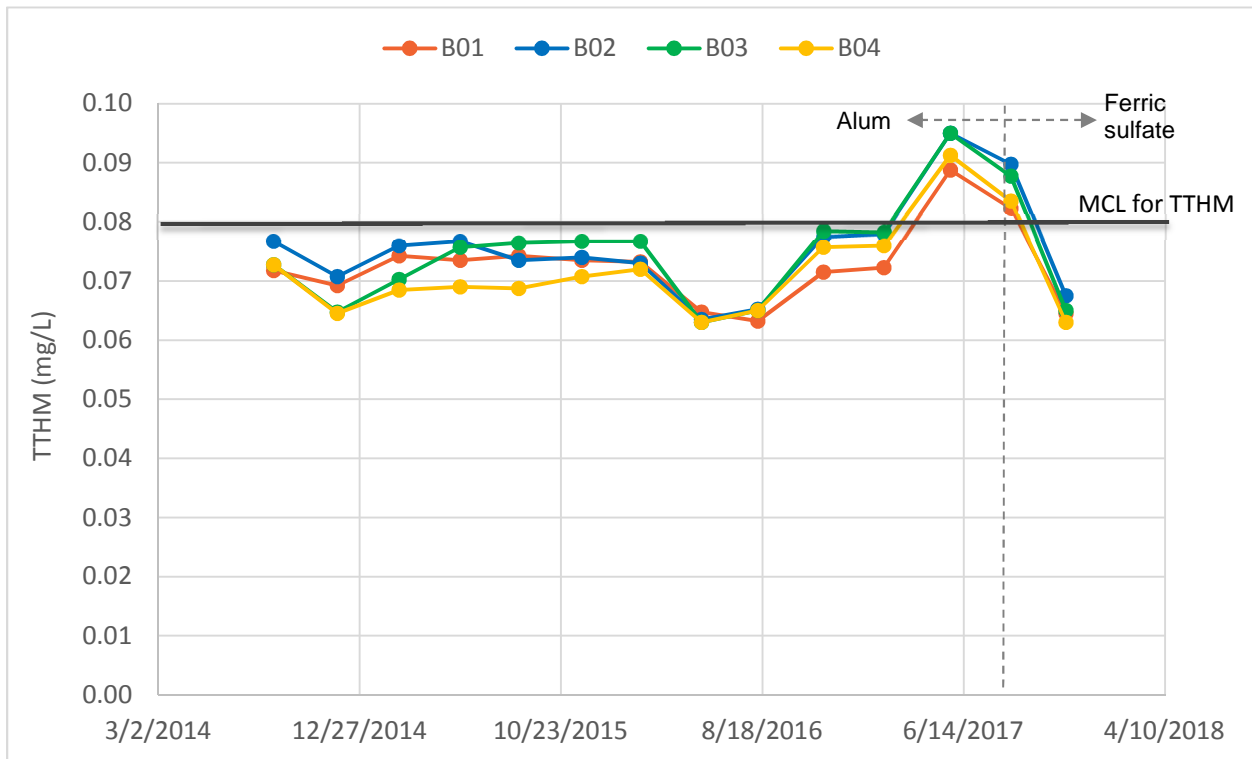


FIGURE 1-3: Locational Running Annual Average (LRAA) for TTHM

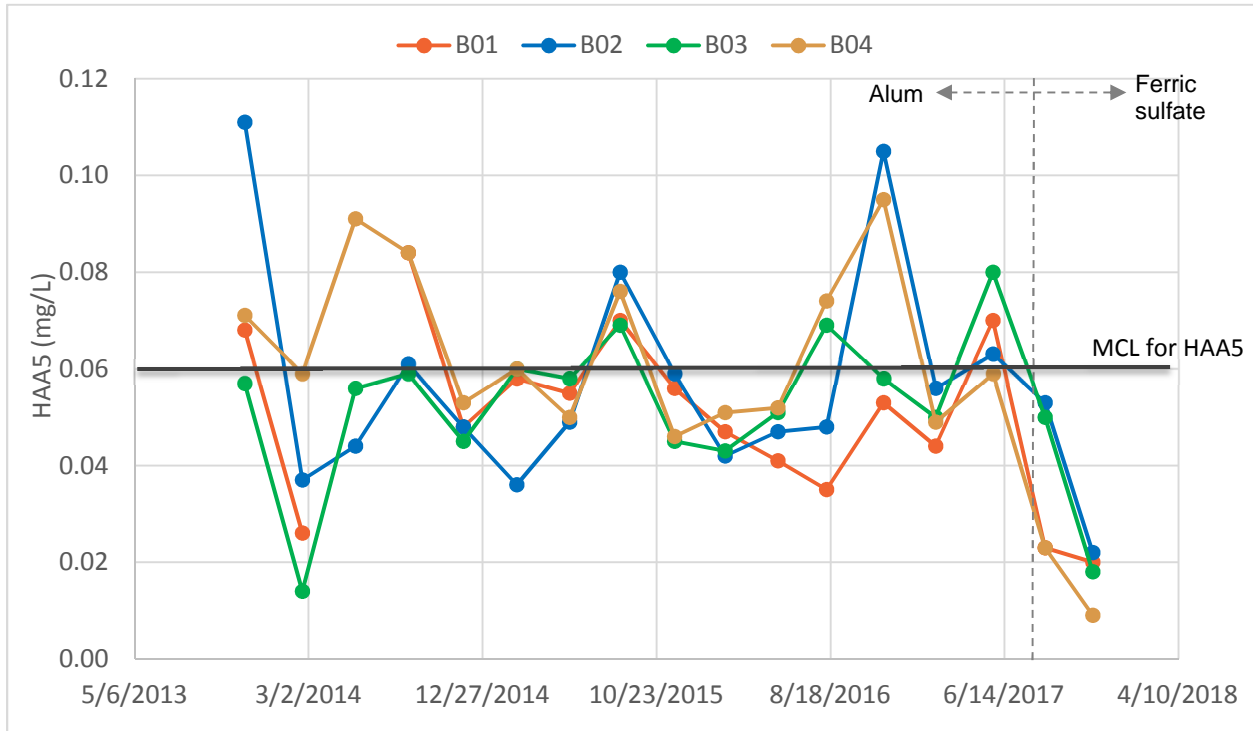


FIGURE 1-4: Quarterly HAA5 data from November 2013 to November 2017

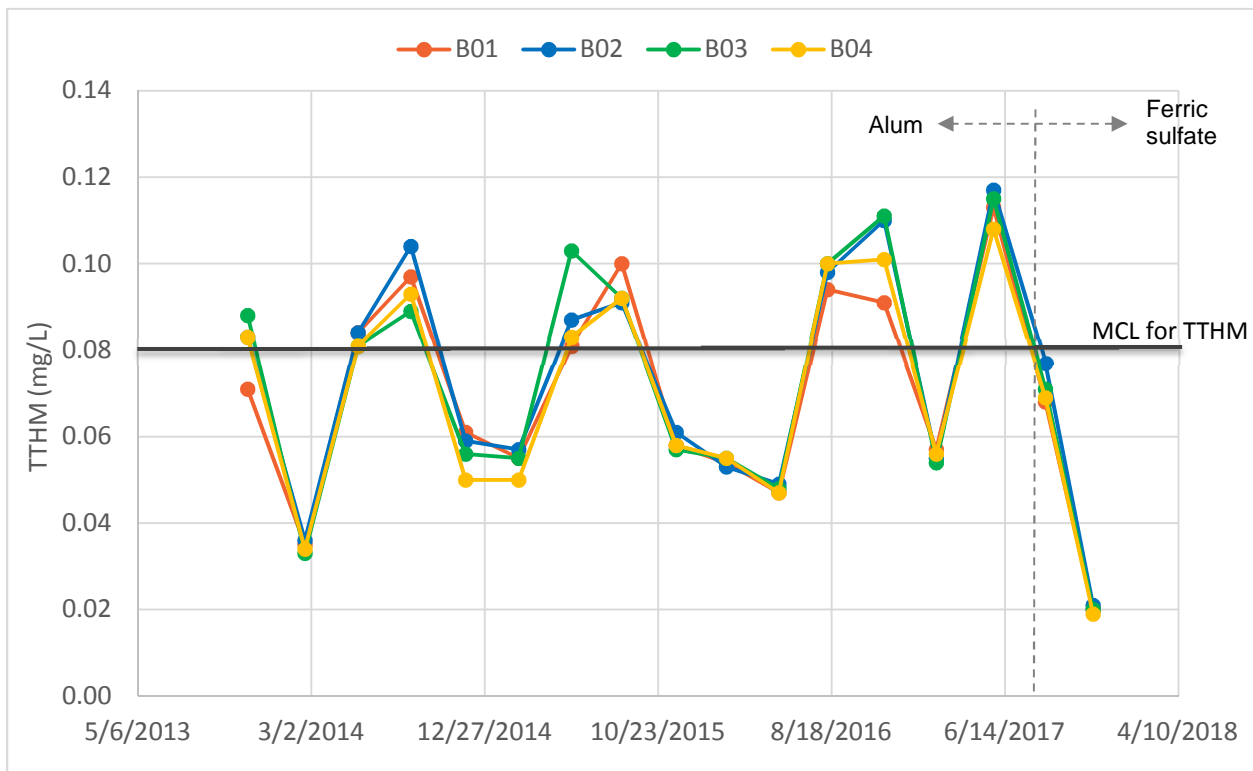


FIGURE 1-5: Quarterly TTHM data from November 2013 to November 2017

1.3 Recent SGWASA Actions to Enhance DBP Control

SGWASA has taken several actions recently to reduce disinfection byproducts in the treatment process. Alum had historically been used as the primary coagulant, but the WTP switched to ferric sulfate coagulation in August 2017 to enhance reduction of total organic carbon (TOC) and DBP precursors. Conversion to ferric sulfate decreased the coagulation pH to 4.5. Plant staff also added a caustic feed point upstream of the filters to increase pH to 6.0 for manganese oxidation. In addition, staff have made efforts to reduce the amount of solids accumulation in the sedimentation basins, and repair failing sedimentation basin drain valves and sludge collection equipment. Hazen is evaluating the sludge collection system and will provide an assessment of that system in a separate report.

1.4 Study Objectives

SGWASA retained Hazen and Sawyer (Hazen) to review SGWASA's plan to reduce disinfection by-production within the water treatment process and make recommendations to the plan. The purpose of this project is to modify the plans such that SGWASA can reliably and consistently maintain compliance with the Stage 2 DBPR. The fundamental objective of this project is to assess the treatment process, and the existing automation and control systems, and develop recommended modifications to enhance DBP control.

Hazen performed bench-scale testing to assess optimal coagulation, and pre-treatment such as pre-oxidation and PAC to provide enhanced reduction of TOC, turbidity, and DBP precursors. Following bench testing, Hazen evaluated chemical feed systems and treatment facility control systems taking into consideration DBP formation. This memo summarizes testing results and presents recommendations for process optimization, chemical system improvements, and enhancements to Supervisory Control and Data Acquisition (SCADA) and automation to reduce DBPs at the SGWASA WTP.

2. Bench-Scale Testing

Preliminary process testing was conducted in August and September 2017 to determine feasible treatment alternatives for the 7.5-mgd WTP.

Hazen mobilized its mobile process laboratory to the WTP for the bench-scale testing program. Raw water was collected in 6-gallon carboys from the sample tap on the WTP site and from the raw water pumping station at Lake Holt and transported to the mobile laboratory located for testing. The primary goal of this testing was to determine feasible treatment strategies to enhance reduction of TOC and DBP precursors.

2.1 Process Testing

Bench-scale testing was performed using Phipps and Bird 6-gang mixers, with 2-liter square jars equipped with sample taps located at a fixed depth. Prepared chemical stock solutions were added to the test jars using biological syringes for accuracy. All testing was conducted by Hazen and Sawyer

personnel in our mobile laboratory facilities. DBPs and TOC samples were collected and sent to James Reed Laboratories, Newport News, VA for analysis.

During bench scale testing, samples are routinely collected from all test jars and analyzed for pH, turbidity, alkalinity, and UV absorbance at 254 nm. The UV absorbance measurement is used as a surrogate indicator to determine the relative concentration of naturally occurring organic precursors that react with disinfectants to form trihalomethanes (THMs) and other disinfection by-products. The UV absorbance readings can then be compared to determine the relative efficiency of a process strategy in removing DBP precursors. Relative TOC levels are also well indicated by UV absorbance results. UV absorbance measurements are used instead of direct measurements of total THMs (TTHMs) and TOC due to the complexity and cost of testing for these compounds. Coagulation strategies that can optimize TOC removal are a major component for compliance with water quality regulations.

Raw water alkalinity and TOC have a direct bearing on chemical dosage requirements. Alkalinity provides the necessary component for chemical reactions and floc formation, while TOC exerts a coagulant demand and will set the levels of chemical dosages needed for treatment. In addition to coagulant demand, TOC impacts oxidant demands, reacts with chlorine to form disinfection by-products, and has an impact on corrosivity.

There are two basic mechanisms to provide TOC removal: charge neutralization and pH adjustment. During charge neutralization, the positively charged coagulant (e.g. aluminum sulfate, ferric sulfate, ferric chloride) can remove the negatively charged TOC from solution. The organics become enmeshed in the floc and are settled out and removed.

Alternatively, when coagulants are added to the water they react with the natural alkalinity present to form a hydroxide floc. As the alkalinity is consumed in floc formation, the pH is reduced. The change in pH allows some of the organics to come out of solution, become enmeshed in the floc, and be settled out and removed. The greater the pH change the greater the TOC removal.

One of the advantages of using ferric coagulants, as opposed to aluminum based coagulants, is that ferric can form hydroxide flocs at much lower pH than aluminum. At low pH values, the raw water organics become insoluble and precipitate out of solution. These “particulate” organics become enmeshed in the floc and are settled out.

When using an aluminum coagulant, the pH of the settled water is limited to approximately 6.0 pH units. At pH values less than 6.0, aluminum becomes soluble and does not form aluminum hydroxide floc, allowing the aluminum to pass through the plant. pH adjustments later on in the treatment train can cause flocs to form and be captured in the filters, reducing run times; flocs could also form in the clear well and in the distribution system. Therefore, ferric coagulants can typically provide greater TOC removal and subsequent lower disinfection by-products in the distribution system, when coagulation is performed at lower pH values.

2.1.1 Jar Test Calibration

For this testing, two sources of water were available. Raw water could be obtained directly from the Lake, or at the plant using water from the 10 MG Terminal Reservoir. Since the full-scale plant takes water directly from the Terminal Reservoir, this water was used for initial testing.

The first step in the bench scale test procedure is to establish a calibration between the full-scale plant and the bench scale testing protocols. Data collected from the full- scale plant includes:

- Chemicals, dosages and application points.
- Plant flow rates.
- Basin surface areas and volumes.
- Settled water samples.

To simulate the full-scale plant in the jars, various mixing conditions were tested, and the settled water results from the jar tests were compared to the settled water from the sedimentation basins until a good match was obtained. Settled water samples from the full-scale plant were collected and analyzed to establish the water quality targets for the jar test procedures.

To develop the jar test procedure, rapid mix time in the jar test was equal to the hydraulic detention time in the full scale rapid mix. Flocculation time in the jar test was equal to the hydraulic detention time in the full scale flocculators. And, mixing energies were determined by trial and error.

Bench scale jar test settling times are directly related to full-scale surface area loading rates. The equation used to convert the settling rates in the 2-liter jars to the full-scale basin loading is:

$$\frac{\text{Settling rate, cm}}{\text{min}} \times \frac{1 \text{ ft}}{30.48 \text{ cm}} \times \frac{1440 \text{ min}}{\text{day}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} = \frac{\text{gpd}}{\text{ft}^2}$$

The sampling tap in each jar is fixed at 10 cm below the surface of the water. Solving the equation for 1, 4 and 10 minute settling times yields the corresponding surface area loading rates (gallons/day/square foot). To determine the settling time for Butner the projected area of the plate settlers was included in the calculations.

Typical examples of bench scale settling times and surface area loading rates are presented in Table 2-1.

Table 2-1: Typical Bench Scale Settling Times and Surface Area Loading Rates

Settling Time (minutes)	Surface Area Loading Rate (gpd/sf)
1	3500
4	880
10	350

The results of the plant calibration testing are presented in Table 2-2.

Table 2-2: Bench Scale Test Calibration

Parameter	Full-Scale	Jar 1-4
KMnO ₄ (mg/L)	2.5+0.4	2.5+0.4
PAC (mg/L)	8	8
Ferric Sulfate (mg/L)	65	80
pH (Units)	4.76	4.88
UV-254 (1/cm)	0.022	0.024
Turbidity (NTU)	0.64	0.56
Alkalinity (mg/L)	2	2
Temperature (°C)	23	23

As shown in Table 2-2, using the same chemicals and adjusted doses, jar test 1-4 produced results that approximated full-scale settled water for the parameters evaluated. The mixing times and energies selected to simulate the full-scale plant at a flow rate of 3 MGD are presented in Table 2-3.

Table 2-3: Jar Test Parameters @ 3 mgd (1.5 mgd/basin)

Treatment Stage	Mixing	Jar 1-4
Rapid Mix	RPM	60
	Duration (min)	6
1st Stage - Flocculation	RPM	40
	Duration (min)	12
2nd Stage - Flocculation	RPM	20
	Duration (min)	95/40
Settling Time (min)		12

Raw water quality parameters for the Terminal Reservoir and for Lake Holt, recorded during the testing period, are presented in Tables 2-4 and 2-5, respectively.

Table 2-4: Water Quality Parameters for the 10 MG Terminal Reservoir

Parameter	Monday 8/28/2017	Tuesday 8/29/2017	Wednesday 8/30/2017	Wednesday 9/6/2017
pH (units)	6.59	6.59	6.67	6.52
Filtered UV-254 (1/cm)*	0.228	0.265	0.288	0.333
Turbidity (NTU)	6.88	6.27	6.80	5.52
Alkalinity (mg/L)	16	20	18	18
Temperature (°C)	23.9	23.0	22.9	22.7

* Filtered with 0.45 µm nylon filters

Table 2-5: Water Quality Parameters for Lake Holt

Analysis	Thursday 8/31/2017	Friday 9/1/2017
pH (units)	6.57	6.45
Filtered UV-254 (1/cm)*	0.324	0.342
Turbidity (NTU)	12.4	13.3
Alkalinity (mg/L)	20	20
Temperature (°C)	20.6	18.7

* Filtered with 0.45 µm nylon filters

As shown, turbidity and UV values in the Reservoir are significantly lower than the raw Lake water. Water from the lake is pumped to the Reservoir and potassium permanganate is added at a relatively high dose of 2.5 mg/L. The Reservoir has a capacity of 10 MG and current plant flows are 3 mgd, so the Reservoir provides approximately 3 days of contact time for the potassium permanganate.

Potassium Permanganate (KMnO₄) is a common oxidant used in drinking water treatment to precipitate soluble iron and manganese, for taste and odor control, and for color removal. Potassium permanganate may also help improve organics removal in coagulation when used as a pre-oxidant.

2.1.2 Coagulant Comparison

Both ferric sulfate and ferric chloride coagulants were tested for comparison. Aluminum sulfate was not tested as the plant recently discontinued its use due to elevated DBP levels. The plant is currently using ferric sulfate as the primary coagulant at a pH of 4.7. This low coagulation pH is aggressive on concrete and not recommended for long-term use for unlined concrete basins. All bench testing was conducted by providing all the alkalinity needed for floc formation; consequently, coagulation pH values during the testing ranged from approximately 5.4 to 5.8. Whereas, this low pH is still aggressive on unlined concrete, degradation of concrete will be at a much lower rate.

Samples were collected from the test jars to determine settled water turbidity and UV-absorbance. The results are presented in Figures 2-1 and 2-2. As shown, using water from the Terminal Reservoir, ferric chloride provided the best settled water turbidities at lower doses, compared to ferric sulfate. UV reduction was slightly greater with ferric sulfate; however, both coagulants provided good reductions.

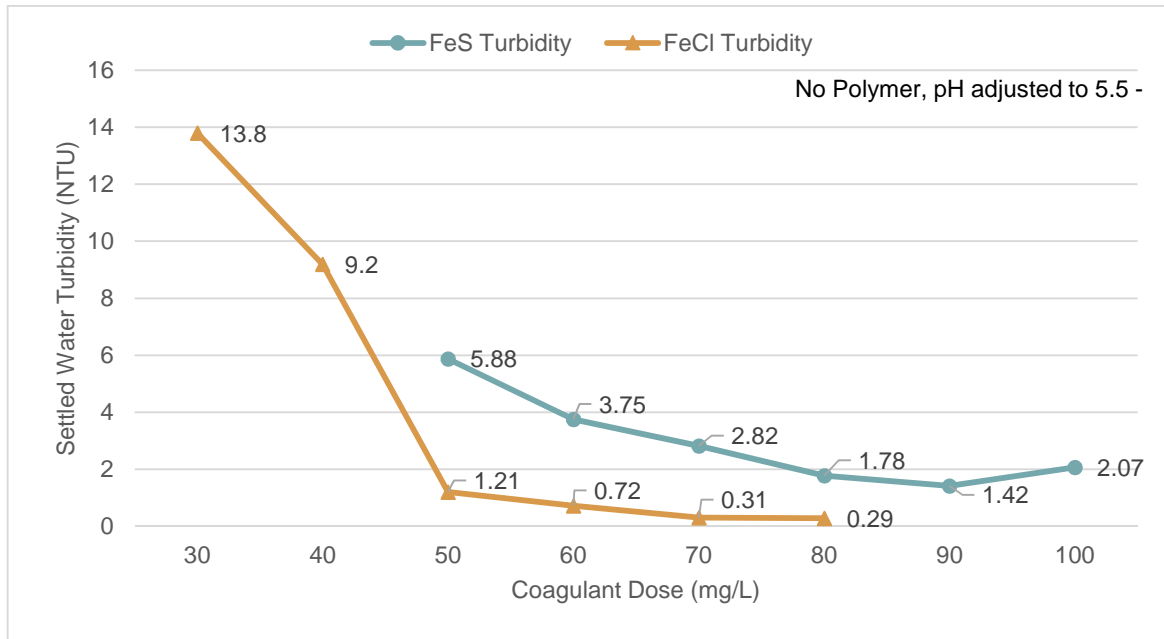


FIGURE 2-1: Ferric Sulfate and Ferric Chloride Settled Water Turbidity

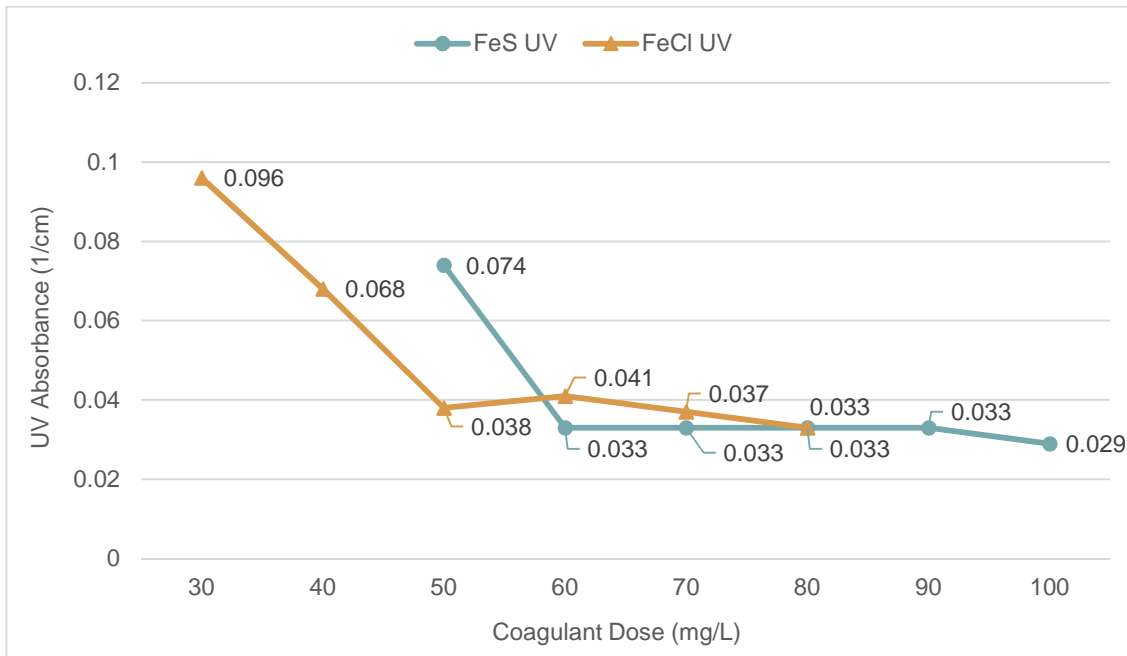


FIGURE 2-2: Ferric Sulfate and Ferric Chloride UV-Absorbance. No Polymer, pH Adjusted to 5.5 - 5.7

2.1.2.1 Polymer Testing

The SGWASA WTP currently feeds Clarifloc N6310 as coagulant aid polymer. To determine the optimum N6310 polymer dose, a dosage screening was conducted using ferric sulfate; plant polymer doses of 0, 0.5, 1.0 and 1.5 mg/L were tested. The results are presented in Figure 2-3.

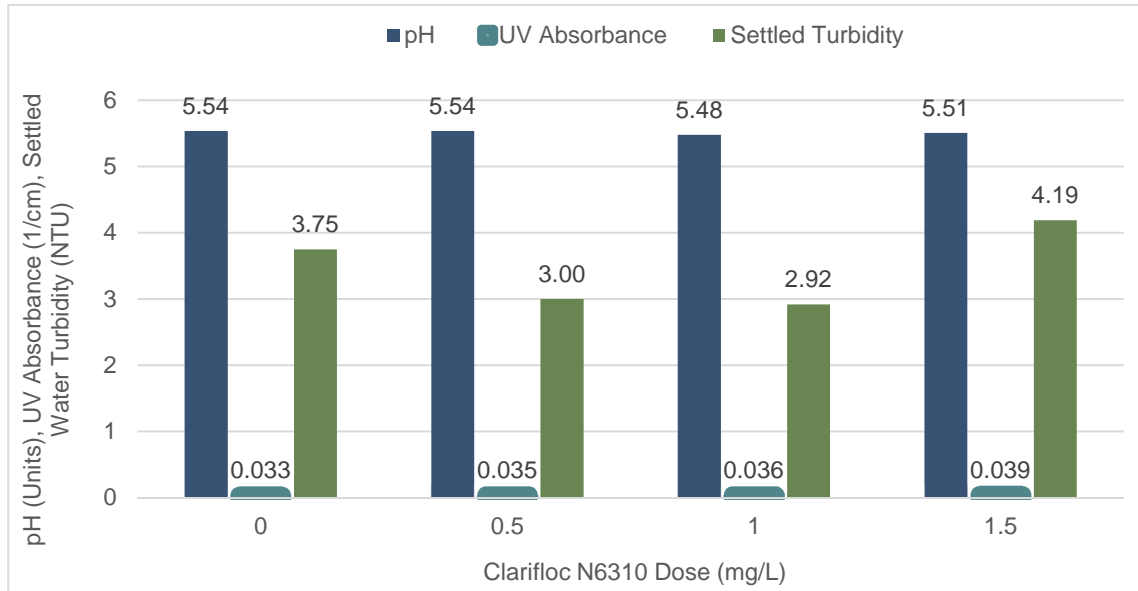


FIGURE 2-3: Clarifloc N6310 Polymer Dosage Screening. Ferric Sulfate Dosed at 60 mg/L.

When sufficient alkalinity is added for all the ferric sulfate to react and form flocs, the pH values are in the 5.5 range, and settled water turbidity is unacceptably high for all doses tested, including when no polymer was added. Accordingly, to determine if a different polymer would help improve settled water turbidity additional testing was conducted. Polymers from several different manufacturers were tested including Kemira, BASF, Clarifloc, and Ashland. The results are presented in Figure 2-4.

The best settled water turbidity results were obtained from Ashland 851 TR and Ashland 650 TR. All other polymers produced significantly higher settled water turbidity. Additionally, when comparing UV results, the lowest UV value was obtained with the Ashland 851 TR at 0.033/cm. To determine the optimum dose for the 851TR, a dose screen was conducted and the results are presented in Figure 2-5. Doses of 0.2 to 1.0 mg/L were tested.

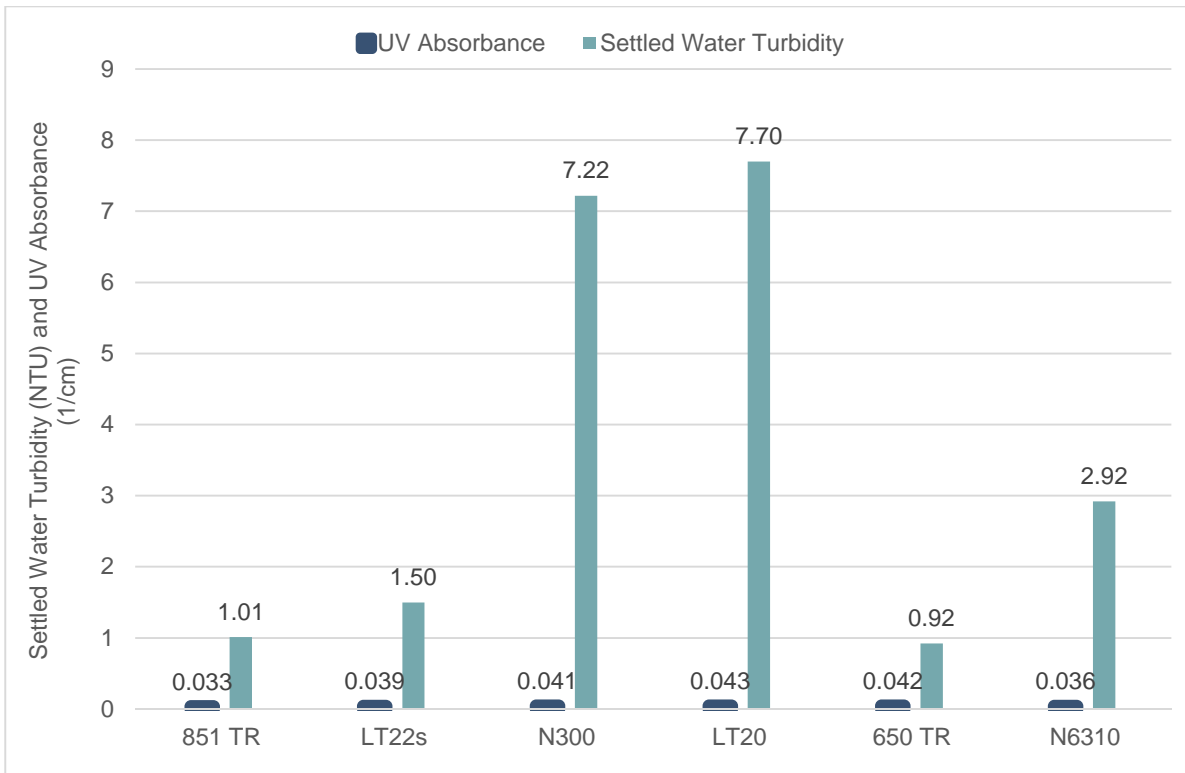


FIGURE 2-4: Ferric Sulfate and Polymer Comparison

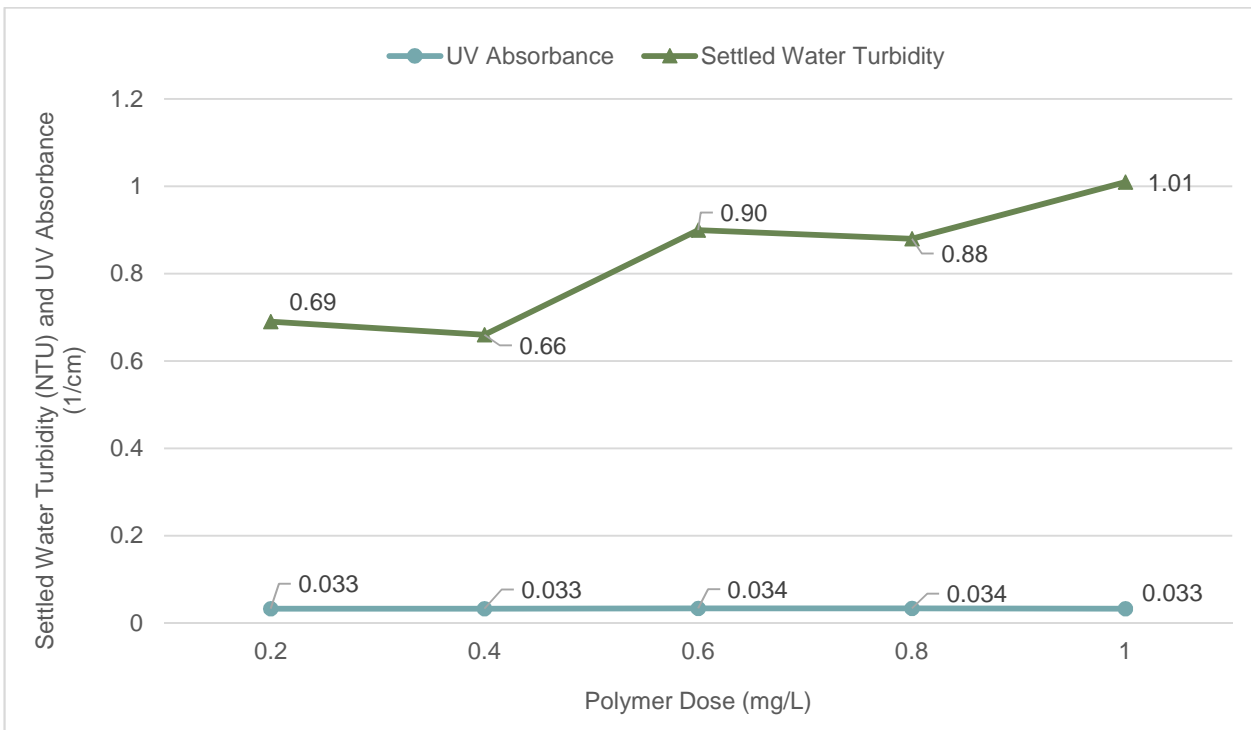


FIGURE 2-5: Ashland 851 TR Dose Screen. Reservoir Water pH at 5.6 - 5.7. 60 mg/L Ferric Sulfate Dose

The best results and lowest settled water turbidity values were obtained at doses of 0.2 and 0.4 mg/L with settled water turbidities of 0.69 and 0.66 NTU, respectively. Based on the results of this testing, it appears that the Ashland 851 TR (Greensboro, NC) can provide low settled water turbidity and UV values at the coagulation pH of 5.5 to 5.7. The plant currently uses Clarifloc N6310 at a dose of 1.0 mg/L. The Clarifloc is a liquid polymer that is mixed with water and then fed using a metering pump. The Ashland 851 TR is a dry polymer so a new polymer system would be needed to feed this polymer.

With the 851TR, coagulation ferric sulfate resulted in low settled water turbidity and UV values comparable to the results with ferric chloride. SGWASA has already converted to ferric sulfate and has had nearly 3 months of operational experience with this coagulant. In addition, the use of ferric chloride would necessitate a review of the corrosion control treatment at the SGWASA WTP. A switch to ferric chloride would alter the chloride to sulfate mass ratio (CSMR) through reduction in sulfate (contributed by alum and ferric sulfate) and increasing chloride levels from the ferric chloride. A pilot study would be required to assess optimal corrosion control treatment with this process change to ensure risks to lead and copper release are mitigated. Given the urgency to achieve and maintain DBP compliance, it is not recommended at this time to consider a switch to ferric chloride.

2.1.2.2 *Pre-Oxidant Testing*

The plant currently uses potassium permanganate as a pre-oxidant and it is added to the lake water as it is pumped to the Reservoir and again as water is pumped from the Reservoir to the WTP. To determine if an alternative pre-oxidant could improve plant performance, chlorine dioxide was tested using lake water.

Chlorine dioxide is a powerful disinfectant and is an oxidant that, unlike free chlorine, does not readily form halogenated DBPs. It can also be used for iron and manganese reduction and odor control. Although there are numerous reactions between chlorine dioxide and constituents in raw water, chlorite (ClO₂⁻) and chlorate (ClO₃⁻) can be formed:



Because of potential health effects, the United States Environmental Protection Agency (EPA) has regulated the maximum concentration of chlorine dioxide residual to 0.8 mg/L in the distribution system. Both chlorite and chlorate are formed when chlorine dioxide is used. The EPA regulates chlorite at a monthly average level of 1 mg/L, with an MCL Goal (MCLG) of 0.8 mg/L in drinking water. The upper limit for the application of chlorine dioxide is expected to be 1 mg/L.

The results of the chlorine dioxide testing are presented in Figure 2-6 and Figure 2-7. Both ferric sulfate and ferric chloride were tested using water from the lake without any potassium permanganate added.

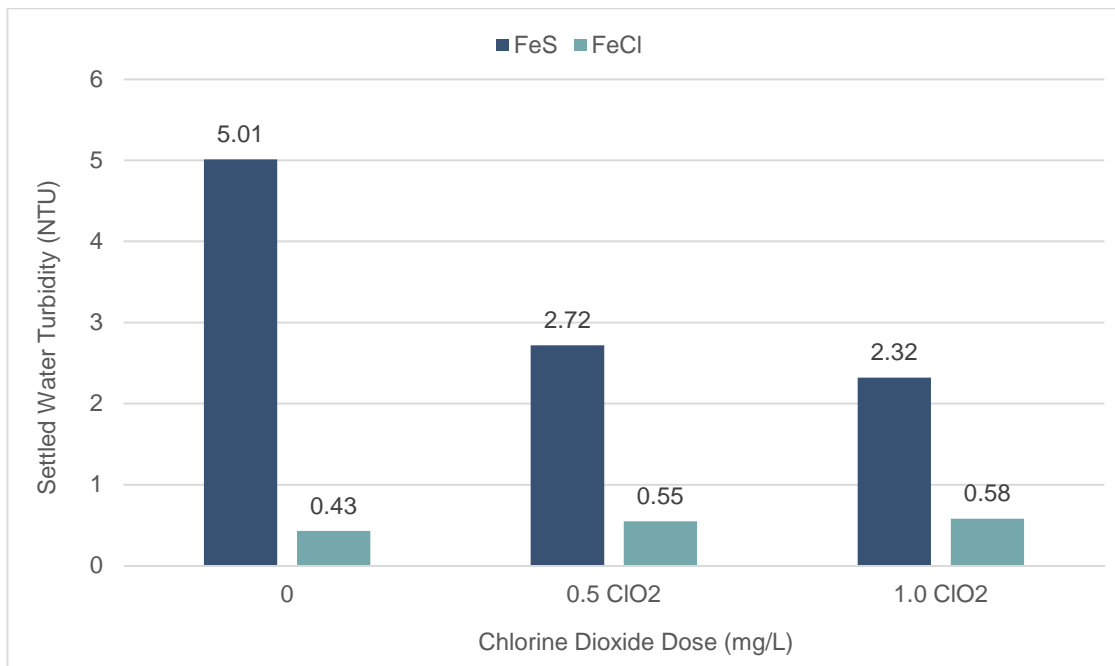


FIGURE 2-6: Chlorine Dioxide Dosage, Comparison of Settled Water Turbidity

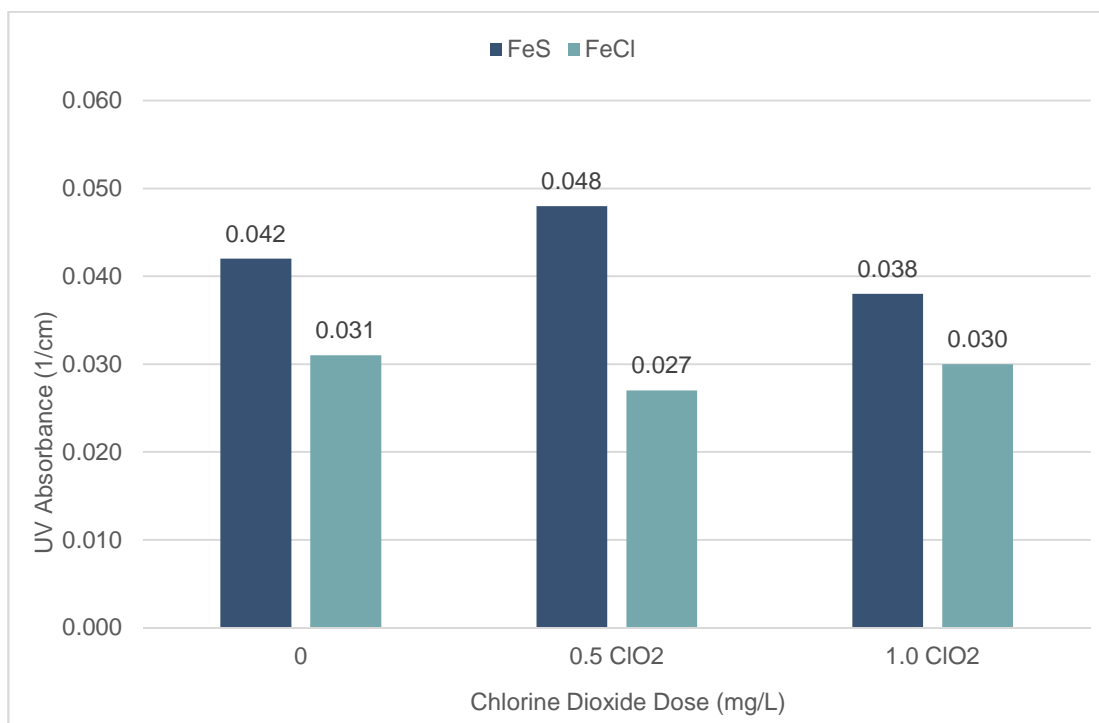


FIGURE 2-7: Chlorine Dioxide Dosage, Comparison of UV Absorbance

Ferric chloride clearly outperformed ferric sulfate in terms of settled water turbidity performance over the range of chlorine dioxide doses tested. In fact, the lowest settled water turbidity was obtained with ferric chloride without any chlorine dioxide addition. Ferric chloride also outperformed ferric sulfate and provided lower UV values for all chlorine dioxide doses. Based on these results, it appears that ferric chloride and chlorine dioxide could be a potential alternative treatment strategy.

2.1.2.3 Potassium Permanganate and Powdered Activated Carbon (PAC) Testing

Both potassium permanganate and powdered activated carbon (PAC) are currently added to the raw water. To determine the appropriate potassium permanganate dose, a demand test was conducted.

The full-scale plant adds a first dose of 2.5 mg/L to the lake and a second dose of 0.4 mg/L to the Reservoir water prior to pumping to the WTP. Accordingly, to conduct the test, raw lake water was dosed with potassium permanganate at doses of 0.2, 0.4, 0.6, 0.8 1.0, and 1.2 mg/L and allowed 120 minutes of contact time for any reactions to take place. The potassium permanganate demand is determined by the highest dose with no color remaining at the end of the contact time. Based on the demand testing a potassium permanganate dose of 0.2 mg/L was selected.

The plant currently uses Aqua NuChar PAC at a dose of approximately 8 mg/L to help control taste and odors and reduce TOC. For comparison, using lake water, the Aqua NuChar was tested against WaterCarb 800. Samples were dosed with both carbons at doses of 5 to 40 mg/L and given 60 minutes of contact time. Based on a comparison of 0.45 µm filtered water, the plant Aqua NuChar provided greater UV removal compared to WaterCarb 800 for all doses tested.

The results of the potassium permanganate and PAC testing are presented in Figure 2-8 and Figure 2-9. Both ferric sulfate and ferric chloride were tested at doses of 60 mg/L. As stated previously, sufficient alkalinity was added to provide a pH in the 5.5 to 5.7 range, and to allow all the ferric added to form flocs.

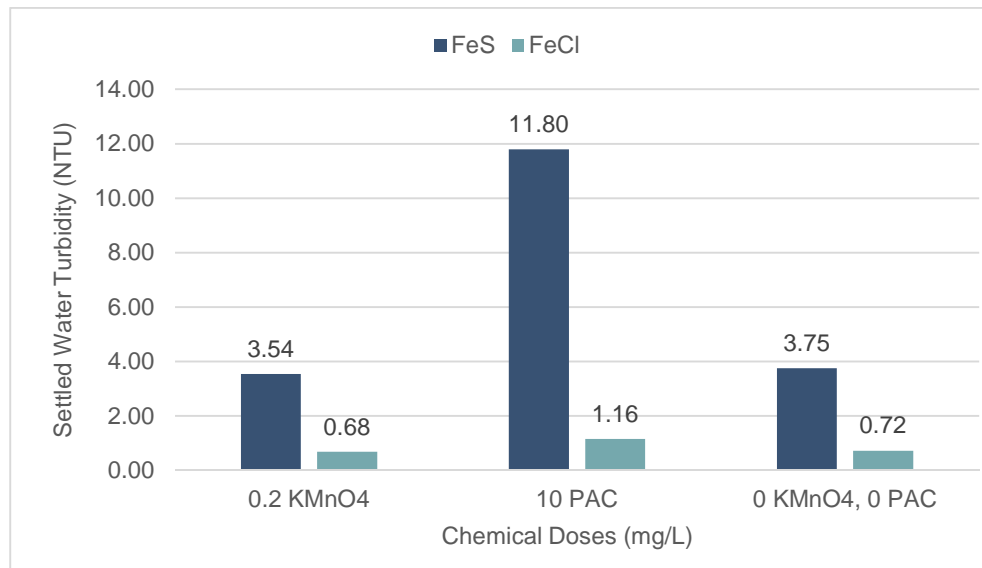


FIGURE 2-8: Potassium Permanganate and PAC Settled Water Turbidity

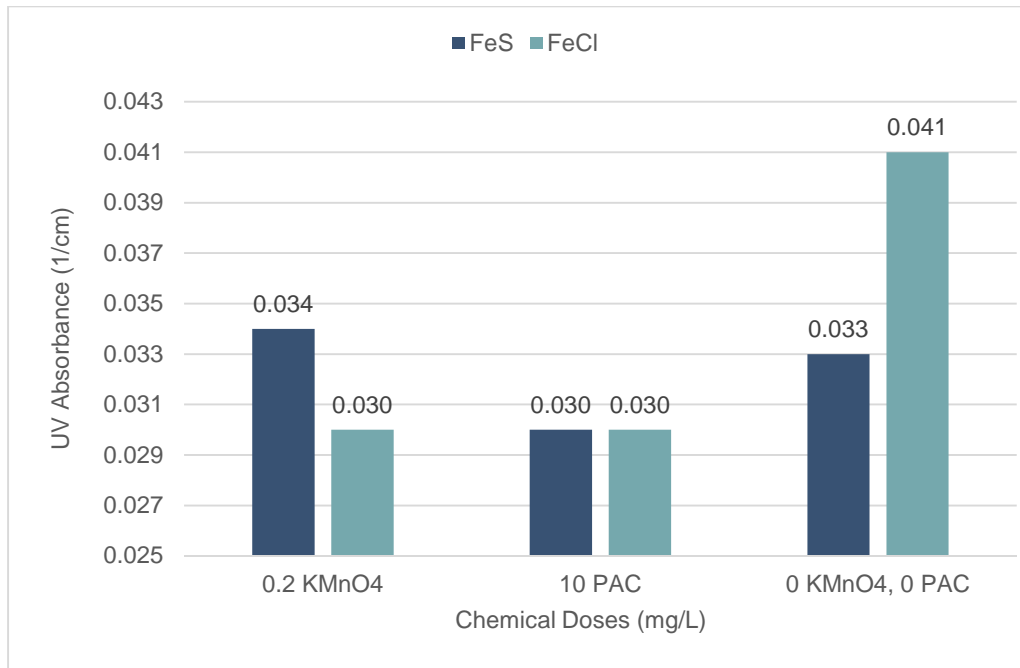


FIGURE 2-9: Potassium Permanganate and PAC UV Absorbance

For the permanganate and PAC testing, ferric sulfate provided unacceptable settled water turbidity results, as presented in Figure 2-8. It should be noted that the full-scale plant provides acceptable turbidities by operating at a pH of 4.7, low enough to damage the concrete basins. On the other hand, Figure 2-9 shows that for potassium permanganate, ferric chloride provided a slightly better UV removal, while for the 10 mg/L PAC, both coagulants provided identical UV removals.

In considering both settled water turbidities and UV removals, the use of potassium permanganate and/or PAC in the current configuration is not recommended with ferric sulfate. The current full-scale treatment strategy using high doses of potassium permanganate and 8 mg/L PAC with ferric is providing acceptable settled water turbidity and UV removals; however, to accomplish this treatment the plant does not provide all the alkalinity needed and operates at a pH of 4.7. This pH is sufficiently low to cause damage to the concrete surfaces in the treatment basins and, therefore, is not recommended as a permanent strategy. In addition, current potassium permanganate dosing significantly exceeds oxidant demand. With the current coagulation pH of 4.7, it is expected that some oxidized manganese could be re-dissolved through coagulation and sedimentation.

If sufficient alkalinity is added, the coagulation pH values are in the 5.5 to 5.7 range and the raw water permanganate/ferric sulfate strategy provides unacceptable settled water turbidity performance. It is expected that acceptable performance would be achieved with a switch to the recommended polymer (851TR) and dose, and adjusted potassium permanganate dosing to limit presence of permanganate residual at the rapid mix.

2.1.3 DBP Testing

Samples from the best test jars were collected, filtered, pH adjusted, and then dosed with chlorine to provide primary disinfection. After primary disinfection, the samples were dosed with ammonia to form chloramines. The samples were held for three days to simulate water age in the distribution system and then quenched to stop DBP formation. The DBP sample preparation details are presented in Table 2-7. The samples were sent to James Reed Laboratories, Newport News, VA for analysis.

Table 2-7: DBP Sample Preparation Details

Coagulant & Dose (mg/L)	1 st Cl Dose (mg/L)	pH	Free Cl @ 80 min. (Primary Disinfection)	2 nd Cl Dose (mg/L)	Caustic Dose (mg/L)	Ammonia Dose (mg/L)	Final pH	Final Total Cl
60 FeCl 0.5 ClO ₂ 0.2 851TR	0.6	5.72	0.20	2.50	7	0.67	7.49	2.50
60 FeCl No Oxidant 0.2 851 TR	0.6	5.63	0.15	2.55	6	0.67	7.57	2.50
60 FeS No Oxidant 0.4 851TR	0.6	5.71	0.16	2.55	7	0.67	7.54	2.56
FS Plant Finished Tap	-	-	-	-	-	-	7.50	2.56

As listed in Table 2-7, primary disinfection only required low doses of chlorine to meet CT because of the low pH value of 5.7. At the end of the 80 minutes of contact time, the free chlorine residuals were checked and then more chlorine was added to match the final chlorine residual of 2.7 mg/L leaving the plant. The bench scale samples were prepared from jar tests using raw water from the lake without potassium permanganate addition. Ammonia was dosed at a 4:1 ratio to form chloramines. The DBP results are presented in Figure 2-10.

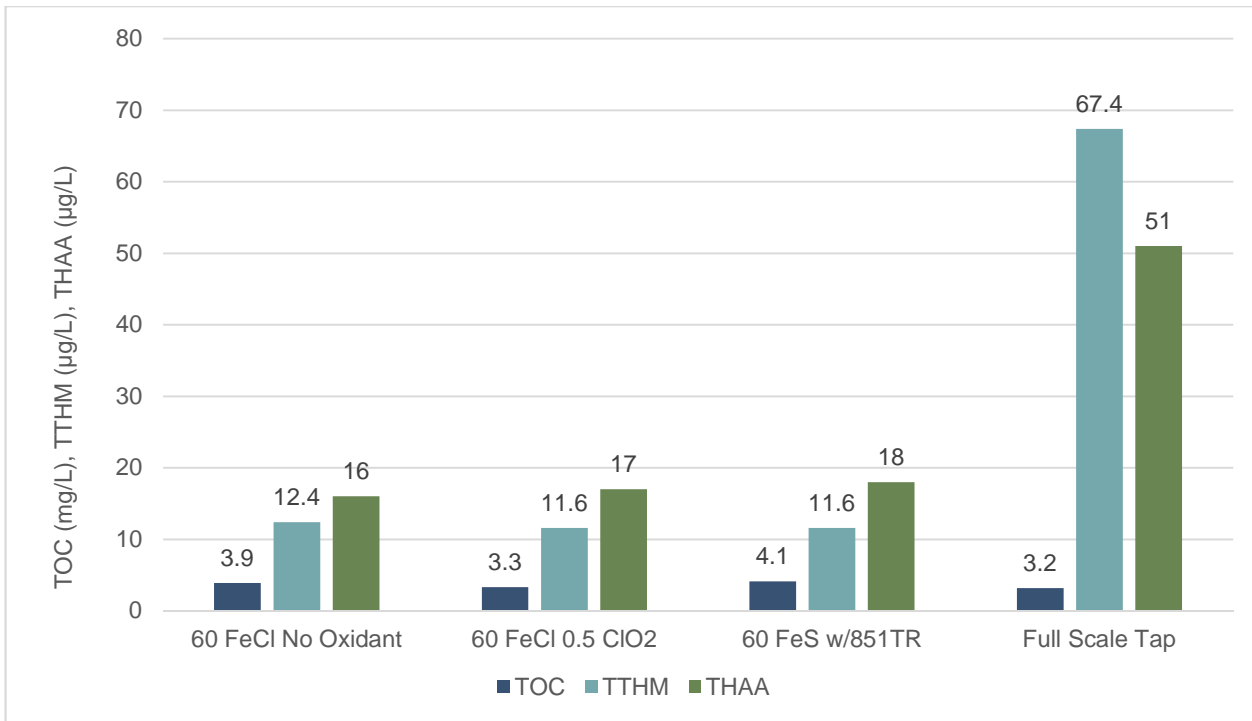


FIGURE 2-10: 4 Day SDS – DBPs (Lake TOC: 10.2 mg/L, Reservoir TOC: 9.2 mg/L)

With a chloramine disinfection strategy, the bench scale DBPs are very low (12-18 ppb) compared to the full-scale plant tap sample (51- 67 ppb) as shown in Figure 2-10. The bench scale samples were dosed with chlorine and held at pH values and contact times to mimic the full-scale plant for primary disinfection, and so the DBP results for ferric sulfate were expected to be similar. Hazen evaluated the full-scale WTP to assess contributing factors resulting in higher DBP formation in the WTP than predicted in the bench scale testing results.

2.1.4 Evaluation of SGWASA WTP DBP Formation

Hazen obtained DBP formation profile data through the WTP from SGWASA to evaluate the location and magnitude of DBP formation. Figures 2-11 and 2-12 present profiles of DBP formation through the treatment process at the SGWASA WTP. Hazen collected samples on September 25th and October 4th and sent them to Reed for analysis to provide an independent verification of the profile data. The DBP profile data include samples from the following locations:

- Filter Eff. – combined filter effluent
- Pre NH₃ – Post chlorine contact tank (prior to ammonia addition)
- Post NH₃ – Post ammonia addition
- Plant Tap – finished water at point of entry into distribution system

Over the last year, the DBP levels in the WTP have been very high, exceeding the MCL within the treatment process. HAA5 levels in the filter effluent have been extremely high (> 50 ppb). These levels are indicative of a WTP practicing pre-chlorination; however, additional sampling conducted in August 2017 confirmed that hypochlorite does not appear to be leaking into the flash mix feed point. On most dates, TTHM and HAA5 levels were similar at the pre-NH3, post-NH3, and Plant Tap sample locations, which suggests that monochloramines are being formed effectively and limiting further DBP production.

In August 2017, SGWASA switched from using alum to ferric sulfate as the primary coagulant, which has had a positive effect in the reduction of HAA5 and TTHM formation. The results from the October 4th sampling indicate that plant tap TTHMs were 44 ppb and HAA5 levels were 38 ppb. These results align closer to the expected results from the bench-scale testing.

DBP compliance samples collected in 4th quarter indicate further reduction in DBP levels (see Figures 1-4 and 1-5) with all samples wells below the MCLs. TTHM levels averaged 20 ppb amongst the monitoring sites whereas HAA5 levels averaged 17 ppb amongst the sites. TTHM levels were the lowest in the last 5 years with November 2017 levels being 81% lower than the same time last year. HAA5 levels were some of the lowest with November 2017 levels being 78% lower than the same time last year.

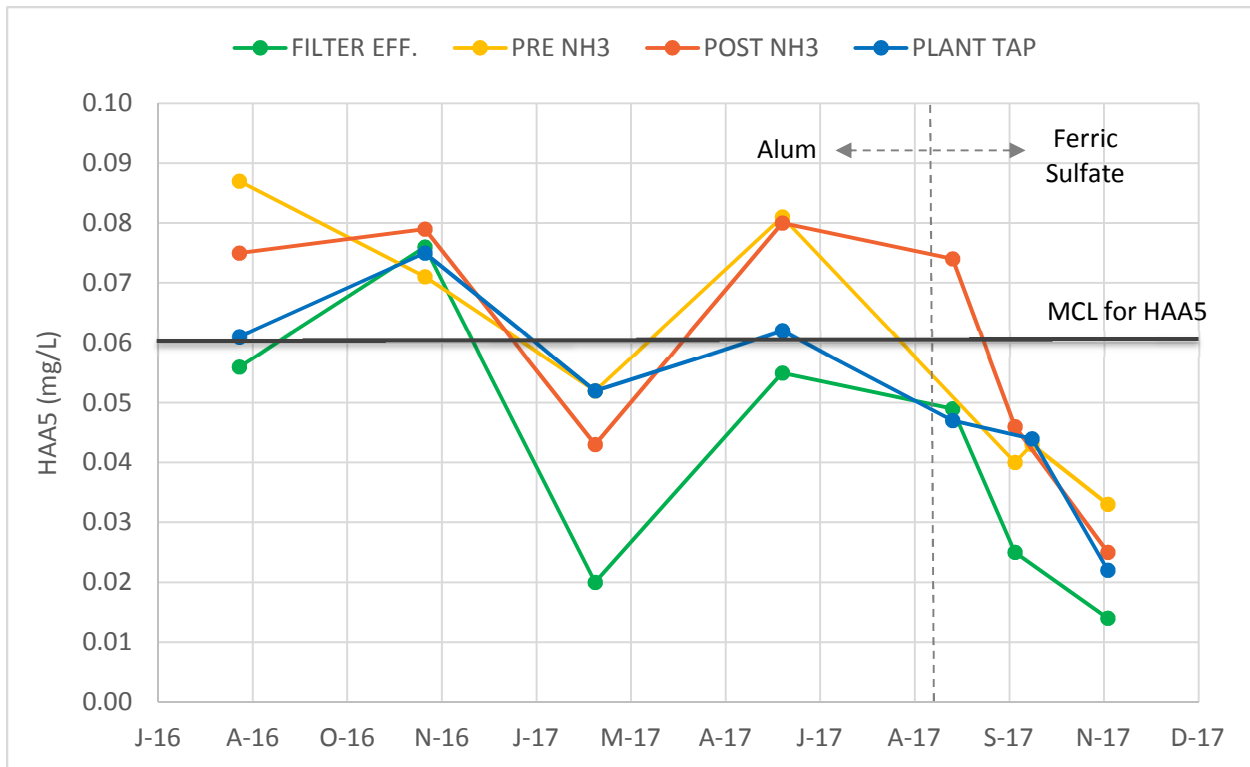


FIGURE 2-11: HAA5 Profile through SGWASA Water Treatment Plant

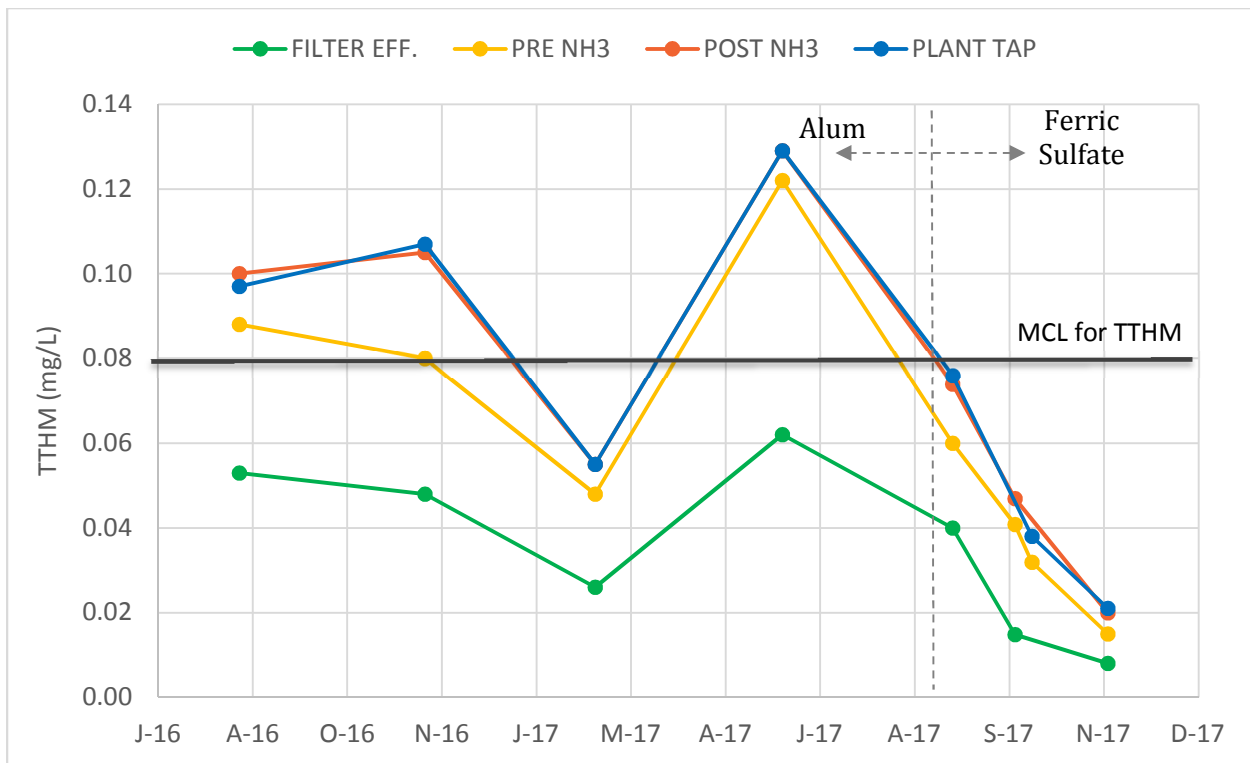


FIGURE 2-12: TTHM Profile through SGWASA Water Treatment Plant

Hazen and Sawyer evaluated several potential factors that could have affected DBP formation in the WTP during this study and resulted in variances between full-scale performance and the bench testing results.

Flow through the WTP is manually controlled by the operator. Therefore, operators must manually adjust filter effluent valves to maintain consistent flow between filters. Filter effluent valves need to be adjusted during each change in flow through the WTP as well as adjusted to account for increasing headloss through the filter media during a filter run. Operators also manually adjust manual valves to balance chlorine and caustic addition between filters. Given the challenges of maintaining flow balance, it is anticipated that there are differences in filter flow and chlorine doses to each filter that may lead to variability in DBP formation in the filters.

Also, there may have been a learning curve with operating the WTP with ferric sulfate coagulation. The bench testing samples were taken on September 9, 2017, which was about 2 weeks after the plant changed coagulant from alum to ferric sulfate. Through the progression of this study, as plant operations were refined for coagulation using ferric, full-scale DBP results decreased and more closely matched what was expected from bench testing.

Also, the SGWASA WTP has been challenged with maintaining proper sludge levels in the sedimentation basins due to failing drain valves and sludge collection equipment. Hazen and Sawyer is evaluating the sludge collection systems and evaluating options to enhance residuals management in the WTP and is preparing a separate report with our recommendations. We have observed significant solids accumulation in the sedimentation basins and believe that solids carryover could be a contributing factor to higher DBP

formation. In addition, solids accumulation could lead to anoxic conditions within the sludge layer resulting in the release of dissolved organic compounds back into the sedimentation basins, which could also carryover in the filters.

Whereas we have been unable to confirm, we are concerned about the mixing conditions at the point of addition for ammonia. There is no mixer downstream of the ammonia point of injection to ensure complete mixing prior to a tee in the 24-inch finished water line that splits flow to the clearwell. The ammonia feed line is a 1.5-inch line that is tapped into the 24-inch finished water line without an injection quill to ensure chemical is added in the center of the pipeline. The ammonia feed line velocities are low (less than 2 feet/sec) as well as velocities in the 24-inch line (1.6 to 2.2 feet/sec), so there is little energy to assure complete mixing. Complete mixing of ammonia is critical to assure optimal monochloramine formation to slow DBP formation in the WTP as well as limit formation of less desirable dichloramine and trichloramine.

2.1.5 Bench Testing Summary

Based on the bench-testing results, ferric sulfate coagulation at a pH of approximately 5.5 yielded low DBP levels; 12 ppb TTHM and 18 ppb HAA5. Settled water turbidity was acceptable (<0.70 NTU) when using an alternate polymer, Ashland 851TR. Coagulation with ferric chloride did show acceptable settled water turbidity without polymer addition. Ferric chloride achieved slightly lower UV absorbance values but DBP levels from the SDS testing were similar to ferric sulfate. Given the concerns over possible corrosion control issues with ferric chloride and the need to further assess optimal corrosion control treatment due to potential changes in CSMR, it is not recommended that ferric chloride be considered at this time.

Settled water turbidity was unacceptable with ferric sulfate coagulation and PAC addition. Currently, PAC is fed upstream of the rapid mix. PAC addition is in close proximity of the coagulant addition and floc formation is likely resulting in interference with PAC adsorption and/or with coagulant performance. SDS results indicated that low DBPs could be achieved without the use of PAC. Raw water TOC at the time of bench testing was approximately 10 mg/L. However, PAC may be useful for additional TOC removal during water quality excursions when raw water TOC values are higher (14-15 mg/L), or for taste and odor control when those episodes occur. We recommend that PAC feed point be relocated upstream to the reservoir pump station to provide additional contact time to enhance PAC effectiveness and to avoid interferences with ferric sulfate coagulation.

Bench testing also revealed that the potassium permanganate demand was much lower (0.2 mg/L) than the total amount of potassium permanganate being fed in the raw water and in the reservoir water (~2.9 mg/L). Settled water turbidity was poor in bench testing results with potassium permanganate added. We recommend that potassium permanganate be fed at the Lake Holt pump station and SGWASA cease feeding potassium permanganate in the reservoir water to avoid permanganate residual interfering with ferric sulfate coagulation.

Recommended treatment strategies determined from bench-scale testing require modifications to the existing chemical application points as shown in Figure 2-13.

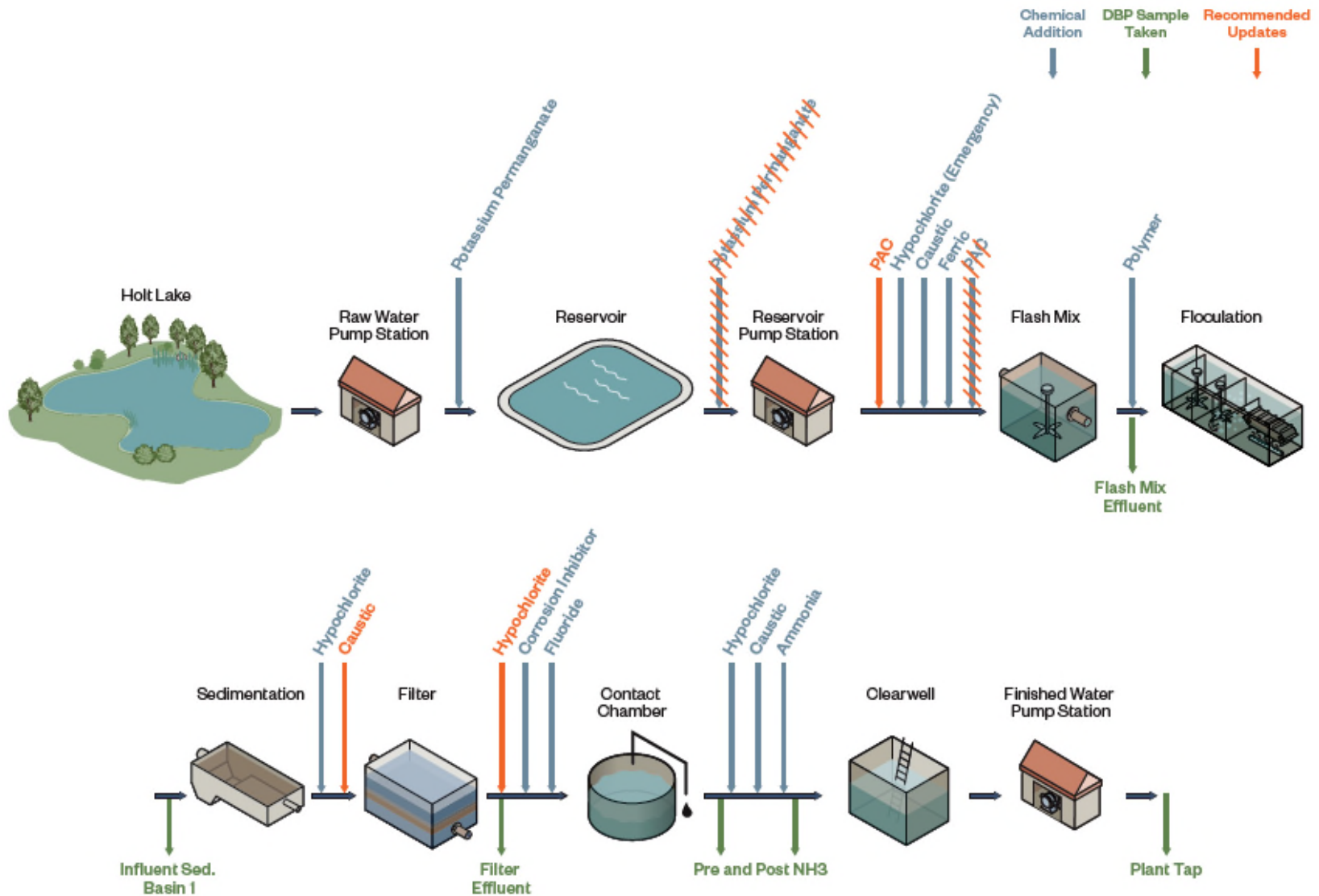


FIGURE 2-13: Recommended Modifications to Chemical Feed Points of Application

3. Chemical System Evaluation

Hazen evaluated several of the existing chemical systems at SGWASA’s WTP to determine their overall condition and capacities relative to the process changes to enhance DBP control. A summary of the existing systems and recommendations for improvements are included in this section.

3.1 Existing Chemical Facilities

The SGWASA WTP is provided with chemical storage and feed facilities as shown in Table 3-1.

Table 3-1: Existing Chemical Systems

Chemical	Purpose	Application Points
Potassium Permanganate	Removal of Iron and Manganese, Taste and Odor Compounds, and TOC	Raw Water Pump Station, Reservoir Pump Station
Powdered Activated Carbon	Removal of Taste and Odor Compounds, TOC	Flash Mix
Ferric Sulfate	Coagulation	Flash Mix
Coagulation-Aid Polymer	Coagulation	Pre-Flocculation
Sodium Hydroxide	pH Adjustment	Flash Mix, Pre-Filter, Pre-Clearwell
Sodium Hypochlorite	Disinfection	Pre-Filter, Pre-Chlorine Contact Chamber
Anhydrous Ammonia	Disinfection	Pre-Clearwell
Hydrofluosilicic Acid	Fluoridation	Pre-Clearwell
Polyphosphate	Corrosion Inhibition	Pre-Chlorine Contact Chamber
Sodium Metabisulfite	Dechlorination of Residuals	Residuals Decant

A process schematic for the SGWASA WTP, including existing points of chemical application and sampling points, is provided above in Figure 1-1. Information on the existing chemical storage and feed systems that was evaluated in this project is shown in Table 3-2.

Table 3-2: Chemical Systems Summary

Chemical	System Location	Storage and Feed Equipment
Potassium Permanganate	Lake Holt RWPS	One (1) 300-gallon HDPE storage tank with mixer One (1) 15-gph metering pump
	Reservoir RWPS	One (1) 250-gallon HDPE storage tank with mixer One (1) 15-gph solenoid metering pump
Powdered Activated Carbon	SGWASA WTP	One (1) 4,000-ft ³ silo One (1) 12.44 ft ³ /hr volumetric feeder One (1) 100-gallon mix tank with 1" water supply rotameter Two (2) 1" eductors with common 1" water supply rotameter
Ferric Sulfate	SGWASA WTP	One (1) 10,000-gallon FRP storage tank, originally designed for alum storage One (1) magnetic drive transfer pump One (1) 400-gallon HDPE day tank One (1) 44-gph peristaltic metering pump
Coagulation-Aid Polymer	SGWASA WTP	One (1) liquid polymer batch system Two (2) 150-gallon polymer solution mix tanks Four (4) 117-gph hydraulic diaphragm metering pumps
Sodium Hydroxide	SGWASA WTP	One (1) 10,000-gallon steel storage tank One (1) magnetic drive transfer pump One (1) 400-gallon HDPE day tank Two (2) 17-gph peristaltic metering pumps
Sodium Hypochlorite	SGWASA WTP	Two (2) 12,000-gallon FRP storage tanks One (2) magnetic drive transfer pumps Two (2) 200-gallon HDPE day tanks Two (2) 100-gph peristaltic metering pumps Five (5) 1.0-gpm rotameters for flow split to filters
Anhydrous Ammonia	SGWASA WTP	One (1) 560-gallon steel storage tank One (1) 500-ppd vacuum regulator Two (2) 500-ppd ammoniators with 100-ppd rotameters

3.2 Evaluation of Chemical Systems

Based on the results of the process optimization study and the evaluation of the condition of the existing chemical facilities, Hazen recommends improvements to several of the WTP's chemical systems. Recommended treatment strategies determined from bench-scale testing result in chemical doses shown in Table 3-3. Using these doses, equipment sizing has been determined for each of the chemicals. Bulk storage and day tank volumes are calculated based on average plant flow and maximum chemical dose, and metering pump capacities are evaluated for both rated capacity and maximum plant flow and for maximum chemical dose. A discussion of recommended improvements for each system is included below. Recommended improvements to existing chemical facilities to allow for monitoring and control of equipment are provided in Section 4 of this document.

Table 3-3: Recommended Chemical Doses and Feed Points

Chemical	Maximum Dose, mg/L	Average Dose, mg/L	Minimum Dose, mg/L
Potassium Permanganate Lake Holt only	1.0	0.2	0.1
Powdered Activated Carbon Reservoir Pump Station	40	Note 1	5
Ferric Sulfate	112	60	20
Coagulation-Aid Polymer	0.8	0.4	0.2
Sodium Hydroxide Rapid Mix	40	15	4
Pre-Filter	15	5	4
Pre-Clearwell	15	7	4
Sodium Hypochlorite ² Pre-Filter	17	6.9	2.3
Pre-Chlorine Contact Chamber	12	4.8	0.75
Pre-Clearwell	12	4.8	0.75
Anhydrous Ammonia ²	2.0	1.1	0

¹PAC to be fed intermittently as raw water quality TOC and T&O dictate

²Hypochlorite and ammonia doses from 2015 – 2017 plant data

3.2.1 Potassium Permanganate

Although storage and feed equipment is provided at both the Lake Holt Pump Station and Reservoir Pump Station, the process optimization study determined that feed should be discontinued at the reservoir. At the Lake Holt Pump Station, an average dose of 2.5 mg/L is currently fed. Hazen recommends a maximum dose of 1.0 mg/L, based on the permanganate demand of 0.2 mg/L during bench-scale testing, which results in a required metering pump capacity of 10 gph.

3.2.2 Powdered Activated Carbon

PAC is currently fed upstream of the rapid mix resulting in interferences with ferric sulfate. This feed location provides very little contact time before the addition of other treatment chemicals which interfere with adsorption of organic compounds onto the carbon. PAC is more effective and can be fed at lower doses when ample contact time is provided prior to the addition of interfering chemicals. Hazen recommends relocating the existing PAC application point to the raw water line just inside the fence around the plant to provide an additional 4.9 minutes of contact time at the average plant flow rate of 3 mgd. Although bench testing results showed good DBP results without the use of PAC, we recommend that the PAC system be upgraded and utilized to address water quality excursion such as taste and odor events and high raw water TOC.

At average plant flow and maximum PAC dose conditions, the existing silo provides well in excess of 30 days of storage. In addition, the existing volumetric feeder's capacity of 12 ft³/hr is more than adequate for the 5 ft³/hr required at rated plant capacity and maximum dose conditions. In addition, the 1-inch rotameters and eductors provided with the existing system are sufficiently sized for the recommended maximum feed rates. Due to the age of the equipment, however, replacement of the volumetric feeder, mix tank/mixer, rotameters and eductors, dust collector, and controls is advised.

3.2.3 Ferric Sulfate

When the SGWASA WTP converted its coagulant from aluminum sulfate to ferric sulfate (originally in October 2016 for few days, permanently in August 2017), the existing 10,000-gallon alum bulk storage tank and 400-gallon alum day tank were used for storage of ferric. The bulk tank, installed in 1993, was originally designed for alum, with a specific gravity of 1.3. Because the tank is now being used for ferric sulfate, with a specific gravity of nearly 1.6, the tank has been de-rated to safely hold the heavier chemical. The tank is located in a shared containment area with sodium hydroxide, which is considered an incompatible chemical.

At average plant flow and recommended maximum ferric dose conditions, approximately 14,000 gallons of ferric sulfate are required for 30-day storage, and approximately 500 gallons are required for 24-hour storage. A metering pump with a maximum feed rate of 49 gph is needed to meet peak flow and maximum dose conditions.

Hazen recommends construction of a new ferric sulfate containment area adjacent to the existing caustic/ferric containment area to separate incompatible chemicals. A new 14,000-gallon FRP tank specifically designed for ferric storage is recommended. Two new magnetic drive transfer pumps would be provided in the containment area for transfer to a new 500-gallon day tank located in a new chemical feed building housing day tanks and metering pumps for ferric, caustic, and hypochlorite. The new ferric bulk containment area and chemical feed building are shown in Figure 3-2. A 50-gph metering pump would be provided to serve as an installed spare to the relocated existing peristaltic pump.

3.2.4 Coagulant-Aid Polymer

Bench-scale testing determined that the liquid polymer currently being fed at the plant is significantly less effective at reducing settled water turbidity than Ashland 851TR polymer, which is available in dry form. Hazen recommends replacing the existing liquid chemical feed system with a dry polymer batching and feed system sized to provide the recommended doses. The new dry system would be located in the existing polymer feed area in the Rapid Mix/Chemical Feed Building. The existing hydraulic diaphragm metering pumps could be reused for feed of polymer solution.

3.2.5 Sodium Hydroxide

At average plant flow and recommended maximum dose conditions, approximately 20,000 gallons of caustic are required for 30-day storage, and approximately 700 gallons are required for 24-hour storage.

Metering pumps with maximum feed rates of 40 gph for rapid mix and 15 gph for pre-clearwell and pre-filter application points are needed to meet peak flow and maximum dose conditions.

Hazen recommends installation of a new caustic bulk storage tank in the existing caustic/ferric containment area to hold a new 10,000-gallon steel tank to provide the required storage. Two new magnetic drive transfer pumps would be provided in the containment area for transfer to a new 700-gallon day tank located in the new chemical feed building shown in Figure 3-2. The three existing metering pumps would be relocated to the new caustic feed area for feed to the filters, pre-clearwell and rapid mix, and a new pump would be provided to serve as a spare for all application points.

Pre-filter caustic feed is currently combined with sodium hypochlorite and carrying water to a rotameter panel where it is distributed to the five filters. Scaling potential is high with caustic given the high pH of the solution, and it increases with both chemicals conveyed in the same line. To reduce scaling potential and improve operator safety and WTP reliability, softened carrier water is recommended to reduce scaling potential and promote mixing. A rotameter panel would be provided in the filter area to split flow to the five filters.

3.2.6 Sodium Hypochlorite

At average plant flow and maximum dose conditions, approximately 26,000 gallons of sodium hypochlorite, diluted to 5% concentration, are required for 15-day storage, and approximately 1,800 gallons are required for 24-hour storage. Metering pumps with maximum feed rates of 75 gph are needed to meet peak flow and maximum dose conditions for pre-filter and chlorine contact chamber application points.

The two existing 12,000-gallon FRP hypochlorite bulk storage tanks installed in 2001 provide 34 days of storage at average plant flow and dose conditions. The existing bulk tanks provide sufficient storage; however, they have reached the end of their service life and will be replaced in the near future. The existing magnetic drive transfer pumps appear to be in good condition for continued use. A new 1,800-gallon day tank and metering pumps would be provided in the new chemical feed building shown in Figure 3-2. The two existing metering pumps would be relocated to the new hypochlorite feed area to serve as duty pumps for feed to the chlorine contact chamber application and pre-filter application points. Two new pumps would be installed to provide for a new feed point post-filter and to serve as an installed spare pump. The new post-filter application point would allow pre-filter chlorine dose to be decreased while providing sufficient chlorine residual to meet CT.

Pre-filter sodium hypochlorite feed is currently combined with caustic and carrying water to a rotameter panel where it is distributed to the five filters. Scaling potential is high with sodium hypochlorite given the higher pH, and it increases with both chemicals conveyed in the same line. To reduce scaling potential and improve operator safety and WTP reliability, we recommend pre-filter caustic and sodium hypochlorite feed be separated into individual feed lines. Softened carrier water is recommended to reduce scaling potential and promote mixing. A rotameter panel would be provided in the filter gallery to split flow to the five filters.

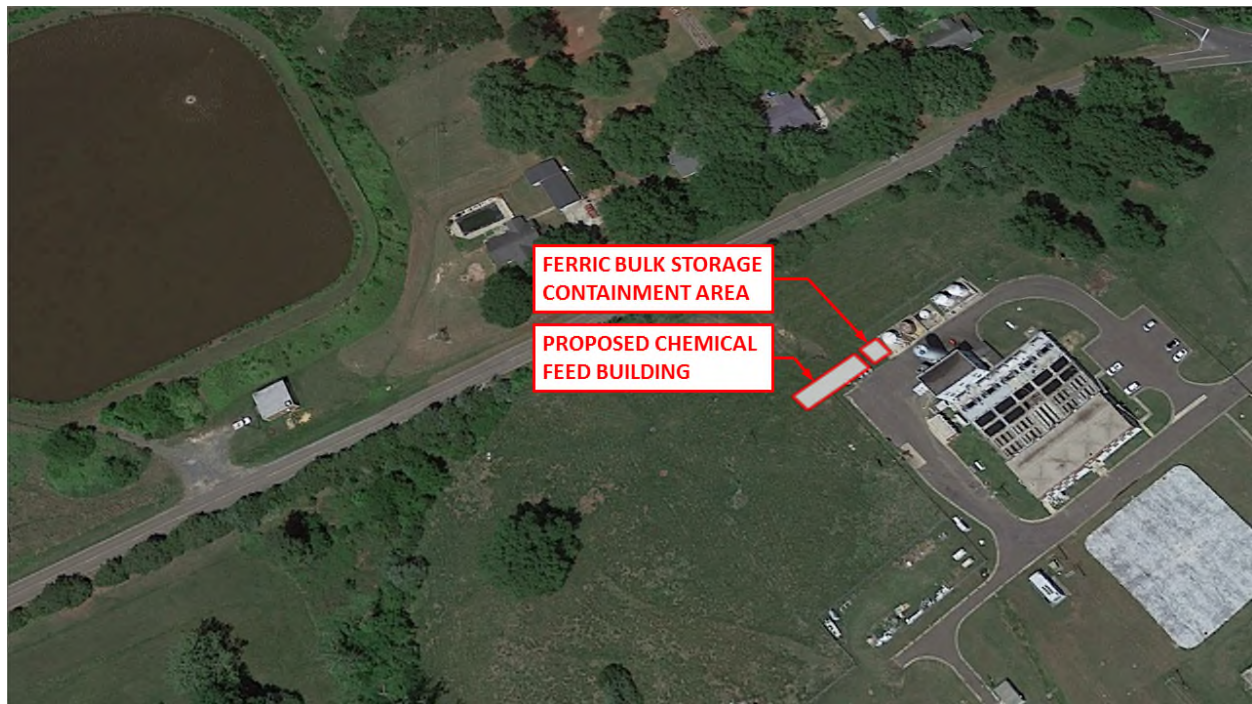


FIGURE 3-2: Proposed Chemical Facilities

3.2.7 Anhydrous Ammonia

At average plant flow and maximum dose conditions, approximately 1,500 pounds of anhydrous ammonia are required for 30-day storage. Vacuum regulators and ammonia feeders with a capacity of 124 pounds per day are needed to meet peak flow and maximum dose conditions and 73 pounds per day at maximum flow and dose conditions.

The existing 560-gallon steel anhydrous ammonia storage tank provides more than 30 days of storage at average plant flow and maximum dose conditions; therefore, Hazen recommends continuing to use the existing bulk tank. The existing vacuum regulator and injectors are rated for 100 pounds per day and are considered adequate for continued use; however, new automatically controlled ammoniators are recommended to enhance control of ammonia addition and monochloramine formation.

4. SCADA System Evaluation

The purpose of this evaluation is to assess the existing monitoring and control system, and determine the level of monitoring and control needed to provide reliable operations. The goal is enhance the tools available to operators to monitor and track WTP performance, quickly make process decisions, and ensure compliance with all regulatory standards, particularly DBPs.

4.1 Existing Instrumentation and Controls

Hazen staff visited the plant on two occasions (September 6 and November 1, 2017) to review existing operations and assess existing instrumentation, monitoring, and control features. At the time, the plant's SCADA workstation was not functional. The plant's existing instrumentation and controls also are largely not functional. Certain field instruments are not operational, and others provide suspect readings. Plant staff has performed with minimal instrumentation and automation, largely operating the plant and its processes manually.

The plant SCADA system consists of a single PC that, as noted, was not operational. The HMI software is not known at this time. Each of the filter consoles is equipped with an Koyo Direct Logic PLC. Although inexpensive, these PLCs are not widely used in the water industry. The automatic filter backwash strategies are not operating, and operators must backwash the filters manually, a task that requires a number of trips up and down the stairs between the filter gallery and the pipe gallery below.

Chlorine feed is adjusted manually using rotameters and needle valves. All other chemical feeds are also manually adjusted. Solids withdrawal from the sedimentation basins is also manually performed.

4.2 Butner WWTP Control System

Hazen staff was invited to visit the Butner WWTP by SGWASA staff as it has a recently installed plant control system that SGWASA has found to be satisfactory and would like to consider for the WTP. There are numerous advantages to installing a control system at the WTP that is as similar as possible to the one at the WWTP, including:

1. Staff familiarity with the hardware and software used.
2. Commonality of spare parts.
3. Common training requirements.
4. The same sources of service and support may be used.
5. The system is non-proprietary, allowing SGWASA choices in service and support.

The WWTP's existing system is similar to the systems that Hazen typically specifies and was installed by ForTech, Inc. The basic components are described briefly below.

Rockwell Automation's FactoryTalk View SE Human-Machine Interface (HMI) software is used to provide operator interface functions. The HMI software runs on redundant SCADA servers to allow for continuous operation in the event of hardware or software failure on the primary server. The servers are

located in the Administration Building. A Network Attached Storage (NAS) device is installed in the Administration Building for data archival.

Historical data storage and reporting is provided by Rockwell Automation's FT Historian software and Sytech, Inc.'s XLR Suite, respectively. Remote alarm dialing is performed by WIN-911 Pro software by Specter Instruments, and is set up for redundancy on the redundant SCADA servers.

Local process control is provided by Allen-Bradley (Rockwell) CompactLogix Programmable Logic Controllers (PLCs). As is common in most systems, the PLCs are not redundant. Networked remote input/output (I/O) assemblies are installed in locations that do not require a central processor. Operator interface terminals (OITs) are placed at locations within the plant that have a PLC.

An Ethernet communication network using fiber optic cable provides for communication among the various devices within the plant. The network is arranged in a star topology, or layout, using a combination of managed and unmanaged industrial grade Hirschmann Ethernet switches. A main, managed central switch is located in the Administration Building.

HMI graphics are typical three-dimensional displays with a plant overview that allows access to more detailed unit process displays. A menu of displays is furnished across the bottom of each screen.

4.3 SGWASA WTP Control System Recommendations

As noted above, Hazen believes that the type of control system currently installed at the Butner WWTP would be appropriate for the SGWASA WTP, and provides the advantages of having similar systems within the utility as described above. Specific recommendations for the WTP SCADA system are described below.

4.3.1 Hardware and Software Recommendations

Redundant SCADA servers running Rockwell FactoryTalk View SE HMI and Historian SE are recommended to be installed in the plant's existing control room. At this facility, mini tower PCs are recommended as opposed to rack-mounted blade servers because there is no acceptable location to place the rack, and their larger computing power and storage are not required for this application.

It is recommended that the plant consider situational awareness (SA) or high-performance HMI (HPHMI) graphics in lieu of the three-dimensional graphics used at the WWTP. These types of graphics reflect the most recent thinking in the field of operator interface and have migrated from areas such as aviation and the process industries to the water industry in the past few years. These graphical techniques seek to enhance operator situational awareness by providing plant data in a more intuitive context so that the status and health of the processes and equipment may be determined more-or-less at a glance. Abnormal or alarm conditions stand out and allow further investigation. Hazen has successfully implemented these graphical standards at Durham's water reclamation facilities, among others. If so desired, this recommendation may be further discussed during the detailed phase.

Non-redundant Allen-Bradley CompactLogix PLCs are recommended to be installed for local monitoring and control functions. These units should replace the existing Koyo PLCs in the filter consoles. A small operator interface unit (OIU) is recommended to be placed in each filter console to replace the obsolete filter rate and backwash rate controllers. A separate, central CompactLogix PLC located in the new chemical building is recommended to monitor and control the remaining plant processes.

An Ethernet network is recommended for communication among the HMI computers and the PLCs, using fiber optic cable and Hirschmann managed switches as used at the WWTP. Fiber optic cable is completely immune to electromagnetic interference and thus will protect the connected devices during lightning storms and power surges. All devices should be powered by uninterruptible power supplies for “clean” power and to allow the control system to operate through brownouts and short-term power loss.

4.3.2 Control Strategies

All chemical feed control is recommended to be flow paced. Chemical feed equipment is either already able to receive a flow pacing signal or is recommended to be replaced with units that can under the preceding sections of this report.

As noted above, the filters were designed originally to be automatically controlled for flow rate and backwash sequence. It is recommended that the controls be upgraded to restore automated operation. It is further recommended that the existing valve actuators be checked for proper operation.

It is recommended that solids handling (currently a manual operation) be automated.

4.3.3 Field Instruments

The field instruments necessary to support the process monitoring and control functions described herein are listed below:

1. Raw water flow meter – replace existing meter with magnetic flow meter for enhanced flow measurement accuracy
2. Residual chlorine analyzers – two free chlorine, one combined chlorine, and one monochloramine for enhanced monitoring and control over chlorine and ammonia addition
3. pH analyzers – one each for raw water, post chem, combined filter, finished water for enhanced monitoring and operational control
4. Ultrasonic level transmitters – one master level controller and one in each chemical tank
5. Radar level transmitter – one in ammonia tank
6. Rotameters – install ten new meters to control hypochlorite and caustic feed in the filter influent.
7. Filter flow meters – replace five existing venturis with new units, including new differential pressure transmitters

8. Turbidity analyzers – reuse existing filter turbidimeters; add one new submersible unit in settled water channel

5. Summary and Recommendations

5.1 Summary

The SGWASA WTP was constructed in the 1940's and operated by the State of North Carolina until formation of SGWASA in 2006. The WTP is an aging facility (nearly 80 years old) and is in need of rehabilitation and upgrades to ensure sustainable and reliable performance. Whereas assessing the condition of the entire WTP is not within the scope of this project, it is recommended that SGWASA develop a master plan to determine needed improvements to enhance condition and improve treatment facilities to current industry standards. Many systems at this facility appear to have reached the end of their service life and in need of replacement or major rehabilitation.

The WTP lacks process monitoring and control systems that meet current industry standards. WTP operations staff operate the facility in a completely manual mode. This presents several challenges for operating the treatment process optimally to maintain high level of water quality and ensure compliance with all regulatory standards, particularly with a conventional treatment process.

5.2 Recommendations for DBP Compliance

Based on recent DBP sampling, the conversion to ferric sulfate coagulation is enhancing removal of DBP precursors. The 4th quarter DBP compliance samples indicate that ferric sulfate coagulation and other refinements are successful in reducing DBP formation in the WTP. TTHM levels averaged 20 ppb amongst the monitoring sites whereas HAA5 levels averaged 17 ppb amongst the sites. With these results, SGWASA is currently in compliance with the Stage 2 DBPR.

To ensure reliable WTP performance and maintain compliance with the Stage 2 DBPR, Hazen recommends the following modifications at the SGWASA WTP:

1. Continue to use ferric sulfate as the primary coagulant permanently.
2. Provide sufficient alkalinity needed for ferric sulfate coagulation to ensure coagulation pH is in the 5.5 to 5.7 range.
3. The condition of the sedimentation basins should be assessed given their age to confirm if repairs or a coating is required to ensure reliable service operating at a low coagulation pH range.
4. Discontinue potassium permanganate addition at the reservoir pump station due to expected impacts on coagulation performance at the recommended coagulation pH.
5. Use Ashland 851TR coagulant aid polymer to enhance turbidity removal. A new dry polymer batching and feed system is required.

6. Continue to feed potassium permanganate for pre-oxidation at the Lake Holt Pump Station.
7. Provide a PAC feed point upstream of the rapid mix (just within the WTP site fence line) to provide additional contact time and avoid interferences with coagulant and polymer addition at the WTP. Upgrade the existing PAC feed equipment to provide for reliable operation.
8. Construct a new ferric sulfate containment area to separate incompatible chemicals. Install a new 14,000-gallon FRP tank specifically designed for ferric storage with two transfer pumps.
9. Install an additional caustic bulk storage tank in the caustic containment area to provide required storage and two transfer pumps.
10. Construct a new chemical feed building to house day tanks and metering pumps for ferric, caustic, and hypochlorite. The new facility will include appropriately sized day tanks and metering pumps, and provide needed redundancy to ensure reliable operation. All existing ferric, caustic, and hypochlorite metering pumps will be relocated to the new building.
11. Install a new ferric metering pump to serve as a spare pump.
12. Install a new caustic metering pump to serve as a spare for all application points.
13. Provide a new sodium hypochlorite metering pump and feed point post-filter so sodium hypochlorite dose can be increased before chlorine contact to ensure CT compliance while keeping pre-filter sodium hypochlorite doses low to limit DBP formation.
14. Provide a new sodium hypochlorite metering pump to serve as an installed spare pump.
15. Provide separate pre-filter caustic and hypochlorite feed lines with a separate rotameter panels to distribute feed to the five filters.
16. Provide a softening system for motive water for caustic and sodium hypochlorite feed.
17. Install new automatically controlled ammoniators to enhance control of ammonia addition and monochloramine formation.
18. Conduct a corrosion control study to assess whether the WTP is providing optimal corrosion control treatment with the change to ferric sulfate as primary coagulant.
19. Upgrade instrumentation, and control systems to enhance process monitoring, and control to provide for more consistent and reliable WTP operation and performance.
20. Make necessary modification needed to manage solids levels in the sedimentation basins (recommendations will be provided in separate report).

5.3 Estimated Implementation Costs

Table 5-1 provides conceptual level capital costs for the recommended improvements. The total project cost for the recommended improvements is approximately \$3.3 million.

Table 5-1: Estimated Costs for Improvements

Item	Cost
Earthwork/Grading	\$ 39,500
Structural/Architectural	\$ 346,000
Plumbing	\$ 51,900
Process Mechanical	\$ 671,700
Electrical and Instrumentation	\$ 735,000
Subtotal Construction	\$ 1,844,100
Contingency (30%)	\$ 553,200
Subtotal with Contingency	\$ 2,397,300
Contractor O&P (15%)	\$ 359,600
Subtotal with Contingency and Contractor O&P	\$ 2,756,900
Engineering	\$ 496,200
TOTAL	\$ 3,253,100