City of Tampa
Jane Castor, Mayor

Contract Administration
Richard Mutterback, Director
306 East Jackson Street, 4N
Tampa, FL 33602

Office (813) 274-8116
Fax: (813) 274-7368

ADDENDUM 1
DATE: March 02, 2026

Contract: 26-D-00019 Water Production Master Plan

Submitters on the above referenced project are hereby notified that the following addendum is made to the RFQ. Any submissions shall conform to this notice.

Item 1 - Attached is a copy of the Pre-Submission meeting Sign-In sheet. Attendance was not mandatory.

Item 2 - Attached are reports regarding the City's S.I.X. program for reference purposes.

All other provisions of this RFQ not in conflict with this Addendum shall remain in full force and effect. Questions are to be e-mailed to ContractAdministration@tampagov.net.

Jim Greiner

Jim Greiner, P.E., Contract Management Supervisor

26-D-00019 Water Production Master Plan

3 PM Pre-Submission Conference 2-23-26

Sign-In Sheet Please Print City of Tampa, Contract Administration Department

	Name	Organization	E-Mail
1	Jim Greiner, PE	Tampa Contract Administration Dept.	Jim.Greiner@tampagov.net
2	JILLIAN HOWARD	CAD	JILLIAN.HOWARD@TAMPAGOV.NET
3	Crickett Luu	Water Dept.	Crickett.Luu@TAMPAGOV.NET
4	Sarah Burns	Water Dept	Sarah.burns@tampagov.net
5	Jorge Atoche	JACOBS	jorge.atoche@jacobs.com
6	Vincent Hart	Carollo	vhart@carollo.com
7	Rebecca Oliva	BV	OlivaR@bv.com
8	Tricia Shuler	Jacobs	tricia.shuler@jacobs.com
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FINAL

DLTWTF SUSPENDED ION EXCHANGE (SIX®) TREATMENT PROCESS - INDEPENDENT REVIEW

Technical Memorandum

BLACK & VEATCH PROJECT NO. 420157
CITY WORK ORDER NO. 26

PREPARED FOR

City of Tampa, FL

22 SEPTEMBER 2025

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Executive Summary

The City of Tampa (City) owns and operates the David L. Tippin Water Treatment Facility (DLTWTF), which provides drinking water supply for the Tampa community. The City is currently implementing a DLTWTF Master Plan Expansion Project to increase the facility's maximum day treatment capacity of surface water supply from the Hillsborough River from 120 million gallons per day (mgd) to 140 mgd. The addition of a suspended ion exchange (SIX®) treatment process at DLTWTF is being considered as part of the expansion project. The addition of the SIX® process would support the facility capacity expansion along with the removal of suspended ion exchange (SIX®) to help achieve the City's goal of < 2.0 mg/L TOC in the finished water.

A SIX® pilot testing study was initially completed in 2022 to evaluate the treatment performance and benefits of adding the SIX® process at DLTWTF. The SIX® pilot study for DLTWTF was conducted by the Tippin Water Team (TWT), which consists of a Garney/Wharton-Smith Joint Venture with Carollo Engineers, Inc. as the lead design engineer. The results of the pilot study were summarized in the City of Tampa DLTWTF Expansion Project SIX® Pilot Report (February 2022; referred to as SIX® Pilot Report).

The City engaged Black & Veatch (a global engineering firm specializing in water treatment plants and treatment technologies) to perform an independent review of the SIX® Pilot Report and related reference documents. This review aims to assist the City in confirming the feasibility of implementing SIX® at DLTWTF. The purpose is to ensure that key considerations and assumptions have been thoroughly evaluated and to provide an additional perspective on the conclusions drawn regarding the addition of SIX® as a pretreatment process at DLTWTF. Benefits, risks, recommendations, and/or possible mitigations are identified throughout this Technical Memorandum and are summarized in a risks and benefits register (Appendix A).

Based on Black & Veatch's experience and the review of the SIX® Pilot Report, the pilot testing study appears to have been performed in a manner consistent with typical industry testing and verification procedures. The pilot study results indicate that the addition of SIX® would support the City's goals for improving finished water quality along with increasing the efficiency of downstream treatment processes at DLTWTF. Black & Veatch agrees that the addition of SIX® as a pre-treatment process at DLTWTF would enable the City to reduce the size and costs of the other planned DLTWTF expansion infrastructure needed to meet the 140 mgd capacity target and enable the City to meet the < 2.0 mg/L TOC goal.

Review of the Benefits of Adding the SIX® Process

The pilot testing and other evaluations completed to date indicate that the City should anticipate the following treatment performance, finished water quality, and operational efficiency benefits with the addition of the SIX® process at DLTWTF:

1. Improved drinking water quality in terms of achieving lower organic content as well as lower amounts of the regulated byproducts of disinfection.
2. Lower chemical use and costs:
    a. 59 to 79 percent lower coagulant chemical dose needed for effective coagulation;
    b. The ability to eliminate two chemical feed systems (sulfuric acid and lime);
    c. 30 percent lower disinfection dose (for ozone, and thus lower power use);
3. Increased productivity of downstream treatment processes:

a. Increased filtration productivity when compared to existing full-scale filters requiring fewer additional filters to meet the target capacity;

b. Lower quantity of solids produced by coagulation, which would likely result in the City not needing to expand solids dewatering capacity as originally planned;

4. Operational flexibility:

a. The ability to change disinfection chemicals when challenging filtration conditions occur.

b. The capability to treat water when organic content is seasonally high.

Based on a review of the pilot study report, Black & Veatch has a high level of confidence that these benefits could be realized with the installation of the SIX® process at DLTWTF.

Review of Budgetary Cost Estimates

The methodology that the pilot study team followed to develop budgetary capital and annual operation and maintenance (O&M) cost information followed standard cost estimating procedures consistent with the planning level information available at this stage of project development. To date, the development and evaluation of O&M costs by the TWT have included chemical, sludge, and power costs. Future cost estimates from the TWT are anticipated to include more detailed capital and O&M costs and considerations, such as system refurbishment and replacement costs anticipated over the infrastructure service life, resources used for the resin regeneration and brine disposal systems, and impacts to the overall DLTWTF O&M labor efforts and costs.

Capital Cost Estimate:

The table below summarizes Black & Veatch's understanding of the current budgetary capital cost associated the addition of a 140 mgd capacity SIX® pretreatment system at DLTWTF. This value is in line with budgetary cost opinions that Black & Veatch has developed for the addition of a SIX® pretreatment system and required ancillary components at similar size and type surface water treatment facilities.

Budgetary Capital Cost Item	Budgetary Estimate*
SIX® Pretreatment System - 140 mgd Capacity *(from December 2020 values in pilot testing report)*	$96,400,000
Escalation of SIX® Pretreatment System Costs to Current Values *(35% inflation from December 2020 to February 2025)***	$33,800,000
Additional Ancillary Systems Required: - Deep Injection Wells (3) System *(February 2025 costs)* - Corrosion Inhibitor System *(February 2025 costs)*	 $47,000,000 $300,000
Total Budgetary Capital Cost Estimate (February 2025 dollars)	**$177,500,000**

* Note: The budgetary estimates are considered to be an AACE Class 4 Cost Estimate (accuracy range of - 30% to + 50%).

** Note: A 35% escalation factor was assumed by Black & Veatch based on an 8.5% inflation rate from 2021, 2022 and 2023, and a 5% inflation rate in 2024.

The review of the budgetary capital cost estimate described above does not include the costs associated with the other process improvements the City is proposing to incorporate as part of the DLTWTF expansion from 120 mgd to 140 mgd. However, it is understood that the addition of SIX® would support reductions in the size or number of conventional treatment process units being considered to achieve the 20 mgd capacity expansion at DLTWTF. The pilot study team appears to have estimated a reduction of approximately $60,000,000 in capital costs (in December 2020) for the DLTWTF capacity expansion project if a SIX® pretreatment system is added. Escalating this estimated capital cost reduction value to current economic conditions would represent an approximately $80,000,000 capital cost savings. The cost analyses regarding budgetary capital cost impacts appear to be appropriate based on this stage of the project planning efforts. It is recommended that these budgetary capital cost assessments be updated as the TWT proceeds with design and more detailed information is developed.

Annual Operating Cost Estimate:
Black & Veatch also reviewed the available information regarding the estimated annual operating costs and savings associated with operating a SIX® pretreatment system at DLTWTF. The review of the cost analysis in the SIX® pilot report indicates that the annual operational cost savings related to reducing chemical use after implementing the SIX® process is estimated to be approximately $1,500,000/year (in 2021 dollars), which could be escalated to an annual savings of approximately $2,000,000/year in current dollars (using an approximate 35% escalation from January 2021 to February 2025). Impacts to the overall power costs for the DLTWTF if a SIX® pre-treatment system is added are anticipated to be minimal. Black & Veatch's review of the pilot testing results indicates that the estimated operational cost savings are reasonable and consistent with expectations based on our industry experience with operational costs associated with facilities that use similar treatment processes and chemicals. It is recommended that all anticipated O&M cost impacts, including but not limited to chemicals, power, labor, sludge handling, and waste brine disposal be further defined and evaluated by TWT as part of the next phases of project development and design.

Assessment of Risks and Associated Risk Mitigation and Management Strategies

Making treatment process improvements at an existing water facility always involves some risks. Black & Veatch independently completed a risk assessment of the concept of adding the SIX® process at DLTWTF to identify key risks. Black & Veatch also reviewed the pilot study report and other information provided by the City to assess if and how each of the risks are being mitigated or managed. A summary of some of the key risks that were identified and evaluated is provided below.

1. Potential for uncertainties in performance due to SIX® being a less established treatment technology compared to conventional processes. The City and TWT have focused a lot of efforts to date to mitigate and manage this risk, as noted below:
   a. Significant pilot testing efforts have been completed to evaluate the performance of SIX® as a pretreatment process at DLTWTF. The results of the pilot testing indicate a high likelihood of achieving the key water treatment performance benefits and the City's goals for improving finished water quality.
   b. The City has proposed the use of performance guarantees from the supplier of the SIX® technology and equipment to provide additional assurances related to achieving the expected performance and efficiency during the operations phase (e.g., capacity, power use, potential resin loss, chemical use, etc.).
2. Risks of variance from the current capital and operations cost estimates based on the current planning level stage of the SIX® improvement project and significant fluctuations and inflation in costs that have been occurring in the construction market over the past five years.
   a. While Black & Veatch's review of the estimated budgetary capital and annual operating cost information from the pilot study report indicate that the values appear to be consistent with expectations based on the current level of project development, it is

recommended that the City and TWT continue to further refine the cost estimates as the project advances into the preliminary and detailed design phases.

b. The proposed use of the progressive design-build delivery method should provide the City with more cost certainty earlier in the design phase (compared to using a traditional design-bid-build method) and also improve the value engineering process during the design phase.

c. Further assessment may determine the ability to optimize the size and capacity of the SIX® system and associated deep injection well system to support reducing the capital costs without significant impacts to the reliability and benefits provided from the SIX® treatment process.

Based on the review of the pilot study results and additional information gathered as part of the independent review performed by Black & Veatch, it appears that the City and TWT have done a diligent job of proactively identifying risks and have either completed or are continuing with efforts to mitigate and manage the potential risks associated with the addition of the SIX® process at DLTWTF.

Conclusion and Recommendations

The addition of SIX® as a pretreatment process at the DLTWTF presents advantages in water quality and operational efficiency, aligning with the City's long-term treatment and expansion goals, including achieving a finished water quality of TOC < 2.0 mg/L. The multi-year history of the City and TWT evaluating and piloting this option, coupled with the results of Black & Veatch's independent review, indicate that there is a high probability in achieving the target treatment performance, finished water quality, and operational efficiency benefits that the City would expect if the SIX® process is added at DLTWTF. Furthermore, this independent review provides an additional opinion that SIX® is an appropriate solution for the DLTWTF based on the City's key goals for achieving enhanced finished water quality and supporting the current 20 mgd treatment capacity expansion project.

If the City continues to move forward with plans to incorporate the SIX® process at DLTWTF, it is recommended that the City continue with its efforts to refine design details, along with updating cost estimates and risk mitigation plans to support informed decision making at the key decision milestones as the preliminary and detailed design phases progress.

1.0 SIX® Project Introduction

As part of the master plan for the DLTWTF, the City identified ion exchange as a promising technology for supporting the City's goals of increasing DLTWTF capacity, improving water quality, and optimizing both capital and O&M costs. From November 2020 through October 2021, a 50 gallon per minute (gpm) pilot plant was operated to evaluate adding SIX® as a pretreatment process at the existing DLTWTF. This study was conducted by the TWT, consisting of Garney/Wharton-Smith Joint Venture with Carollo as the Lead Engineer. The findings were documented in the SIX® Pilot Report dated February 2022 (Carollo Engineers, Inc.).

1.1 Background

The pilot study aimed to represent a possible future, upgraded treatment train with SIX® to aid in the removal of organics from the source water. Additional organics removal not only improves water quality, but also improves the efficiency of downstream treatment processes, and reduces the expansion infrastructure needs of conventional treatment processes. The existing DLTWTF, the SIX®, and the pilot treatment train are described herein.

1.1.1 Description of Existing DLTWTF

Currently, DLTWTF is a surface water treatment plant that produces an average of 77.1 mgd of potable water, serving a population of 739,910 across 142,393 service locations. The primary water source for DLTWTF is the Hillsborough River, with the Tampa Bypass Canal Middle Pool as a secondary source. The facility also utilizes an aquifer storage and recovery (ASR) system to store treated water during high river flow periods and recover it during low flow periods.

The existing DLTWTF treatment process includes coagulation, flocculation, sedimentation, ozonation, biofiltration, and disinfection. Water from the Hillsborough River is initially screened to remove debris and then pumped to four conventional treatment trains (Trains 5 through 8) for coagulation, flocculation, and sedimentation, handling 70 to 80 percent of the plant flow. The remaining flow is treated using Actiflo® in Trains 1 and 2. Both systems use ferric sulfate as a coagulant and sulfuric acid for pH adjustment. After sedimentation, lime and caustic soda are added for further pH and alkalinity adjustment before ozonation for primary disinfection. The water then undergoes biological activated filtration (BAF) using sand and granular activated carbon (GAC) media, followed by chloramine formation for secondary disinfection. The treated water is stored in clearwells before distribution. Sludge and filter washwater are thickened on-site, the supernatant and belt press filtrate are recycled back to the head of the plant, and thickened residuals are sent off-site for further processing and dewatering.

During the development of the master plan in 2018, Black & Veatch, as part of the Transmission and Distribution System Master Plan for the City, determined that the DLTWTF will need to meet a maximum day demand of 134 mgd by 2032. This day demand indicated the necessity to expand the DLTWTF's process capacity to 140 mgd (i.e., raw water flow) in the near future to accommodate both consumer and in-plant water demands. The TWT and Jacobs are currently constructing upgrades to the DLTWTF to increase the capacity from 120 mgd to 140 mgd. The expansion includes the following: High Service Pump Station (HSPS) Upgrades and Expansion, Intake Improvements and Raw Water Pump Station Upgrades, Ozone Improvements, Chemical Systems Improvements, Sitewide Electrical Improvements, and Filter Improvements. If SIX® is added, it will be located downstream of raw water screening and upstream of coagulation with a proposed process (i.e., raw water flow) capacity of 140 mgd.

1.1.2 Description of SIX®

The SIX® process was developed by equipment vendor PWNT in the Netherlands (and the information presented in this section is courtesy of PWNT) to treat surface waters with anion exchange for TOC removal. For projects in North America, all PWNT technology will be manufactured at the Nijhuis Americas headquarters in Knoxville, Tennessee. The technology design and implementation will be supported by the Americas team and the PWNT team.

Figure 1 shows a rendering of the process equipment, and Figure 2 and Figure 3 show the full-scale installation regeneration vessel and plate settlers, respectively, at the Andijk III water treatment plant which is owned and operated by PWN, the drinking water company in the North Holland province of the Netherlands.

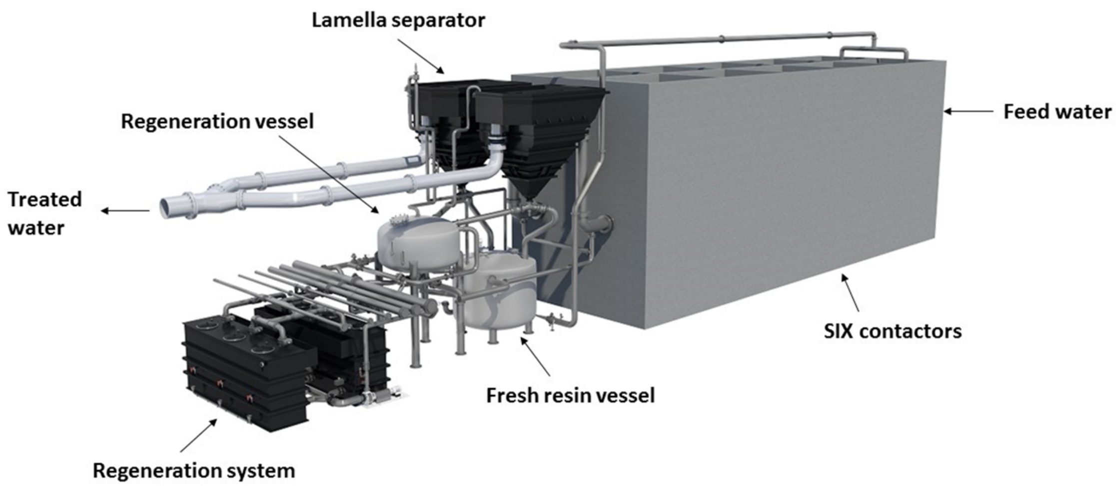

Figure 1 SIX® Process (includes contacting with air mixing, resin removal by Lamella plate settling, and resin regeneration)

Figure 2 **Full-Scale Installation Regeneration Vessel**

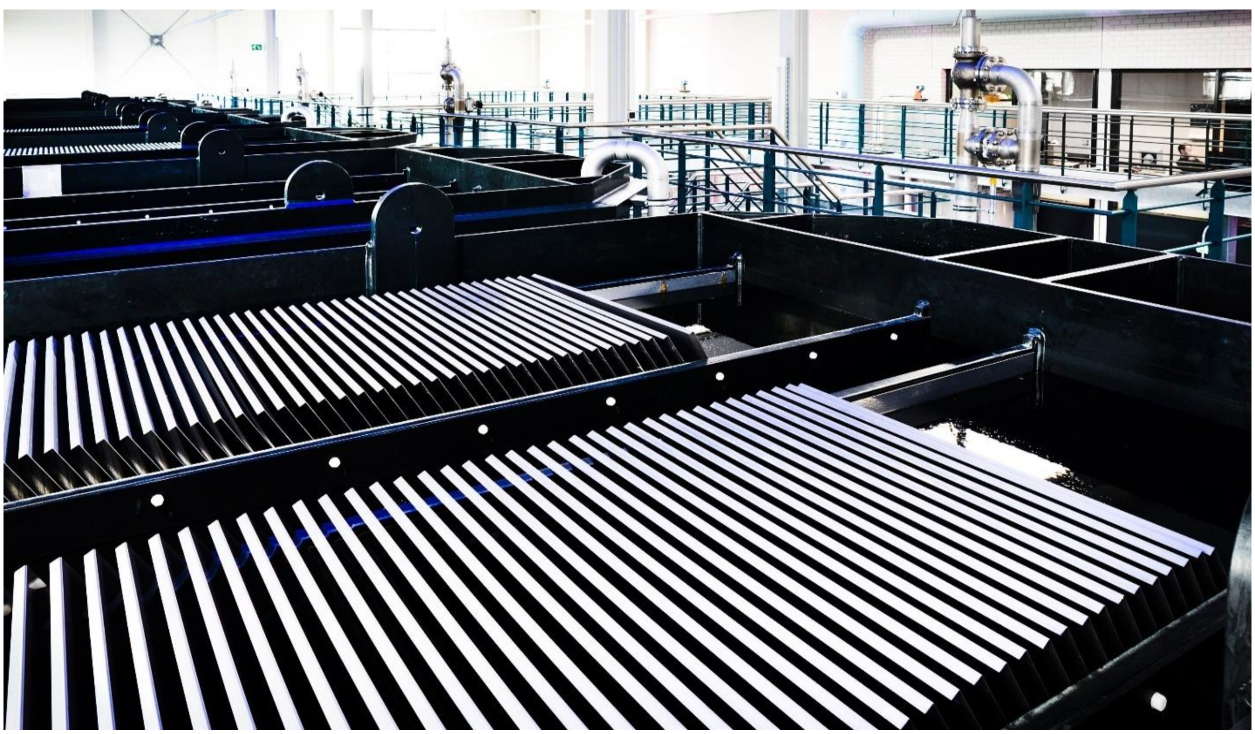

Figure 3 **Full-Scale Installation Lamella Plate Settlers**

The philosophy of the SIX® process is based on a plug flow reactor followed by a specially designed Lamella settler for sedimentation of resin. The settled resin is then completely regenerated and re-used. This continuous adsorption process has been modeled and operates under stable kinetics. A simplified process flow diagram is shown on Figure 4.

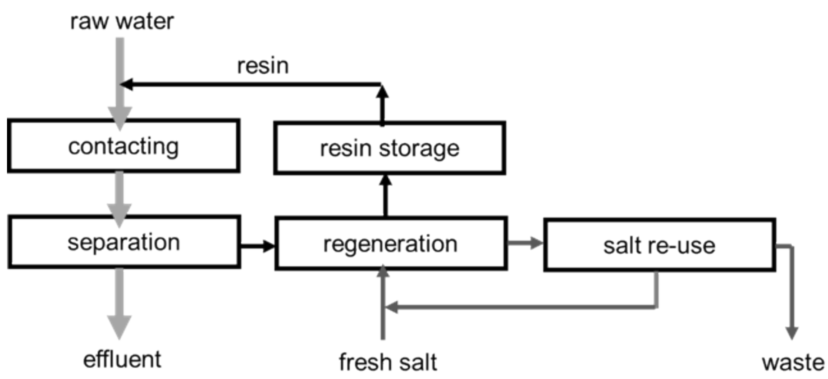

Figure 4 Process Flow Diagram for SIX®

1.1.2.1 SIX® Contactors

Water is delivered into the SIX® contactors, which are usually tall concrete tanks, with five compartments per contactor. The raw water is dosed with resin immediately upstream of the contactors via a resin dosing injector. Raw water (which is typically pre-screened to remove large debris), process water, or treated water are typically used as the resin carrier water through the resin dosing injector. It is advised to check with the resin supplier to determine if chlorinated or chloraminated treated water can be used as carrier water.

The amount of resin dosed per cubic meter (m^3) of raw water is a process variable that must be determined for a specific water to be treated, and this dose can be adjusted to treat the seasonal changes in source water quality. The resin dose is a function of the feedwater quality (e.g., dissolved organic carbon [DOC], as the target compound to be removed) and the desired SIX®-treated water quality (e.g., the DOC entering the downstream process).

Typically, bench-scale or pilot testing is performed to identify the required resin concentration and contact time. While in the contactors, the resin adsorbs the target compound from the water. In addition, other anions (e.g., bicarbonate, nitrate, sulphate) that are present in the feedwater are adsorbed, and the types of adsorbed ions depend on the resin being used.

Feedwater with the added resin passes through five mixed contactor chambers in series. Each of the contactors acts as a 100 percent mixed system. The total volume of the contactors is typically selected on the basis of the desired contact time (e.g., 30 minutes) between water and resin, at average or maximum capacity; thus the size of contactors varies for each project. The height of the contactors is also site-specific and depends on the overall plant hydraulics as well as SIX® process design requirements.

Mixing in each contactor chamber is by air, which enters the contactors via air distributors that are located at the bottom of each chamber. The air is brought into the system with an oil free blower or air compressor. The air feed system will operate continuously, provided that the treatment train is in operation.

The purpose of air mixing is two-tiered to:

- Optimize the contact between the water and resin for DOC absorption, and
- Keep the resin in suspension.

The performance of the resin for removing a target compound is monitored by on-line analyzers when possible, or by frequent manual samples. For example, for resins targeting the removal of DOC, removal is typically tracked by means of the ultraviolet (UV) transmission (at 254 nanometers) measurement in the treated flow. By comparing the UV transmission after the SIX® with the raw water UV transmission, the DOC removal efficiency can be estimated, because DOC and UV usually correlate well for individual source waters.

1.1.2.2 Lamella Separator

After the SIX® contactors, the resin is separated from the treated water by means of sedimentation in a Lamella separator. The water passes through the Lamella separator by gravity with no pumping. The water enters a Lamella separator, which contains a package of slanted, thin plates, from the side of the plate pack. The water flows up between the plates. This creates a minimum sedimentation level between the plates, and as a result, the resin quickly settles to the lower plate, and slides down the plate to the hopper (cone).

The size of the Lamella separator varies with each application, due to flow differences and production capacity flexibility preferences for each water plant.

A hopper is below the plate (Lamella) pack, and it collects the settled resin. The resin is periodically drained by gravity from the hoppers of the Lamella separators into the regeneration vessel that is situated below the Lamella separator hopper. The frequency of a resin discharge from the hopper is set in accordance with timing of resin use and the regeneration process. Note that the total hopper volume per train that is drained to the regeneration vessel is equal to the bed volume (BV) of the resin in the regeneration vessel. The BV is an important process parameter, because it dictates the regeneration frequency, and thus the regenerant (i.e., brine) use.

1.1.2.3 Regeneration System

After the resin passes through the SIX® contactors, many of the active exchange sites are occupied by adsorbed ions (e.g., DOC, sulphate, nitrate, phosphate). A regeneration procedure with brine, or regenerant (typically sodium chloride; NaCl, but for some resins, other regenerant solutions may be used, in accordance with resin manufacturer instructions) is passed through the resin to recondition the resin by removing the adsorbed ions. During this regeneration, the adsorbed ions are exchanged for chloride ions when using NaCl brine. Regeneration also removes all, or a portion of, bio-film that can develop if operating conditions allow for microbial growth during treatment.

In the SIX® process, after the resin is used in the contactors and passed through the Lamella separators, all of the resin is regenerated before returning to the system. This is referred to as a single pass system which provides the benefit of microbiological growth control continuously in batched regenerations. Resin is not retained in the contactors for extended time and does not build up biogrowth prior to regeneration.

The entire SIX® regeneration system includes the resin regeneration vessel, brine circulation pump and piping, five brine storage tanks, and a rinse tank. Four of the five brine storage tanks hold brine that has already passed through a previous resin bed. These four tanks are referred to as follows:

- 1st brine storage tank (holds brine that has been used in 4 previous regenerations; 4x used)
- 2nd brine storage tank (holds brine that has been used in 3 previous regenerations; 3x used)
- 3rd brine storage tank (holds brine that has been used in 2 previous regenerations; 2x used)
- 4th brine storage tank (holds brine that has been used in 1 previous regeneration; 1x used)

The 5th brine storage tank contains fresh brine solution. The 6th tank is the rinse tank, which captures the first rinse volume, and contains an elevated brine (i.e., salt or other) concentration, after regeneration. This volume is used in the next regeneration cycle to make up the new fresh brine solution. By using this volume, a reduction in the regenerant (e.g., salt) consumption is achieved.

The SIX® regeneration procedures include first transferring by gravity the exhausted resin from the hopper below the Lamella separator into the regeneration vessel. The interstitial water that is between the resin beads is drained from the resin bed. This drained water is SIX®-treated water and can be returned to the treatment process. Next, the brine solution from the 1st brine storage tank is pumped through the resin bed. The volume of this 1st brine storage tank, as well as the remaining brine storage tanks, is typically two-fifths of the regeneration tank BV.

Used brine solutions from the 2nd, 3rd, and 4th brine storage tanks are pumped sequentially to and through the resin bed. Then, the fresh brine solution is pumped through the resin bed, followed by the water in the rinse tank (which has the lowest salt concentration).

This sequence is sometimes then followed by additional BVs of ”sweet,” or fresh, water for extra rinsing. The use of extra rinsing is a variable that is determined based on the residual ion concentrations (e.g., sodium and chloride levels when salt is the brine) in the feedwater, and the allowable concentrations of these ions in the finished water. This fresh water for rinsing can be SIX® treated water or other process water (check with the resin supplier to determine if a chlorine or chloramine residual is allowed for the rinse water).

During this pumping of regenerant to the regeneration vessel, brine fluid begins to fill the voids between the resin beads, and then begins to exit the regeneration vessel. The first volume (e.g., generally two-fifths of a BV) after the initial drain of the SIX®-treated interstitial water, will be discharged to waste. This brine solution will have been used for five different regenerations. It contains significant concentrations of target ion or compound for removal, and possibly other ions that were removed from the feedwater.

Subsequent brine flow from the resin bed is transferred (under the available pump pressure) to the appropriate brine storage tank (e.g., the next brine fluid volume to be transferred would be delivered to the 1st brine storage tank because it was three times used and now four times used), the next to the 2nd brine storage tank, and so on.

The rinse water flow is initiated after the last brine regenerant from the rinse tank has been pumped to the resin. The rinse flow is fed from the top to the bottom. Sometimes the rinse is a limited amount (e.g., 2/5 BV) or in some applications, it is continued until the conductivity of the water leaving the resin bed meets a target value (e.g., the conductivity of the feedwater). The initial portion of rinse flow would contain a low concentration of the target ion or compound, and possibly other ions as the residual regenerant is flushed from the resin bed, and this initial portion of rinse is stored in the rinse tank. The rest of the rinse flow has lower concentrations of brine (e.g., salt) and target ions (e.g., DOC) and can sometimes be recycled within the water plant.

After regeneration and rinsing, the resin is drained by gravity to the fresh resin vessel. At the end of the resin drain, a small stream of process water (i.e., SIX® treated, process water, or treated water) is added to rinse any remaining resin from the regeneration vessel.

According to PWNT, the supplier of SIX® equipment, there are also design changes to improve the efficiency of the regeneration cycles. These changes involve the incorporation of a set of regeneration tanks to eliminate the fresh resin vessel. This new concept has not been installed in a full-scale plant, and this design can be considered for future plants. If this new design is implemented, it presents some risk associated with the new design concept.

1.1.2.4 Salt Concentration Correction

Concentrated brine is dosed between the regeneration vessel and 5th regenerant storage tank into the return line for filling 5th brine tank during a regeneration. This is the rinse water coming from the regeneration vessel to the fresh brine tank, and it is adjusted to the correct brine (e.g., salt) concentration. The dosage is controlled by measuring the conductivity after the injection point.

1.1.2.5 Fresh Resin Vessel and Resin Dosing

After the resin has been regenerated, it is drained by gravity to the fresh resin vessel and brought to a known resin concentration with process water. The resin is dosed from the fresh resin vessel to the SIX® inlet piping by means of the resin dosing system. The fresh resin vessel is mixed continuously via a mechanical mixer to prevent settling in the tank.

A pump combined with a resin dosing injector is used for resin dosing. Raw water (or process water, or treated water) flowing through the resin dosing injector at sufficient pressure creates vacuum in the injector, which draws resin into the flow stream. The feed pressure to the injector can be used to set the desired resin flow. The pressure of the resin transport pump is controlled by a frequency controller. The resin flow is measured by comparing the flow before and after the injector.

The amount of resin to be dosed is based on the feedwater quality and the desired quality of the SIX®-treated water. At times when less resin is dosed, it is stored in the fresh resin tank. During this time, the frequency of regeneration is less. The regeneration frequency also depends on the feed flow.

1.1.3 Description of the Pilot Treatment Train

The pilot plant process flow diagram is shown on Figure 5. Modular or skid units were provided for each process.

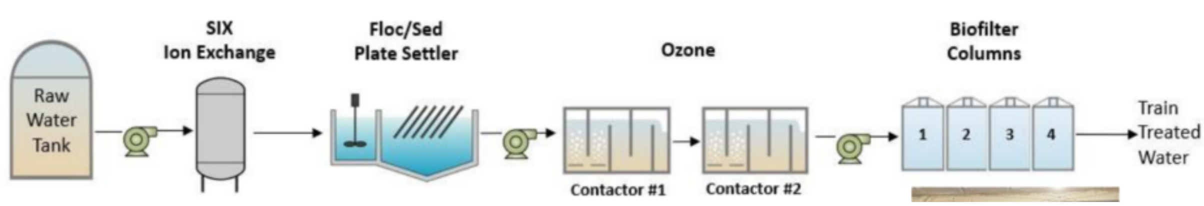

Figure 5 **Process Flow Diagram of the Pilot Treatment Train**
(*from CoT DLTWTF Expansion Project_SIX® Presentation to Veolia 2023-06-15*)

Raw water was pumped to the influent water tank of the SIX® pilot plant. From there, it was pumped through the SIX® process unit and flowed by gravity to a flocculation/sedimentation pilot unit where coagulation chemicals were added. The clarified water was then pumped to the ozone skid. Ozonated water was pumped to each filter by its influent pump on the biofiltration skid, testing four different filter media configurations:

- The first filter media configuration mimicked full-scale operations.
- The second and third filter media configurations reflected potential new full-scale designs based on hydraulic availability after the post-clearwell project.
- The fourth filter media configuration maximized existing filter box dimensions, potentially raising filter troughs to improve loading rates or unit filter run volumes (UFRVs).

1.2 Independent Review Purpose and Aspects

The City has engaged Black & Veatch to provide an independent review of the SIX® Pilot Report and related reference documents. This review aims to assist the City in confirming the feasibility of implementing SIX® at DLTWTF. The purpose is to ensure that all key considerations and assumptions have been thoroughly evaluated, and to provide an additional perspective on the conclusions drawn regarding the addition of SIX® as a pretreatment process at DLTWTF.

The desktop independent review of the SIX® Pilot Report was performed for the following topics (sections of this technical memorandum [TM] are indicated in parentheses):

- Pilot System Design (Section 2.0)
- Water Quality (Section 3.0)
- Operations and Maintenance Considerations (Section 4.0)
- Performance Guarantees (Section 5.0)
- Cost Review (Section 6.0)

Risks and recommendations and/or possible mitigations are listed throughout these chapters for the various aspects of design or operation. These are also collected into a risks and benefits register (Appendix A).

1.3 Data Collection for This Review

The City provided relevant data and information to conduct this review, and additional data was researched and requested as needed. Black & Veatch maintained a Data Inventory Log (Appendix B). The following items were reviewed:

- SIX® Pilot Report backup documents including Excel files with pilot related data, cost estimates, lab data, calculations, and assumptions.
- Existing plant information including raw and finished water quality data, chemical usage, and costs, and as-builts.
- Documentation of any decision-making processes, including evaluation criteria and weighting, used to arrive at the selected alternative.
- Existing master plan reports and capacity analyses.
- Status and information of other relevant projects.

- Operations interviews to better understand existing water quality and processes.
- City Council meeting materials.

Discovery meetings with the City and TWT were held to enhance Black & Veatch's understanding of TWT's processes used and methodology followed.

2.0 Pilot System Design

The DLTWTF is being upgraded and many components and processes require replacement or improvement to add resiliency and robustness in treatment to meet capacity and water quality targets. While the aim of this independent review is to assess the evaluation and suitability of SIX®, SIX® would serve as a pretreatment to all key downstream processes (i.e., clarification, primary disinfection, and filtration). This independent review therefore also includes an assessment of the impacts on downstream processes and also other ancillary processes (e.g., deep well injection of brine waste) that could impact the operation or performance of a full-scale SIX® installation. Results from the pilot study were used by the TWT to develop operating conditions for an upgraded treatment train implementing SIX® at the DLTWTF, and these were then also used to develop operating costs for chemical, sludge, and power costs of the upgraded treatment train.

Improving filter performance at the DLTWTF will help to achieve the capacity goals for the facility. The existing filters (with existing pretreatment) are limited by the backwashing capacity of the system, and this limits the maximum treated water flow that can be achieved. The pilot study included the evaluation of four filter designs to ascertain the best performing filter media configuration with the pretreatment that was tested.

2.1 Overview of Pilot System Design and Pilot Results with Black and Veatch Analysis

The pilot plant aimed to evaluate all aspects of the water treatment train (Figure 5). This included the following processes (in order of treatment):

- Raw water screening
- SIX®
- pH/alkalinity control
- Coagulation (with conventional coagulation and flocculation)
- Inclined plate sedimentation
- Ozone for primary disinfection
- Filtration

Some aspects of the treatment scheme were not pilot tested. Coagulation and sedimentation by Actiflo® were not included in the pilot train. Final disinfection testing was completed on a bench-scale with chloramines and chlorine in July, August, and October 2021. Brine samples were also collected in January and September 2021 from the SIX® pilot to check the brine quality for permitting for deep well injection. Solids samples (July/August 2021) were also collected to assess dewatering on a bench scale.

The capabilities of the pilot equipment were reviewed and are summarized below.

2.1.1 Raw Water Straining

The feedwater to the SIX® requires straining to remove debris that could block the resin feed line eductors or other internals of the SIX® process. The SIX® Pilot Report indicates that "operational issues were met at the pilot with clogging of the SIX® eductor by RW [raw water] particles." The TWT remedied this issue with a 1/16 inch pre-strainer for the raw water entering the pilot.

It is Black & Veatch's understanding that the full-scale plant is in final design review (at the time of this writing) for a new raw water pump station that includes 1/8 inch screens.

While the screening remedy for the pilot plant had a smaller (i.e., 1/16 inch) opening than the full-scale design, it is understood that the pilot equipment diameters for piping and eductors are much smaller than for full-scale treatment trains and thus more prone to clogging events.

It is recommended that the technology supplier for SIX®, PWNT, confirm the level of pre-screening of solids for full-scale SIX® for the DLTWTF.

2.1.2 SIX®

The SIX® pilot plant that was used at the DLTWTF was provided by the Ramboll Group for the duration of the study and served as pre-treatment to downstream coagulation/sedimentation, ozone disinfection/oxidation, and various filter columns (i.e., one to represent the existing DLTWTF filters and three other possible filter designs).

The main process variables for evaluation of SIX® include resin dose, contact time, and brine concentration for regeneration. These are discussed in more detail in the following sections of this TM.

The pilot equipment capabilities were suitable in evaluating the impact of these process variables on water quality. The main purpose of the SIX® process TOC removal, and each of these process variables play a role in the overall TOC removal that can be achieved.

2.1.2.1 Resin Dose

Higher resin doses typically equate to higher TOC removal due to the increase in adsorption sites when more resin beads are in suspension. The pilot plant was capable of dosing the typical range of resin dosages (i.e., 10 to 35 milliliters per liter [mL/L]) of the SIX® system. Preliminary bench-scale resin dosing jar tests had been performed as a feasibility check for resin performance, so it was not needed to perform a full matrix of resin doses on a pilot scale (refer to also Subsection 2.2.1.1 of this TM).

During the pilot study, 15 and 20 mL/L resin doses were tested; these are typical doses for surface water plants studied by PWNT. The full-scale design basis in the SIX® Pilot Report allows for dosing from 20 mL/L up to 30 mL/L, which would provide some safety with regards to being able to dose and regenerate higher resin dosages if additional TOC removal is needed. (*Note that the historical raw water TOC concentration has been higher than what was tested during the pilot plant, so this is one mitigation measure to minimize the risk of not meeting the TOC removal target – discussed in more detail in Section 3.0, Water Quality*).

2.1.2.2 Contact Time

During the pilot study, 23, 30, and 42 minutes were tested as resin contact times. The design basis in the SIX® Pilot Report, however, is 20 minutes at maximum flow. Having 20 minutes at maximum flow means that for most of the operation time, the contact time is greater than 20 minutes due to operating at average flow within the design capacity size of the contactors if all contactors are in service. There are no known negative impacts of longer contact times in the SIX® contactors for operations or water quality.

An elevated risk of biofouling on the resin with longer contact times is possible; however, the pilot study included trials at 42 minutes of contact time (which would be similar to the contact time at half of maximum flow, or approximately the expected average flow of 80 mgd) and experienced no biofouling during the study. Also, the SIX® plant could operate with fewer trains in service if plant flows are low, and long contact times are not desired or needed. This would require that the resin be stored in a brine solution to prevent biogrowth while the resin is not being used in the SIX® process. The design of the SIX® should take into consideration how often this may occur and the steps that operators would take to put resin off-line and to bring resin back into service.

2.1.2.4 Brine Concentration

One of the process variables of SIX® is the brine concentration that is used as fresh brine for the regeneration process. The SIX® process uses brine five times before disposal. This is done by recirculating and storing batches of brine during the regeneration steps. Essentially, five main types of stored brine are as follows: 4 times used, 3 times used, 2 times used, 1 time used, and fresh brine. These are sequentially pumped through the regeneration tank holding the used resin, with the four times used transported first and then sent to disposal after it has now been used five times. The initial rinse is also stored and used to make up brine for the upcoming regeneration, and this helps to lower overall salt use.

During the pilot study, the brine concentration was monitored as mS/cm. The majority of testing occurred with a brine concentration of 40 and 55 mS/cm, but during the study, the brine strength ranged from 18 to 123 mS/cm (equating to 10,400 to 81,200 mg/L total dissolved solids (TDS); Table 7 of Subsection 4.3.2 of the SIX® Pilot Report). Note that at startup, the brine concentration was 135 mS/cm (Figure 24 of SIX® Pilot Report), which was quickly lowered once the pilot operation seemed stable.

Also, the brine strength varied in the pilot stages as follows:

1. Phase 1: SIX® Optimization (11/30/2020 to 03/15/2021) was operated with brine at 135 mS/cm decreasing to 18 mS/cm and rising again to about 50 mS/cm (~30,000 mg/L TDS) (with an apparent adverse impact on TOC removal that dropped to about 40 percent whereas it as around 60 percent removal previously; but this was a single sample when sampled at 25 mS/cm, or ~14,700 mg/L TDS, brine for regeneration). Note that the impact of lowering the brine concentration was evident in the alkalinity removal by the SIX® process, with a relatively steady decline in removal and a noticeable impact based on three samples when the brine was 25 mS/cm (~14,700 mg/L TDS).
2. Phase 2: Coagulation Optimization with Zeta Potential (03/16/2021 to 06/27/2021) was operated with brine at 30 to 55 mS/cm (but nearly the entire period except for a few days was at 55 mS/cm; ~33,000 mg/L TDS).
3. Phase 3: High TOC Season (06/28/2021 to 10/15/2021) was operated with 37 to 70 mS/cm (~22,000 to ~42,000 mg/L TDS), which appears to have been adjusted due to the changing water quality that occurred during this period.

A discovery meeting indicated that the brine use estimate of 1,545 lb/MG for the full-scale cost calculation of the report was based on the number of bags of salt used in the 50 gpm pilot study. It is not known if design factor differences (e.g., pipe volumes and tank volumes) between the pilot and full-scale mean that the bags of salt used in the pilot is representative to the salt use at full-scale.

Carollo did try optimizing the salt use during the pilot by lowering the concentration of the brine but did operate the majority of the pilot with a conservative salt level for regeneration. The salt use estimate of 1,285 lb/MG was made by Carollo after a review of costs and the level of conservatism. This updated, lower salt estimate should be assessed for maximum versus average flow conditions, as well as the differing feedwater quality seasons.

As a mitigation to the unknowns around salt use, it is recommended that the supplier of SIX® be consulted to provide a salt use estimate based on their calculations related to full-scale as well as based on the pilot finding of 50 mS/cm conductivity (~30,000 mg/L TDS) for the brine to be used for design.

The risk would be associated with the volumes of salt storage on-site being sufficient to meet the design intent, with the mitigation being more frequent salt deliveries if more salt is used than planned. Having a higher salt use also increases operating costs, and if more ion exchange occurs due to 'cleaner' resin, then the chloride levels in the finished water would also shift higher, which affects the corrosion indices calculations.

The range of brine concentrations (as mS/cm) are typical for SIX®, and it is possible to operate periodically with higher conductivities to provide additional cleaning of the resin.

2.1.2.5 Resin Type

An advantage of the SIX® process is the ability to use other commercially available resins that are on the market, as long as the resin has the appropriate settling characteristics and regeneration properties for use with SIX®. Two existing full-scale SIX® plants use the Lewatit® S5128 anion exchange resin from LANXESS, and the pilot study also used this type of resin. Most pilot experience with SIX® is also with this resin.

The main risks for evaluating only one type of resin are potential price escalation by the supplier of the resin and also delivery time or availability of the resin in the unlikely event a resin replacement is needed urgently. One mitigation is to have extra resin stored on-site (this was done at the Andijk III facility).

Jar tests of alternate resins (e.g., Purolite and DuPont) were conducted as part of the study, with results presented in the SIX® Pilot Report. These bench-scale tests can best replicate the water quality results of SIX® contactors, and the main parameters of interest were sampled (e.g., TOC and alkalinity). While a second acceptable resin for the SIX® at the DLTWTF could be identified eventually with more jar testing, pilot testing is recommended to ensure this alternative resin performs satisfactorily for water quality as well as operations (e.g., regeneration, resin settling and dosing via the eductor/injector).

2.1.3 Coagulation and Sedimentation

The coagulation and sedimentation pilot was a packaged unit that was supplied by Meurer Research (MRI) with a capacity of up to 110 gpm (operated at 30 gpm). The following design differences were noted in the SIX® Pilot Report:

1. The flocculation and plate sedimentation used in the MRI unit would mimic the conventional treatment trains that would be downstream of the SIX® process in the full-scale plant.
2. The SIX® Pilot Report noted that the pilot plate area for sedimentation was less than the plate area of the full-scale DLTWTF. This means that the loading rate for sedimentation was higher in the pilot plant than would be observed in the full-scale, which translates to better particle removal in full-scale than in the pilot.
3. Coagulation was with ferric sulfate and briefly with aluminum chlorohydrate (ACH; to test how TOC removal compared to the ferric sulfate); however, ferric sulfate will be used for the foreseeable future at the DLTWTF.
4. The full-scale plant uses sulfuric acid to help depress the pH for improved TOC removal by coagulation. With SIX®, the alkalinity during coagulation was less, so sulfuric acid was not needed to achieve the low pH for optimized TOC removal.

The Actiflo® process was not tested during the pilot downstream of SIX® (and upstream of the new filter design). This presents an unknown about any impact of the SIX® process on the Actiflo®, but the impact is expected to be related to a lower coagulant dose, and then changes to the sand and polymer dosages as well. There may be other impacts of Actiflo® on ozone and/or new filter performance.

2.2 Operations and Monitoring Procedures

The pilot study plan to evaluate SIX® and the downstream treatment train was extensive. The feedwater quality could change, and blended flows for feedwater occurred. Several process variables of SIX® could be adjusted, and process variables of downstream processes could be adjusted as well. This meant the pilot operator needed to track, record, and respond to changes to keep the pilot operating and to be able to evaluate the pilot objectives. The SIX® Pilot Report outlines in a clear way the testing phases and main impacts of these variables.

The following is a more in-depth review of operations and monitoring procedures that may have impacted results, and thus could also impact the implementation to full-scale.

2.2.1 Target Resin Dose

Two topics are covered in this section: the bench-scale tests performed prior to pilot testing to determine the dose for testing and the confirmation of the target resin dose during pilot testing.

2.2.1.1 Selection of Target Resin Dose

Bench-scale testing was performed by the TWT to evaluate TOC removal that could be achieved with various resin dosages and contact times before pilot testing began. This was performed in August 2020 (DLTWTF SIX® Bench Testing January 2020 Report, by Ramboll Group). A sample was shipped to the Netherlands for testing by PWNT.

The water sample had a TOC concentration of 17.2 mg/L (similar to high season TOC of Phase 3 of the pilot study), a sulfate concentration of 11.7 mg/L, and a bromide concentration of 47 ug/L. Jars were dosed with resin, and the resin was mixed by a traditional jar stirrer and samples withdrawn over time to track the UV254 (which is a surrogate for DOC).

The results showed that a resin dose of 20 mL/L with 30 minutes of contact time would produce a SIX®-treated water with 2.0 mg/L TOC (or 88 percent removal). The data also showed 80 percent removal of sulfate, 75 percent removal of bromide (although this could be a result of virgin resin, as piloting showed 15 to 40 percent removal of bromide; refer to Figure 46 of the SIX® Pilot Report), and 70 percent removal of alkalinity.

The TWT could have decided to use a lower the resin dose (i.e., <20 mL/L) and/or contact time in the pilot study, because the treatment train would include coagulation and BAF processes that would also remove TOC. Several factors would feed into the decision to use 20 mL/L with 30 minutes. Some factors are as follows:

- Achieving 2.0 mg/L TOC in SIX®-treated water at the DLTWTF was one of the highest levels of removal observed for a water for SIX®. The removal was believable from the suite of results from the matrix testing (i.e., not an anomaly as other jars also had high removal).
- From a pilot planning perspective, selecting 20 mL/L was a reasonable starting resin dose, and if more or less TOC removal was needed during the pilot, adjustments to the resin dose could be made. The 20 mL/L dose allowed for operating at a higher resin dose, e.g., 30 mL/L, if higher

influent TOC concentrations occurred. Historically, the raw water TOC could be as high as 35 mg/L (Figure 10 of the SIX® Pilot Report; occurred in 2017), and these jar tests were with 17.2 mg/L (~50 percent of the maximum), so it could be possible to need a higher resin dose.

- For contact time, 30 minutes showed higher TOC removal than 20 minutes, but the impact was less at the highest resin dosages tested (40 and 60 mL/L). Having 30 minutes allows for operation with lower resin dosages, and the higher TOC removals could be achieved. This shows how the contact time and resin dose can be adjusted to achieve a specific TOC removal, with the benefit of generating less brine when operating with lower resin dosages.
- The jar tests were performed with virgin resin, and a decrease (e.g., about 5 percent) in adsorption performance occurs once the resin has been in use in full-scale with regeneration cycles. It is believed that this adjustment to adsorption capacity occurs over a few days after the resin has had been through some adsorption and desorption regeneration cycles. Starting with an intermediate dose allowed for the adjustments in resin dosing over time if needed.

According to PWNT, most SIX® plants have resin dosages between 10 and 20 mL/L. With the very high TOC that occurs seasonally at the DLTWTF, having a baseline dose of 20 mL/L will achieve significant TOC removal to meet the overall treatment goal. A higher resin dose could be needed (e.g., when TOC and/or competing ions are in higher concentrations). The SIX® Pilot Report states that the design will allow for up to 30 mL/L, and Black & Veatch agrees that having this higher dosing capacity allows for treatment during times when there is more challenging water quality.

Note that the sample used for jar testing had a much lower sulfate concentration (11.7 mg/L) than the average for the pilot (64 mg/L). The jar results were better for TOC removal (e.g., 88 percent) than the pilot (which was overall 40 to 60 percent TOC removal). The lower TOC removal during the pilot by SIX® is due to scaling up from jar to pilot (i.e., mixing differences), the use of virgin resin in the jar test, and the fact that pilots are dynamic studies with varying water quality (e.g., sulfate was higher, on average, in the pilot-scale). Parameters like sulfate, along with other anions and TOC, influenced the pilot results.

2.2.1.2 Confirmation of Actual Resin Dose During Pilot Testing

One of the key monitoring procedures for SIX® is measuring the actual resin concentration manually in the contactors. The auto-dosing of resin is based on a calculation of flows and resin concentration setpoints, so the target resin dose that is input into the human-machine interface can have an offset to the actual resin dose in the pilot. In data reporting, it is common to show the setpoint and the actual resin dose concentration.

The pilot operations log (Master Data_analyzed main Excel file; SIX® Ops worksheet) shows a target and measured resin dose on several operating days of the SIX® pilot study. It is listed as an average resin dose, and the TWT confirmed the actual resin dosages are averages of five resin concentration readings.

From the data set provided in the Master Data_analyzed main Excel file, when comparing the resin dose setpoint and resin dose data, it appears that the actual measured dose was usually lower than the target dose (Figure 6). This is not unusual and is due to variability in the fresh resin tank concentration in the pilot, which is the basis for the dosing flow calculations.

The organics removal achieved during the pilot was meeting the overall target of 2 mg/L in the finished water, so this dosing offset is not considered an issue. With the actual measured resin dose being less than the target dose, the performance of SIX® full-scale is expected to be similar or better in terms of DOC removal with more accurate and consistent dosing. In full-scale, once the plant is operational, operators can fine tune the settings to get the setpoint and manual resin measurements to match as closely as possible.

This data set also showed that during the three phases of testing, the average difference in the resin setpoint and the actual measured resin dose was 4.9 percent, 9.3 percent, and 3.5 percent for Phases 1, 2, and 3, respectively. The measured dose was much lower (i.e., >10 percent of target dose) for a few dates, and the pilot operations were adjusted to correct for the discrepancy.

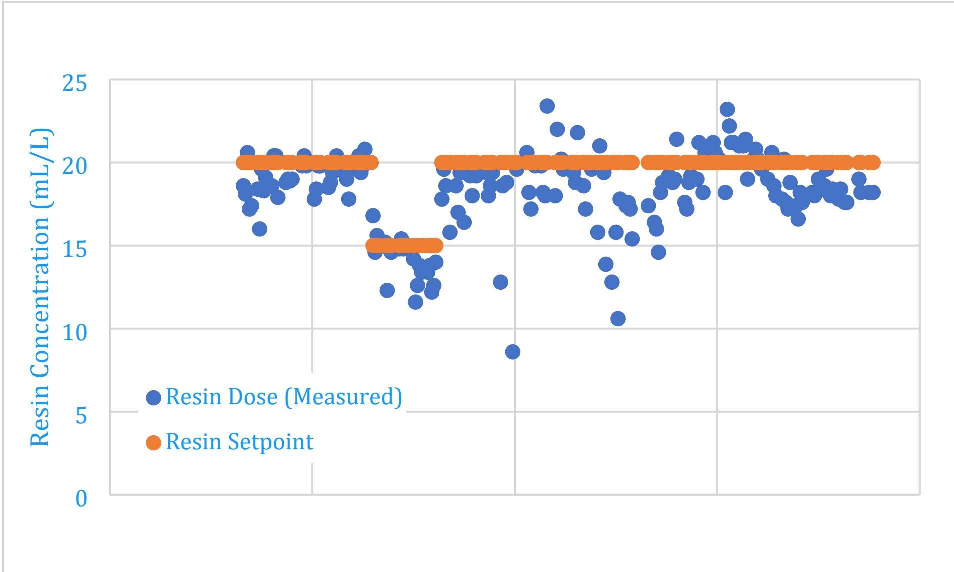

Figure 6 SIX® Resin Dose Setpoint and Measured Resin Concentration (data from Master Data_analzed_main.xls)

2.2.1.3 Resin and System Biofouling

During the pilot study, no fouling (biological or other) was observed. This was an encouraging observation considering most SIX® operating experiences are in colder climates with cooler water temperatures than at DLTWTF. It was not known before the pilot study if continued cycles of resin contacting and regeneration in the SIX® would adequately control biofouling of the resin in this high TOC and higher temperature water. The previous MIEX® pilot study for the City had experienced biofouling, but the regeneration scheme for MIEX® involves partial regeneration of the resin inventory at one time, leaving the bulk resin inventory exposed for longer to feedwater organics and nutrients that promote biogrowth.

Near the end of the pilot study, the pilot team executed a resin cleaning treatment, referred to as a caustic squeeze, but it did not show any different anion removal performance after bringing the resin back into service. It did seem to lessen the effects of microflocculation (refer to Subsection 4.2.3.2, Microflocculation) on filter performance (refer to Figure 74 of the SIX® Pilot Report). The caustic squeeze included a 24-hour soak of the resin while the SIX® was off-line, with the resin being soaked at pH 12 with 50 g/L sodium chloride.

It should be noted that even though fouling was not observed during the pilot study, and because SIX® impacts many downstream processes, mitigation measures should be in place in the event of fouling. The SIX® system supplier has options for cleaning resin from foulants and can advise on plans for periodic cleaning (e.g., by caustic squeeze, by operating with higher salt concentrations in the brine, or other). The City can also consult with the resin supplier about its experiences with resin fouling and mitigation measures. Several design options are available, as well for how and where to store the volume of resin for a caustic squeeze. These can be discussed with the system supplier to identify the advantages and disadvantages of the various options (e.g., oversized fresh resin vessel versus off-line storage tank).

In addition to cleaning of the resin beads, it may also be necessary to clean biomass from the walls of the contactor and in the plate settler. This can include chemical cleaning (chlorine or hydrogen peroxide, for example) and physical cleaning (e.g., power washing walls and Lamella plates). Sufficient valving and draining capacity would be needed to waste these cleaning wastes from the water treatment train. Also, during design, alternatives for access for cleaning can be evaluated, and options include permanent platforms, manholes, and removable covers over the contactors and Lamella settlers.

Furthermore, previous pilot studies at other locations (e.g., in the Netherlands and in the United Kingdom) have had algal growth on the plates develop over time. This can be mitigated by adding covers over the Lamella plates and contactor in design to minimize sun exposure. If algal growth does occur, the cleaning measures mentioned above can be used to clean the contactor and plates.

2.2.1.4 Blockages

A blockage of the resin eductor occurred during the pilot study (Refer to Subsection 2.1.1 of this TM). This was due to the strainer size and the small diameter piping used on a pilot scale.

2.2.1.5 Resin Attrition and Condition

Resin attrition, or wear by friction, is a risk with fluidized media systems. If resin breaks into smaller pieces, the resin will more readily pass through the Lamella settler and enter the downstream processes, resulting in resin loss from the process. Resin condition relates to the adsorptive capacity of the anion exchange sites, and it can be checked over time to track its condition.

To assess the risk of attrition, the process of moving and mixing the resin in the SIX® system was considered. In the SIX® process, resin is mixed with air in the contactors and is transported via eductor flow without pumping for resin feed into the contactor. These mixing and transport methods are considered to be gentle and to not cause attrition. There is mechanical mixing in the pilot plant in the fresh resin tank to keep the resin suspended, and this could possibly cause some attrition; however, historically, there has been no significant attrition in SIX® pilot- and full-scale installations, according to PWNT.

No evidence of attrition was observed in the pilot study, and the pilot processes were operated as per the standard PWNT procedures of SIX®. Coagulation and sedimentation are downstream of SIX® in the pilot process train, and it was not reported in the SIX® Pilot Report if resin was found in these basins during the pilot study. Also, there was no resin loss, which is an indicator of attrition, that required a top-up of resin during the pilot study. The SIX® pilot was operated and performed as would be expected. Table 1 shows the results of a resin condition assessment that was conducted by LANXESS, the supplier of the resin used in the pilot study (Refer to Ramboll - Ion Exchange resin analyses WR #3184 August 2021; dated 08/19/2021), with results showing whole beads of resin being present after the pilot study. This shows that attrition was not occurring during the pilot study.

Although no resin carry-over was observed during the pilot, it is recommended to consider design features in the full-scale to allow for capture and removal of any resin that might carry over. TWT advised in a Discovery Meeting No. 1 (10/21/2024) that feed flow control measures are being considered in design to minimize flow surges through the SIX® (i.e., surges would potentially carry over smaller resin beads through the Lamella). The possibility of a slower velocity zone (i.e., wide-spot) downstream of the SIX® to capture resin was also discussed.

Resin condition can be assessed by tracking the performance of the resin in the pilot study over time for the target compound being removed (e.g., TOC). Jar tests can be performed with the resin from the SIX®

system to see if performance has been maintained or has deteriorated over time. Resin can also be scientifically checked by the resin supplier, and this was done for samples sent by the TWT to the resin supplier.

Resin condition was assessed by the resin supplier, LANXESS, after the pilot study (See: Ramboll - Ion Exchange resin analyses WR #3184 August 2021; dated 08/19/2021; Table 1). Two resin samples were tested: a "fresh" resin from the fresh resin tank, with resin that had been used throughout the pilot study (November 2020 to August 2021), and a resin that was "loaded" meaning it traveled through the contactor and had not been regenerated.

Table 1 Resin Condition Assessment by the Resin Supplier (for resin that was in operation from November 2020 to August 2021)

Parameter	"Fresh" Resin (August 2021)	"Loaded" Resin (August 2021)	Virgin Resin Specification	Before Cleaning* (October 2021)	After Cleaning* (October 2021)
Total Capacity (meq/mL)**	1.33	1.34	1.35	1.26	1.29
Water Retention (%)	48	48	48 to 55	45	48
Microscopic Exam					
% whole perfect	100	100	--	100	
% cracked	0	0	--	0	
%broken	0	0	--	0	
Foulant (g TOC/ft^3 as C)	8.5	8.5	--	7	2

*Cleaning was a 24-hour soak with caustic soda (0.1 N NaOH) and sodium chloride (5 percent).
**meq/L is milli-equivalents per liter

The conclusions of the condition report were that the resin samples of fresh (regenerated) and loaded resin had "retained most of their total capacity," that the water retention was within specification, and that the resin beads were in "excellent physical condition at 100 percent whole perfect beads." One interesting observation is that the foulant load was the same for the two samples, and the resin was still performing well for TOC removal.

Two additional samples were also analyzed by LANXESS before and after a caustic squeeze cleaning in October 2021. Those analyses showed that before cleaning, there was a lower water retention, but after cleaning, the retention was within specification range (i.e., 48 percent). The caustic cleaning procedure lowered the TOC on the resin from 7 to 2 grams TOC per cubic foot (g/ft^3 as carbon, C). Also, the resin beads where still whole with no pieces found.

2.2.1.6 Resin Carry-Over

Resin carry-over is when resin is not settled in the Lamella settler, and resin carries over to the downstream processes. This is a loss of resin from the process, and it should be avoided.

Carry-over of resin was not observed during the pilot study; however, it is recommended to identify the places in the full-scale plant (e.g., settled solids in plate unit and solids handling facilities) where resin could be found in the event of carry-over.

If algal growth proliferates in the feedwater and algal mass develops on the plates of the SIX® process, channel velocities increase, and this can lead to resin carry-over from the SIX®. Cleaning measures are discussed in Subsection 2.2.1.3, Resin and System Biofouling, and these can be used periodically if algal growth occurs on the plates.

Resin carry-over is also discussed in Subsection 2.2.1.5, Resin Attrition and Condition.

2.2.1.7 Regeneration Operation

During the pilot study, the regeneration flow procedures were not optimized (Discovery Meeting No. 3 minutes). The resin in the regeneration tank seemed to be rinsed/washed with brine instead of being submerged with brine. Carollo discussed this in Discovery Meeting No. 3 along with the estimated salt use for the SIX®. The pilot plants for SIX® are known to have many options for regeneration (e.g., drain interstitial water or not, regeneration top to bottom or in reverse, etc.). These options are available for research purposes. The supplier of SIX® technologies knows which regeneration regime best resembles full-scale operation, and it is recommended that the supplier be consulted for their opinion about any impact of the piloting regeneration procedures on the salt usage estimate.

In summary, the risks regarding regeneration flow were assessed as follows:

1. Even though it is believed that the regeneration procedures of the pilot were not optimized (the brine traveled from top to bottom in the regeneration tank of the pilot and the resin was not submerged in brine), the regeneration was sufficient to allow sustained performance for TOC removal without a biofouling event (over 10.5 months of pilot testing). The regeneration flow procedures of full-scale would likely be more robust than those used in the pilot study; thus, it is believed that the performance of a full-scale SIX® would be equal to or better than the performance of SIX® on the pilot scale.
2. Because the regeneration procedures of the pilot study were more like rinses and washes instead of submerging the resin in brine, it could be that less salt was applied for regeneration during the pilot. The full-scale regeneration procedures could require more brine and thus result in higher salt use. The risk is that the estimates for salt use from the pilot study are lower than what will be observed in the full-scale. It is recommended to discuss this with the supplier of SIX® technology to confirm salt use estimates prior to design and potential impacts to capital and operational costs. The pilot plant program could also be checked to verify the amount of brine used per regeneration. (Note that it was also discussed in the discovery meetings that the regeneration brine concentration was also not optimized during the pilot study, meaning that the salt use was higher during the pilot that what could be used in the full-scale. The salt use estimates were based on higher (unoptimized) brine concentrations for regeneration while using the rinse/washes regeneration flow procedures, so it is recommended to check with PWNT for a projected salt use based on the pilot results.)

2.2.1.8 Coagulation Chemistry

The SIX® process will remove a significant portion of the organic compounds that comprise TOC. This translates to a lower coagulant demand for achieving TOC removal and floc development for turbidity reduction (e.g., to <1 nephelometric turbidity unit [NTU]). If SIX® is not operational, higher dosages of coagulant would be needed as the pilot showed that SIX® lowered the required coagulant dose, on average, by 59 to 71 percent in the low and high TOC seasons, respectively.

The pilot study indicated that sulfuric acid was not needed because the SIX® process removed sufficient alkalinity to allow the ferric sulfate to naturally depress the pH for maximum TOC removal. Without SIX®, it would be necessary to dose sulfuric acid before coagulation to achieve the optimized pH for TOC removal.

It was noted in Discovery Meeting No. 2 (11/06/2024) that with the lower ferric coagulant dose after SIX®, the project for the expansion of the belt filter press capacity for solids handling could be paused. This means that the City could save not only on chemical costs due to a lower ferric sulfate concentration and elimination sulfuric acid dosing, but also the capital cost of expanding the solids handling facilities as well as the operational costs for solids handling. These are benefits of adding SIX®.

2.2.1.9 Ozone Oxidation and Disinfection

With SIX® in the pretreatment, the pilot plant data showed that the ozone dose was reduced by 24 to 41 percent (Section 8.3 of the SIX® Pilot Report), with an average in the pilot of 30 percent reduction. If the existing ozone generators and bubble diffuser contactors remain in service, SIX® will allow the City to dose less ozone to achieve the same disinfection targets for 0.5 log *Giardia* inactivation (e.g., 0.5 mg/L residual after 5 minutes).

Ozone also provides oxidation of other compounds and lowering the ozone dose may result in less oxidation of compounds like geosmin and methylisoborneol (MIB). The City has a <3.0 nanograms per liter (ng/L) water quality goal for geosmin and also <3.0 ng/L for MIB. Elevated geosmin and MIB were measured in the City's source water (from Tampa DLTWTF Master Plan_(Carollo)_2018-07-01_Volume 1; Table I1). Moderate geosmin or MIB concentrations were encountered during the pilot study, so the impact of lower ozone dosages for disinfection on finished water geosmin and MIB was not fully assessed for times when taste and odor (T&O) concentrations are at their highest. If higher ozone dosages are needed for geosmin and MIB, than for disinfection, higher ozone residuals could exist in the feedwater to the filters. This is not desirable, because ambient air ozone at the filters would be a health hazard. It was discussed in the fourth Discovery Meeting that hydrogen peroxide could be used to quench any excess ozone, but the existing mixing and dosing equipment for hydrogen peroxide needs to be assessed and improved to allow for consistent quenching.

Other potential processes in the DLTWTF would remove geosmin and MIB: 1) aeration via the SIX® constant air addition in the contactors, if installed, 2) hydrogen peroxide addition in the ozone contactor effluent for an advanced oxidation process; and, 3) the available contact time with the biological GAC deep bed filters (new filter installation is currently in construction).

2.2.1.10 Recycle Flows

The DLTWTF operates with recycle flows from the solids dewatering facility. One aspect of operations is that dewatering is not conducted on weekends; Monday mornings, the initial recycle flow upon restart has high organics concentrations. Samples (results shared in an email from Carollo with subject: RE TOC data of recycle streams 2024-11-19.msg) showed elevated TOC concentrations (87 mg/L in an unsettled sample, and 51 mg/L in a settled sample, so some particulate fraction of organics was present) for recycle flows on a Monday morning.

The pilot plant did not operate with recycle flows to the feedwater, so there is a process risk in terms elevated organics in the feedwater. A short-term peak in organics concentrations on Mondays when dewatering recycle is resumed is expected, and it is not known how much of an impact this would have on treatability, as blended flow ratios are not known.

It is recommended that the City conduct more frequent sampling of the recycle stream for organics. Also, it is recommended that the City conduct a small study of periodic samples tracking the TOC and DOC concentrations of the dewatering recycle flow as well as the raw and blended raw water, after dewatering resumes on Monday mornings. It would be beneficial to know how the quality of the recycle flow changes over time on Mondays, because the potential impact on SIX® performance could be evaluated. It may also be beneficial to install a surge tank for the recycle flow, so that this flow can be fed at a slower rate into the feedwater.

2.3 Evaluation of Adherence to Standard Engineering Practices

The pilot plant was composed of various packaged units with the SIX® pilot being designed in the Netherlands, and other components were designed in the United States.

2.3.1 Permitting Requirements

The Florida Administrative Code (FAC) outlines the requirements in preparation, design and construction of any innovative or alternative process. The SIX® process would fall into this category, and the FAC then has certain requirements to allow a permit for construction.

According to the SIX® Pilot Report, a preliminary design report or design data must be submitted to show that the technology is fit for the purpose of producing drinking water to the applicable standards. Carollo also confirmed that the primacy agency, the Florida Department of Environmental Protection (FDEP), has been informed since before pilot testing of SIX® and received the pilot test protocol and report. Other information to support any permit application would need to be submitted, including: 1) technical information from the manufacturer, 2) data and reports from piloting or other similar full-scale plants, and, 3) the operation and maintenance procedures and requirements, as well as the availability of technical support.

It appears that the risk of issues due to facility permitting is low because of the involvement of the primacy agency throughout the project.

2.3.2 SIX® Pilot Equipment Design

The SIX® pilot design did not necessarily follow US-based standards for access or materials, but the pilot plant replicated the water and resin flow paths quite closely to what would be in full-scale. The SIX® is designed to represent the full-scale contact time for resin, resin dosing, mixing energies with air in the contactors, settling by Lamella, regeneration and rinsing of resin, fresh resin tank storage, and movement of the resin (i.e., no pumping of the resin).

Tank or basin sizing can be scaled to full-scale, and this has already been demonstrated in two full-scale plants for SIX®: Andijk III 32 mgd water treatment plant of PWN, the water company in the Netherlands, and the 24 mgd Mayflower Water Treatment Works of South West Water UK.

The process parameters of the SIX®, while new to the American water industry, are typical parameters that can be accommodated in design.

2.3.3 Other Process Units of the Pilot Plant

Other process units in the pilot study were supplied by either MRI (the coagulation and plate settler) or Carollo (ozone unit and bank of pilot-scale filters).

2.3.4 Chemicals Compliance in Pilot

The resin was purchased from a US-based resin supplier, and the resin meets National Sanitation Foundation (NSF) 61 approval for use in a drinking water installation.

All chemicals that were used in the pilot study were in conformance with the NSF/American National Standards Institute Standard 60.

The salt used for piloting was Solar Salt (from Odyssey), a high-quality grade of salt already used by the City. This seems of sufficient quality for SIX® brine regenerant, but it is recommended that quality and form (i.e., powder, granules, pellets) should be confirmed by the SIX® system supplier (and if necessary, the designer of the salt saturation system) as a precaution.

3.0 Water Quality

This section reviews the water quality targets for treated water to determine if the treatment train with SIX® could achieve the desired water quality.

3.1 Historical Raw Water Quality

A summary of the raw water quality is shown in Table 2 for samples collected between December 2019 and September 2024. Raw water was collected at the river, and without any blends from ASR wells or recycle flows.

Table 2 Historical Raw Water Quality* at DLTWTF December 2019 to September 2024

Parameter	Maximum	Minimum	Average
TOC, mg/L	23.5**	3.4	12.9
Dissolved Oxygen, mg/L	9.33	1.9	6.0
pH	8.4	6.6	7.4
Temperature, °C	32.1	14.9	24.1
Turbidity, NTU	4.73**	0.55	1.9

*Data provided by the City of Tampa for intake water quality monitoring for river source only (i.e., does not include Harney canal, ASR or recycle flows).

** The sampling of pilot plant inlet had a maximum TOC of 28.3 mg/L and a maximum of 5.7 NTU for turbidity.

The historical water quality of Table 2 (spanning 5 years) shows a significant variability in feedwater TOC, with a minimum of 3.4 mg/L and a maximum of 23.5 mg/L. The pH also has a wide range for raw water. Turbidity is relatively low for a surface water, and the temperature range is as would be expected for the region.

3.2 Treated Water Quality Objectives

The treated water quality goals from the SIX® Pilot Report are shown in Table 3. Note that the TOC goal of <2.0 mg/L 95 percent of the time was a goal to achieve in piloting, and the performance guarantee for TOC is to achieve <2.0 mg/L 90 percent of the time (refer to Section 5.0, Performance Guarantees).

The whole treatment train including SIX®, coagulation/clarification (with conventional and Actiflo®), ozone, filtration, and chlorine contact provides an array of chemical and physical processes to target the removal or addition of the parameters that are listed as goals for the DLTWTF. Table 3 shows that most of the parameters were evaluated during the pilot study, but some were not the focus of the pilot trials because of the simple chemical addition (e.g., for alkalinity) to meet the goals. Most of the risks with not meeting the water quality goals are deemed “low,” because either there are multiple treatment processes available to address the removal/addition of a water quality parameter, or a chemical addition can be used to achieve the goal.

Table 3 DLTWTF and Pilot Finished Water Quality and Water Quality Goals[1]

Parameter	DLTWTF Finished (max/min/avg)	Goal[5]	Pilot Finished (max/min/avg)	Goal Met?		Risk of Not Meeting Goals	Risk Mitigation
				During Pilot Study?	By Chemical Addition?		
Alkalinity (mg/L as $CaCO_3$)	109/45/82.5	46[2]	98/10/37	No	Yes	Low	Chemical addition
pH	8.13/7.6/7.88	7.8 – 8.0	7.6/6.4/6.9[3]	No	Yes	Low	Chemical addition
Turbidity (NTU)	0.2/0.05/0.09	<0.08	ND	Unknown	No	Low	Adequate pre-clarification, and monitoring of filter run times
TOC (mg/L)	4.3/1.1/2.6	<2.0 mg/L 95% of the time [4]	2.6/0.5/1.5	Yes	No	Low	SIX® resin dose and contact time, coagulant dose, GAC in filter bed contact time with biological activity
Color (apparent, CU)	<5/<5/<5	Unapparent (<5)	8/<5/<5	No	No	Low	SIX® resin dose and contact time, coagulant dose, GAC in filter bed contact time with biological activity
T&O (Geosmin, ng/L)	2.4/1/1.6	<3.0	1.2/<1/<1	Yes	Yes	Low	Ozone dose and GAC in filter bed contact time
T&O (MIB, ng/L)	<1/<1/<1	<3.0	<1/<1/<1	Yes	Yes	Low	Ozone dose and GAC in filter bed contact time
Free Ammonia (mg/L)	ND[6]	0.1 – 0.18	ND	Unknown	No	Unknown	Adequate/controlled chemical dosing
Fluoride (mg/L)	0.75/0.6/0.65	0.65 – 0.75	ND	Unknown	Yes	N/A	Fluoride is no longer dosed at the DLTWTF
Chlorine Residual (mg/L) [4]	5.4/3.5/4.4	4.25 – 4.75	NA	NA	Yes	Low	Chemical dosing with adequate pretreatment to lower the chlorine demand

Notes:

1. Data summarized from pilot test period 11/30/2020 to 10/15/2021 *(first four columns are from SIX® Pilot Report).*
2. Suggested minimum by RTW [Rothberg, Tamburini, and Winsor]; historic minimum for DLTWTF = 46 mg/L.
3. pH on the pilot was adjusted to 7 throughout the piloting. It is anticipated that final pH adjust to a CCPP of 0 to 13 mg/L as $CaCO_3$ would occur after filtration.
4. Suggested by City as part of the master plan meeting held on 09/10/2020.
5. Chlorine residual goals were not met during piloting; three rounds of chlorine demand testing were done at bench scale.

ND – no data; was not tested.

3.3 Specific Water Quality Parameters Related to SIX®

Several water quality parameters were monitored during the pilot study. The main parameters of interest that are impacted by SIX® are discussed in more detail herein.

3.3.1 Total Organic Carbon

During various phases of pilot study and under varying testing conditions (i.e., brine concentration trials, feedwater quality variation, periodic addition of copper sulfate, etc.), as a pretreatment process SIX® was able to remove 40 to 60 percent of the TOC. The TOC removal was summarized in the SIX® Pilot Report, Table 20 of Section 8.1, and is provided as Table 4, showing the TOC and UVA removals through SIX®, the flocculation and sedimentation process, and ozone/filtration of the pilot.

Overall, the entire treatment train could achieve the <2 mg/L (95% of the time) TOC goal for filtered water, and the entire treatment train was achieving 81 to 91 percent TOC removal. As reported in the SIX® Pilot Report, the UV-adsorbing organics are usually quite reactive and contribute to disinfection byproduct (DBP) formation, and the data of Table 4 also show that the combined processes of the pilot treatment train achieved 95 to 99 percent removal of UVA.

Table 4 Pilot TOC and UVA Removal (from SIX® Pilot Report; as Table 20)

	Raw	Filtered	SIX®	Floc/Sed	Ozone/Filters(1)
TOC	**mg/L**	**mg/L**	**% Removal**	**% Removal**	**% Removal**
Phase 1	12.5 (3.2)	1.4 (0.4)	61% (8%)	82% (4%)	88% (4%)
Phase 2	6.2 (2.4)	1.2 (0.3)	49% (12%)	71% (9%)	81% (7%)
Phase 3	19.7 (3.5)	1.8 (0.3)	41% (8%)	85% (5%)	91% (2%)
UVA	**/cm**	**/cm**	**% Removal**	**% Removal**	**% Removal**
Phase 1	0.52 (0.16)	0.028 (0.053)	67% (7%)	82% (5%)	95% (7%)
Phase 2	0.29 (0.08)	0.009 (0.002)	59% (12%)	74% (10%)	97% (1%)
Phase 3	1.07 (0.27)	0.014 (0.008)	44% (10%)	93% (2%)	99% (1%)

Notes:
1. Filtered water data is based on Filter 2.

Black & Veatch note: Data are mean weekly values; standard deviation shown in parentheses.

3.3.1.1 Historical TOC Removal Throughout the DLTWTF

It is interesting to compare the TOC removal of the pilot train with SIX® to that of the historical data from the existing full-scale DLTWTF. The TOC concentrations throughout the treatment processes of the full-scale DLTWTF are shown in Table 5 for samples from January 2015 to May 2016. These samples would have covered the seasonal changes that can occur, such as high and low TOC seasons.

This data set did capture high and low influent TOC water (with a minimum value of 5.1 mg/L and a maximum values of 20.0 mg/L being recorded). This also shows that the average TOC concentration of the filtered and finished water was about 2.6 mg/L. The DLTWTF achieved <2.0 mg/L TOC for 18 percent of the time (using the January 2015 to May 2016 data set). Adding the SIX® process allows the DLTWTF to achieve the treatment goal of <2 mg/L 95 percent of the time.

Table 5 TOC Concentrations Throughout the DLTWTF (data from January 2015 to May 2016)

Parameter	TOC Concentration (mg/L)			Count
	Min	Avg	Max	
Raw TOC, mg/L	5.1	12.16	20.00	217
Post Actiflo®, mg/L	2.2	3.2	5.10	65
Post Basin 5, mg/L	2.4	3.5	4.60	70
Post Ozone, mg/L	2.4	3.35	4.50	71
Combine Filter Effluent, mg/L	1.6	2.63	4.30	142
Finished Water, mg/L	1.5	2.58	3.90	217

3.3.2 Sulfate

Sulfate was found to be the anion with the highest affinity to the resin, and SIX® showed 87 to 88 percent sulfate removal (Table 25 of the SIX® Pilot Report). Sulfate is of interest, because it competes with TOC for adsorption sites on the resin.

During the pilot period, some of the inputs of sulfate into the feedwater were as follows:

- ASR wells
  - Rome Avenue Wells 1 to 8 were used in Phase 2 from 04/05/2021 to 06/01/2021; and,
  - Rome Avenue Wells 2 to 4 were in operation for a short time in Phase 3 (08/10/2021 to 08/25/2021).
- Copper sulfate was applied from 04/05/2021 to 06/01/2021 (Subsection 4.2.1 of SIX® Pilot Report) and data of Figure 12 shows that the feedwater sulfate concentration increased from about 22 to 28 mg/L to about 45 to 55 mg/L before and after copper sulfate addition to the reservoir began.
- In May 2021, copper sulfate was applied and ASR wells were blended with the Hillsborough River supply, and the sulfate levels were about 55 mg/L or less (this was in Phase 2; Table 15 of the SIX® Pilot Report).

It appears that the blending with ASR wells will increase the sulfate concentration to about 55 mg/L and possibly higher depending on the blends and sulfate levels of the ASR wells in use and the application of copper sulfate (note: according to Carollo, copper sulfate might be used less often in the future, or discontinued due to the City's implementation of ultrasonic buoys for algae mitigation; the City has not needed to apply copper sulfate where buoys have initially been implemented). It is recommended to evaluate ASR blends (and copper sulfate use) and estimate the possible maximum sulfate concentrations that can occur. This can guide Operations on the best way to manage feed flows to the SIX®.

When ASR wells were blended into the feed flow and copper sulfate was being applied, TOC removal did not deteriorate. Figure 25 of the SIX® Pilot Report shows that SIX® TOC removal was initially low (about 25 percent) but then increased to about 55 to 60 percent during the Phase 2 testing (with 20 mL/L resin dose and 23, 30, 42 minutes of contact time) and when ASR wells were blended in with the river water and copper sulfate was being applied to the reservoir. The sulfate concentration was between about 40 and 55 mg/L during this time (Figure 28 of the SIX® Pilot Report), with fairly consistent sulfate removal by

SIX®. This shows that this level of sulfate did not significantly reduce the TOC removal by SIX®, and that other variables, such as resin dose (that was consistently 20 mL/L during this time) and brine concentration (at 30 to 55 mS/cm during this Phase 2 test period), were maintaining TOC removal. Although there was not a significant decline in TOC removal with higher sulfate during the pilot study, plant operators can monitor over time the impact of sulfate on TOC removal in the full-scale plant.

As a point of reference regarding the sulfate level of the ASR wells, Figure 7 shows the sulfate concentration of all eight ASR wells from 2021 to 2024. The sulfate levels in the ASR wells show variability over time (ranging from about 90 mg/L to 210 mg/L), with some wells experiencing higher fluctuations than others, such as ASR 4, ASR 5, and ASR 6.

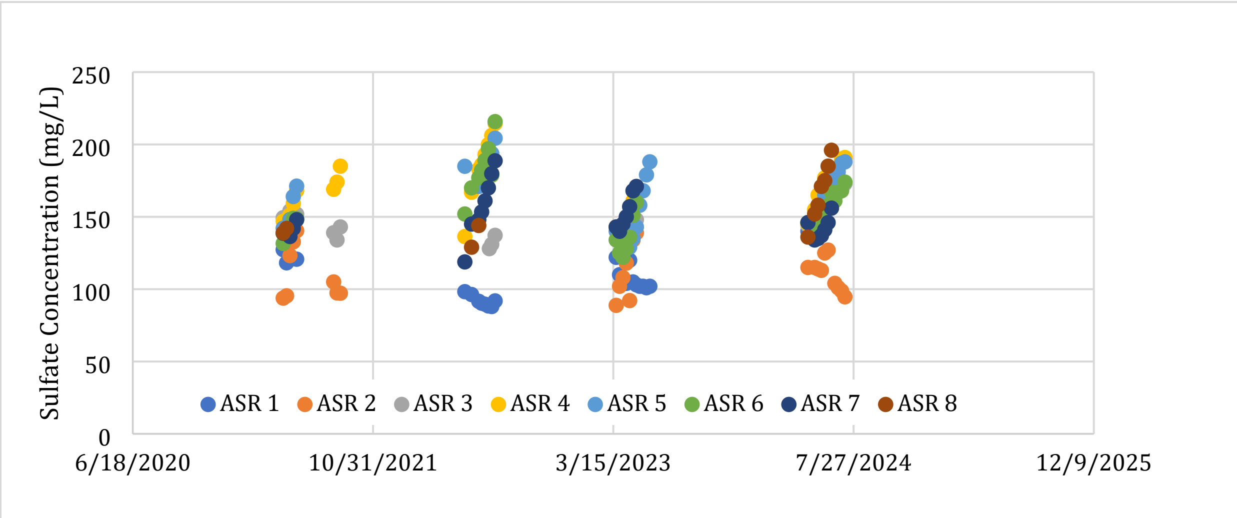

Figure 7 **Sulfate Concentrations of the Eight Rome Avenue ASR Wells** ***(from compiled Rome ASR data Excel files of 2021 to 2024 from the City)***

3.3.3 Bromide and Bromate

Bromide can be incorporated into regulated DBPs. Bromate is formed during ozonation, and brominated trihalomethanes (THMs) and haloacetic acids (HAAs) are formed during chlorine disinfection (which may be used at the DLTWTF for primary disinfection when ozone is not used due to microflocculation downstream; Discovery Meeting No. 1 minutes). The SIX® Pilot Report notes that the existing bromate mitigation is needed for times when bromide concentrations are highest, and ozone is used.

The City currently controls bromate formation very well at the DLTWTF. Bromate concentrations are <4 ug/L (Discovery Meeting No. 4 minutes; the maximum contaminant level [MCL] for bromate is 10 ug/L). SIX® should improve control of bromate formation, because SIX® can remove some bromide and SIX® will lower the ozone demand of treatment, so less ozone is dosed.

The bromide levels were reviewed in the feed and treated waters from the pilot plant and DLTWTF.

1. At the DLTWTF, the bromide concentration in the Hillsborough River (Table 3 of the SIX® Pilot Report) averaged 58.3 ug/L during the pilot study, with a minimum and maximum concentration measured at 33.6 and 84.4 ug/L, respectively.
2. During Phase 3 of the pilot study, the maximum bromide level was 147 ug/L. During Phase 3, the Rome Avenue Wells 2 to 4 were blended in from 08/10/2021 to 08/21/2021. (Because the Hillsborough River data had a maximum of 84.4 ug/L, it could be that the ASR flows contributed

bromide making the maximum bromide in the pilot feed 147 ug/L.) It is also interesting to note that the SIX®-treated bromide levels in April/May 2021 (Figure 46) were higher, near 170 ug/L, than the measured raw bromide concentrations that were approximately 150 ug/L. The SIX® Pilot Report states that it could be leaching from the resin back into the water, or because of poor resin dosing due to eductor clogging during this time period (refer to Objective 6 discussion on page 53 of the SIX® Pilot Report).

3. SIX® removed 15 to 40 percent bromide under varying testing conditions with different feedwater blends, different concentrations of competing ions, and different brine regeneration concentrations. The bromide removal, while variable, was still above about 30 percent for the final three months of piloting. From these data, the pilot did not show a decline in bromide removal by SIX® over time.
4. Data on Figure 64 of the SIX® Pilot Report shows that the bromate concentration from Filter 2 in the pilot plant was always below 10 ug/L (the MCL for bromate). The pilot plant did not have any bromate mitigation strategies, and it was mentioned that with the lower ozone demand after SIX®, less bromate was produced.
5. Table 31 of the SIX® Pilot Report shows the historical bromide levels (with varied historical blends with ASR wells that have higher bromide concentrations than the Hillsborough River) of the DLTWTF. The maximum measured bromide was 927 ug/L in 2017; whereas the maximum bromide concentration from the Hillsborough River was 221.5 ug/L in 2015. The average bromide concentration was about 80.5 ug/L from 2014 to 2021.
6. Bromide was measured in the SIX® brine waste on two occasions: 01/25/2021 and 09/16/2021 (Table 49 of the SIX® Pilot Report). The concentrations were 3,100 and 2,100 ug/L, respectively. This shows that bromide was being removed by the SIX® process over time and accumulating in the brine. It is not known from other installations of SIX® if bromide removal would be sustained over a longer operational period.

While the pilot data show 15 to 40 percent bromide removal by SIX®, the DLTWTF will not necessarily need to rely on bromide removal by SIX® for compliance with bromate. The SIX® provides a high level of organics removal upstream of ozonation, so less ozone is dosed to maintain a primary disinfection residual, and this will correspond to lower bromate formation.

In Discovery Meeting No. 4, it was discussed that if the ozone concentration in the ozone contactors needs to be increased for T&O control, the ozone residual could carry over to the biological filters. An existing hydrogen peroxide quenching system exists, but the City noted that the dosing and mixing needs to be evaluated and improvements made. This is because previous operation has shown that quenching is not entirely completed, and the ozone residual is carried over to the filters.

3.3.4 Per- and Polyfluoroalkyl Substances

It is understood that the DLTWTF finished water contains concentrations of per- and polyfluoroalkyl substances (PFAS) that are sometimes slightly higher than the proposed MCLs (Figure 8). This means that PFAS removal in the new treatment train is required before the MCLs compliance date of 04/26/2029, though the EPA may extend the compliance deadline to 2031.

PFAS was not monitored during the SIX® pilot study, because the analytical methods available for PFAS measurement at that time did not have a low enough detection limit to record the low levels in the river supply (< 20 ng/L).

	UCMR 5					
	Q1 Jan '23	Q2 Apr '23	Q3 Jul '23	Q4 Oct '23	April '24	Aug '24
PFOS	4.0	5.0	6.8	6.9	7.3	4.5
PFOA	ND	ND	4.4	4.6	6.5	4.8
PFBS	4.4	4.8	6.4	6.0	5.3	13.0
PFHxS	ND	4.0	3.7	4.1	3.8	3.6
Raw Water TOC	13.9	4.3	16.9	11.7	11.9	26.5

Figure 8 **PFAS in the Finished Water at the DLTWTF (provided by Tippin Water Team as part of Discovery Meeting No. 2 request)**

While the proposed treatment train likely has some PFAS removal by SIX® (reports differ on the amount of removal by SIX® from site to site, and PFAS was not monitored during the pilot study, but additional pilot testing could show how much PFAS removal is achieved by the resin in SIX®), the GAC in the deep bed filters can provide additional PFAS removal. One benefit of adding SIX® would be that the additional removal of TOC by SIX® will help to increase the service life of GAC for removal of PFAS, because TOC competes with PFAS for adsorption sites.

The design for the new deep bed GAC filters for the upgraded DLTWTF (from Discovery Meeting No. 3 responses) is to have a surface loading rate of 6 gpm/ft^2 at maximum flow and this provides 6.5 minutes of empty bed contact time (EBCT) at maximum flow. At average flows, the EBCT will be longer, but this depends on how many filters are in operation.

Standard practice is to provide 10 to 20 minutes of EBCT in GAC gravity-fed contactors for PFAS removal; however, when the GAC is also the filtration media, shorter EBCTs are often used due to the filter bed design standards. If the proposed GAC filter design is to be used for PFAS compliance, this should be checked with the regulatory agency to ensure agreement.

The City could consider conducting a bench-top study of PFAS removal by GAC (e.g., via rapid small-scale column tests [RSSCTs] with the GAC media to be used in the filter beds), however these are typically used to compare GAC media types for PFAS treatment life cycle costs analysis. Because the GAC would serve as both a filter media and adsorber for PFAS removal, it is likely that piloting would be required. Piloting also gives a more accurate estimate of bed service life, and there is time to conduct pilot to get results ahead of the compliance date.

Some important considerations regarding RSSCTs or other ways to test the breakthrough of PFAS through the GAC filter media are as follows:

- As GAC filter beds require frequent backwashing, the mass transfer zone for adsorbed PFAS would be disrupted. This means that the breakthrough for PFAS would be expected sooner than what is predicted by RSSCTs.
- Because the GAC in the filters would need to be replaced after PFAS breakthrough, it would be beneficial for the City to have an indication of how often filter beds will need to be taken off-line for media replacement. RSSCTs can give an indication, and then the City can effectively stage GAC replacements to minimize operational disruptions. Note that the number of filters should also be carefully considered, as filters will come in and out of service for GAC media replacement, and removing and installing media usually takes a few days per filter, depending on the size of the filters.
- It may be possible to perform a full-scale trial with GAC in one of the existing filters with approval of the regulatory agency.

Another aspect of PFAS is that if it is removed by SIX®, the SIX® brine waste will contain a concentrated mass of PFAS. A limit for PFAS in the brine is currently not noted in the deep well injection permit, and the United States Environmental Protection Agency (USEPA; 2024) has published a technical note with language that deep well injection of Class I non-hazardous industrial waste poses low risk for contaminating drinking water supplies. Future rules for permitting brine disposal injection wells may have PFAS limits. If this is the case, some form of PFAS removal from the brine, or another type of brine disposal method would need to be used. It is advised that the City stay aware of PFAS regulatory changes and disposal options.

One recommendation is for the City to measure each source of water to the DLTWTF individually to determine if any source contains higher PFAS concentrations compared to other sources. This would allow decisions to be made about sources as a part of the PFAS strategy. Another recommendation is to conduct pilot testing with SIX® to monitor PFAS concentrations in the raw water, treated water, and brine.

3.4 Corrosion Control and Mitigation

Corrosion control is considered a risk, and the City and TWT performed water quality monitoring during the pilot study to address this risk. Adding the SIX® process to the head of the treatment plant will change the ion composition of the treated water. Also, the changes to water quality after the SIX® will result in dramatic changes in treatment chemistry downstream for enhanced coagulation with ferric sulfate with much lower coagulant dosages and no sulfuric acid addition during coagulation.

Concentrations of chloride and sulfate are important parameters for finished water stability, because they affect metal solubility and contribute to the conductivity and corrosivity of the water. Metal ions such as lead, copper, and iron can complex with ligands present in the water, such as carbonate, sulfate, and chloride. Chloride and sulfate form more soluble complexes with metal ions in water, which can inhibit the formation of less soluble metal-carbonate complexes. High concentrations of chloride and sulfate increase the aggressiveness of water and can induce corrosion of metal piping, such as the pitting of copper pipes (Stets, Lee, Lytle, and Schock, 2017).

Larson's ratio (LR) is one parameter used to assess the interference of chloride and sulfate ions on the solubility of metal complexes with carbonate species. LR is defined as Equation 1 below, where all concentrations are expressed in meq/L.

$$Equation\ 1.\ LR = [Cl^{-}] + [SO_4^{2-}]\ [HCO_3^{-}] + [CO_3^{2-}],\ where\ LR < 0.8\ is\ recommended$$

Because metal-ligand complexes with chloride and sulfate are orders of magnitude more soluble than carbonate complexes, the LR is used to assess the relative contribution of chloride and sulfate to metal complexes relative to carbonate complexes. LR was also shown to predict iron release from cast iron pipes in drinking water in a study by Lytle et al. 2020 (Lytle, Tang, Francis, O'Donnell, and Newton, 2020). It is generally recommended to maintain a LR less than 0.8 to ensure carbonate reactions are predominant and controlling of metal solubility (Imran, Dietz, Mutoti, Taylor, and Randall, 2005).

Additionally, the relationship between concentrations of chloride and sulfate in water has been used to understand and predict galvanic lead corrosion in distribution systems and premise plumbing (Hill and Cantor, 2011). This relationship is largely independent of the traditional lead solubility chemistry and instead is based on the chloride-to-sulfate mass ratio (CSMR) as defined in Equation 2.

$$Equation\ 2.\ CSMR = Cl^{-}\ (mg/L)/SO_4^{2-}\ (mg/L)$$

The CSMR theory predicts that galvanic corrosion potential for lead increases as the CSMR increases (Nguyen, Stone, and Edwards, 2011). Galvanic corrosion occurs where a dissimilar metal is galvanically connected to lead; for example, copper piping joined with lead solder or in the case of most partial lead service line replacements. Decreased CSMR reduces the potential for galvanic corrosion, because sulfate forms highly insoluble precipitates with lead, forming protective lead-sulfate coatings over lead materials in contact with water. In contrast, chloride can form soluble complexes with lead that prevent the formation of protective coatings and cause corrosion of lead materials. CSMR has not been shown to impact lead release from brass or pure lead pipe not galvanically connected to a dissimilar metal; nor has it been shown to impact copper release.

A 1999 study of 24 water utilities demonstrated that utilities with a CSMR less than 0.58 had a 90th percentile lead concentration that met the USEPA action level (AL) of 15 µg/L (Edwards, Jacobs, and Dodrill, 1999), whereas utilities with CSMR greater than 0.58 had a much higher probability of exceeding the AL. Many of the utilities that exceeded the AL for lead had recently made water treatment and/or operational changes that resulted in an increased CSMR in the finished water. Treatment changes include transitioning from sulfate-based coagulants to chloride-based coagulants, addition of ion exchange, or changes in chemicals used for disinfection.

For the City's DLTWTF planned upgrade, many of the process considerations will increase the chloride concentration and decrease both the sulfate concentration and the alkalinity. This is because SIX® introduces chloride into the water through ion exchange, SIX® effectively removes sulfate and alkalinity, and sulfate addition via coagulation chemicals and sulfuric acid addition is lessened or eliminated (i.e., for sulfuric acid) after SIX®. During the pilot, the average chloride added to the finished water by SIX® was 75 mg/L (Discovery Meeting No. 2 minutes). The sulfate concentrations tend to range from about 20 to 40 mg/L, which equates to an 80 percent removal of sulfate. Pilot testing also showed a 70 percent removal of alkalinity. These water chemistry changes result in an increased CSMR and an increased LR that increase the potential for metals leaching. This SIX®-treated water had 69 to 111 mg/L chloride, 31 to 95 mg/L as CaCO3 alkalinity, and 1.3 to 5.1 mg/L sulfate.

On 01/15/2021, the Lead and Copper Rule Revisions were promulgated by the USEPA. This rule required an initial service line inventory by 10/26/2024, of all service lines in the system. At the time that this TM was written, there have been no lead service lines identified. The inventory process is still underway but will be completed by the time SIX® is implemented at the full-scale. By the time SIX® would be installed, there will be few, if any, private service lines having unknown material. As a precaution against this risk, the City is planning to install an orthophosphate dosing point (Discovery Meeting No.1 minutes) for corrosion control at the outlet of the DLTWTF.

Orthophosphate combines with various metals found in distribution system and plumbing materials to form insoluble compounds that precipitate and form a coating on the pipe wall surfaces. The passivating layer formed through the addition of orthophosphate minimizes the potential for corrosion of pipe materials and metals release. Once orthophosphate is added to a distribution system, it should be used in perpetuity as there are concerns of increasing lead levels if orthophosphate were ever to be stopped. For this reason, the use of orthophosphate should be evaluated prior to introduction to the distribution system. Alternative corrosion control strategies involve raising the pH and alkalinity to minimize the corrosivity of the finished water. The pH/alkalinity adjustment alternative could be beneficial, because lead service lines are not currently identified and historical Lead and Copper Rule monitoring results have been well below the actions levels.

3.5 Impacts to Disinfection Byproducts

As a general rule, having lower TOC results in a variety of avenues for lower DBP formation by downstream processes. For example:

1. Lower TOC concentrations lead to lower chlorinated DBPs when chlorine is used for oxidation and/or disinfection; and,
2. Lower TOC concentrations result in a lower ozone demand; thus, a lower ozone dose is applied, which can result in lower bromate formation.

It is our understanding that the lower TOC concentrations achieved in the pilot study with SIX® may also allow periods of operation without ozone, which would be beneficial in times when microflocculation (Refer to Subsection 4.2.3.2 Microflocculation) occurs and adversely impacts filter run times. Improvements to the DLTWTF HSPS (Discovery Meeting No. 1 minutes) included the possibility to operate with a free chlorine residual to achieve primary disinfection (i.e., 0.5 log *Giardia*) in those times when the City would decide to operate without ozone. Having maximum TOC removal, via the SIX®, enhanced coagulation, and biofiltration, will allow for temporary and periodic disinfection with free chlorine without having DBP formation above MCLs.

DBP formation potential tests were performed with water from the filters of the pilot plant. This included a contact time of 10 minutes, with either 4 or 2.75 mg/L chlorine residual after the contact time. The findings were as follows (from SIX® Pilot Report; Section 1.3):

- HAAs from the pilot study with free chlorine remained under the MCL of 60 ug/L for samples up to 10 days contact time, regardless of the residual chlorine after the disinfection contact time.
- Total trihalomethanes (TTHMs) were less than the 80 ug/L MCL at 1 day of contact time with the 4 mg/L chlorine residual after the disinfection contact time. This is based on two samples in July and August 2021 (Figure 18 of the SIX® Pilot Report), in Phase 3, the high TOC season. Note that all TTHM samples exceeded the MCL after 5 days of contact time.

This suggests that the HAA and TTHM concentrations would be below the MCLs if free chlorine is used in the chlorine contact tank of the HSPS improvement project but are switched to chloramines for distribution.

It was noted that on a few occasions during the pilot study (Discovery Meeting No. 2 minutes), free chlorine was fed to the influent to the filters to help improve filtration run times. Samples were collected, and the TTHMs and HAAs were all very low (e.g., <2 ug/L). The chlorine dosage was only to meet the immediate chloride demand, so it was a low dose with a short contact time. Adding chlorine to the full-scale filters periodically, as was done in the pilot, to improve filter performance is not expected to cause any operational or water quality issues.

In summary, adding the TOC removal capabilities of SIX® to the treatment train at DLTWTF not only provides better water quality in terms of DBPs, but also better operational flexibility. Note that the secondary disinfection will remain chloramines in the distribution system, so the risk of DBP issues is minimal.

3.6 Comparing Raw Water Quality During Pilot Study to Historical Extreme Concentrations

The pilot study spanned 12 months (and operated for about 10.5 months) with the aim to study treatment of the seasonal variations and extremes of raw water quality at the DLTWTF. If during the pilot study extremely high or low values for certain water quality parameters did not occur, risks for full-scale could exist.

Table 6 shows the extremes of historical raw water quality and the extremes of water quality during the pilot to assess if the pilot study captured treatment to the extreme high or low limits of observed historical water quality. Historical raw water quality data for the DLTWTF were acquired from the City and from Discovery meeting discussions, while pilot data is from the SIX® Pilot Report.

Table 6 Raw Water Quality Extremes Experienced During the Pilot Study or From Historical Data

Parameter	Historical Extreme	Pilot Extreme	Risks of Not Pilot Testing the Extremes
TOC	Approx. 35 mg/L (from October 2017 data set of Figure 10 in SIX® Pilot Report)	28.3 mg/L (from Table 3 of SIX® Pilot Report; note that DLTWTF maximum between 2019 and 2024 was 23.5 mg/L; Table 2 of this TM)	During extremely high raw water TOC periods: • Finished water TOC might exceed the goal of <2 mg/L TOC in 95% of time • Higher chemical dose and cost needed to achieve satisfactory TOC removal • More solids generated from coagulation • Higher resin dose used, thus creating more brine volume
Bromide	221.5 ug/L in 2015 and 927.1 ug/L as max entering ozone in 2017 (Table 31 in SIX® Pilot Report)	147 ug/L in Phase 2 of pilot study (Raw Water at Pilot; Table 14 and Figure 64 of SIX® Pilot Report)	In times of very high bromide concentrations: • Bromate concentrations could exceed the MCL of 10 ug/L (although historical bromate data have been low, e.g., <3 ug/L per Discovery Meeting January 2025) • SIX® brine wastes will have higher bromide concentrations (the two pilot brine waste samples had 3,100 and 2,100 ug/L bromide), although not monitored now for injection permit

Parameter	Historical Extreme	Pilot Extreme	Risks of Not Pilot Testing the Extremes
Alkalinity (as $CaCO_3$)	46 mg/L (from Table 2 of SIX® Pilot Report; footnote)	47 mg/L from the Master Data-analyzed_main.xls file and Table 3 of SIX® Pilot Report	The pilot study tested the extreme low alkalinity, and chemical dosages can be calculated for design
Sulfate	64.5 mg/L (From river source alone; From DLT Raw Water Intake Quality Dec 2019 to Sept 2024.xls.) 214.6 mg/L from ASR Well No. 4 (from City provided 2021 to 2024 sulfate data for all eight wells; see also Subsection 2.2.3 of SIX® Pilot Report)	~55 mg/L (Figure 13 from SIX® Pilot Report)	During times of higher sulfate due to copper sulfate addition or blending with ASR wells: • Increased sulfate level can reduce the SIX® TOC removal efficiency by competing for exchange sites on the resin.
pH	8.4 (DLT Raw Water Intake Quality Dec 2019 to Sept 2024.xls)	8.38 (Table 14, of SIX® Pilot Report; Phase 2)	• No risk as values are the same and can be adjusted with chemical feeds
Temperature	32.1° C (DLT Raw Water Intake Quality Dec 2019 to Sept 2024.xls)	30.9° C (Table 3 of SIX® Pilot Report)	• Elevated temperature may cause biogrowth on SIX® components which can lead to the resin carry-over. • Higher temperature also has positive impact on coagulation process
Geosmin and MIB	183 ng/L Geosmin 53.1 ng/L MIB (data from March to June 2015) (from Tampa DLTWTF Master Plan_(Carollo)_2018-07-01_Volume 1; Table I1.)	~100 ng/L Geosmin and ~12 ng/L MIB (Figure 82 of SIX® Pilot Report)	• Note that SIX® Report states all pilot filtered samples were less than detection limit of 1 ng/L, but the short duration high raw geosmin and MIB was not sampled extensively • Geosmin and MIB are not impacted by SIX® except for a possible small percent loss by aeration in the SIX® contactors. With downstream ozone and GAC, these should be removed as well
Turbidity (NTU)	4.7 NTU (DLT Raw Water Intake Quality Dec 2019 to Sept 2024.xls)	5.7 NTU for pilot test period (Table 3 of the SIX® Pilot Report)	Minimal risk identified as turbidity is historically low, and the pilot experienced moderate turbidity. SIX® can handle much higher turbidity in feedwater.

From the above observations:

- For TOC and bromide: It is evident that historical extremes of TOC and bromide exceeded the pilot extremes. These pose some risks (refer to Subsection 7.1, Risks Register) for meeting TOC and bromate water quality targets.
- For alkalinity: the historical extreme low for alkalinity was experienced in the pilot and testing represented full-scale chemical dosing needs.
- For sulfate: During the pilot study, only two of the eight ASR wells were operated. The anion equivalence from these wells was considered (additional discussion in Section 3.1.2). A higher sulfate concentration contributed by the ASR wells could affect the SIX® efficiency for TOC removal, but this was not observed during the pilot study. One mitigation being considered by the TWT is to add ASR flows downstream of SIX®, because those ASR flows introduce sulfate, and have low concentrations of TOC.
- For pH and temperature: It should be noted that even though the difference between historical and pilot extreme of pH, temperature is negligible, these are critical parameters for the optimum coagulation as well as TOC removal; and, therefore, these should be closely monitored.
- For geosmin and MIB: The pilot experienced some peaks for these T&O compounds, and all of the samples of filtered water were less than detection. In the January 2025 Discovery Meeting No. 4, it was noted that the existing ozone and BAC filters effectively control these compounds; however, if the ozone dose is lower for disinfection due to less ozone demand with SIX®, then the City may need to monitor geosmin and MIB more regularly in case a higher ozone dose is needed for T&O control. If there are times of higher ozone dosing and if the ozone carries over to the filters, quenching is needed. A hydrogen peroxide feed system exists, but the City advised at that meeting that mixing and dosing capability needs to be evaluated and improved.

3.7 Impact of Daily Feedwater Quality Fluctuations on Performance

Fluctuations in feedwater quality to water treatment processes are considered challenging to manage as some processes require time for changes in chemical dosing and flows to take effect. This is often in large basins with long (e.g., >1 hour) detention times. A subsequent issue is that the impact of the dosing or treatment changes made by operators is not known immediately, so even longer periods with sub-optimal treatment or over-reaction by operators is a risk when treatment challenges are occurring.

Common fluctuations in water quality for surface water plants are from rainfall events, when turbidity and organic concentrations can rapidly increase in a source water. The City has different feedwater sources (e.g., the Tampa Bypass Canal Middle Pool supply and ASR wells), and each has a different water quality that can cause sudden water quality changes to the feedwater.

The TWT pilot team shared that the dramatic shift in water quality due to seasonal changes in Fall 2021 was also somewhat difficult to track and adjust pilot settings in a timely manner. The manual nature of most pilot operations, however, would contribute to this challenge. The full-scale DLTWTF is accustomed to anticipating and reacting to the seasonal low TOC season changes to high TOC, and with automated systems (for example, operational algorithms for resin dose based on feedwater quality), the adjustments should be more efficient.

With SIX® in the treatment train, other water quality fluctuations need to be considered. Turbidity is not a parameter that affects SIX® performance, but fluctuations in the raw water organic concentration (e.g., due to rainy season affects or the recycle flow addition from the dewatering facilities) would need to be managed with resin dose and downstream coagulation dosing in real time. On-line UV254 analyzers could be beneficial to identify rapid changes and alert operators to adjust operational settings.

One other impactful parameter is from the ASR wells that are blended into the feedwater supply during the dry season. The ASR wells recharge and recovered water quality is assessed by the City annually, and 2023 information is summarized herein. The water quality for recharge water that is treated water from the DLTWTF during the wet season is monitored for primary and secondary State Drinking Water Standards each year. If ASR flows are introduced downstream of the SIX®, there would be an impact on coagulation and ozonation settings.

Sulfate is present in the recovered water of the eight ASR wells at concentrations that are two to three times higher than the Hillsborough River supply (maximum was 64.5 mg/L in historical data). The City provided a spreadsheet of the sulfate in the eight wells (data from 2021 to 2024). A summary is shown in Table 7.

Table 7 Sulfate Concentrations of the Eight ASR Wells (data from 2021 to 2024 monitoring)

Parameter	Sulfate Concentration (mg/L) for Each ASR Well							
	ASR 1	ASR 2	ASR 3	ASR 4	ASR 5	ASR 6	ASR 7	ASR 8
Maximum	140.0	172.0	173.0	214.6	204.3	215.8	188.7	196.0
Minimum	88.0	88.8	128.0	136.4	129.0	122.0	118.8	129.0
Average	106.4	113.3	149.6	169.1	163.0	156.6	149.6	157.0
5th Percentile	88.6	92.5	132.2	142.7	133.3	126.5	134.3	132.5
95th Percentile	136.4	164.1	171.4	209.2	197.5	206.4	186.03	196
Median	102.0	113.5	148.0	168.6	169.5	154.0	146.0	158.0

The sulfate concentrations in the ASR wells from 2021 to 224 are summarized as follows:

- The maximum sulfate concentration was 215.8 mg/L in ASR Well 6.
- The minimum sulfate concentration was 88.0 mg/L in ASR Wells 1 and 2.
- The average concentration of sulfate ranged from 106.4 to 169.1 mg/L for all eight wells.
- The overall average of the data was 145.6 mg/L (data not shown in Table 7).
- The 95th percentile shows that the sulfate would be from 136.4 to 209.2 mg/L.

In terms of fluctuations, if ASR wells are brought into and out of service to the feed of the SIX®, there could be an impact on the TOC removal from the SIX® (although this was not observed during the pilot study). Adding ASR wells will increase the sulfate concentration, and the final concentration will depend on the blending ratio and which wells are used. One design consideration is to blend ASR water in after the SIX®. This eliminates the risk of higher sulfate affecting SIX® performance for TOC removal.

ASR water was blended at varying ratios in Spring 2021 during the pilot study for a few weeks, and blends in the SIX® Pilot Report on Figure 13 show about 30 to 55 mg/L sulfate in the feedwater. This is somewhat higher than 20 to 30 mg/L sulfate in the feedwater without ASR well contributions or copper sulfate addition.

One other possible impact is the recycle flows from the solids dewatering systems. The TOC concentration is likely to be high, and it is recommended to do an evaluation to check the possible concentration increase during low flow periods when the impact would be the greatest.

3.8 Brine Quality

During the pilot study, two SIX® brine waste samples and one caustic brine sample from the caustic squeeze were collected and analyzed. The SIX® brine wastes were analyzed pH, conductivity, alkalinity, TOC, TDS, nitrate, chloride, sulfate, and bicarbonate, while the caustic squeeze brine waste was analyzed for pH, TDS, and chloride.

3.8.1 SIX® Brine Waste Quality and Flow and Considerations

The brine waste quality would reflect the feedwater quality being treated by the SIX®, because the brine is a mixture of the anions that were exchanged and removed from the feedwater. One brine waste was collected in January, during the low TOC season and one was collected in September 2021 during the high TOC season. The results are shown in Table 8.

Table 8 General WQ of SIX® Brine Waste (from SIX® Pilot Report; Table 48)

Sample	Date Sampled	pH (SU)	Conductivity (uS/cm)	Alkalinity (mg/L as $CaCO_3$)	TOC (mg/L)	TDS (mg/L)	Nitrate (mg/L-N)	Chloride (mg/L)	Sulfate (mg/L)	Bicarb (mg/L)
Brine Waste	01/25/21	8.7	26,100	760	350	20,000	2.2	6,000	2,000	920
Brine Waste	09/16/21	8.6	NT	2,700	730	13,000	3.7	4,200	2,600	NT
Caustic Brine Waste	10/01/21	10	NT	NT	NT	110,000	NT	50,000	NT	NT
Notes: NT = not tested.										

The observations from the brine waste samples were as follows:

1. TOC: The TOC concentration in the brine sample that was collected during the low TOC season was about half of the sample from the high TOC season.
2. Alkalinity: Alkalinity was much higher (about three times) in the high TOC season compared to the low TOC season.
3. pH and sulfate concentrations: These were similar for the samples.
4. TDS and chloride: These were somewhat higher in the low TOC season samples.

It is important to have an indication of the possible maximum and minimum values for the brine waste water quality parameters and be sure they are acceptable for the deep well injection.

The monthly monitoring requirements for injectate into the deep wells are: pH, specific conductance, temperature, chloride, sulfate, TDS, total Kjeldahl nitrogen, TOC, bicarbonate, calcium, total iron, magnesium, potassium, sodium, aluminum, manganese, gross alpha, uranium, $radium^{226}$, and $radium^{228}$. All of the primary and secondary drinking water standards must be monitored annually as well. This is shown in Table 3 Monitoring Schedule of the DEP UIC Permit: 115938-001-003-UC/1X.

The permit for a Class 1 Injection Well System Construction and Testing Permit from the FDEP (UIC Permit Number: 415938-001-003-UC/1X) to construct and operationally test three non-hazardous injection wells and three associated dual-zone monitoring wells allows for flows of 1,042 gpm for each individual well, with a daily combined flow to the three wells not to exceed 1.5 mgd.

The following are considered possible risks for further checking and clarification:

1. The wells are referred to as nonhazardous brine injection wells, and the USEPA has issued guidance that informs that brine injection to aquifers that cannot impair drinking water sources is one disposal option at this time. There can be the accumulation of PFAS compounds as well as heavy metals in the brine, if these are present in the raw water. This is a potential risk if the brine would fall into a hazardous category based on quality in the future. The water quality sampling for the permit is for typical water quality parameters (e.g., inorganics, aluminum, manganese, iron, calcium, magnesium, TOC, etc.), including radionuclides, but not heavy metals or PFAS.
2. PFAS waste disposal from treatment plants is a new challenge for water treatment plants. Thus far, USEPA has issued technical guidance that indicates deep well injection is an option as long as there is no risk to drinking water systems (i.e., in a confined aquifer).
3. While three (3) wells are listed in the permit, it is Black & Veatch's understanding that two wells will be constructed initially (according to the 11/15/2024 Discovery Meeting) and the other well would be constructed if necessary. The projected flows are shown in Table 9. The 0.8 percent waste estimate is the five-times-used brine waste; but at some plants, rinse water is also sent for disposal due to the high chloride level. This can be up to 3 percent, so 3 percent as a waste flow is calculated below for comparison.

Table 9 Brine Volumes for Deep Well Injection and Well Capacities

Brine Waste Percentage or Injection Well	DLTWTF SIX® Operating Flow		
	80 mgd*	120 mgd*	140 mgd*
Brine as 0.8 percent of SIX® treated flow	0.64 mgd	0.96 mgd	1.12 mgd
Brine as 3 percent of SIX® treated flow**	2.4 mgd	3.6 mgd	4.2 mgd
Capacity of one brine injection well	1.5 mgd		
Capacity of two brine injection wells	3.0 mgd		
Capacity of three brine injection wells	4.5 mgd		

*Plant capacities shown here are for raw water flow, and brine estimates were calculated as a percentage of these raw water flows.

**The 3 percent is a worst-case waste flow rate if rinse is included in the waste brine flow; note that the caustic squeeze waste (expected to be periodic and small volume per train) may also be blended with brine waste and sent to the injection well, and this would need to be factored into the calculation.

One risk is that if rinse water that contains an elevated concentration of chloride is mixed with the brine for disposal, the volumes will exceed the capacity of one and two wells, and the third well will be needed. It is recommended to evaluate the rinse flows and concentration of chloride to determine if the rinse can be recycled internally within the works.

Another consideration for the City is the volume of waste from the DLTWTF from the SIX® process. While 0.8 percent of treated flow is a relatively low percentage, for a 140 mgd plant, it may be a higher loss than was considered or expected (and 0.8 percent is the bottom of the range of possible waste flows up to 3 percent). Water resources are critical for the City, so this is an important aspect to consider.

3.8.2 Caustic Squeeze Waste Quality and Flow and Considerations

The SIX® brine waste will comprise the majority of brine for deep well injection; however, periodic caustic squeezes to be performed to control biofouling of the resin will possibly be needed. While it is unclear if the caustic squeeze will be needed, the TWT intends to include design features to allow for caustic squeeze if necessary (Discovery Meeting No. 3 minutes).

The caustic squeeze is a procedure to soak the resin for 24 hours at pH 10 (using sodium hydroxide) and with a high salt concentration of 50 g/L as NaCl. Table 8 shows the TDS and chloride concentrations of the caustic squeeze that was performed in October 2021.

The waste volume of each caustic squeeze procedure will depend on the vessel size used for storing the resin, but it can be expected to be a much lower volume than the daily SIX® brine waste. The caustic squeeze waste pH was 10, compared to the SIX® brine waste at pH 8.6 to 8.7. The caustic squeeze brine waste also had a much higher TDS concentration (i.e., 110,000 mg/L) and a higher chloride concentration of 50,000 mg/ than the SIX® brine wastes (i.e., 13,000 to 20,000 mg/L TDS and 4,200 and 6,000 mg/L chloride).

The following can be considered despite the unknowns about the caustic waste:

- The caustic squeeze waste will likely be pH adjusted prior to disposal, and this will further increase the TDS and anion content. The type of acid would need to be considered.

- It may be that the volumes of caustic squeeze waste would be stored and blended into the SIX® brine over time to lessen any concentration surge from the high TDS (and chloride) being added to the disposal site.
- It is not clear if this waste could be included in the allowable waste flows to the deep wells for injection.

3.9 Contaminants of Emerging Concern

Contaminants of emerging concern (CEC) include contaminants that fall into a variety of categories, such as endocrine disruptors, emerging pollutants micropollutants, pharmaceuticals, trace organic compounds, etc. These compounds are typically not already regulated by the USEPA, but evidence exists to show they are potentially harmful to health and/or environment, and research is underway to study their impact and prevalence in drinking water.

SIX® was not specifically developed for CECs removal and studies are being conducted to evaluate the effectiveness of the SIX® process in removing CECs. Two of the processes typically used for these categories of contaminants are ozone oxidation (sometimes as an advanced oxidation process, AOP) and adsorption onto GAC. For the near term, the DLTWTF is expected to oxidize and remove CECs to a high degree with ozone and GAC filter beds. As more studies take place about treatment optimization for CECs, process enhancements (e.g., pH adjustments, AOP, etc.) could help control CEC concentrations in the finished water. It may also be necessary to exchange the GAC in the filter beds more frequently than what is currently expected if compounds of concern have high breakthrough rates or the load to the GAC is high.

Having SIX® at the head of the works would lower the ozone demand and lower the organic load to the GAC, meaning that ozone will be more effective for oxidation of CECs, and the GAC will stay in service longer for CEC removal.

4.0 Operations and Maintenance Considerations

The risks associated with operating and maintaining the SIX® are discussed herein. It is also recommended to discuss with plant operating staff at full-scale SIX® installations about their experiences with the process and equipment. As with any new water treatment process, there will be a learning curve for operations staff to become familiar with the operational set-points, equipment operation and maintenance, as well as troubleshooting.

4.1 System Evaluation for Maintaining Steady Operation

In this section, operational aspects of adding SIX® are presented and discussed. This includes not only the SIX® process but other downstream processes that could have operational changes from current operation or challenges.

4.1.1 Introduction of SIX®-Treated Water

If SIX® is implemented at the DLTWTF, there will be a change in water quality not only within the treatment facility, but also in the distribution system. Dramatic shifts in water quality in the distribution system can cause water quality shifts, due to sloughing of films or deposits on pipe walls.

The Mayflower facility in the UK implemented a blending plan, such that SIX®-treated water was introduced over several weeks to minimize the possibility of sloughing in the distribution system. Perhaps the commissioning plan could also include a gradual introduction of SIX®-treated water if SIX® is installed at the DLTWTF.

4.1.2 Resin Loss and Replenishment

If there is a loss of resin over time from the SIX® process, it is recommended for the City to examine operations (i.e., flows) and cleanliness of the plates to minimize further losses. Extra resin can be purchased at the start of operation and stored in super sacks on site for "topping up." There can be long lead times (e.g., > 6 months) for large orders of resin, so having extra resin on site should be considered. Also, other suppliers of a TOC removal anion exchange resin might have inventory available. There are unknowns, however, about mixing resins from two suppliers (e.g., do they regenerate in the same way, etc.).

4.1.3 Resin Loss by Flow Surges

Although it was not observed in the pilot study, resin carry-over and loss from the SIX® process can occur if there are surges in water flow through the SIX®. The TWT mentioned in Discovery Meeting No. 1 that the in the design stage, passive flow and valve control would be considered to minimize surges in flows (this involves operating with open valves, which would be throttled when a flow target for a train is exceeded). Supervisory control and data acquisition controls will be added so that increases in flow cannot occur if the available train capacity is off-line.

Methods for removal of resin from downstream processes should be evaluated as some resin will likely carry over to the sedimentation process over time. Methods for easy ‘topping up’ of resin into the system should also be in the design.

4.1.4 Loss of Resin from Facility

The potential for resin to leave the treatment process should be carefully mitigated, as resin beads would be considered a microplastic and efforts should be made to minimize release into the environment. Microplastics are being studied as they are prevalent in the environment and are considered an environmental concern as they are not degrading quickly over time and are accumulating in the food chain. This is not only a consideration for the treatment train and waste flows, but also the drainage flows from the plant or floors that could contain resin beads.

The risk is that resin leaves the treatment process and enters the environment.

4.1.5 Resin Suspension in Fresh Resin Vessel

The existing SIX® full-scale plants, and pilot plants, use a fresh resin tank with a mechanical mixer to keep the high resin concentration that is in this tank in suspension. The mixing is enough to keep the resin suspended for consistent dosing via the eductor. There could be abrasion of the resin within the fresh resin tank due to the mixing, but thus far there has been no evidence that this has occurred in pilot- or full-scale systems. The resin analysis after the pilot study for the DLTWTF showed the pilot's resin was of the same size distribution as new resin. Using another mixing mechanism, such as air, could be considered, but this would require confirmation testing by PWNT, the equipment supplier.

The new regeneration system design concept eliminates the fresh resin tank, and if this new system is implemented, there is no risk of abrasion by mechanical mixing.

4.1.6 Maintenance of Equipment

4.1.6.1 Access to Maintain Valves and Pumps

A key element in the design review will be the accessibility to the pumps and valves associated with the SIX® system and/or any other associated improvements. Adequate horizontal and vertical access surrounding these components is required so the equipment can be cleaned, maintained, and inspected without reaching around other equipment or piping, or positioning the body in odd angles for access to hard-to-reach areas. A clear workspace is also needed for the tools required for maintenance and/or if motorized lifts are needed to raise/lower pumps, motors, valves, or piping segments. All electrical panel breakers to the pumps, actuators, etc. should also have the same type of access to the disconnect(s) along with any LOTO requirements. In the event a pump or valve is located above ground at higher elevations a platform or something similar should be considered for not only the maintenance activities but also fall protection.

The SIX® process has an elevation of several feet, so it is likely that some valves and equipment are not easily accessible from a working floor level. In this case, scaffolding would be required. This type of access can be evaluated in the design stage of the project.

4.1.6.2 Method for Cleaning Resin, if Necessary

As mentioned in Subsection 2.2.1.3, Resin and System Fouling, a risk of biofouling exists on the resin due to warm water conditions and the accumulation of organics and other nutrients on the resin. The single pass regeneration of SIX® helps mitigate biofouling by having resin regenerated about every hour.

It is recognized, however, that if biofouling occurs, steps to clean the resin would be needed. Some considerations would be the following:

1. Ability to perform caustic squeeze;
2. Ability to chemically (e.g., with chlorine or hydrogen peroxide) remove biomass and clean contactors and Lamella plates for resin settling; and
3. Ability to physically remove biomass and clean the contactors and Lamella plates with a high pressure wash.

4.2 System Operations

If SIX® is installed into the DLTWTF, it would the third full-scale installation of SIX® for water treatment. This means that a control philosophy and functional description of the SIX® treatment process has had two iterations of development, and lessons learned have been applied, meaning that the implementation for the City of Tampa should benefit from the previous designs.

There will be a learning curve for the operators to learn a new treatment process, and only a few operators in the world have experience operating the SIX®. One recommendation is to visit and network with operators from the other full-scale installations to hear lessons learned. It is also recommended to have a thorough training program for operators to learn not only about the SIX® process, but to also learn about the impacts of SIX® on downstream processes.

4.2.1 Chemical Systems

One of the findings from the SIX® pilot study was that the chemical feed systems for alkalinity and pH control can change once SIX® is operating. SIX® removes enough organics to impact the downstream coagulation, and less coagulant is needed. SIX® also removes bicarbonate, and coagulation can be optimized without sulfuric acid addition. This was observed in the pilot results.

As a result of adding SIX®, coagulation pH can be controlled with caustic and alkalinity can be controlled with caustic and CO_2 addition. The existing lime and sulfuric acids systems can be removed from site once the SIX® is operational (Subsection 11.1 of the SIX® Pilot Report).

Removing lime and sulfuric acid feed and storage systems from the DLTWTF is beneficial for operators in terms of safety and maintenance/reliability. Sulfuric acid is a highly hazardous chemical to work around and requires specialized personal protective equipment when offloading to storage tanks, performing metering pump drawdowns to confirm calibration, and/or maintaining chemical feed piping. Eliminating operator and maintenance staff exposure to sulfuric acid will remove a significant safety concern for staff and not affect the treatment processes after the SIX® process is online. Lime is a messy chemical that can affect air quality (lime dust) and creates heat (superficial burns to the skin) when in contract with water (i.e., moisture on the arms, etc.) while cleaning the feed area. On the treatment side, lime will add calcium back to the treated supply during periods when the source water has low calcium concentrations (several weeks or so per year). This can be offset with caustic and CO_2 by increasing the alkalinity and pH levels to meet the desired Langelier Saturation Index indices.

4.2.2 Raw Water Particulate Impacts on SIX®

Because SIX® would be installed as the first process after screening, it will receive water that has the natural turbidity (or particulates) of the feedwater. PWNT has not provided a maximum allowable turbidity for the feedwater to SIX®, but it does have requirements or recommendations for feedwater straining to prevent debris from entering and getting lodged, for example, in the eductor or plate settlers.

The raw water turbidity would enter the SIX® and pass through the contactors with the resin. The plate settlers are designed by PWNT to have a loading rate that allows resin to settle and turbidity to travel with the SIX®-treated water to the downstream process. If turbidity were to settle in the Lamella settlers of the SIX®, it would travel with the resin to the regeneration tank, and ultimately be sent to the fresh resin tank. The fresh resin tank is continuously mixed to allow for a consistent resin concentration for dosing into the feedwater to the contactors, and any turbidity would also be sent to the feedwater.

The raw water turbidity during the pilot for the Hillsborough River was quite low (i.e., the maximum was 5.7 NTU and the average was 1.9 NTU; Table 3 of the SIX® Pilot Report). ASR turbidities are even lower (average 0.6 NTU; Table 4 of the SIX® Pilot Report) so blended waters will have lower turbidity. The historical maximum (data from December 2019 to September 2024) was 4.7 NTU. These data suggest turbidity less than 5 NTU is common at the DLTWTF and should not adversely impact SIX® operations or performance.

PWNT has conducted pilot plants on river sources, such as the Rivers Tamar and Tavy in the UK that can have turbidity as high as about 200 NTU. The full-scale plant was installed in 2018, with no reported issues with turbidity. PWNT has also pilot tested at a site in Spain, and the turbidity was as high as 300 NTU; the pilot performance was not impacted.

4.2.3 Pretreatment to Filters and Impact on Filter Capacity

In the pilot study, coagulation, flocculation and plate sedimentation were used as pretreatment to the pilot filter columns. The UFRVs of the deep bed GAC filter were better than the UFRVs of the other media designs in the pilot study.

The upgrade project for the DLTWTF includes an evaluation of the coagulation, flocculation, and clarification system at the facility. The existing facility has trains with coagulation, flocculation, and sedimentation, and also has two trains with Actiflo®. The Actiflo® process was not tested as part of the SIX® pilot. The TWT will evaluate options of having only coagulation, flocculation, and plates sedimentation, or a mix of treatment also with Actiflo® trains in the next phases of the project.

4.2.3.1 Actiflo®

One risk is that the pilot achieved high UFRVs with the coagulation, flocculation, and plate sedimentation pretreatment. Actiflo® uses microsand and polymer for ballasted flocculation and sedimentation, and some utilities have experienced issues with polymer/sand mass carry-over to the filters. The TWT also mentioned that the existing DLTWTF has sand in the ozone contactors that are downstream of Actiflo®. If this carryover passes through the ozone contactors, then polymer and sand 'mud balls' could form and cause rapid headloss on the filters. This would affect the performance of the new filters that will be designed to achieve higher UFRVs. If the new filters operated at lower than design UFRVs, there would be higher backwash waste flows, more downtime for backwashing, a lower plant recovery, and the possibility of not meeting plant capacity flows due to short UFRVs.

It was noted in a Discovery Meeting No. 1 that the pilot filters that were downstream of the conventional train were backwashed based on meeting the maximum allowed headloss, except when the seasonal shift in TOC concentrations occurred and pretreatment was not optimized (and turbidity was the reason for backwashing during this time). This means that if the UFRVs from this pilot are used for design, those UFRVs would be based on conventional pretreatment and not Actiflo®. The impact of Actiflo® on the UFRVs can be evaluated further by the TWT.

4.2.3.2 Microflocculation

Microflocculation was also observed during the pilot study, and it caused elevated headloss in the filters. This was observed during the high TOC (Phase 3) season. The microflocculation mitigation procedures that were evaluated during the pilot trial were: 1) sodium bicarbonate dosing, 2) ozone quenching with peroxide, 3) no ozone, 4) floc aid polymers, and 4) prefilter chlorine. It was also noted (page 52 of the SIX® Pilot Report) that a decrease in the microflocculation impact occurred after a caustic squeeze was performed.

The sodium bicarbonate addition helped mitigate the effect of microflocculation (page 54 of SIX® Pilot Report) with a 200 percent improvement in UFRVs. Operating without ozone or with pre-filter chlorine also resulted in longer filter run times. Flocculant aid polymers were also tested but caused adverse effects. Quenching ozone had no noticeable impact on microflocculation effects.

One mitigation planned by the TWT (Discovery Meeting No. 1 minutes) is to allow operation with no ozone during times of microflocculation. The design of the chlorine contactor at the HSPS allows for meeting disinfection requirements temporarily until the ozone can be operated again.

While microflocculation is expected to occur, the pilot study has shown that there are several possible operational tools to help mitigate the effects on filtration, and the City can choose to implement those based on their preferences.

4.2.4 Aquifer Storage and Recovery Supplementation to Feedwater

The ASR well supplies are used during dry weather periods to supplement the surface water supply to the DLTWTF. As documented in Subsections 3.3.2 and 3.3.3, the ASR wells have a different water quality that poses some challenges to treatment. These are discussed below:

1. ASR Bromide: The bromide levels in the ASR supplies can be high, and this would require bromate mitigation to be continued and closely monitored for the DLTWTF. This has been managed successfully in the past and shows no reason to that this will be a problem in the future. In addition, the SIX® will remove organics upstream of the ozone system and the ozone demand will be less, so less bromate will be produced. No additional risk is identified.
2. ASR Sulfate: Because sulfate competes with organics for adsorptive sites on the resin in times when ASR is blended into the feedwater, SIX® could remove less organics. This could be countered by the lower DOC concentration of the ASR in the blend, and a more in-depth review of ASR blending impacts is recommended. The risk is that with lower organics removal by SIX® due to ASR blended into the feedwater, the downstream processes will be adversely impacted.

One mitigation option is to feed the ASR water into the DLTWTF downstream of the SIX® process (Discovery Meeting minutes No. 4). This is possible as ASR water has low concentrations of organics so this should not significantly impact the downstream coagulation or ozonation systems. The sulfate in the ASR also does not impact the downstream systems, and in fact helps with the CSMR for corrosion control.

5.0 Performance Guarantees

The DLTWTF is being delivered as a progressive design-build project and in that approach, performance guarantees (PGs) will be included in the contract. PGs are included in these types of projects to give assurance to the Owner that the aims of the treatment are met by the newly installed infrastructure.

In addition to PGs, there are also warranties. In simple terms:

- PGs are related to measurable performance metrics of the installation and can include parameters such as water quality, chemical use, energy cost, and flows; and,
- Warranties are related to equipment life and equipment functionality within the warranty time period.

Warranties are standard for infrastructure projects and are typically based on the warranties that are provided by equipment suppliers (e.g., for pumps, valves, instrumentation, etc.). PGs are developed either by the Owner of the project or in conjunction with the design-builder.

The document reviewed for this evaluation was 23.07.31 Draft Performance Guarantee from the SIX® Pilot Report.docx (referred to herein as the PG document). Warranties are not evaluated herein.

5.1 Reasonableness of Performance Guarantees

The reasonableness of the PGs was assessed, and strengths and deficiencies are identified for the City to consider. The PG document defines a testing time, operation and allowed actions during the testing period, finished water TOC concentrations PG, TOC removal by the SIX® process, and resin loss from the SIX®. The PGs for SIX® itself are a TOC removal PG (35 percent removal over a 28-day average) and a resin loss PG (≤0.2 L per ML treated flow). Other treatment processes (i.e., filters and HSPS) are being upgraded or replaced in the overall upgrade to the DLTWTF, and, at the time of this independent review, it is not known if other PGs (e.g., combined filter turbidity, individual filter turbidity, final chlorine, and chloramine disinfection) were or will be developed for these process units.

It is important to recognize that PGs for this project are negotiated between the design-builder and City (Owner). Balance needs to be considered when developing PGs. Typically, more stringent/inflexible PGs result in the supplier increasing conservatism in design and installation to ensure the design-builder can achieve the PGs in the performance testing period. The additional conservatism reduces risk for both the Owner and the supplier, but would likely come at an increased capital cost.

The PGs for the SIX® system are shown in a table in the PG document. This table is shown in Table 10 for clarity for the evaluation of the PGs in the following sections of this TM.

Table 10 Performance Guarantees for the SIX® System (from the PG document)

Parameter	Unit	PWNT Guarantee	Description
TOC	Percent*	35% removal (28-day average)	TOC removal by SIX® during the pilot study was between 25% and 70%, with an average of 52%. During the pilot study, the goal of achieving ≤2 mg/L TOC in the finished water after SIX®, coagulation**, ozonation**, and BAC was achieved >90 percent of the time***. TOC concentration measured twice per day in the feed to the SIX® system and the SIX® treated flow at times to represent flow through the SIX®.
Resin Loss	Liters	≤0.2 L per ML treated flow	

*Percent removal calculated with paired (raw and SIX®-treated samples) data sets using the equation: [(raw TOC)-(SIX®-treated TOC)]/(raw TOC); and the guarantee is the average of all calculated percent removals from the paired data sets over the test period (e.g., the average of 56 paired data sets in a 28-day test period).

**Coagulation shall be the required coagulation to achieve 0 mV zeta potential, and ozone will be the required dose to maintain a residual of 0.5 mg/L after 5.5 minutes of contact time.

***From Carollo; SIX® Pilot Workshop, City of Tampa, DLTWTF Expansion Project, 01/21/2022.

5.1.1 Performance Guarantee Testing Period

The proposed testing period of the PG document is 1 month with an option to shorten the testing period if initial results are satisfactory to the City. The SIX® PGs of the PG document relate to a 28-day average, and this may or may not match exactly the 1-month test period in duration. It is also not clear if the testing is over consecutive days or not.

The TOC PG is directly related to the testing period, as it is an average of all samples within the testing period. The resin loss PG is not necessarily related to the length of the testing period, as it is a loss per volume of water treated. If the City agrees with the design-builder, then the monitoring and measurement of resin loss could be as short as a day, if deemed representative of operation.

The 1-month testing period will be as follows:

- Initiated after commissioning and startup activities are completed for SIX®,
- The SIX® system has been operating within "normal tolerances and steady-state operating parameters (assumed to be a 5-month period prior to performance testing)," and,
- Follow a testing plan, including schedule, water quality sample frequencies, analysis methods, and reporting requirements.

As mentioned in a footnote of the draft PGs, the testing period could be shorter than the 1 month if agreed to by the City, but if the SIX® is underperforming, then the City and the SIX® system supplier will request the full testing time due to the calculation of an average TOC removal with all samples, because TOC is the main PG for the SIX® supplier.

A longer testing period is sometimes proposed, but 28 days is an industry norm for the following reasons:

1. The testing occurs at the end of a project, and a longer testing period leads to more costs for the Owner because of staffing and sampling/monitoring costs;

2. Many times PG testing is at maximum flow conditions, and it is not always possible to receive or use/store maximum flow at the time of testing; and,
3. Sufficient time to observe performance is 4 weeks, and water quality variations, if any, are likely to occur within this time.

Because the raw water quality shifts dramatically at the DLTWTF, an option could be to have a second testing period to capture a different water quality. With a 1-month testing period after substantial completion and a few months of normal operation, the timing relative to the raw water quality is not easily controlled to happen within a targeted season. Construction delays, for example, could push the start of testing to later than scheduled. Issues with downstream process units could require additional time. As a result, the Owner would need to accept the PG testing results for the season in which the testing period falls.

A single, 1-month testing period is deemed to be acceptable for this project for the following reasons:

1. Pilot testing was performed with the entire treatment train, thus verifying performance in real time with seasonal raw water quality changes. This should give the City confidence that the targets are achievable.
2. Pilot testing over the high and low raw water TOC concentration seasons was performed and showed the TOC removal target could be achieved in both seasons. This should give the City confidence that the targets are achievable for the envelope of likely possibilities for both ends of the spectrum.
3. The design parameters described by the TWT include some conservatism, meaning that some parameters can be adjusted to deal with future water quality excursions. This should give the City confidence that the targets are achievable.

If the City does not have confidence in any aspect of achieving the PGs for TOC removal due to the raw water seasonal quality shifts, then this should be discussed with the TWT to determine testing or design options to minimize uncertainty.

Refer to Section 5.2, Proposed Contractual Guarantee Clarifications (of this TM) about possible modifications for the conditions of testing.

5.1.2 Performance Guarantee Test Period Specifics

The Performance Guarantees document explains some of the testing intent and specifics. These are addressed in Table 11:

Table 11 Assessment of Performance Testing Intent and Specific Requirements

No.	Performance Testing Intent or Specific Requirement	Reasonable (Yes/No)
1	The influent water flow rate shall not exceed the combined maximum design flow rate of the SIX® System (this is anticipated to be 14 mgd per SIX® train but the final value will be based on the maximum design capacity per SIX® train).	Yes
2	The influent water quality shall be within the range tested and the combination of water qualities as measured during the 2022 SIX® Pilot Study[1].	Yes

No.	Performance Testing Intent or Specific Requirement	Reasonable (Yes/No)
3	The raw water quality constituents that inhibit TOC removal such as sulfate, alkalinity, chlorides, and TOC (and fractionation) have not materially increased or changed as measured during the 2022 SIX® Pilot Study[1].	Yes
4	The Performance Test operation and maintenance parameters shall be as delineated during the 2022 SIX® Pilot Study[1].	Yes
5	If the Performance Test does not meet the requirements, the following are potential remedies, which are limited to correction and re-running the Performance Test: 1. Adjust process settings (e.g., brine dose, resin dose, and coagulation chemistry) as deemed necessary by TWT, and, if necessary, 2. Additional steps based on the performance data and agreed upon by TWT and City.	Yes

5.1.3 Finished Water Total Organic Carbon Concentration Performance Guarantee

The finished water TOC concentration PG is set at <2.0 mg/L for 90 percent of the time. This PG seems reasonable because of the following:

1. It was an identified target prior to pilot testing, meaning that it has merit with the City (and a different lower target is not expected).
2. The proposed treatment train has multiple units that achieve some form of TOC removal: SIX®, enhanced coagulation, and GAC biofilters. If one process is not capable of additional removal due to design settings or character of the organics, another unit process can be used to increase TOC removal.
3. It was confirmed in pilot testing that this PG could be met in all seasons of testing.
4. The TWT has identified conservative design parameters (e.g., higher resin dosing capability in the SIX®) in the event the TOC PG is not being met.
5. The PG gives an allowance that for 10 percent of the time, the TOC concentration of the finished water can be above the target. This is a realistic approach for a numerical PG, because variations in quality or measurement can occur, and in the event that TOC concentrations are greater than or equal to 2.0 mg/L, the TWT can showcase the facility's functionality in terms of what process changes can be used to meet the target. Also, if a firm numerical target is used, without any deviation allowed for a parameter that does not have a regulated, fixed MCL, then the likelihood of failure is higher during a PG performance test. This adds costs to the project for extra testing when the more flexible approach to the PG is acceptable.

There are no recommended changes for this PG. This overall TOC removal PG (<2 mg/L 90 percent of the time) is less stringent that the goal outlined in the SIX® Pilot Report (<2 mg/L 95 percent of the time; refer to Table 3 of this TM).

5.1.4 Total Organic Carbon Removal by SIX® Performance Guarantee

The specific PG for TOC removal by SIX® is 35 percent removal over 28 days, based on the average of two paired sample sets per day. The PG document also notes that "TOC removal by SIX® during the pilot study was between 25 percent and 70 percent, with an average of 52 percent. During the pilot study, the goal of achieving ≤2 mg/L TOC in the finished water after SIX®, coagulation**, ozonation**, and BAC was achieved >90 percent of the time***." [Note: Refer to Table 10 for the ** and *** footnotes.] This means that during the pilot study, the TOC removal was less than the guaranteed 35 percent removal at times; thus, the SIX® supplier is willing to accept some risk.

Those periods of lowest TOC removal were when a dramatic shift occurred in water quality, and sometimes when competing anion concentrations were highest (i.e., higher bicarbonate or when copper sulfate was added for algal control and/or when ASR water was blended into the water entering the pilot).

The PG document references a separate PG document with the SIX® supplier. This may be of interest to the City to know if there are other limits on the PG for TOC removal by SIX®.

5.1.5 Resin Loss Performance Guarantee

A resin loss PG is a standard PG for fluidized ion exchange systems where resin loss can occur. This guaranteed maximum resin loss of ≤0.2 L/mL treated is provided by the SIX® system supplier.

It is difficult in a full-scale installation, however, to accurately measure the actual resin loss. It is recommended that the TWT consider what is possible to verify resin loss in a 1-month test period, or less time if agreed to by the City. If this is not possible, perhaps there could be another remedy for resin loss compensation with the SIX® system supplier if resin loss is observed after the PG testing period.

Refer to Section 5.2, Proposed Contractual Guarantee Clarifications of this technical memorandum about possible modifications for this PG.

5.2 Proposed Contractual Guarantee Clarifications

The following are recommendations for the City to consider for the PGs:

1. The SIX® PGs shown in the PG document (and Table 10 of this TM) relate to a 28-day average for TOC removal that may or may not match exactly the 1 month of the test period in duration and are also not establishing if the testing is consecutive days or not. Perhaps this should be clarified in the document.
2. Because the PGs include a TOC concentration guarantee in the finished water, the performance test should be conducted after confirmation of performance of the entire treatment train, and not just after the SIX® has been operational for about 5 months. This is because SIX® is not the sole process providing TOC removal, and the remaining processes need to be functioning as intended to achieve the TOC target.
3. For resin loss, consideration should be made about how to measure resin loss accurately in the PG test period and identify possible remedies if resin loss is only identified after the 1-month test period.
4. The PG draft document relates to the SIX® TOC removal performance and resin loss limits, as well as the finished water TOC concentration. It is recommended that the City consider other possible PGs for parameters such as turbidity, chloride, chloride-to-sulfate, bromate, or taste and odor for this, or other phases, of the project. Additional guarantees can also be considered for operational aspects, such as power use, chemical use, and flow capacity.

5.2.1 Risks During Startup and Commissioning

5.2.1.1 Resin Fouling Prior to Substantial Completion

During commissioning, starts and stops, delays, and limits to what can be done could occur because of the ongoing commissioning work. If resin is loaded into the system and starts and stops occur, recommendations are to have the capability to store resin in a high salt concentration temporarily to minimize the risk of biofouling prior to the PG testing period.

5.2.2 Resin Performance

Resin for the SIX® is purchased from a resin supplier. While supplier quality assurance/quality control procedures are routine for their industry, there could be a risk that the full-scale delivery of resin from the supplier performs differently than the resin that was procured for the pilot study. While this risk is low, recommendations are that this be investigated to minimize any potential shortcomings in performance due the batch of resin delivered. This is of interest to not only TWT and the City, but also the SIX® supplier.

6.0 Cost Review

6.1 Background

Black & Veatch completed a review of the estimated capital cost, O&M cost, and life cycle cost information provided for the addition of the SIX® treatment process at DLTWTF. This included performing sensitivity analyses of the variables and assumptions that may impact the planning level cost estimates developed to date. The cost review was intended to be consistent with an Association for the Advancement of Cost Engineering (AACE) cost estimate class Level 4 to the extent possible based on the available information and level of detail provided for the conceptual plans to add the SIX® process at DLTWTF.

Black & Veatch reviewed Section 10, Economic Analysis, of the SIX® Pilot Report (2022, by Carollo) and the SIX Econ Analysis_1.xlsx spreadsheet, that were provided from the initial data request as part of the independent review services. The "SIX Econ Analysis_1.xlsx" spreadsheet that accompanied the SIX® Pilot Report of 2022 was relied upon for assessing how the cost estimate was originally prepared. Additional questions from Black & Veatch regarding cost estimates were discussed with the City and the TWT during a series of four Discovery Meetings.

6.2 Capital Cost Estimate

Table 12 summarizes Black & Veatch's understanding of the current capital costs estimate associated with the addition of a 140 mgd capacity SIX® pretreatment system at the DLTWTF. This value is in line with planning level cost estimates that Black & Veatch has developed for the addition of a SIX® pretreatment and required ancillary components at surface water treatment facilities of similar size. Historical capital cost estimates from the TWT were escalated to February 2025 dollars to arrive at a total capital cost estimate for the implementation of the SIX® and associated systems.

Table 12 Analysis of Capital Cost Estimates for SIX® and Associated Systems

Capital Cost Item	Previous Estimate	Current Estimate (February 2025 Dollars)***
SIX® Pretreatment System - 140 mgd Capacity *(Original value from: 20-C-00008 DLTWTF Master Plan Improvements Task Order 002 Updated CIP April 2021)*	$96,400,000 *(December 2020 Dollars)*	$130,200,000*
Deep Injection Wells (3) System *(Original value from: 20-C-00008 DLTWTF Master Plan Improvements "Spending Per Fiscal Year" August 2024 Update)*	$45,800,000 *(August 2024 Dollars)*	$47,000,000**
Corrosion Inhibitor System *(Black & Veatch developed conceptual cost opinion)*	$300,000 *(February 2025 Dollars)*	$300,000

Capital Cost Item	Previous Estimate	Current Estimate (February 2025 Dollars)***
Total Capital Cost Estimate	**N/A**	**$177,500,000**

Notes:
* Black & Veatch added a 35% capital cost escalation factor from December 2020 to February 2025 based on industry data and experience with planning level cost estimating efforts for similar projects in Florida. The 35% escalation factor assumes an 8.5% annual inflation rate from 2021, 2022 and 2023, and a 5% inflation rate in 2024.
** A 2% escalation rate was assumed for August 2024 to February 2025.
*** These budgetary estimates are considered to be an AACE Class 4 Cost Estimate (accuracy range of - 30% to + 50%).

The review of the capital cost estimate in Table 12 does not include the costs associated with the other process improvements the City is proposing to incorporate as part of the DLTWTF expansion from 120 mgd to 140 mgd. However, it is understood that the addition of SIX® would support reductions in the size or number of other treatment process units being considered to achieve the 20 mgd raw water capacity expansion at DLTWTF. TWT is evaluating the process units' size reductions during the design phase. The pilot study team estimated a reduction of approximately $60,000,000 in capital costs (in December 2020; with cost savings for filters, solids handling thickeners, and elimination of some chemical systems) for the DLTWTF capacity expansion project if a SIX® pretreatment system is added. Escalating this estimated capital cost reduction value to current economic conditions would represent an approximately $80,000,000 capital cost savings.

One additional future capital cost saving opportunity identified by the TWT is the potential to avoid future renewal or replacement costs for the existing (old) filters at DLTWTF if the SIX® pretreatment system is added in combination with the design of the new filters for the DLTWTF expansion project. Black & Veatch supports the claim that SIX® in combination with the new filter design will give the City better performing filters while lessening the surface area of filters that is required to meet the treatment capacity goals. The TWT has also recommended that the City keep the existing filters in operation along with the new deep filters, to lower the overall capital cost to meet the new capacity.

The value (future savings) associated with the impact that SIX® would provide towards the ability to decommission the existing filters in the future is not easily defined since this benefit is also driven by the new filter design. However, Black & Veatch agrees that the City will likely realize substantial savings in the future due to the higher filtration loading rate that was demonstrated as part of the SIX® pilot study results.

6.3 Annual Operating & Maintenance Cost Estimate

Black & Veatch reviewed the available information regarding the estimated annual operating costs and savings associated with operating a SIX® pretreatment system at DLTWTF. The review of the cost analysis in the SIX® Pilot Report indicates that the annual operational cost savings related to reducing chemical use (i.e., coagulant, ozone, and pH adjustment chemicals), reducing sludge production, and including annual power costs after implementing the SIX® process is estimated to be approximately $1,500,000/year (in 2021 dollars), which could be escalated to an annual savings of approximately $2,000,000/year in current dollars (assuming an approximate 35% escalation factor between January 2021 and February 2025). The review of the pilot testing results and operational cost savings data (i.e. chemicals, sludge and power) indicate that the estimates of operational savings are reasonable for this planning level estimate and are consistent with expectations based on our industry experience with operational costs associated with facilities that use similar treatment processes and chemicals.

The chemical costs utilized in the SIX® Pilot Report and associated spreadsheet are reasonable and in line with chemical costs for other water treatment facilities in the Tampa Bay area. The assumed escalation rates for chemical and power usage were lower than what Black & Veatch has been using for similar planning level estimates for operating costs, however, the methodology used to arrive at the annual operating costs seemed appropriate. It is recommended that future operational cost development include costs for waste brine disposal and labor costs.

Black & Veatch also performed a sensitivity analysis of the individual components that make up the operating costs associated with the SIX® pretreatment system (i.e., power, sludge, individual chemicals) to determined which items are anticipated to have the most impact on the overall operating costs if the unit pricing for those individual items significantly increase or decrease in the future. The results of the analysis indicated that future variances in the costs for salt and caustic would be the most impactful to the operating costs associated with the addition of the SIX® pretreatment system at DLTWTF.

6.4 Life Cycle Cost Estimate

The life cycle cost information provided in the SIX® Pilot Report was reviewed and the methodology was consistent with standard engineering financial principles of totaling the annualized O&M costs for a 30-year period to calculate a net present value of O&M costs, then adding this to the capital cost estimates. Following that method, the life cycle costs of $354M (for Baseline Alternative 1B) and $342M (for SIX®) were calculated. The life cycle cost analysis should continue to be updated and reviewed as project details and cost estimates are refined in further design stages for the SIX® pretreatment system at DLTWTF.

6.5 Conclusions

The methodology that the pilot study team followed to develop the planning level capital and annual O&M (operation and maintenance) cost information followed standard cost estimating procedures consistent with the information available at this stage of project development. The cost information presented was found to be reasonable for this level of project development.

If the City proceeds into the preliminary and detailed design stages for the SIX® pretreatment system at DLTWTF, the level of certainty in the capital cost estimates should increase as additional design details are refined. The estimated operating costs and life cycle cost analyses should also continue to be refined as additional project details are developed and operational costs such as waste brine disposal and labor costs should be added to the cost analyses.

7.0 Summary

The City owns and operates the DLTWTF, and the City is considering the addition of SIX® at this facility as part of an expansion project. A pilot study of SIX® upstream of conventional treatment with intermediate ozone was conducted in 2021 and 2022. This technical memorandum summarizes findings of the independent review by Black & Veatch regarding the potential benefits of adding SIX® as well as an assessment of unknowns and risks with suggested mitigations for the City to consider.

The findings of this review show the potential for water quality benefits with the addition of SIX®, as well as capital cost savings for other infrastructure as part of the expansion of the DLTWTF and lower operating costs for downstream processes. This technical review of the pilot study and the SIX® process is accompanied by a risk and benefit register, with recommended mitigations for the unknowns. Other general recommendations were also noted.

7.1 Review of the SIX® Pilot Design and Study

A comprehensive pilot study was conducted by the TWT. The pilot plant included the entire treatment train, including SIX® followed by conventional coagulation, flocculation, and sedimentation, ozone contacting, followed by filtration. This enabled a review of the impacts of SIX® on downstream processes. There were multiple objectives for the pilot study, and those were each tested and examined, with findings presented in the SIX® Pilot Report. Extensive water quality sampling was conducted, and special tests were performed when performance or water quality impacts were observed.

The pilot equipment for SIX® was a standard pilot plant that was equipped with automated functions and process elements to represent the full-scale process. The pilot study included evaluations of the typical process parameters, such as resin dose, contact time, and brine concentration.

The only deviation in pilot performance was the regeneration procedure that was a rinse/wash instead of a submersion of the resin in brine. This did not negatively impact the water quality results, but it was noted as a difference from the full-scale operation and may mean that the salt use during the pilot study was less than what would be used in a full-scale plant.

Overall, the SIX® pilot study was conducted in a manner that provides the City with assurance about the capabilities of SIX® for achieving water quality targets and continued performance with regeneration cycles and resin fouling control. Black & Veatch agrees with the SIX® pilot study recommendation for a preliminary design basis to have the capability to dose 30 ml/L resin (with normal dosages being 20 mL/L), 20 minutes of contact time at maximum flow, and a projected brine concentration of 50 mS/cm conductivity (~30,000 mg/L TDS).

7.2 Water Quality Impacts of SIX®

SIX® is primarily used for improved removal of TOC in a water treatment facility, and that is one of the main reasons SIX® was evaluated at the DLTWTF. The SIX® pilot study, which also included testing of the downstream processes, showed that the addition of SIX® at the head of the works provided many water quality benefits, and introduced other water quality changes that require some attention. These are summarized below.

7.2.1 Water Quality Benefits of Adding SIX®

1. **TOC Removal:** The addition of the SIX® process along with downstream processes was shown to achieve the TOC removal ranging from 81 to 91 percent, while meeting the goal of < 2.0 mg/L TOC in the finished water, 95 percent of the time. This was an improvement over the current TOC removal at the DLTWTF that achieves <2 mg/L, 18 percent of the time.
2. **Bicarbonate Removal:** Bicarbonate removal by SIX® is considered beneficial, because it eliminated the need for sulfuric acid addition to achieve the optimum coagulation pH for organics removal by ferric sulfate.
3. **Bromide Removal:** SIX® removed 15 to 40 percent of bromide in the pilot study, and this was maintained during the 10.5 months of pilot testing. Bromide removal is considered beneficial as it would minimize formation of brominated DBPs as well as bromate by ozonation.
4. **PFAS Removal:** SIX® is expected to provide some removal of PFAS, but the amount and consistency of removal is unknown due to PFAS removal not being evaluated during this pilot study (due to the unknowns at the time about future regulatory requirements and high detection limits for analytical methods at the time). Some PFAS removal by the GAC media in the planned upgrades with biological filters is also likely. The capabilities of PFAS removal by SIX® in combination with downstream biological filters with GAC media can be further evaluated through additional studies and pilot testing.
5. **DBPs:** By removing organics from the water, SIX® lowered the potential for the formation of DBPs by chlorine and chloramines. SIX® also lowered the ozone demand of the water by removing organics, and this would result in less bromate formation. Additionally, SIX® removed bromide, and this also lowered the formation potential of bromate.
6. **Geosmin and MIB:** Geosmin and MIB are not impacted by SIX® except for a possible small percent removal by aeration in the SIX® contactors. With downstream ozone and GAC, Geosmin and MIB should be removed to an acceptable level.
7. **CECs:** While not monitored in this SIX® pilot study, it is our understanding that SIX® is not expected to remove CECs, but instead provides benefit for CEC control by lowering the TOC concentration, which makes ozone and GAC more efficient in oxidizing and removing, respectively, CECs.

7.2.2 Other Water Quality Impacts to Consider

1. **Sulfate removal:** Sulfate was preferentially removed by the anion exchange resin in the SIX® process (removal ranged from 87 to 88 percent in the pilot study). While sulfate removal is not related to meeting primary or secondary regulatory levels, lower sulfate does change the corrosion potential of the water, by increasing the chloride-to-sulfate mass ratio. Having SIX® also led to lower coagulant dosages, which means less sulfate was introduced to the water due to the lower ferric sulfate coagulant dose for coagulation in the pilot study. Further, sulfuric acid for pH suppression was not needed with SIX® pretreatment, so this source of sulfate was eliminated. This is important in relation to corrosion in the distribution system, and compliance with the lead and copper regulations. The City is aware of this potential, and the TWT and City are considering necessary mitigations to minimize this impact if SIX® is installed.
2. **Chloride addition:** The SIX® process involves anion exchange with chloride on the resin. This translated to about a 75 mg/L increase in chloride in the SIX® treated water. While this is not a concern for the secondary MCL for chloride, it did affect the CSMR, which shows a higher potential for corrosion in the distribution system with increased values. This is important as it

relates to compliance with the lead and copper regulations. The City and TWT are aware of this potential, and are considering necessary mitigations to minimize the impacts if SIX® is installed.

3. **Bicarbonate removal:** While also beneficial for achieving optimum pH for organics removal by coagulation, bicarbonate removal also contributes to corrosion control potential. Supplemental alkalinity addition will be needed during certain times of the year, but this is already the case at the DLTWTF and would be implemented if SIX® is installed.

7.2.3 Water Quality Impacts from Source Water Blends and Treatment

The pilot study evaluated the impact of ASR flows and copper sulfate on feedwater quality and the impact on SIX® performance. Recycle flows from the full-scale dewatering facility were also discussed at discovery meetings with TWT and the City.

1. **ASR and Copper Sulfate Addition:** Increased sulfate concentrations from blends with ASR wells and from copper sulfate application to the feedwater reservoir were not detrimental to TOC removal by SIX® during the pilot study. It is known that sulfate competes with TOC for adsorption sites on the resin, so it is likely that ASR well water would be added downstream of SIX® in the full-scale plant to avoid this potential impact. Copper sulfate addition also did not have a noticeable impact on TOC removal by SIX®, and the City is aiming to lower or eliminate the use of copper sulfate in the future with other algae control measures.

2. **Recycle Flows:** From the limited sample data that were available for the recycle flow from the solids dewatering processes, it is recommended that the City conduct more frequent sampling of the recycle stream for organics, because the available data showed that it contained high levels of TOC, that are stored and recycled intermittently. It would be beneficial to know how the quality of the recycle flow changes over time, especially after recycling resumes on Mondays, and assess the potential impact on SIX® performance. It could be that a recycle surge control tank or converting the existing five day per week solids dewatering operation to a seven day per week operation, would be beneficial, if SIX® is installed.

7.2.4 Water Quality in the Distribution System

1. **Lead and Copper Corrosion:** There is an increased potential for corrosion in the distribution system if SIX® is added as a treatment process at DLTWTF. This is because SIX® removes sulfate preferentially (e.g., 87 to 88 percent removal in the pilot study) and adds chloride to the treated water (i.e., on average, 75 mg/L chloride was added). Other inputs of sulfate would be less or discontinued if SIX® is installed; the sulfuric acid could be discontinued and the ferric sulfate dose for coagulation could be lowered (i.e., 59 to 79 percent lower ferric sulfate was used in the pilot study). This would affect the CSMR that should be within certain limits for adequate lead and copper control in the distribution system. The City and TWT have discussed mitigations, such as addition of orthophosphate to minimize corrosion risks if SIX® is installed.

2. **DBPs:** SIX® lowers TOC concentrations, which also lowers chlorinated DBP formation. Results from this pilot study showed that chlorine can be used as a primary disinfectant at the DLTWTF when ozone use is not desired, and simulated distribution system tests with pilot filtered water showed that the HAA and TTHM concentrations were below the MCLs if free chlorine is used in the chlorine contact tank (10 minutes of contact time and the residual converted to chloramines for distribution).

7.3 Operations and Maintenance Review of SIX®

Part of the independent review was to assess operations and maintenance aspects of the SIX® process. No significant issues were identified; however, findings and recommendations for the City were identified, and are listed below.

7.3.1 Operations Considerations

1. **Ability to Treat Challenging and Variable Raw Water Quality:** The pilot testing study showed that SIX® was able to operate consistently through fluctuations in raw water quality, particularly during seasonal variations in TOC levels. Note that turbidity did not impact the SIX® process. Also, the warm water temperatures at the DLTWTF did not cause any operational issues with SIX®.
2. **UFRVs:** Filtration run times were shown to improve compared to the existing full-scale filter performance (partly due to SIX® in the pretreatment and partly due to a new filter media design).
3. **Introduction of SIX®-Treated Water Into The Distribution System:** If SIX® is installed, it is recommended to gradually introduce SIX®-treated water into the distribution system, if possible, during and after commissioning and startup, to minimize the potential for sloughing of deposits or film from distribution system pipe surfaces.
4. **Measures to Remove Biofouling on SIX® Surfaces and Resin:** Although biological fouling of the resin was not observed during the pilot study, it is recommended to include methods to allow for cleaning of the resin and internal surfaces of SIX®. The TWT is aware of the measures taken at the two existing SIX® installations. These include: 1) covers over the SIX® process equipment to minimize algal growth; 2) ability to power-wash contactor walls and lamella plates; and, 3) having connections for simplified and automated application of caustic and salt brine to stored resin to remove the biomass from the resin.
5. **Resin Carry-over:** If SIX® is installed, it is recommended to consider design features in the full-scale to allow for capture and removal of any resin that might carry over. TWT advised that feed flow control measures are being considered in design to minimize flow surges through the SIX® (i.e., surges would potentially carry over smaller resin beads through the Lamella to a downstream process) and the possibility of having a slower velocity zone downstream of the SIX® to capture resin was also discussed. Further, having spare resin on-site can help minimize the risk of resin shortages due to long lead-times for resin orders, in the event that more resin needs to be added to the system.
6. **Temporary Use of Chlorine for Primary Disinfection:** The pilot study showed that SIX® provided additional TOC removal, thus allowing to temporarily change from ozone primary disinfection to chlorine primary disinfection during times when microflocculation occurs. This added flexibility in operations would allow operators options to maintain production levels during microflocculation events.
7. **Bromate Formation:** The City currently is able to maintain low bromate concentrations in the finished water (e.g., <4 ug/L). The full-scale plant has bromate mitigation with the ozone system and this should be maintained to cope with higher bromide levels that have historically occurred in the feedwater. The hydrogen peroxide system likely needs improvements as City staff have detected ozone residual carry-over at the existing plant, even when hydrogen peroxide was being dosed.
8. **Microflocculation:** Microflocculation occurs seasonally and temporarily limits the production of the filters. The pilot treatment train with SIX® also experienced microflocculation, and the pilot study evaluated possible mitigations. The successful mitigations were the temporary change

from ozone to chlorine for primary disinfection, and the use of chlorine dosing to have a chlorine residual on the filters. The extra TOC removal by SIX® would allow both of these mitigations to be possible, without concerns about DBP formation.

9. **Waste Volume for Deep Well Injection:** At this stage of the evaluation of SIX®, the TWT is using a projected brine waste volume of 0.8 percent for deep well injection waste disposal. It is recommended to also evaluate the rinse flow volumes as well as possible caustic squeeze volumes to assess if the planning to have two deep injection wells initially is sufficient, or if the third well needs to be installed if/when SIX® is installed.

10. **Operational Changes:** The potential to eliminate sulfuric acid addition would improve safety conditions on site, and removal of lime addition also removes a chemical feed system that requires attention and maintenance.

7.3.2 Maintenance Considerations

Maintenance for equipment was also reviewed, and no significant issues were identified. The following are findings and recommendations for the City to consider if design begins for SIX®. These include having easy access to SIX® contactors, Lamella settlers, and regeneration equipment, and having platforms and manholes for safe observation and entry. The review of SIX® did not identify any unusual or problematic maintenance requirements.

Cleaning of the resin and/or SIX® system was not required during the pilot study, but it is recommended to include provisions for it in the design of SIX®. There can be physical cleaning of the walls of the contactor and plates of the Lamella with power washers, and there can be chemical cleaning of these surfaces too (e.g., with a temporary dose of chlorine or peroxide). The caustic squeeze can also be performed on the resin to remove biofouling.

7.4 Review of Performance Guarantees

Progressive design-build may be the project delivery approach if SIX® is installed at the DLTWTF. Progressive design-build projects usually include performance guarantees for process units, and the draft performance guarantees for SIX® were reviewed.

The performance guarantees seem reasonable for the process parameters (e.g., TOC removal and resin loss) of SIX®, and this independent review recommended that the City consider other common guarantees if the SIX® project proceeds. These include possible guarantees for capacity, power use, and salt use. It is also recommended to consider in design how to monitor for resin loss during the performance guarantee period, or to identify a method for assessing compliance with this guarantee. There is also a recommendation to clarify the performance testing period duration as well as the operational continuity requirements (i.e., 28 continuous days or intermittent days) of that test period.

7.5 Capital and Operating Costs Review

The capital cost for installing SIX® was reviewed along with the potential cost savings in infrastructure and operating costs for the remainder of the treatment plant.

1. **Lower Chemical Costs**: Implementing SIX® in the treatment train is anticipated to reduce the coagulant dose needed for effective coagulation, eliminate the need for sulfuric acid and lime for pH adjustment, lower ozone demand by an average of 30 percent,

2. **Reduction in Solids Generation**: The lower ferric coagulant dose associated with adding SIX® as a pretreatment process may avoid or reduce the need for the City to complete a previously

planned project for the expansion of its belt filter presses for solids handling. This previously planned project is currently paused.

3. **Economic Considerations**: Black & Veatch's understanding of the current planning level capital cost estimate for the addition of a 140 mgd capacity SIX® pretreatment system and associated deep injection wells at DLTWTF is $177,200,000. This value is in line with budgetary cost opinions that Black & Veatch has developed for the addition of a SIX® pretreatment system and required ancillary components at similar size and type surface water treatment facilities.

   a. The current planning level cost opinion is assumed to be an AACE Class 4 estimate (AACE International Recommended Practice No. 18R-97), based on being at an approximately 10 percent level of project definition at this time, which is consistent for projects in the study or feasibility assessment phase. The expected accuracy range for a Class 4 estimate ranges from -30 to +50 percent. With a budgetary cost of $177,200,000, the -30% to +50% range is $124,040,000 to $265,800,000.

   b. The 2022 Pilot Report life cycle cost information was reviewed and sensitivity analyses were performed to assess which components or aspects of the capital costs and annual operations and maintenance costs (or savings) have the most influence on the net present value (NPV) for the addition of the SIX® process at DLTWTF. The potential for variance in the capital costs had the greatest impact to the NPV, followed by the potential for variance/inflation in future power costs, and variance in the costs for chemicals (caustic soda) and the salt used for the SIX® resin regeneration process.

   c. The following significant reductions in chemical use and operating costs are anticipated based on the results of the pilot testing study and evaluations related to adding the SIX® process at DLTWTF:

      i. 59 to 79 percent lower ferric sulfate use.

      ii. 30 percent, on average, lower ozone demand.

      iii. Significantly longer filtration run times are expected if the SIX® process is added along with the new treatment train at DLTWTF, which will minimize filter backwashing frequencies.

      iv. O&M cost savings from the 2022 Pilot Report were estimated to be approximately $1.5M/year. Escalated to February 2025 dollars, the estimated O&M cost savings would be approximately $2M/year.

7.6 Summary of Risk and Benefits Register

A risks and benefits register is presented in Appendix A. The risks and benefits register is intended to assist the City in understanding the key risks and benefits, along with recommended action items and risk mitigation plans that are proposed to support the City in making key decisions. Some of the main unknowns and risks are highlighted below.

1. **New Process:** The addition of any new treatment process and modifications at an existing water treatment plant involves some risks and unknowns. The City has completed a variety of assessments and pilot testing studies to help reduce the number of unknowns and risks associated with the concept of adding the SIX® pretreatment process at DLTWTF; however, the SIX® process is still considered a new technology with only two full scale installations currently in existence, neither of which is in the United States. There is also the possibility that new design

elements are proposed for the SIX®, and the risks associated with these new features should be reviewed in future stage of evaluation.

2. **Footprint and Site Considerations:** The currently proposed site location for a new SIX® pretreatment system at DLTWTF is in an area between the river and coagulation basins. Black & Veatch agrees this area makes sense for siting the anticipated SIX® infrastructure because it would provide an ideal treatment process flow path based on the vicinity of the existing coagulation process at DLTWTF. At this stage of process evaluation, design aspects of SIX® are not detailed, so a thorough footprint and site evaluation are recommended to be performed as soon as possible during the design phase. With a 140 mgd capacity, SIX® could potentially have 10 to 14 individual trains, and the design team will confirm that the footprint can be accommodated on-site.
3. **Brine Disposal Challenges**: The full-scale operation of SIX® would generate concentrated brine waste that would be disposed of via deep well injection. While this is permitted and planned, one potential risk is the presence of PFAS contamination in the brine. The USEPA issued guidance that states there is a low risk of PFAS -laden, Class I non-hazardous waste contaminating a water source (i.e., injection into a confined aquifer), so deep well injection is an option at this time. This mitigates the risk at this time, but it is advised that the City stay aware of PFAS-related regulatory changes in the future. There are also unknowns with the total volume of waste for injection, due to unknown rinse flows and frequency of caustic squeeze events. It may also be necessary to neutralize the caustic squeeze waste prior to blending and injection. These unknowns can be addressed future evaluations and design.
4. **Cost Uncertainty**: The costs were estimated by the TWT based on preliminary data. Black & Veatch recommends further refinement of cost estimates in the next project phase to support an updated cost versus benefits assessment. The use of the progressive design-build delivery method should also support the City in having more cost certainty during the preliminary design stage of the project and provide an opportunity for the City to perform value engineering efforts if warranted to balance costs, benefits, and risks.
5. **Corrosion Potential**: Corrosion in the distribution system is considered a risk, once SIX® is added to the treatment train at the DLTWTF. The City is aware of this risk and is currently evaluating and considering corrosion control options.
6. **Operational Adaptation**: SIX® implementation will require adjustments in plant operations, including resin handling and regeneration processes. As this would only be the third SIX® full-scale installation in the world, very few operations teams are familiar with the process and troubleshooting methods. This necessitates additional operator training and potentially networking with the other utilities using SIX®.
7. **Filtration Efficiency:** Although not directly related to SIX®, this independent review identified a risk of not achieving the higher filtration run times that were observed in the pilot study and are to be factored into design. This risk stems from having Actiflo® treating some of the flow upstream of the new filter media design in the full-scale plant. In the pilot study, conventional pretreatment, and not Actiflo®, was pilot tested as pretreatment. It could be that polymer/sand carry-over from Actiflo® could make it difficult to achieve the longer filter runtimes.
8. **SIX® Brine and Waste Water Loss:** The brine waste flow from the SIX® process is estimated to be 0.8 percent of flow, but could be as much as 3 percent, depending upon how much rinse is desired to remove chlorides from the resin after regeneration. The waste volumes at maximum flow would be 1.1 mgd for 0.8 percent waste and 4.2 mgd for 3 percent waste. Water resources

for the City are limited, and efforts are made to recycle flows were possible to minimize wastes. This potential for 1.1 to 4.2 mgd of water loss by SIX® should be reviewed and considered by the City.

7.7 Conclusions and Recommendations

The addition of SIX® as a pretreatment process at the DLTWTF presents advantages in water quality and operational efficiency, aligning with the City's long-term treatment and expansion goals, including achieving a finished water quality of TOC < 2.0 mg/L. The multi-year history of the City and TWT evaluating and piloting this option, coupled with the results of Black & Veatch's independent review, indicate that there is a high probability in achieving the target treatment performance, finished water quality, and operational efficiency benefits that the City would expect if the SIX® process is added at DLTWTF. Furthermore, this independent review provides an additional opinion that SIX® is an appropriate solution for the DLTWTF based on the City's key goals for achieving enhanced finished water quality and supporting the current 20 mgd treatment capacity expansion project.

If the City continues to move forward with plans to incorporate the SIX® process at DLTWTF, it is recommended that the City continue with its efforts to refine design details, along with updating cost estimates and risk mitigation plans to support informed decision making at the key decision milestones as the preliminary and detailed design phases progress.

As this is still in the preliminary assessment stage of process selection, there are still unknowns, risks, and potential benefits that are outlined in this TM. The City can consider these as part of their decision making moving forward. If a decision to proceed with the addition of the SIX® process is made, it is recommended that a phased decision approach is followed to allow the City to reassess the footprint/ site layout, costs, risks, and benefits at key milestones as the preliminary and detailed design processes progress.

Some additional technical recommendations associated with the installation and operations of SIX® were identified during the review of the SIX® Pilot Report, and are summarized below:

1. Check if chlorinated or chloraminated water can be used for resin carrier water and for rinsing resin.
2. Review the raw water straining recommendations from PWNT and determine if they match the new straining at the DLTWTF.
3. Evaluate how often resin would be stored, for example when taking trains out of service or when production is low, to develop a plan for treating the resin while in storage to prevent biological growth.
4. If a second resin is to be identified for use at the DLTWTF, it is recommended to conduct bench-scale screening and then pilot testing, to confirm that the second resin not only performs well, but also settles well and regenerates to a satisfactory level in the SIX® system.
5. Check that the planned type of salt is compatible for the salt saturators and the SIX® process.
6. Evaluate the possible blends of ASR wells flows during seasons with copper sulfate addition to assess the maximum possible feedwater sulfate concentration in relation to the added chloride by SIX®, to evaluate the CSMR.

7. Consider having on-line UV analyzers for the feed and SIX®-treated water, as they would assist operations staff in monitoring SIX® performance over time, especially in times of rapid and dramatic seasonal shifts in the TOC concentration.
8. Have the caustic squeeze procedure as an automated procedure and confirm neutralization requirements of this waste for disposal.

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Appendix A. Risks and Benefits Register

Appendix A

Risks and Benefits Register

A risks and benefits register has been prepared for a variety of technical aspects of adding SIX® to the DLTWTF. The risks and benefits that have been identified during this independent review are shown in the following pages.

Risks Register

The risks identified include water quality, cost, operational, and other risks that can be evaluated further with mitigation plans where necessary. Some recommended further evaluations and mitigations are also listed in the register. “Significant Risks” are considered any risk items that scored above 14 when multiplying the Likelihood (1 to 5) and Consequence of Occurrence (1 to 5) scores together. Out of a maximum score of 25 (5 x 5), the highest risk item (Capital Cost) was calculated to be 16 (64% of the maximum). Figure 1 is a heat map count of the risks which is also available in Excel format for an easier examination of the risks. The red end of the risks heat map is less desirable and the green end is more desirable.

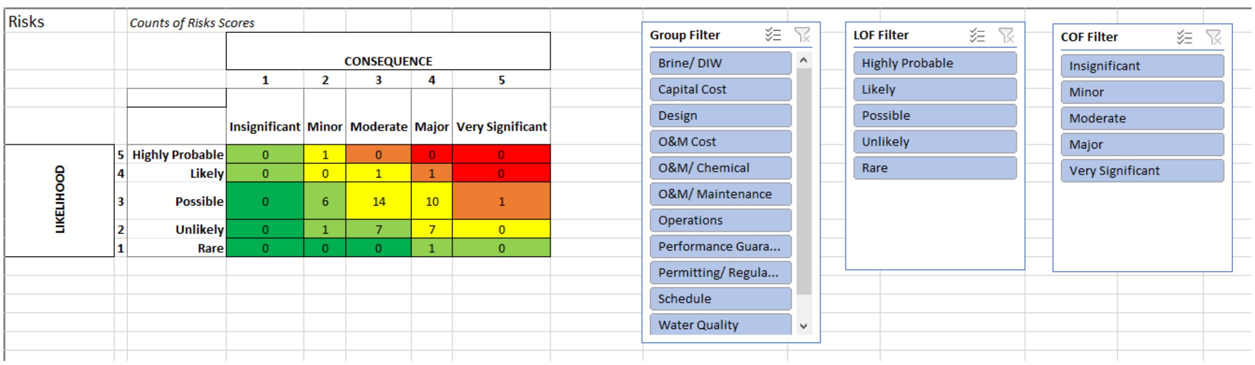

Figure 1 Heat Map of Risks

Benefits Register

The benefits of adding SIX® are also shown in the pages that follow as well as the Figure 2 heat map below. These include benefits in terms of water quality and operational performance. All of the benefits are on the strong and favorable side (towards green) of the heat map and none are in the red zone (less strong of a benefit).

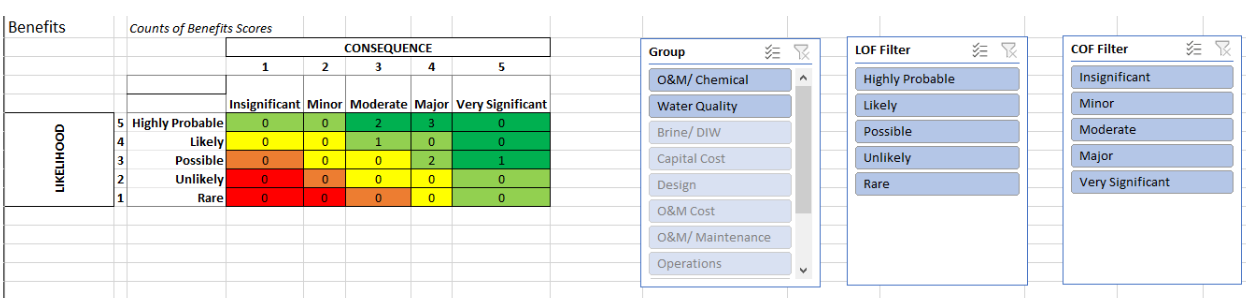

Figure 2 Heat Map of Benefits

					Likelihood		Consequence			
Item #	**Group**	**Description**	**Type (Risk or Benefit)**	**Category (Cost/Non-Economic Consideration)** Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	**Likelihood** *1 - Rare 2 - Unlikely 3 - Possible 4 - Likely 5 - Highly Probable*	**Reasoning/ Justification**	**Consequence** *1 - Insignificant 2 - Minor 3 - Moderate 4 - Major 5 - Very Significant*	**Reasoning/ Justification2**	**Likelihood x Consequence Scores**	**Proposed Resolution/ Timing**
1	O&M/ Chemical	Fewer new filters.	Benefit	Capital Cost O&M Cost Other	3 - Possible	Design is still to be finalized (and it is unknown if the existing filter beds will remain or be removed), but with a higher surface loading rate, fewer filters (or less surface area) is needed to meet the capacity requirements.	4 - Major	This would result in a lower capital cost and a lower cost, potentially for media change out (depending if GAC is used for adsoption of contaminants like PFAS, or not).	12	
2	O&M/ Chemical	SIX, coagulation, clarification, and ozone pretreatment will yield higher filter UFRVs.	Benefit	O&M Cost Other	3 - Possible	A range of UFRVs were observed with the deep bed GAC media configuration in the pilot study. This was after plate settler conventional treatment, but tests were not done with Actiflo for clarification.	4 - Major	The existing plant capacity is limited by the filters, and with a higher loading rate, the deep bed filters are also expected to have higher UFRVs. This will lead to higher overall plant recovery and less downtime for backwashing.	12	
3	O&M/ Chemical	The SIX will contribute to a lower concentration of filtered water TOC.	Benefit	O&M Cost Other	5 - Highly Probable	SIX with ferric sulfate will achieve lower TOC concentration in the finished water, thus the disinfectant residual dose will be less, and the residual will persist longer in the City's distribution system.	3 - Moderate	This will save on chemical costs and provide a water quality benefit.	15	
4	O&M/ Chemical	Decrease in ferric sulfate coagulant use.	Benefit	O&M Cost Other	5 - Highly Probable	The pilot study showed that the ferric sulfate dosage would be significantly less due to upstream TOC removal by SIX.	4 - Major	This will be a significant impact on O&M costs as well as sludge production. It may also change the dewatering facility design/operation.	20	It is recommended to assess the maximum ferric sulfate dose that is expected with SIX and perform a risk analysis of operation if SIX is not operating (how much ferric sulfate would need to be dosed?).
5	O&M/ Chemical	Lime use to be discontinued.	Benefit	O&M Cost Other	5 - Highly Probable	The water chemistry of the pilot study showed that lime use could be discontinued, and NaOH and carbon dioxide could be used for alkalinity and pH adjustment.	4 - Major	Removing lime from the site removes a difficult chemical to feed as well as lowers the required (high) maintenance hours to keep it operating is a stable manner. O&M cost is also lowered.	20	
6	O&M/ Chemical	Sulfuric acid dosing to be discontinued.	Benefit	O&M Cost Other	5 - Highly Probable	Because SIX lower TOC as well as bicarbonate concentrations, sulfuric acid is not needed during ferric sulfate coagulation to achieve the optimum pH for TOC removal.	4 - Major	Removing sulfuric acid removes a potentially dangerous chemical, and also lowers O&M costs.	20	It is recommended that sulfuric acid feed capability be evaluated in more detail during design to see if there is the possibility of it being needed or not (e.g., if SIX were not operating).
7	O&M/ Chemical	Increased safety and reliability due to elimination of sulfuric acid.	Benefit	Other	4 - Likely	Sulfuric acid is considered a more dangerous chemical, and if eliminated this health/safety risk is also eliminated.	3 - Moderate	This is overall a health and safety improvement by eliminating a risk.	12	It is recommended that sulfuric acid feed capability be evaluated in more detail during design to see if there is the possibility of it being needed or not (e.g., if SIX were not operating).
8	O&M/ Chemical	Adding SIX will result in lower concentrations of DBPs.	Benefit	Regulatory	5 - Highly Probable	SIX removes a wide variety of TOC fractions, and bromide is also possibly removed to an extent. These contribute to DBP formation with ozone (reacting with bromide) and chlorine.	3 - Moderate	The City already achieves satisfactory DBP control, however, with lower TOC and possibly lower bromide concentrations, the finished water is expected to have lower DBP concentrations than before.	15	
9	Water Quality	PFAS removal from water is likely needed based on monitoring data at the DLTWTF. The addition of SIX as a pre-treatment process combined with the currently planned filter configuration improvements at DLTWTF may (or may not) provide sufficient PFAS removal for compliance with current PFAS regulations (without adding another post-treatment process).	Benefit	Regulatory	3 - Possible	The URCM data shows some elevated concentrations of PFAS.	5 - Very Significant	PFAS concentrations above the MCLs will need to be addressed. Compliance with the PFAS regulation is required by April 2029.	15	The SIX process may have the ability to remove some PFAS, but there are mixed results on PFAS removal by the LanXess resin and it should not be considered a reliable method of PFAS removal at this time (and no data were collected for PFAS during the pilot trial for confirmation). It is also possible that the GAC media in the new filter configuration could be sufficient for PFAS control (e.g., 6.5 min EBCT at max flow) considering the relatively low PFAS levels in the water supply source. The addition of SIX as a pre-treatment process may increase the possibility that the GAC media in the new filter configuration could be sufficient for PFAS control at DLTWTF.

Item #	Group	Description	Type (Risk or Benefit)	Category (Cost/Non-Economic Consideration) Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	Likelihood: Likelihood 1 - Rare 2 - Unlikely 3 - Possible 4 - Likely 5 - Highly Probable	Likelihood: Reasoning/ Justification	Consequence: Consequence 1 - Insignificant 2 - Minor 3 - Moderate 4 - Major 5 - Very Significant	Consequence: Reasoning/ Justification2	Likelihood x Consequence Scores	Proposed Resolution/ Timing
10	Brine/ DIW	PFAS in SIX waste brine was not measured but is expected to be present, and permits for injection well disposal of this brine currently do not include PFAS limits, but limits could be required in the future.	Risk	Regulatory O&M Cost	3 - Possible	The fate of PFAS disposals or discharges (as from wastewater plants) will likely be regulated in the future. (Current EPA guidance for PFAS disposal states that deep well injection into a confined aquifer poses little risk to drinking water supplies.)	4 - Major	If SIX brine waste can not be disposed of by deep well injection, another method of disposal will be needed.	12	Stay aware of PFAS legislation for wastes and deep well injection. Also, promote or participate in research studies of brine treatment for removal of PFAS.
11	Brine/ DIW	There could be unanticipated changes to the water quality allowed for deep well injection. SIX brine waste includes concentrations of heavy metals and high concentrations of organics and other anions.	Risk	Regulatory O&M Cost	3 - Possible	Permitting changes could occur in future, and SIX brine includes metals and high concentrations of anions.	4 - Major	If SIX brine waste can not be disposed of by deep well injection, another method of disposal will be needed.	12	Stay aware of permitting changes for wastes and deep well injection. Also, promote or participate in research studies of brine treatment for removal of contaminants of concern.
12	Brine/ DIW	Mixing rinse water with elevated chloride levels into brine may exceed the capacity of two injection wells, necessitating the use of a third injection well.	Risk	Regulatory O&M Cost	3 - Possible	Rinse is a variable not well defined from the pilot study. Chloride rose by about 75 mg/L from SIX. If rinse is blended with SIX brine, this could exceed the predicted total SIX brine flow.	4 - Major	An additional injection well would add significant capital and O&M costs to the project.	12	Evaluate in more detail the volume of rinse flows and chloride concentration in finished water to determine if blending rinse flow to SIX-treated water is feasible.
13	Capital Cost	Potential for higher than anticipated construction and material cost escalation since the budgetary estimate was developed.	Risk	Capital Cost	3 - Possible	Construction capital costs have been increasing at a higher rate than historical average inflation rates and there continue to be pressures resulting in higher than normal escalation in costs for equipment, material and construction labor.	3 - Moderate	Changes in the capital cost for the addition of the SIX project would impact the City's cost vs. benefits assessment for adding the SIX process.	9	During the preliminary and detailed design stages, the use of the progressive design build delivery method could allow the City to more accurately price in contingency for cost escalation for the construction costs of the project.
14	Capital Cost	There is uncertainty in the current preliminary opinion of probable capital cost (based on TWT August 2024 estimate).	Risk	Capital Cost	4 - Likely	The current cost opinions are based on conceptual planning level information. Further development and preliminary design of the SIX system will likely result in refinement of the cost estimate for adding the SIX process at DLTWTF.	4 - Major	Significant changes in the capital cost for the addition of the SIX project would impact the City's cost vs. benefits assessment for adding the SIX process.	16	If the City moves forward with the preliminary design of the SIX system with TWT, the Progressive Design Build delivery method could be used to provide a more accurate cost estimate to support the City's decision on whether or not to proceed with the addition of SIX. Updated cost estimates at different phases of the design process could also be used to support Value Engineering assessments. Sensitivity analyses could also be completed and updated to proactively determine what range of costs (vs. range of benefits) the City may be comfortable with proceeding with. (Note: The details for the most recent cost estimate (TWT, August 2024) have not been provided to Black & Veatch to date for review).
15	Design	Potential downtime of the SIX process or treatment trains for maintenance and cleaning. Possible lack of spare parts or replacement equipment.	Risk	O&M Cost	3 - Possible	Known O&M issues are algal growth on Lamella plates of SIX, and biogrowth in the contactors. Spare parts are needed to replace broken equipment and maintain adequate treatment.	2 - Minor	If contactors and lamellas are needing repair, maintenance or cleaning, the capacity of the plant is reduced and operators need to spend time performing the activities.	6	Monitor and inspect the contactor condition and cleanliness of the plates. If the plates are too dirty, resin will carry over due to higher velocities. Include capability to treat contactor with chlorine or peroxide if necessary, and have means of cleaning plates with chemical and/or power washing. Also, block sun exposure if possible in design of the contactors and lamella. A review of necessary spares and lead times for replacement equipment would aid in alleviating this risk.
16	Design	Difficulty accessing equipment for maintenance and repair.	Risk	O&M Cost	3 - Possible	There are several valves placed at height under the lamella hopper, for example. Access for routine maintenance could be cumbersome.	3 - Moderate	If maintenance and repair are difficult for access, there will be delays in bringing basins back online.	9	This will be the third design of a full-scale SIX, so lessons learned can be applied for maintenance tasks. Access platforms and design decisions for placement of equipment should be reviewed with operations and maintenance in mind.
17	Design	Resin biofouling associated with longer contact time.	Risk	O&M Cost	3 - Possible	With the plant operating at average flow the majority of the time, the resin in the contactor has longer to develop biofouling. The pilot was operated at max flow, thus the shorter contact time.	3 - Moderate	If biofouling occurs, clean with chemical soaking as done in the caustic squeeze of the pilot.	9	Allow for easy application of a caustic squeeze in the design of the plant.

					Likelihood		Consequence			
Item #	Group	Description	Type (Risk or Benefit)	Category (Cost/Non-Economic Consideration) Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	Likelihood *1 - Rare* *2 - Unlikely* *3 - Possible* *4 - Likely* *5 - Highly Probable*	Reasoning/ Justification	Consequence *1 - Insignificant* *2 - Minor* *3 - Moderate* *4 - Major* *5 - Very Significant*	Reasoning/ Justification2	Likelihood x Consequence Scores	Proposed Resolution/ Timing
18	Design	The source water to the DLTWTF is a blend of river water, ASR flows, Harney Canal flow, and recycle flow. The pilot study tested river and ASR flows. The combined water quality in blended flows is not fully characterized and performance of SIX and the treatment train may differ in full-scale than what was observed in the pilot study. The introduction of the recycle flow from the solids dewatering facility to head of DLTWTF may have greater impacts on treatment performance than estimated (as the recycle flow was not included in the SIX pilot testing).	Risk	Other	2 - Unlikely	The input flows are used regularly at the DLTWTF. 'Recycle streams were not included in the feed flow to the SIX Pilot. Two samples were collected to show very high TOC concentrations in the recycle flow. Recycle flow only occurs on weekdays, with a higher flow on Mondays after the weekend.	2 - Minor	The Harney Canal and recycle flow volume is expected to be very low compared to the plant feed flow, so this high concentration will be diluted. Operators may need to temporarily adjust SIX and/or coagulation due to the changes of feed water quality. On Mondays and on Fridays before the weekend , recycle flows are transferred.	4	Collect more recycle flow samples and measure TOC concentrations to determine range of concentrations. Also, perform an evaluation of recycle volumes from dewatering to know the dilution and possibly impacts on water quality on weekdays (and especially Mondays). A possible mitigation option is to include a surge tank to provide steady state recycle flows to the head of the works in the future. Also review the water quality of the Harney canal to identify an water quality risks.
19	Design	Reduced efficiency of the SIX® process performance over time.	Risk	Regulatory O&M Cost	2 - Unlikely	SIX resin may lose some of its adsorptive capacity over time. Thus far, the two full-scale plants with resin have not reported significant changes in resin capacity. If the SIX process performance with TOC removal declines over time, it could be due to higher concentrations of competing anions, higher or different types of TOC, or biofouling on the resin. There could also be turbidity collected in the regeneration process.	3 - Moderate	Could result in some decline in TOC removal performance and/or result in the need for a resin change out, which would be an added O&M cost.	6	Periodically do jar tests with virgin and full-scale used resin to track the adsorptive qualities. Be prepared for a resin change out (and also know the typical resin delivery times) for replacement. Assess the risk with PWNT about turbidity and SIX.
20	Design	The new deep bed GAC filters do not meet their UFRV targets at the DLTWTF	Risk	Regulatory O&M Cost	2 - Unlikely	Construction capital costs have been increasing at a higher rate than historical average inflation rates and there continue to be pressures resulting in higher than normal escalation in costs for equipment, material and construction labor.	4 - Major	If the UFRVs specified in design are not achieved, the plant capacity will be lower than the expected design capacity, and there will be more backwashing water loss.	8	The TWT and the City plan to keep the existing filters in operation in parallel with the new filters, and the existing filters can be used if there are any issues with achieving the higher UFRVs on full-scale.
21	Design	Unknowns in plant performance due to pilot testing without Actiflo	Risk	O&M Cost	3 - Possible	The full-scale plant operates with clarification by conventional sedimentaiton and by Actiflo. These processes are very different from one another, and without data from pilot tests with Actiflow, there are possible unforeseen consequences.	4 - Major	The main consequence is that the new filter media design does not achieve as high of UFRVs as the conventional clarification, that was pilot tested. If UFRVs are lower than the design target, the plant output is less than expected, and the waste flow is higher than expected.	12	Consider a pilot study to evaluate the performance of Actiflo, followed by ozone contact, followed by the new filter media design. It is not known if the ozone assists with degrading polymer that carries over from the Actiflo, and this could be confirmed with pilot testing.
22	O&M Cost	Potential for higher resin cost escalation than anticipated.	Risk	O&M Cost	3 - Possible	Resin costs can fluctuate over time, and it is difficult to accurately predict how resin costs may increase (or decrease) at a different rate than the overall inflation rate.	2 - Minor	A higher resin cost escalation than anticipated could result in higher maintenance costs for the SIX process over time.	6	Consider sensitivity analysis of how changes in resin costs could impact the cost-benefit analysis of adding the SIX process at DLTWTF.
23	O&M Cost	The predicted savings for chemcial use are not realized in full-scale if the estimated chemical cost savings are less than expected, due to fluctuation in costs and inflation.	Risk	O&M Cost	3 - Possible	Individual chemical costs can fluctuate over time, and it is difficult to accurately predict how certain chemical costs may increase (or decrease) at a different rate than the overall inflation rate.	2 - Minor	One key value of SIX is the reduction in the use of current chemicals used at DLTWTF: ferric sulfate, lime, and sulfuric acid. If the costs for these chemicals reduced over time, this benefit of the SIX process would be less impactful.	6	Consider sensitivity analysis of how changes in chemical costs could impact the cost-benefit analysis of adding the SIX process at DLTWTF.
24	O&M Cost	Amount of waste flow at the DLTWTF	Risk	Regulatory O&M Cost	3 - Possible	Waste flows from SIX are 0.8% (up to 3% if rinse flow is implemented), and with limited water resources, this amount of loss could be an issue for supply.	3 - Moderate	The City aims to minimize waste flow volumes from the DLTWTF, because there are source water limitations.	9	As design progresses, define the waste volumes and coordinate this waste rate with the City to ensure it does not prohibit the aim of achieving 140 mgd capacity.

					Likelihood		Consequence			
Item #	Group	Description	Type (Risk or Benefit)	Category (Cost/Non-Economic Consideration) Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	Likelihood *1 - Rare* *2 - Unlikely* *3 - Possible* *4 - Likely* *5 - Highly Probable*	Reasoning/ Justification	Consequence *1 - Insignificant* *2 - Minor* *3 - Moderate* *4 - Major* *5 - Very Significant*	Reasoning/ Justification2	Likelihood x Consequence Scores	Proposed Resolution/ Timing
25	O&M/ Chemical	Microflocculation negatively impacts filter productivity (i.e., UFRVs)	Risk	Regulatory Other	2 - Unlikely	Microflocculation was observed during the pilot trial, and the City has informed that the existing DLTWTF also experiences microflocculation, so the likelihood of microfiltraiton occurring is highly probable. Several process adjustments were tested during the pilot study to mitigate the microflocculation. Chlorine on the filters and operating without ozone were two options that were found to control microflocculation.	4 - Major	The consequence of uncontrolled microflocculation would be a major decrease in the UFRV of the new filter media configuration. This would result is reduced plant output and higher backwash frequency (and lower overall recovery).	8	For the design of the upgraded facility, the ability to add chlorine to the top of the filters should be included (Black & Veatch's understanding is that this feature is planned). The TWT indicated that the DLTWTF will be able to operate for short durations without ozone by using the chlorine contact capabilities of the recent upgrades to the DLTWTF clearwells and high service pump station. This approach was confirmed in the pilot study and allows for sufficient disinfection to be achieved while avoiding the formation of excessively high chlorinated TTHMS or HAAs.
26	O&M/ Chemical	Insufficient salt storage volumes on site to meet design intent.	Risk	Capital Cost O&M Cost Other	3 - Possible	SIX salt use was estimated from the recorded salt use during the pilot study.	4 - Major	If the salt use is underestimated, then storage on site might be limited and more frequent deliveries of salt required. This would require more operator attention as well.	12	Check with the SIX system supplier for an estimate of salt use, and check storage design against truck volumes to be sure there is sufficient storage on site.
27	O&M/ Chemical	Off-spec regeneration during the pilot had brine washing of the resin but the resin was not fully submerged.	Risk	O&M Cost	3 - Possible	If the salt use estimate was based on the actual use from the pilot study, which had the regenerant wash or rinse the resin versus submerged contact, then the volume of salt could be less from the pilot than what would be needed in the full-scale system.	4 - Major	The City is already aware of the salt consumption based on pilot data, and an increase in salt use due to this pilot discrepancy could result in higher salt usage overall.	12	Check with PWNT about salt consumption estimates. Examine the pilot data sets or internal programming to see if the same amount of salt was used for the wash/rinse versus what would have been used for the submerged regeneration.
28	O&M/ Chemical	Higher than estimated increase in SIX chemical unit costs over time due to inflation and market fluctuations.	Risk	O&M Cost	4 - Likely	SIX chemical unit costs historically increase over time due to inflation and are projected to increase by more than 3% used in the 2021 cost estimates.	3 - Moderate	Higher than estimated chemical unit costs in the future would result in increased O&M costs and life cycle costs, for those chemicals but depends on dosage and usage.	12	Complete Sensitivity Analysis with different chemical unit cost inflation assumptions to better understand impacts to Life Cycle Cost.
29	O&M/ Chemical	Inaccurate salt usage estimates from the pilot study would not reflect full-scale salt usage requirements.	Risk	O&M Costs	3 - Possible	SIX salt use was estimated from the recorded salt use of the pilot study.	3 - Moderate	Actual Chemical costs could be higher in full=-scale than predicted by the pilot study.	9	Check with the SIX system supplier for an estimate of salt use, and check storage design against truck volumes to be sure there is sufficient storage on site.
30	O&M/ Chemical	Only pilot testing with and verifying one resin for SIX, thus relying on a sole supplier (with possibloe price hikes or delivery time risks).	Risk	O&M Costs Non-Economic Considerations	3 - Possible	Resin is supplied by a third party and is critical for the performance of SIX for TOC removal (and bicarbonate removal).	4 - Major	Costs for furture resin purchases could be higher than expected. Also, if resin from LanXess is not available when a change-out is needed, there could be a period of time when SIX is offline.	12	Establish multiple suppliers for the resin by conducting bench- and pilot-scale tests. Piloting is to check if the resin settles and is regenerated in the same manner as the LanXess resin. Also, it is recommended to store a spare stock of resin, perhaps a full load/fill if SIX is deemed critical to meeting water quality goals. Also, investigate the manufacturer's resiliency to produce the resin (for the resin with known performance at DLTWTF).
31	O&M/ Chemical	Type of salt procured for full-scale.	Risk	O&M Costs Other	2 - Unlikely	The type of salt procured for the full-scale system should cost-effective, suitable for on-site storage, and for making a saturated solution for brine.	3 - Moderate	If the form of salt (e.g., pellets versus powder) does not dissolved well, it could cause operational issues.	6	Check salt solubility for the saturator to be used at the full-scale plant. PWNT will also have recommendations for the form of salt to be used.
32	O&M/ Maintenance	Accessing manifolds of the air distributors in the bottom of SIX contactors for maintenance.	Risk	O&M Cost Other	2 - Unlikely	Increased downtime and maintenance costs, as well as operator frustration.	3 - Moderate	If air distributors can not be accessed easily, there could be issues with air distribution and this could impact TOC removal.	6	Design the system to allow easy access to air manifolds, either through manholes with tank drain down or by lifting from the top. Ensure maintenance procedures are well-documented and the procedures are safe/accessible.
33	Operations	Potential incompatibility of the resin with chlorinated or chloraminated carrier water that is used for resin dosing. (If raw water to the SIX can carry a chlorine or chloramine residual, this is also a risk)	Risk	Capital Cost O&M Cost Other	3 - Possible	If chlorinated or chloraminated water used for resin feed carrier water or rinsing, is not compatible with the resin, resin degradation/attrition or performance issues may occur.	4 - Major	If resin is damaged, there would need to be design changes and a new batch of resin installed.	12	Check with the resin supplier to determine if chlorinated or chloraminated treated water can be used. Evaluate in design the possible options for the carrier and rinse water for the SIX process.
34	Operations	Potential of full-scale operating performance related to key design parameters being different than pilot scale performance and associated design assumptions.	Risk	Capital Cost O&M Cost Other	3 - Possible	While the team performed a pilot scale, there's always a potential that the full-scale behaves differently than expected.	3 - Moderate	Changes in performance could impact the cost or benefits of the SIX process.	9	The team has performed a comprehensive pilot testing to define the key design parameters and is incorporating Performance Guarantees related to the design parameters for SIX performance.

Item #	Group	Description	Type (Risk or Benefit)	Category (Cost/Non-Economic Consideration) Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	Likelihood: Likelihood 1 - Rare 2 - Unlikely 3 - Possible 4 - Likely 5 - Highly Probable	Likelihood: Reasoning/ Justification	Consequence: Consequence 1 - Insignificant 2 - Minor 3 - Moderate 4 - Major 5 - Very Significant	Consequence: Reasoning/ Justification2	Likelihood x Consequence Scores	Proposed Resolution/ Timing
35	Operations	New design concept for regeneration of the resin being proposed for new WTPs by PWNT. Note that this design approach has not been proposed by the TWT, and new designs carry some risks of unforeseen consequences.	Risk	Capital Cost Other	3 - Possible	With any new design concepts, there are unknowns about operability and performance. PWNT has tested this in their R&D facility and is proposing to install in the next full-scale SIX® installation.	4 - Major	If regeneration does not perform efficiently, the SIX® process performance could be inhibited (i.e., poor TOC removal) or if resin is not moving adequately through the regeneraton tanks, then SIX® operation is hindered.	12	Discuss with the TWT and PWNT the new regeneration concept and perform a risk assessment. Perhaps visit the R&D facility in the Netherlands to view operation in their demonstration plant. If the risk consequence is deemed too high, consider installing the existing design that is installed at the two existing WTPs.
36	Operations	SIX is a newer technology, with only two existing full-scale plants in operation at this time, and there could be some unknown operations and performance issues in full-scale.	Risk	Non-Economic Consideration	3 - Possible	The likelihood related to SIX operations and performance issues is mitigated by the fact there are two operating plants, with lessons learned.	4 - Major	If there are issues with performance and operation, due to SIX being a relatively new treatment technology, the consequence is major due to the importance of SIX for achieving water quality and cost savings goals.	12	Tour and interview operators at the full-scale installations to identify lessons learned and any recommendations from their experiences. Consider having a permanent SIX pilot plant on site for continued learning about SIX, training, and trials at different conditions (e.g., resin dose, contact time, brine concentration, and resin supplier). Having a permanent pilot helps with the learning curve for a new technology.
37	Operations	SIX not having been proven in a climate similar to Tampa. Warm/humid weather climates in Florida and surface water conditions (temp and WQ) of the Hillsborough River.	Risk	O&M Cost	3 - Possible	Warm water with higher TOC level can be subject to microbial growth on media. Previous MIEX study had experienced resin fouling. However, SIX pilot plant did not see biofouling.	2 - Minor	To maintain treatment efficacy - additional cost/time/materials for addressing biofouling through resin operations. Worst case would be increased resin replacement rate.	6	Study examined impacts of “caustic squeeze” – high pH conditions for regeneration as one option. Provide mitigation plan as part of design.
38	Operations	Resin biofouling due to starts and stops during commissioning if not properly managed.	Risk	O&M Cost	3 - Possible	During commissioning, there are a lot of unplanned starts/stops, and if resin is allowed to sit in (warm) raw water, there is increased risk of biofouling before performance testing.	3 - Moderate	This could require a caustic squeeze prior to performance testing and may delay final completion.	9	Train commissioning staff about this risk, and ensure the capability to store resin in a high salt concentration temporarily to minimize biofouling risk before the testing period. Load resin into the contactors just prior to start up and commissioning.
39	Operations	Resin attrition (breaking of resin into smaller pieces) over time.	Risk	O&M Cost Other	2 - Unlikely	Resin attrition risk is mitigated in the SIX design, which does not pump resin during the treatment process and does not mechanically mix resin in the contactors.	3 - Moderate	If small pieces of resin exist due to attrition, they will carry over to the clarification stage and be captured in sludge blow-down. There would be the need to add more resin at some point.	6	Include in design a way to monitor resin loss and attrition. This could be a small side stream with bag filter to monitor resin carry-over from the SIX process. Note that when virgin resin is installed, some fines need to be removed. Check with PWNT about methods that are used to remove these fines.
40	Operations	Inconsistent resin performance (full-scale vs pilot) due to supplier QA/QC variations.	Risk	O&M Cost Other	2 - Unlikely	Delivered resin does not perform as well as resin used in pilot testing.	4 - Major	If resin is underperforming, the project is at risk of not achieving the TOC removal target. The performance testing and completion schedules would also be affected.	8	Confirm with jar tests that the delivered resin performs similarly to the resin used in the pilot study. Do not load the resin into the full-scale plant until this is confirmed.
41	Operations	Potential for issues with resin suppliers when the City needs to add ("top up") resin for the SIX process.	Risk	O&M Cost Other	3 - Possible	If the City needs to add extra resin due to some losses during operation, there is a risk that the extra resin is not available quickly.	3 - Moderate	Topping up resin for the SIX system is not expected to be frequent and there should not be a large loss of resin inventory over time with normal operations. The DLTWTF can still operate on its existing inventory, but TOC removal would likely be impacted if operating at max flow or max resin dosing.	9	If there is a loss of resin over time, it is recommended for the City to examine operations and cleanliness of the plates to minimize further losses. Also, extra resin can be purchased at the start of operation and stored in super sacks on site for "topping up". There can be long lead times (e.g., >six months) for large orders of resin, so having extra resin on site should be considered if SIX is a critical process at the DLTWTF. Also, other suppliers of a TOC removal anion exchange resin might have inventory available. There are unknowns, however, about mixing resins from two suppliers (e.g., do they regenerate in the same way, etc.).
42	Operations	Resin carryover from SIX to downstream processes	Risk	O&M Cost Other	3 - Possible	Resin can carry-over from SIX to the clarification stage and end up in the sludge.	3 - Moderate	This would result in resin loss from SIX and thus higher O&M cost, as well as an environmental issue of capturing lost resin (i.e., microplastic risk).	9	Carollo plans for passive flow control to minimize flow surges through the SIX, as well as SCADA settings to limit the possibility of flow surges when taking basins in/out of service. Minimize algal growth (which contributes to higher velocity through the Lamella settlers) by limiting sun exposure on the SIX process, and keep Lamella plates clean to minimize operation with higher velocities. Include in the design a way to monitor resin loss and attrition. This could be a small side stream with bag filter to monitor resin carry-over from the SIX process.

					Likelihood		Consequence			
Item #	Group	Description	Type (Risk or Benefit)	Category (Cost/Non-Economic Consideration) Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	Likelihood *1 - Rare* *2 - Unlikely* *3 - Possible* *4 - Likely* *5 - Highly Probable*	Reasoning/ Justification	Consequence *1 - Insignificant* *2 - Minor* *3 - Moderate* *4 - Major* *5 - Very Significant*	Reasoning/ Justification2	Likelihood x Consequence Scores	Proposed Resolution/ Timing
43	Operations	Resin loss and entry into the environment	Risk	Other	3 - Possible	Resin can enter the environment by carryover to sludge blow down, by drains on site, or by drains of treatment basins to area ponds or overflows.	3 - Moderate	Resin is considered a plastic and it is not considered good practice for resin to be released to the environment.	9	Check in design for all possible pathways for resin to escape the SIX process. If possible, add a way to capture it, with settlement tanks or bag filters.
44	Operations	New water treatment process presents learning curve for operating staff.	Risk	Other	5 - Highly Probable	This would be the third SIX® full-scale plant in the world, so the process is new to the water industry and would be new to City operations(and maintenance) staff.	2 - Minor	While there will be a learning curve for the City operations staff for the SIX process and downstream impacts to the existing DLTWTF processes, it is anticipated that City staff would quickly learn the basics of the system operations. The SIX process appeared to operate without many issues in the pilot study, including handling seasonal variances in the incoming raw water quality.	10	Operators need training and access to resources to troubleshoot any issues. The resin dose, salt concentration for regeneration, and contact time are the main variables of the SIX. It will also be necessary to train on the potential changes to downstream processes, which the operators are already familiar with.
45	Performance Guarantee	The Performance Guarantee (PG) for resin loss is ≤0.2 L per ML treated flow, but it is unclear how to monitor this during the PG testing period before accepting the plant from the DB team.	Risk	O&M Cost Other	3 - Possible	Resin loss can occur and measurement of loss is difficult on full-scale.	3 - Moderate	if resin is lost from the system, new resin must be added periodically to maintain sufficient inventory within the SIX system.	9	Develop a plan to capture any resin carry-over during performance testing, perhaps with a side stream bag filter. This would give confidence about whether the PG is being met, or not.
46	Performance Guarantee	The performance testing period of the PG document is not clear for one month or 28-days, and it is not stated if this must be consecutive days or not.	Risk	Other	3 - Possible	This could lead to a misunderstanding between the design-builder and SIX supplier with regards to meeting the requirements during the performance test.	2 - Minor	This can be negotiated with the SIX supplier to come to an agreement.	6	Clarify the language in the PG document prior to contract execution.
47	Performance Guarantee	If the City desires to observe compliance with the <2 mg/L TOC for 90 percent of the time in finished water, then the whole treatment train should be tested at the same time.	Risk	Other	3 - Possible	If performance testing is done in separate phases, the City will possibly not be able to confirm that the <2 mg/L for 90% of the time is achieved.	3 - Moderate	This could mean that the City can not confirm that the DLTWTF can meet the TOC removal goal for finished water prior to completion of the plant.	9	Clarify the language in the PG document prior to contract execution, but recognize that this may have schedule consequences.
48	Performance Guarantee	The PG draft document relates to the SIX® TOC removal performance and resin loss limits, as well as the finished water TOC concentration. It is recommended that the City consider other possible PGs for parameters such as turbidity, chloride, chloride-to-sulfate, bromate, or taste and odor for this, or other phases, of the project.	Risk	Other	3 - Possible	The City may desire additional PGs for the balance of the DLTWTF upgrades.	3 - Moderate	If these PGs are not established, the City will not be able to require the design-builder to rectify an aspect of the design.	9	The City can consider and define the most important process parameters for the upgrade, and discuss PGs with the design-builder.
49	Permitting/ Regulatory	Facility permitting in the State of Florida.	Risk	Regulatory	2 - Unlikely	The FDEP must permit new or upgraded facilities. TWT has kept FDEP included in all preliminary design plans and piloting plans/results.	4 - Major	If the FDEP were not informed, there could be delays and major capital infrastructure changes to the design or installation when it came time to apply for a permit for treatment.	8	Maintain good contact with the FDEP and keep them updated about plans for the final design of the DLTWTF.
50	Schedule	Unknowns and risks with the delivery and start-up of the SIX process considering that SIX is not an established treatment process in the US, with no current full scale installations and start-up of full scale SIX systems in the US.	Risk	Capital Cost	3 - Possible	There may be delivery risks or delays associated with SIX equipment (from a Dutch entity); however, PWNT and NSI are anticipated to have a strong focus on the successful delivery of a SIX system in the U.S., since this would be the first installation in U.S. and a high profile project for them.	2 - Minor	Delays in SIX equipment delivery and/or longer than anticipated start-up efforts can result in overall delays in the completion of the DLTWTF improvements, which could also result in increased project costs.	6	TWT and the City can engage PWNT early to allow for proper QA/QC and planning/coordination/updates of schedule milestones.
51	Water Quality	Poor design/under-design resulting in errors or reduced treatment effectiveness.	Risk	Capital Cost	2 - Unlikely	During upgrade, several aspects of the DLTWTF will be modified, including hydraulics, adding SIX, filters, HSPS.	4 - Major	If there are design flaws, the DLTWTF will not achieve capacity or water quality targets.	8	Include contractual performance guarantee. Conduct thorough design reviews and QA/QC checks.

Item #	Group	Description	Type (Risk or Benefit)	Category (Cost/Non-Economic Consideration) Capital Cost O&M Cost Regulatory Non-Economic Consideration Other	Likelihood: Likelihood 1 - Rare 2 - Unlikely 3 - Possible 4 - Likely 5 - Highly Probable	Likelihood: Reasoning/ Justification	Consequence: Consequence 1 - Insignificant 2 - Minor 3 - Moderate 4 - Major 5 - Very Significant	Consequence: Reasoning/ Justification2	Likelihood x Consequence Scores	Proposed Resolution/ Timing
52	Water Quality	Inadequate screen-size for raw water straining.	Risk	Other	2 - Unlikely	Raw water screening has been in place at existing plant, and will need to be upgraded for SIX.	3 - Moderate	If debris enters SIX, the eductor could get blocked, or the internals of SIX could get blocked, causing shutdowns to remove debris.	6	Check with the SIX supplier for recommended screening for full-scale SIX system.
53	Water Quality	Inadequate disinfection resulting from lower ozone dosing after SIX.	Risk	Regulatory	1 - Rare	The existing ozone system has achieved primary disinfection and SIX will only lower the ozone dose to achieve sufficient disinfection.	4 - Major	If insufficient CT with ozone, then primary disinfection is not achieved, primarily for Giardia and Cryptosporidium.	4	Monitor disinfection residuals and contact times to ensure primary disinfection targets are met. Also ensure that the lower ozone concentration range can be dosed with equipment.
54	Water Quality	Not meeting TOC goal (<2 mg/L) due to inadequate design criteria (historical extreme for TOC is higher than the pilot extreme: 35 mg/L vs 28.5 mg/L).	Risk	Regulatory	2 - Unlikely	The proposed SIX design includes the use of higher resin dosages to cope with higher inlet TOC. Also, downstream coagulation and BAC will remove some TOC.	3 - Moderate	The spikes in TOC are expected to be short-term, so higher dosages (and higher chemical use) would be short term.	6	Include contractual performance guarantee. Plan and train operations' staff for times of higher TOC, and check for design basis for resin dosing and coagulant dosing to manage TOC short term.
55	Water Quality	Potential high bromate formation due to high raw water bromide concentration from ASR system.	Risk	Regulatory	2 - Unlikely	The existing plant bromate mitigation has worked well to keep bromate formation to less than 4 ppb; SIX will also likely remove some bromide.	4 - Major	Violating the bromate MCL would mean having to modify the primary disinfection, which could cause notification to customers/boil orders.	8	Maintain bromate mitigation and keep ASR use to same levels as in past years. Ensure quenching with hydrogen peroxide is functioning properly as well.
56	Water Quality	Not meeting Geosmin/MIB goals due to lowering of ozone dose required for primary disinfection after SIX.	Risk	Regulatory	3 - Possible	Geosmin and MIB concentrations can be high, and although historically the ozone dose for primary disinfection would oxidize and remove these to acceptable levels, with SIX, the ozone dose will be lower than historically dosed.	3 - Moderate	If geosmin and MIB are higher than the goals, there could be a higher number of customer complaints.	9	Review historical data from the City's last geosmin/MIB event to understand its duration and impact. Adjust ozone dosing strategies to ensure effective oxidation of geosmin and MIB. If higher ozone dosages are used in T&O events, then ozone could carry over to the BAC. A hydrogen peroxide system is in place and would need to be used to quench any excess ozone. The City reported that there need to be improvements to mixing and dosing for peroxide at the plant.
57	Water Quality	Change in ionic character of finished water after SIX® addition increases the potential for corrosion in the distribution system and/or customer's systems.	Risk	Regulatory Non-Economic Consideration	3 - Possible	The chloride to sulfate mass ratio is much higher after SIX pretreatment so there is an increased risk of corrosion.	5 - Very Significant	If lead or copper is detected at customers' taps in violation of LCR, then emergency measures would be needed.	15	Carollo mentioned the addition of orthophosphate to the finished water as a mitigation step to prevent corrosion. The City has done a required pipe material inventory and found no piping of concern in the City's distribution system up to the customers' water meters; however, the piping material after the water meter is the customers' responsibility. Sampling for the LCR is at the customers' tap. The City shared with BV that they will need to share educational materials with customers about this risk.
58	Water Quality	Increased sulfate from ASR wells may disrupt TOC removal, requiring adjustments in SIX® resin dosing, ozone demand, and coagulation chemistry.	Risk	Regulatory O&M Cost	2 - Unlikely	ASR wells have high sulfate concentrations relative to the Hillsborough River (DLTWTF surface water source). But historical blends have made the maximum sulfate only about 64 mg/L.	3 - Moderate	If ASR blend ratios lead to higher sulfate concentrations for significant operating times, TOC removal by SIX could be impacted.	6	The TWT is considering blending in ASR flows downstream of the SIX to alleviate the sulfate impact on TOC removal. ASR water has very low TOC, so this will have no impact on the overall TOC removal of the plant. If ASR flows must be added to the feed to the SIX, monitor sulfate concentrations and TOC levels closely when ASR wells are brought into/out of service. Also, create a plan for maximum sulfate allowed through blending after identifying any impacts.
59	Water Quality	Not meeting finished water quality criteria.	Risk	Regulatory O&M Cost	2 - Unlikely	The 10.5 month pilot showed the ability to meet TOC removal and other WQ targets over the low and high TOC seasons.	4 - Major	If not meeting the water quality targets, the City may have regulatory violations.	8	Include contractual performance guarantee. Include robust training for processes to ensure proper steady state operation, and monitor frequently with sampling to confirm performance.

Appendix B. Data Inventory Log

Appendix B - Data Inventory Log

Data Description	Responsible Party	Date Requested to City	Date Received	City/ TWT Comments	BV Comments/Notes
Documentation of any decision-making processes, including evaluation criteria and weighting, used to arrive at the selected alternative.	TWT	7/24/24	9/17/24	See SIX Pilot Report, MIEX pilot report, Process Alts Cost Comparison.xlsx, MP Vol 1 & 2	
Previous SIX® Jar Testing or Bench-Scale Testing Reports	TWT	7/24/24	9/17/24	Alternatie resin test (Ramboll) - SIX Pilot Report App C 3- backup docs> Ramboll SIX Bench testing - Kickoff meeting_09102020, slides 12-15	
SIX® Pilot Report back-up documents including monthly updates, presentations, excel files with pilot-related data and daily/weekly logs/notes of pilot operation, observations, and maintenance activities. Waste stream water quality data, any media testing results.	TWT	9/4/24	9/17/24		
SIX® Pilot photographs collected throughout the course of the pilot study.	TWT	7/24/24	9/17/24		
SIX® Pilot Report cost estimates	TWT	7/24/24	9/17/24	An economic evaluation was performed (SIX Pilot Report Section 10). Supporting calculations included.	Updated unit chemical costs was sent by Vinnie Hart (Carollo) via email on 11/8/24. TWT provided additional cost-related information throughout the project, for example "TWT 2024-11-07 DLTWTF CIP Update Aug 2024.pdf" (provided 11/21/14) and "Updated Unit Chemical Costs_ 2022-03-29.docx" .
SIX® Pilot Report lab data and laboratory reports	TWT	7/24/24	9/17/24	WQ data was analyzed by Tippin Lab. Lab staff filled out Tippin Pilot_Grab sample_Data Sheet UVT was measured in the field by pilot operator DLTWTF - full-scale plant data during pilot test period Misc - solids testing, filter headloss data, PHOGLY, LC-OCD	
SIX® Pilot Report calculations and assumptions		7/24/24	9/17/24	See MASTER DATA_analyzed_main	
SIX® Pilot Report quotes from vendor(s) for Full-scale system		7/24/24	N/A	These do not exist	
CoT DLWTF Expansion Project_SIX Presentation to Veolia 2023-06-15		N/A	8/23/24	Presented by Stacey Duff from CVIWater during a BV Lunch and Learn	
David L. Tippin Water Treatment Facility - SIX Pilot Information/Summary		N/A	8/23/24	Emailed by Stacey Duff	
Other previous engineering reports, including plant condition assessment, water quality analysis or studies, and capacity reports.	TWT	7/24/24	9/17/24	This information is in the Master Plan. Also sharing the Op Flow article (zeta potential) and WRF #4731 (Tippin filter headloss + nutrient addition)	
Most Recent Sanitary Survey completed for the DLTWTF.	COT	7/24/24	11/25/24	2021 Sanitary Survey provided, 2024 Sanitary Survey not yet finalized.	11/19/24 note from City: sanitary survey – crew was out there week of 11/11/24 to finish that up. Last one was done in 2021 – the one at the time of the pilot. Sarah Tsang will send BV the 2021 survey and will send the 2024 one when it's available.
Summary of existing plant information including raw and finished water flows, raw and finished water quality data, chemical dosages, usage and costs, solids production as-builts for the last three (3) years	COT	7/24/24	11/25/24	TWT does not have data from last 3 years	
Draft Performance Guarantee from the SIX pilot report	TWT	9/4/24	9/17/24		
ASR well information/data	COT	9/4/24	11/25/24	Provided WQ data from plant. Requested flow data and any data from 2024. ASR flow and WQ data from the pilot test period are included in the Tippin Pilot Report. TWT does not have data from last 3 years.	
City of Tampa WQ goals following implementation of SIX process (e.g., per individual process units, finished water, etc.)	COT	9/4/24	10/21/24	See the master plan water quality goals uploaded 10/21. These have not been established by COT / shared with TWT	
City of Tampa Corrosion Control Plan (preferred stability indice(s) and target levels leaving the plant along with distribution targets)	COT	9/4/24	10/1/24	This is not TWT project. Corrosion Control Response provided by TWT via email in August of 2023. Will work on getting the current optimization plan from production.	
City of Tampa current WQ goals per individual process units (e.g., pretreatment pH, settled water turbidity, ozone/chlorine residuals, top of filter turbidity, filter effluent turbidity, TOC, DBP's, etc.)	TWT/COT	9/4/24	9/18/24	All WQ goals are included in the Master Plan. No additional WQ goals have been established with TWT.	
Summary of available data from any existing raw water intake on-line monitoring, such as water level, pH, DO, conductivity, TDS, or turbidity.	COT	7/24/24	11/22/24	The water quality data recorded under the water use permit from COT lab. Analyzed and reported monthly, 2019 to present.	
Any available PFAS sampling and testing results collected for the raw and finished water (POE).	COT	7/24/24	10/18/24	TWT is currently executing a bench-scale SIX PFAS study. TM anticipated late October '24.	Following data received from Vinnie via email on Nov 8, 2024 PFAS data – finished water (Jan 2023 to Aug 2024) Brine PFAS data from Curren (Aug 2023 to Jan 2024)
Status and information of other relevant projects, including planned or ongoing changes in plant operations and improvements at the water treatment facility.	COT	7/24/24	10/21/24	Ongoing TWT projects: Raw water intake, filters, TECO, potable water loop, ozone. Gareny to share overall TWT program schedule	Includes: • DLTWTF Chemical Systems Improvements 100% Design and Technical Specs (March 2021) • DLTWTF HSPS and Misc Improvements Conformed Drwgs (March 2021) • HSPS and Misc Improvements 2024 Project Schedule • HSPS and Misc Improvements (Sequence & Outages) • DLTWTF DEP UIC IW Construction and Testing Permit March 2024 and April 2024 • Raw Water PS 100% Design and Technical Specs (Sept 2009) Ozone Improvemens 100% Design and Technical Specs (Dec 2003) • Electrical Improvements 100% Design and Technical Specs (Nov 2023) • Filters 100% Design and Technical Specs (Feb 2023) • DLT Campus Layout
Tampa DLTWTF Expansion SIX Pilot Report_(Carollo)_2022-02-01	N/A	N/A	5/17/24		Ian C. sent Rebecca O. the link to City's website and she downloaded it from there and shared with the BV team.
Tampa Potable Water Master Plan Report_(Black & Vetach)_2018-10-01	N/A	N/A	5/17/24		Ian C. sent Rebecca O. the link to City's website and she downloaded it from there and shared with the BV team.
Tampa DLTWTF Master Plan_(Carollo)_2018-07-01_Volume 1	N/A	N/A	5/17/24		Ian C. sent Rebecca O. the link to City's website and she downloaded it from there and shared with the BV team.
Tampa DLTWTF Master Plan_(Carollo)_2018-07-01_Volume 2	N/A	N/A	5/17/24		Ian C. sent Rebecca O. the link to City's website and she downloaded it from there and shared with the BV team.
Operations interviews to better understand existing water quality and processes.		City and BV PMs will schedule			
Half-day site visit with City staff. Up to 3 Firm professionals will participate in the site visit.		City and BV PMs will schedule			
SIX Supplier's Performance Guarantee		10/17/24			
Lead and Copper Inventory data		10/21/24			
Lead Service Line (LSL) information past meter		10/21/24			
TBW data ((e.g., the point of connection (POC) at Morris Bridge, water quality, concentrate from desal)		10/21/24			WQ Data for 2023 received (11/13/24)
TBW Desal Concentrate Characterization Data (January and March 2019)	BV	N/A	10/23/24		
Op Flow article on Zeta Potential	TWT		9/17/24		
WRF #4731 (Tippin filters)	TWT		9/17/24		

City of Tampa
DLWTF Expansion Project

SIX® PILOT REPORT

FINAL | February 2022

City of Tampa
DLTWTF Expansion Project

SIX® PILOT REPORT

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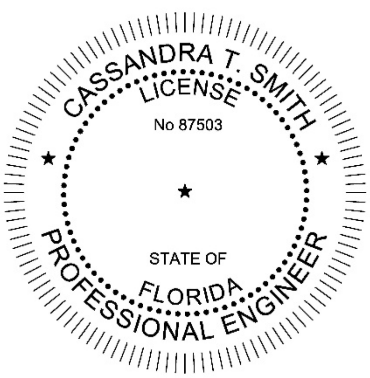

This item has been digitally signed and sealed by Cassandra T. Smith on the date adjacent to the seal.

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Carollo Engineers, Inc.
101 East Kennedy Boulevard, Suite 700
Tampa, FL 33602
813-888-9772

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Abbreviations

ANSI	American National Standards Institute
ASR	aquifer storage and recovery
Carollo	Carollo Engineers, Inc.
CBHL	Clean bed headloss
cf	cubic feet
cfs	cubic feet per second
city	City of Tampa
DLTWTF	David L. Tippin Water Treatment Facility
DS	distribution system
EC	enhanced coagulation
ES	effective size
F	Fahrenheit
ft	feet
FRV	full resin volume
FRV	Fresh resin vessel
gpcd	gallons per capita per day
HR	Hillsborough River
MDD	maximum day demand
MIEX®	magnetic ion exchange
µg/L	micrograms per liter
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
MP	master plan
MRI	Meurer Research, Inc.
msl	mean sea level
NSF	National Science Foundation
PS	pump station
psi	pounds per square inch
RO	reverse osmosis
RW	raw water
SCADA	supervisory control and data acquisition
SIX®	suspended ion exchange
SPF	solids processing facility
TOC	total organic carbon
TWT	Tippin Water Team

WQ	water quality
WTP	water treatment plant
ZP	zeta potential

EXECUTIVE SUMMARY

Through master planning efforts and a robust capital improvement program (CIP), a facility expansion project was developed to address the needs and challenges at the David L. Tippin Water Treatment Facility (DLTWTF) in Tampa, FL. The CIP was updated in January 2021 by the Tippin Water Team (TWT). The Tippin Water Team includes a joint venture of Garney Construction and Wharton-Smith, Inc. with Carollo Engineers, Inc. (Carollo) leading a team of consultants including Ramboll and others.

Existing plant challenges highlighted in the Master Plan (MP) include high chemical use and cost (DLTWTF is currently an enhanced coagulation plant); low coagulation pH and corresponding corrosion issues; use of aggressive chemicals; high ozone doses (which combined with high bromide requires bromate mitigation); low filter loading rates and low unit filter run volumes (UFRVs); a limited backwash water handling system; and high solids production which is compounded by poor dewaterability of the solids. Additional information on existing plant challenges can be found in Section 1.2 of this report.

Ion exchange (IX) was determined to be a promising technology to best address DLTWTF goals, predominantly a finished water total organic carbon (TOC) below 2.0 mg/L. Magnetic Ion Exchange (MIEX®) was piloted in 2017/2018 and matched current TOC removal while lowering downstream chemical usage. However, critical risks were identified with MIEX®: single-source proprietary resin, continual resin replacement, and potential for resin fouling. In addition, the MIEX® process could not achieve the City's finished water TOC goals of less than 2 mg/L. Suspended Ion Exchange (SIX®), is an alternative ion exchange technology designed to overcome these risks.

SIX® is a continuous IX process that utilizes a generic strong base anion (SBA) exchange resin with multiple potential manufacturers. Lamella plates are used to separate the resin and avoid washout efficiently. A significant feature of the SIX® process is its regeneration frequency; SIX® operates like a plug flow reactor where 100 percent of the SIX® resin inventory gets regenerated after each pass through the reactor. This regeneration frequency keeps the resin's ion exchange sites lightly loaded, minimizing the potential for fouling. Additional information on the MIEX® and SIX® process can be found in Section 1.2.1 of this report. For these reasons, SIX® was piloted (November 30, 2020-October 15, 2021) as a pretreatment process to the overall treatment train. This report details the findings of the SIX® pilot at DLTWTF.

The SIX® pilot, like the MIEX® pilot, incorporated the entire treatment train at DLTWTF to understand the effects on downstream processes during seasonal RW WQ variability. The pilot configuration is shown below in Figure ES1. Additional details can be found in Section 3 of this report.

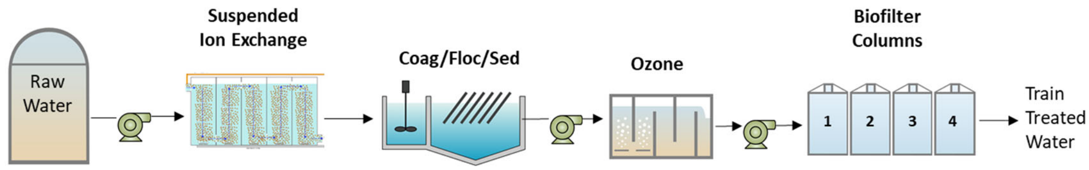


Figure ES1 DLTWTF SIX® Pilot Treatment Train. Raw water was prefiltered to 1/16".

Pilot objectives for this study are dictated by full-scale operational needs and water quality goals. Key water quality goals are highlighted in Table ES1 below. Additional information on the water quality goals can be found in Section 2 of this report.

Table ES1 DLTWTF Key Finished Water Quality and Water Quality Goals (1,2)

Parameter	Goal	DLTWTF Finished (max/min/avg)	Pilot Finished (max/min/avg)
TOC (mg/L)	<2.0 mg/L 95% of the time(3)	4.3 / 1.1 / 2.6	2.1 / 0.5 / 1.5
T&O (Geosmin, ng/L)	<3.0	2.4 / 1 / 1.6	1.2 / <1 / <1
T&O (MIB, ng/L)	<3.0	<1 / <1 / <1	<1 / <1 / <1

Notes:
(1) All data summarized from pilot test period 11/30/20-10/15/21.
(2) Data does not include test periods with alternative operations (e.g., ACH or cationic polymer coagulant).
(3) Suggested by City as part of the master plan meeting held on 9/10/2020.

The SIX® pilot successfully achieved the WQ goals (Table ES1). TOC (Figure ES2), color, Taste and Odor (T&O), and pH goals were regularly met. Due to the alkalinity removal by the SIX® process, the alkalinity goal was not consistently met, especially during high TOC season when raw water (RW) alkalinity drops, but this can be adjusted full-scale by chemical addition. This report estimates the chemical usage required to achieve the alkalinity goal (46 mg/L as $CaCO_3$). Disinfection was not tested at the pilot-scale, but instead at the bench-scale with pilot samples. Bench-scale testing followed the current DLTWTF protocol, and disinfection by-products (DBPs) were maintained well below maximum contaminant levels (MCLs). Based on lower finished water TOC at the pilot, finished water from a full-scale SIX® treatment train is expected to be the same or better than current operations in maintaining residual chloramine concentrations and minimizing DBP formation.

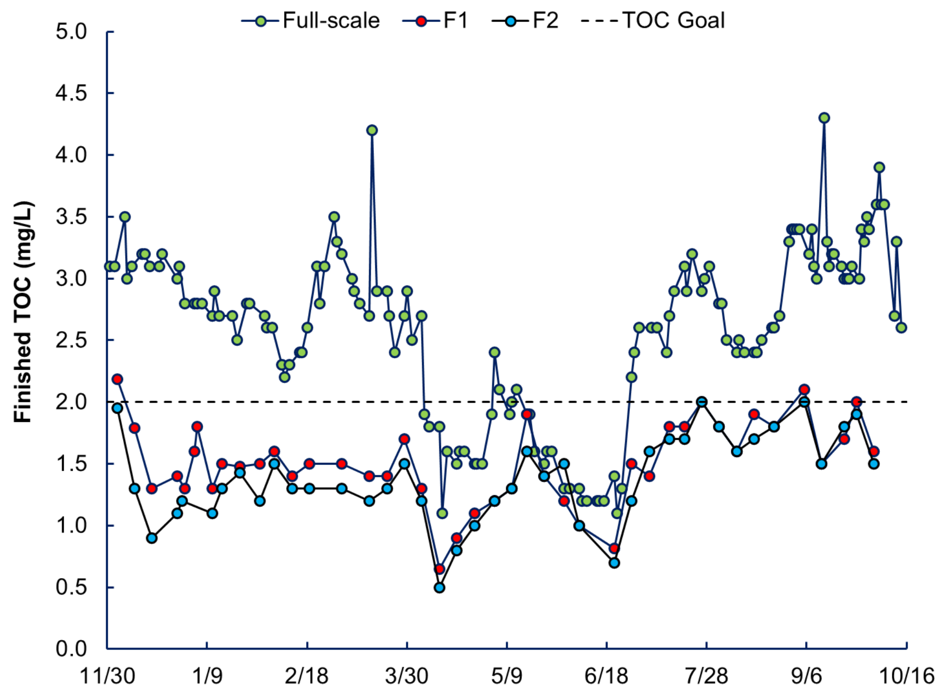


Figure ES2 Full-Scale and Pilot Filter 1 and 2 Finished TOC

In addition to meeting the major WQ goals, other achievements were realized via the SIX® pilot train, specifically with the filter performance. Neutral zeta potential (ZP) was targeted to determine coagulant demand; it was with neutral ZP that filter performance excelled. Pilot filters were operated at loading rates (LRs) up to 6-8 gpm/sq ft with unit filter run volumes (UFRVS) up to 20,000-45,000 gal/sq ft, respectively; full-scale filters are operated at 2-2.4 gpm/sq ft with UFRVs around 5,000 gal/sq ft (Figure ES3). More filter configuration information is provided in Section 4.3.5 of this report. Additional information on filter performance can be found in Section 8 of this report.

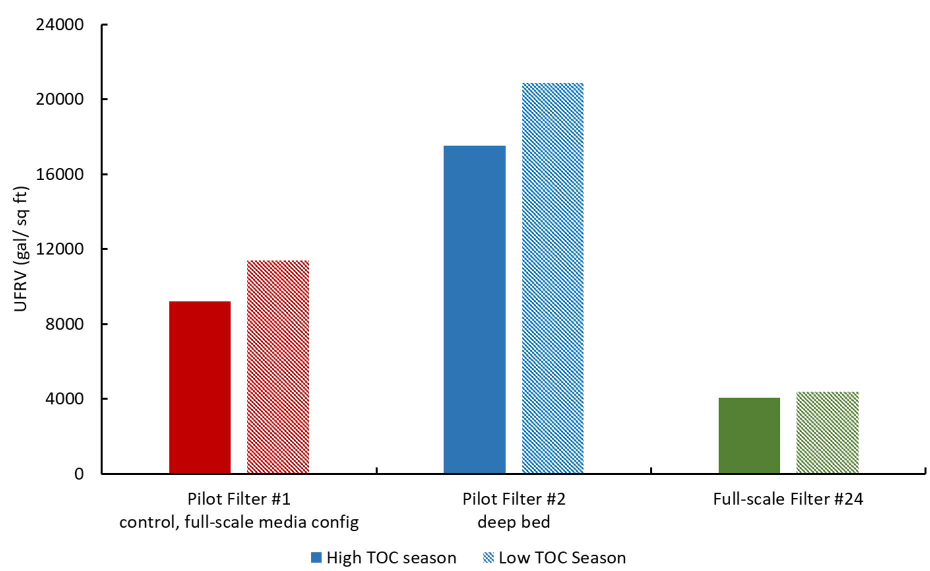


Figure ES3 Full-Scale and SIX Pilot Average Filter UFRV Comparison

In addition to enhanced filter performance/production and improved water quality, the SIX® pilot also reduced chemical consumption downstream.

- Coagulant (ferric sulfate) usage was reduced on average by 59 percent and 71 percent for low and high RW TOC season, respectively. (See Objective 8 results)
- With the SIX® alkalinity removal, pH depression for coagulation was achieved with lower coagulant doses and eliminated the need for sulfuric acid (currently utilized most of the year at full-scale). (See Objective 9 results)
- With lower pre-ozone TOC, the ozone dose was also reduced by 41 percent and 32 percent for low and high RW TOC season, respectively. (See Objective 13 results)

With any IX technology, salt will be required as an input for resin regeneration. The SIX® pilot salt usage was determined to be 1545 lb/MG treated and this is used throughout the analysis. It is expected that full-scale operations can further optimize and reduce this usage. Additional bench-scale testing may assist with further optimization for full-scale design. (See Section 9 of this report for more details). It should be noted that the use of the Tampa Bay Seawater Desal Concentrate for the salt supply for the SIX® process was tested and is a potentially viable solution. This option is discussed in the Economic Analysis (Section 10) of this report.

With the incorporation of any new technology, there are identified risks. Risks associated directly with SIX® include the following:

- Resin fouling.
- Resin attrition.
- Raw water particulate material causing problems.

Resin fouling was not observed at the pilot-scale throughout the 10.5-month test period, but it is important to note that chloraminated process water was utilized for resin rinsing during the regeneration process (Objective 4 results). A caustic squeeze chemical cleaning of the resin was tested at the pilot-scale. This high pH (~12) brine soak resulted in improved initial performance and would be a common technique to assist in fouling mitigation (Objective 19). SIX® resin attrition is minimal (compared to other IX technologies); the economic analysis conservatively estimates $200,000 annually which is 4.4 percent of the resin inventory. Operational issues were met at the pilot with clogging of the SIX® eductor by RW particles; this issue was resolved at the pilot-scale with prefiltration at 1/16-inch, and this size screening is being evaluated for the full-scale intake design. In addition to risks associated directly with SIX®, additional water quality risks have been identified as:

- Higher chlorides, lower sulfate, lower alkalinity and coagulation pH could require additional efforts to abate downstream corrosion and manage stability of the product water.
- Microflocculation was observed during high TOC season which affected filter headloss (some mitigation measures were identified).

With SIX® salt use, higher chlorides result in the finished water. Chloride-to-sulfate mass ration (CSMR) is much higher (with higher chlorides in conjunction with lower sulfate); however, due to the lack of lead in the distribution system, this is not a concern (See CSMR 9.5.3.1). Alkalinity is expected to be added back into the process via CO_2 and caustic. Estimates of chemical usage to achieve CCPP 0-13 mg/L and finished water pH 8-8.5 are described under Objective 7 results. Microflocculation was observed during the pilot to have adverse effects on headloss accumulation rates in the filters; microflocculation control strategies are also described within this report, specifically Objective 20 results.

An economic analysis was performed to evaluate the SIX® process compared to current full-scale operations. Both high TOC (RW>15 mg/L) and low TOC (RW<15 mg/L) seasons were assessed separately, as the RW WQ shifts significantly seasonally. Seasonal costs are shown in Table ES2. The most significant contributing factors for SIX® cost are (1) salt usage and (2) the use of caustic for alkalinity recovery post coagulation. Salt and caustic in the SIX® pilot constitute $205/MG of the $263/MG, respectively in the high TOC season and $113/MG of the $153/MG in the low TOC season. Non-cost benefits of alkalinity reduction (e.g., improved TOC removal with lower chemical usage during coagulation), along with other non-economic benefits of SIX®, such as improved water quality (e.g., lower finished water TOC, lower DBPs), higher filter UFRVs, and fewer new filters to meet future capacity are also essential factors to consider when evaluating the merits of SIX®. With higher filter UFRVs with the SIX® pilot, it is estimated that future full-scale filters with SIX® will operate at higher LRs providing more redundancy and reliability compared to current operations (as well as with MIEX®). Refer to Section 10 of this report for more information.

Table ES2 Seasonal Total Chemical Costs

Operation(1)	Units	High TOC Season(2)	Low TOC Season(3)
Existing, Full-Scale	$/MG	$222	$271
SIX® Pilot	$/MG	$263	$153
Differential		+$41	-$118
% Difference		18.5% increase	43.5% decrease

Notes:
(1) During pilot operations from November 30, 2020 - October 15, 2021.
(2) High TOC season occurred from June 28, 2021 - October 15, 2021.
(3) Low TOC occurred from December 15, 2020 - June 28, 2021.

With the findings from this pilot testing in combination with other full-scale successes, the TWT recommends the implementation of SIX® full-scale at DLTWTF. The full-scale SIX® design will be designed based on the preliminary specifications described in Table ES3.

Table ES3 Full-Scale SIX® Design Specs

Component	Detail
Contactor Size	20 min
Number of Trains	10
Train Size	14 mgd
Resin Dose	20-30 mL/L
Resin Type(1)	LanXess Lewatit S5128
Resin Inventory(2)	$4.5 mil
Salt Use	1545 lb/MG

Notes:
(1) Resin used during pilot testing.
(2) Based on 20 min CT, 30mL/L dose.

Section 1
INTRODUCTION

1.1 Acknowledgments

It is essential to acknowledge the work, commitment, and endless hours many of the City's staff, TWT, and equipment suppliers put forth for this effort. The success of this study would not have been possible without the City's dedication to the pilot's operations in particular, the Tippin lab team for accommodating the extensive water quality testing; the Tippin purchasing and receiving team for efficiently ordering pilot chemicals and delivering pilot packages to the operator; Tippin operations team for supplying ferric sulfate and effectively communicating relevant full-scale operations; Tippin maintenance staff for, at times, going above and beyond to assist with pilot maintenance; Tippin management for supporting of the SIX® pilot so strongly, and ensuring its success. The effective teamwork of TWT also played a large role in the accomplishments of the pilot; in particular, Wharton-Smith for meticulous mobilization and demobilization of the pilot; Garney for their support in regular (and non-regular) maintenance throughout testing; and Ramboll for the SIX® expertise.

1.2 Background

The City of Tampa's (City) Water Department owns and operates the David L. Tippin Water Treatment Facility (DLTWTF) located in Tampa, Florida. In 2020, the plant produced about an average of 76.7 million gallons a day (mgd) of potable water for its service, which has a population of 717,000 and 205,466 service locations. Carollo Engineers, Inc. (Carollo) prepared a comprehensive master plan (MP) that was finalized in July 2018 and included a prioritized capital improvement program (CIP) that, among 16 other projects, included a facility expansion project. The CIP was updated in January 2021 as a part of the master plan update completed by the Tippin Water Team (TWT). The Tippin Water Team includes Garney Construction, Wharton-Smith, Inc.

Findings from the MP efforts highlight existing plant challenges. These challenges include high chemical cost and use; low coagulation pH and corresponding corrosion issues; use of dangerous chemicals; high ozone doses (which combined with high bromide requires bromate mitigation); low filter loading rates and low unit filter run volumes (UFRVs); limited backwash waste washwater handling system; and high solids production and poor dewaterability.

Given the DLTWTF's existing challenges, need for expansion, and extensive chemical use and solids generation, a detailed alternatives analysis was completed as a part of the master planning efforts. (The DLTWTF Master Plan Report and other documents referenced for this document are listed in the References section). The high chemical usage, aggressive water quality in specific unit processes, and solids production are largely due to the enhanced coagulation treatment method currently used at the plant (which includes both high doses of coagulant and acid addition at certain times of the year). Five alternatives were evaluated to optimize or replace the plant's current enhanced coagulation (EC) treatment approach and corresponding solids-handling processes while still achieving or improving the City's goals for total organic carbon (TOC) removal and all other finished water quality goals.

1.2.1 Piloting Ion Exchange at DLTWTF - MIEX® and SIX®

As a result of the alternatives analysis from the original master plan, two treatment train alternatives were selected for piloting to confirm feasibility. The magnetic ion exchange (MIEX®) process (Figure 1), which was piloted approximately 50 percent of time from October 2017 to April 2018, was found to match current TOC removal and lower chemical demands for downstream EC. However, due to critical risks identified as a result of the pilot study along with Carollo's previous full-scale MIEX® experience, full-scale implementation was deferred.

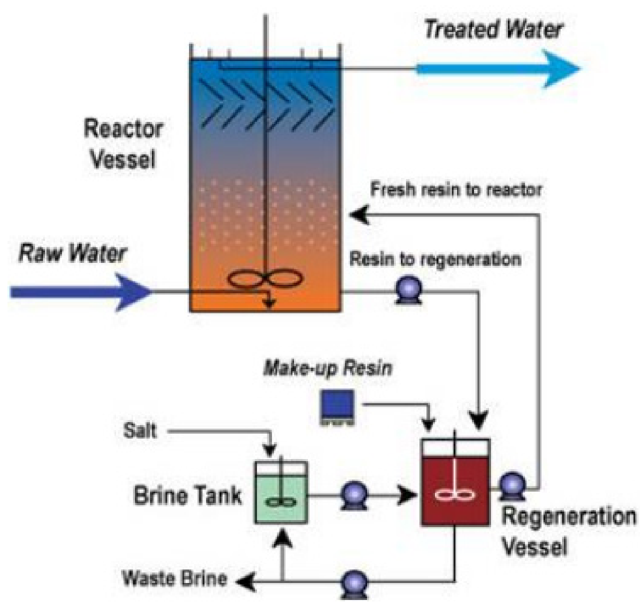


Figure 1 MIEX® Treatment Process Flow Diagram

Instead, a longer-term pilot study was suggested for an alternative ion exchange technology, called suspended ion exchange (SIX®). A white paper was prepared that detailed what was known about the SIX® process (its use in the United States is limited) and was included as an appendix to the Master Plan Report. Figure 2 presents an overview of the SIX® process.

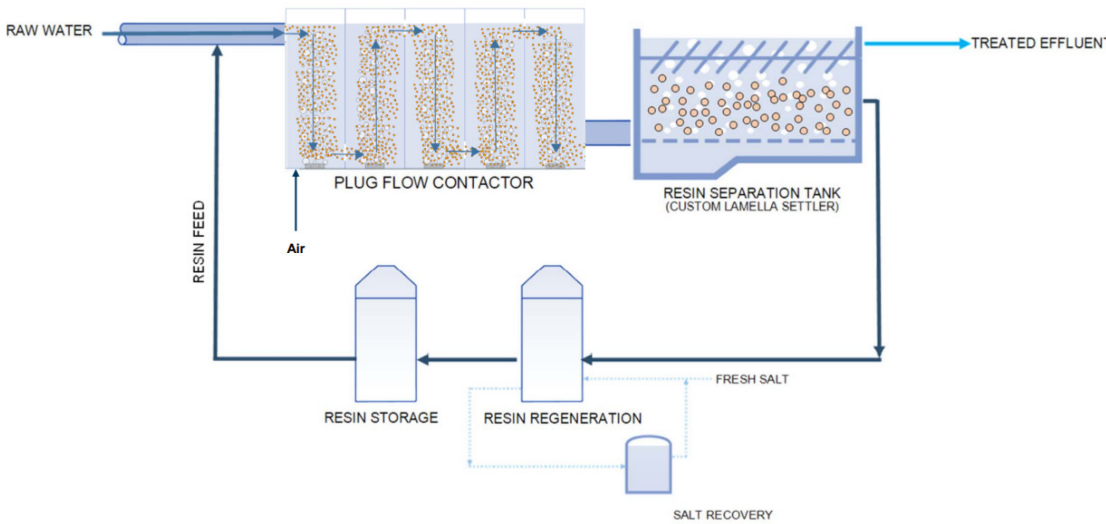


Figure 2 SIX® Treatment Process Flow Diagram

Based on preliminary bench studies, the SIX® process was expected to produce similar or enhanced TOC removal compared to MIEX® while addressing other risks detailed in the MIEX® Pilot Report. Table 1 highlights the major differences between the MIEX® and SIX® processes. Like MIEX®, SIX® will be used as pretreatment to a coagulation, flocculation, sedimentation, ozone, filtration process.

SIX® has the following anticipated advantages over MIEX®:

- Limited resin attrition (based on previous experience).
- Ability to use commercially available gellular, strong base anionic resins.
- Lightly loaded resin (in terms of anions exchanging with sites) reduces the potential for resin fouling and reduces interferences from other anions (carbonates and sulfates).
- Resin approach promotes the enhanced removal of organics.
- Complete resin inventory regeneration for each pass reduces microbial fouling.

Table 1 Comparison of Ion-Exchange Technologies: MIEX® vs. SIX®

Parameter	MIEX®	SIX®
TOC Loading on the Resin	Heavy	Light
Resin Inventory Replacement	Continuous	7-10 years(1)
Resin Characteristics	Proprietary (one supplier)	Non-proprietary(2)
Brine Concentration (saturation)	100%	2-10.8%
Resin Regeneration per Cycle (percent of inventory)	10%	100%
Biogrowth Potential	High(3)	Low to Medium
SO_4^{2-} and HCO_3^- Competition	Medium	Low

Notes:
(1) The Andijk WTP in the Netherlands has been operating with minimal resin replacement since 2014.
(2) Only one supplier has been used in existing full-scale installations.
(3) During MIEX® pilot, chlorine was required to mitigate biofouling.

At the end of the master planning effort, the potential for the SIX® was discussed with the City. It was decided that these advantages warranted piloting the SIX® process to understand better its effects on the overall treatment and downstream processes. Due to the anticipated impacts of the SIX® process on downstream processes, coagulation, flocculation, sedimentation, ozone, and biofiltration were also piloted. Figure 3 shows a simplified version of the pilot-scale process train. This document details the pilot results.

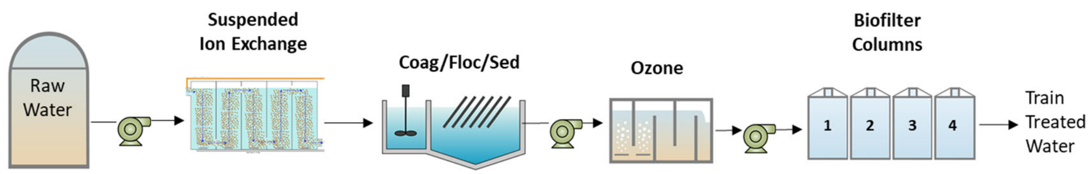


Figure 3 DLTWTF SIX® Pilot Treatment Train

Section 2

GOALS AND OBJECTIVES

Pilot objectives for this study are dictated by full-scale operational needs, as determined by the original MP. In general, the SIX® process is being investigated for improved organics removal, and downstream processes are included to mimic the existing, full-scale plant and observe SIX®'s subsequent downstream effects. The purpose of the pilot is to confirm the bench results and demonstrate dynamic systems that cannot be tested at the bench scale (i.e., filter operations).

2.1 Treated Water Quality Goals

This pilot was run for 10.5 months (November 30, 2020-October 15, 2021). It was crucial to run the pilot for this duration to capture the seasonal variation in the source water at DLTWTF. Table 2 summarizes the DLTWTF's finished water quality and water quality goals, as described in the master plan CIP or updated by the City.

Table 2 DLTWTF and Pilot Finished Water Quality and Water Quality Goals(1)

Parameter	DLTWTF Finished (max/min/avg)	Goal(5)	Pilot Finished (max/min/avg)
Alkalinity (mg/L as $CaCO_3$)	109 / 45 / 82.5	46(2)	98 / 10 / 37
pH	8.13 / 7.6 / 7.88	7.8 - 8.0	7.6 / 6.4 / 6.9(3)
Turbidity (NTU)	0.2 / 0.05 / 0.09	<0.08	ND
TOC (mg/L)	4.3 / 1.1 / 2.6	<2.0 mg/L 95% of the time(4)	2.6 / 0.5 / 1.5
Color (apparent, CU)	<5 / <5 / <5	Unapparent (<5)	8 / <5 / <5
T&O (Geosmin, ng/L)	2.4 / 1 / 1.6	<3.0	1.2 / <1 / <1
T&O (MIB, ng/L)	<1 / <1 / <1	<3.0	<1 / <1 / <1
Free Ammonia (mg/L)	ND(6)	0.1- 0.18	ND
Fluoride (mg/L)	0.75 / 0.6 / 0.65	0.65-0.75	ND
Chlorine Residual (mg/L)(4)	5.4 / 3.5 / 4.4	4.25-4.75	NA

Notes:
(1) Data summarized from pilot test period 11/30/20-10/15/21.
(2) Suggested minimum by RTW; Historic minimum for DLTWTF = 46mg/L.
(3) pH on the pilot was adjusted to 7 throughout the piloting. It is anticipated that final pH adjust to a CCPP of 0-13 mg/L as $CaCO_3$ would occur after filtration.
(4) Suggested by City as part of the master plan meeting held on 9/10/2020.
(5) Chlorine residual goals were not met during piloting; 3 rounds of chlorine demand testing were done at bench-scale.
(6) ND - no data, was not tested.

Specific pilot objectives are broken down by each pilot skid, respectively.

2.1.1 Suspended Ion Exchange (SIX®)

1. Assess and determine the optimum resin dose, contact time, and corresponding required contactor size.
2. Understand the implications of contactor size on brine use and waste stream volume.
3. Demonstrate the TOC and color removal during different seasons and the impact of other anions on TOC removal.
4. Understand the long-term fouling characteristics of the suspended ion exchange resin (limited to 10.5-month study period).
5. Understand potential biological fouling's impact on settleability (resin).
6. Understand the removal of bromide from the SIX® process.
7. Understand the removal of bicarbonate from the SIX® process.

2.1.2 Conventional Treatment (Coagulation, Flocculation, Sedimentation)

1. Understand the impact of the SIX® process on the charge demand of the raw water seasonally.
2. Establish the impact of pH adjustment versus metal salt coagulants on additional TOC removal and ozone demand.
3. Establish the impact of pH adjustment versus metal salt coagulants on the settleability and dewaterability of solids residual.
4. Determine the potential for using or supplementing with a cationic polymer and the impacts on TOC, ozone demand, settleability, and dewaterability of solids residual.
5. Determine the best floc aid polymer for the different coagulation schemes.
6. Evaluate potential impacts of conventional floc/sed versus ballasted flocculation.

2.1.3 Ozone

1. Determine the overall ozone demand and dose with ion exchange and coagulation/ flocculation/ sedimentation.
2. Determine the approach to contact time based on the demand curves for each of the ion exchange and coagulation approaches.
3. Determine the potential for bromate formation and associated mitigation measures based on the overall ozone demand and the selected pretreatment approaches. (This analysis shall include the impact of the ASR well if the City is running the well during piloting).
4. Determine the chlorine demand when ozone is not operational or if ozone is being used for oxidation only and the approach to CT.
5. Determine the impacts of the different pretreatment methods on the potential for sidestream injection (in terms of getting CT with one application point).
6. Determine the impacts and approach to quenching (hydrogen peroxide only).
7. Impact of ozone dose and pretreatment on TOC removal through biological filtration.
8. Understand the implications of intermediate-ozone on microflocculation and filter headloss. (new objective)

2.1.4 Filters

1. Evaluate different filter loading rates and media configurations (sizes and depth) based on pretreatment approaches.
2. Evaluate the combined use of hydrogen peroxide and phosphorus addition (if needed) in combination with pH adjustment to improve filter loading rates.
3. Evaluate the impacts of improved backwash protocol, different media configurations, and potential filter design changes (additional headloss).
4. Perform analysis of biological growth with different pretreatment (ability to handle T&O, TOC removal).

Section 3

PILOT PLANT DESIGN

3.1 Process Flow

Figure 4 shows a detailed schematic of the pilot system process flow. Raw water from the Actiflo® pipe was pumped to SIX®'s influent water tank (located in front of Building 9). Water was then pumped from the influent tank through the SIX® process, whose effluent flows by gravity to a conventional flocculation/sedimentation pilot unit where coagulation chemicals were added. The initial doses were determined from bench-scale demand testing; subsequently, a zeta meter was used to assess pilot coagulant demand to achieve a neutral charge (this is further discussed during Phase 2). Additional bench testing was conducted during the pilot to screen options and evaluate optimal coagulant type for the SIX® effluent.

The clarified water was then pumped to the ozone skid. The ozone dose was initially determined by bench testing. Subsequently, doses were automatically adjusted to meet the demand necessary to achieve 0.5 mg/L residual at 5.5 min contact time to best match full-scale. The ozonated water was pumped to each filter by its filter influent pump located on the biofiltration skid, where four different filter configurations were tested.

The first filter media configuration will mimic full-scale, as-is operations, while the second and third configurations reflect potential new full-scale filter designs based on the hydraulic availability once the current clearwell project is complete. Finally, the fourth configuration is an alternative configuration for the existing full-scale filters to maximize existing filter box dimensions, potentially raising filter troughs to improve loading rates or UFRVs. During the pilot, filter loading rates were periodically changed (mostly raised) to understand a large range of performance.

A detailed PFD with initial starting conditions and chemical dosing is outlined inFigure 5. All chemicals used in the pilot study conform to the American National Standards Institute/National Sanitation Foundation (ANSI/NSF) Standard 60.

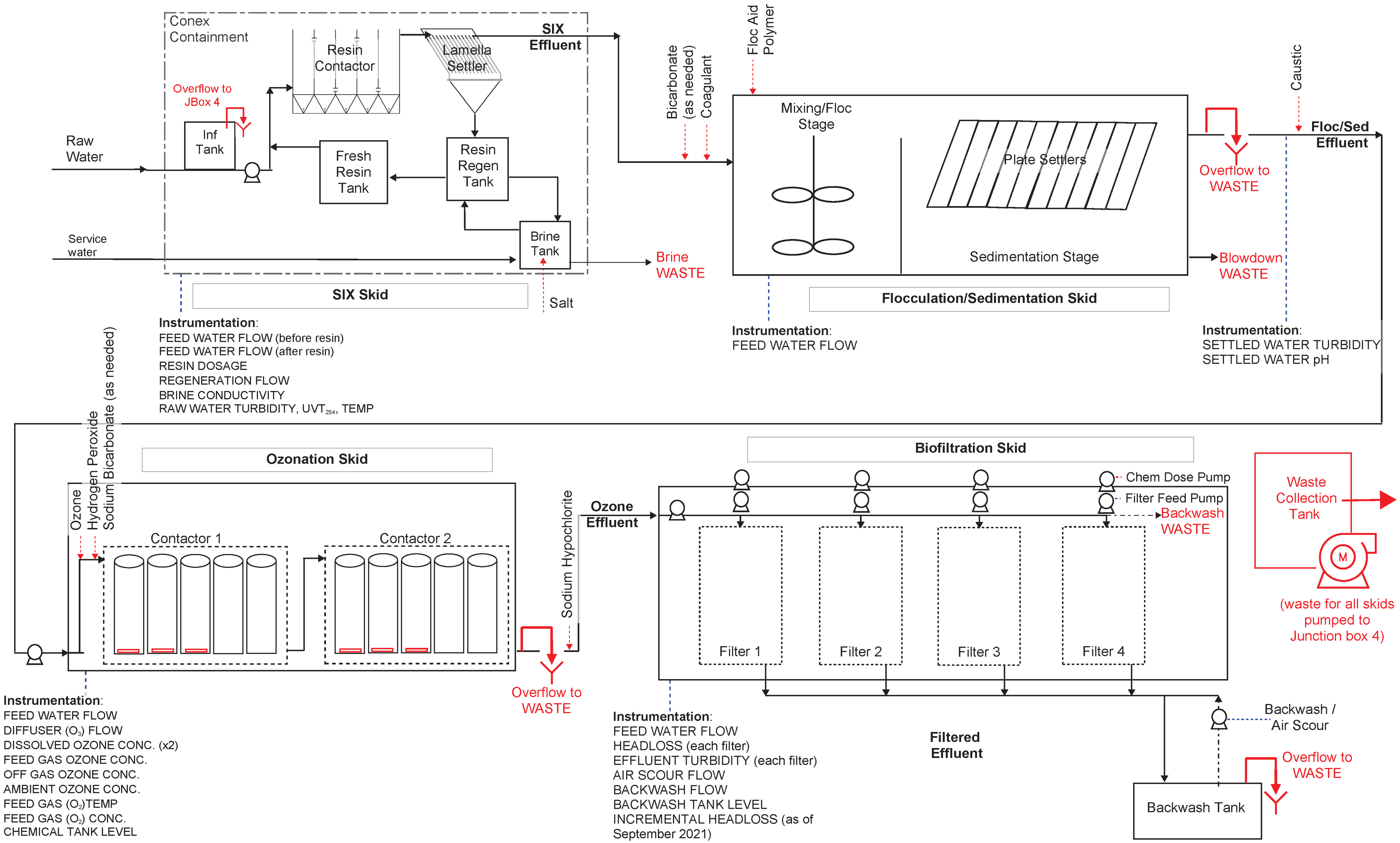


Figure 4 Detailed Schematic of SIX® Pilot Process Flow

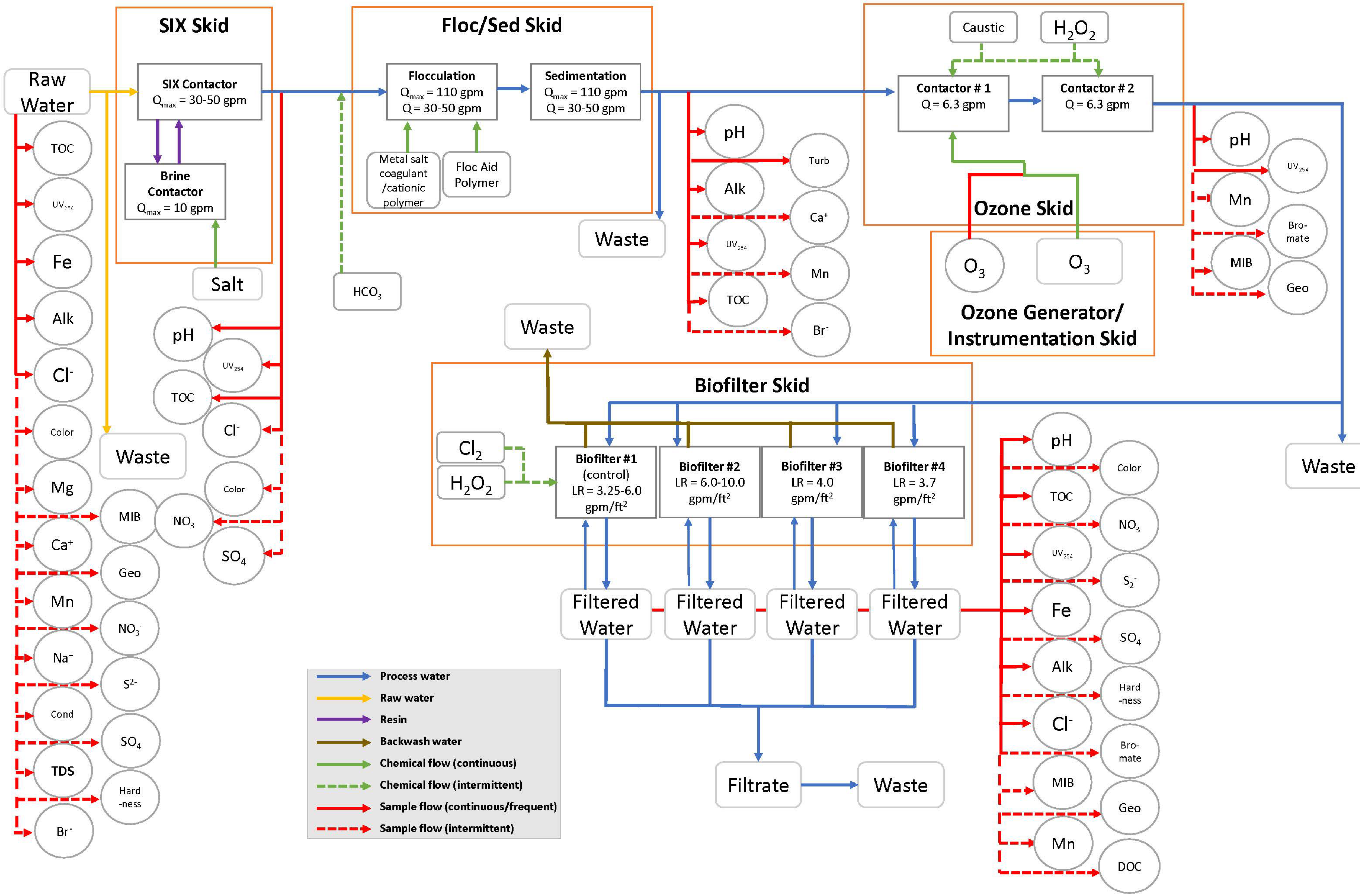


Figure 5 Pilot PFD with Chemical Dosing

3.1.1 Pilot Testing Equipment

The following section introduces specifications for the major process testing equipment. Appendix A offers additional details for each skid.

3.1.1.1 SIX® Ion Exchange

The SIX® pilot unit, provided by Ramboll Inc., is designed to perform as a plug flow reactor. The resin is dosed into the raw water flow just before it flows through the contactor, where it is kept in suspension utilizing air fluidization. Since the resin and raw water flow together, both have the same hydraulic retention, or residence time, allowing for a more uniform distribution of resin and fully utilize the resin functional group sites for the exchange process.

After the contactor, the resin is continuously separated from the flow stream by gravity settling using a lamella plate settler. After it is collected, the resin is regenerated in a batch process with a dilute salt brine solution (NaCl) in the regeneration tank and transferred to the resin storage tank, where it is continuously returned to the beginning of the contactor. Figure 6 provides a 3D rendering of this unit.

Figure 6 SIX® Pilot Unit

The SIX® pilot unit consists of the following parts:

- Raw water influent tank and pump.
- Raw water flow meter.
- Resin contactor.
- Lamella settler.
- Resin regeneration system.
- Brine hold tanks.

3.1.1.2 MRI Floc/Sed

A demonstration-scale flocculation and sedimentation treatment pilot unit was provided by Meurer Research, Inc. (MRI). The floc/sed unit was used to simulate the full-scale DLTWTF conventional floc/sed process. This unit employs settling plates for solids removal. While the plates for the DLTWTF may be larger than those in the MRI pilot unit, plate efficiency and performance generally improve with size. Therefore, the pilot results are expected to be conservative relative to full-scale. Additional details of the MRI Plate Settler Pilot Unit (floc/sed) are provided in Figure 7. provides a visual of this unit.

Figure 7 Pilot Floc/Sed Unit - Sside view (left) and top view (right).

3.1.1.3 Ozone

A demonstration-scale ozonation pilot unit was provided by Carollo and manufactured by Intuitech, Inc. Figure 8 provides a 3D rendering of this ozone unit. This ozone unit consists of the following parts:

- Influent water feed pumps (two).
- Two contactors with five contact chambers each.
- An ozone generator with oxygen concentration and ozone destruct unit.
- Additional chemical metering pumps, as needed.

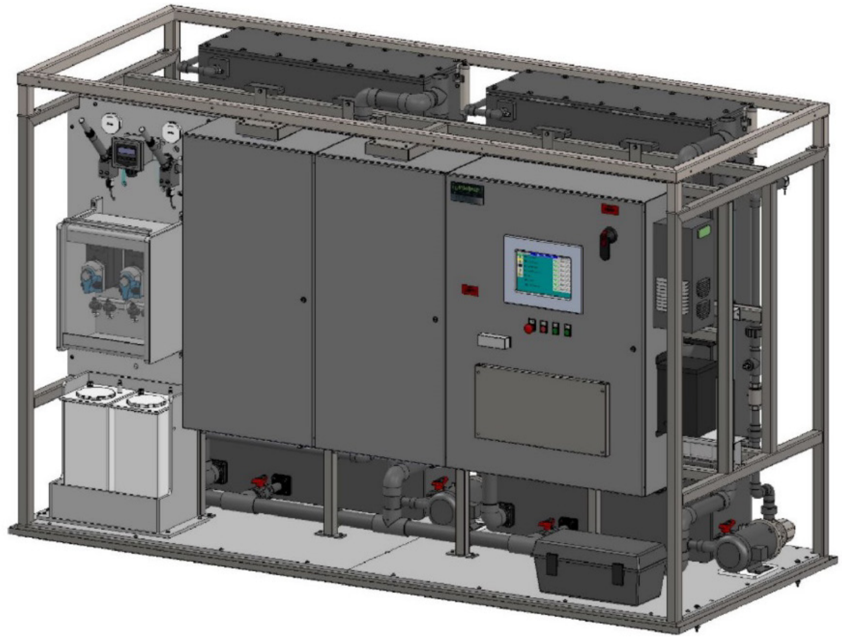


Figure 8 Pilot Ozone Unit

3.1.1.4 Biofiltration

A demonstration-scale biofiltration pilot unit was provided by Carollo and manufactured by Intuitech, Inc. Figure 9 provides a 3D rendering of this unit. This biofiltration skid consists of the following parts:

- Four constant-rate filters with individual feed pumps.
- Five chemical feed pumps, as needed.
- An air scour and backwash system.

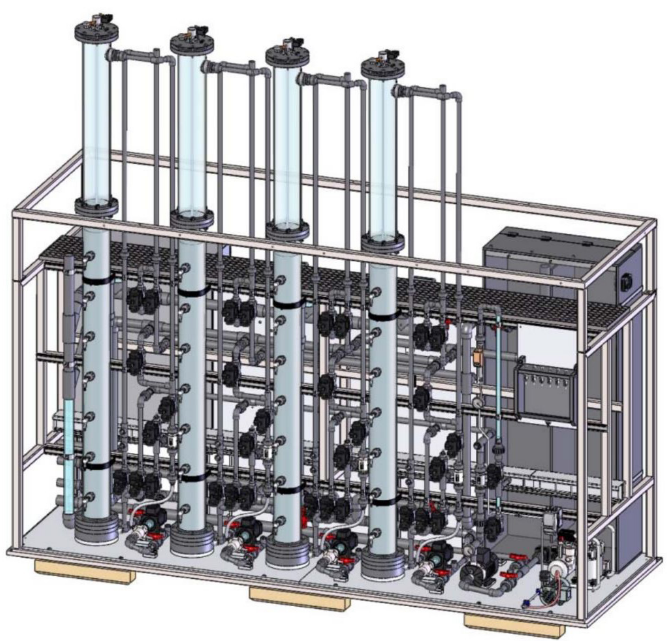


Figure 9 Pilot Biofiltration Unit

Section 4

PILOT OPERATIONS AND MONITORING

4.1 Source Water Quality

The DLTWTF's primary water source is the Hillsborough River (HR), followed by its secondary source, the Tampa Bypass Canal Middle Pool. The DLTWTF also uses an aquifer storage and recovery (ASR) system of wells that store treated water in an aquifer during wet seasons when river flows are high and recovers that water for use when river flows are low and other supplies are limited. Table 3 summarizes the DLTWTF's raw water quality data. Note that the Hillsborough River's high seasonal variability makes it challenging to maintain high-quality effluent under the wide range of influent water quality conditions throughout the year. It should be noted that this water quality does not include recycle streams or ASR contributions.

Table 3 DLTWTF HR Raw Water Quality(1)

Parameter	N Data	Raw		
	(#)	Max	Min	Avg
Alkalinity (mg/L as $CaCO_3$)	222	155	47	119
pH	221	8.4	6.8	7.5
Turbidity (NTU)	222	5.73	0.69	1.88
TOC (mg/L)	142	28.3	3.5	13.5
Color (apparent, CU)	222	325	35	119
T&O (Geosmin, ng/L)	59	99.3	<1	8.5
T&O (MIB, ng/L)	33	8.1	<1	3.6
Iron (total, mg/L)	40	0.49	0.033	0.2
Manganese (dissolved, mg/L)	42	0.018	0.004	0.01
Calcium Hardness (mg/L as $CaCO_3$)	221	180	56	115
Bromide (µg/L)	48	84.4	33.6	58.3
Temperature (degrees C)	222	30.9	11.6	23.8

Notes:
(1) Data summarized from pilot test period 11/30/20-10/15/21.

Figure 10 shows the TOC variability of the HR over the past decade, emphasizing the importance of capturing the range of raw water TOC. RW TOC captured during this pilot is bolded in red for reference.

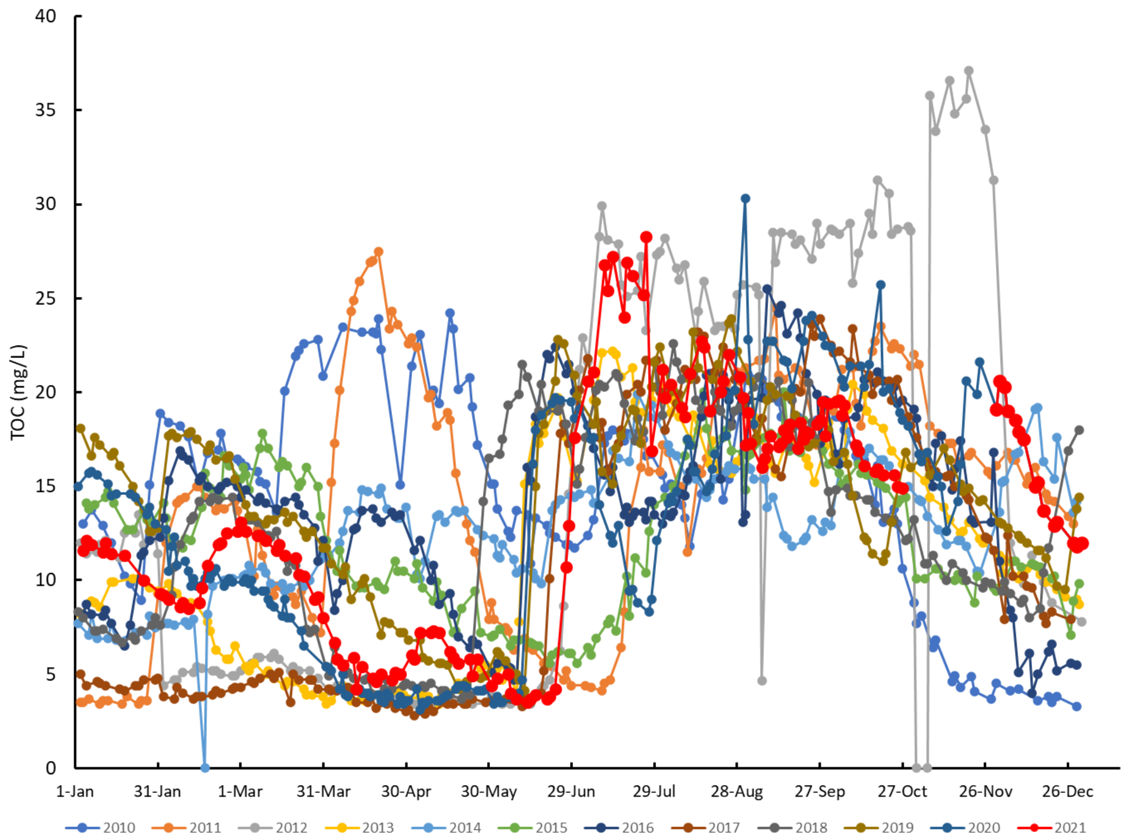


Figure 10 Historical TOC at the Hillsborough River (HR) DLTWTF Intake[1]

4.2 Full-Scale Operations Affecting the Pilot

4.2.1 Copper Sulfate - HR

Copper sulfate has historically been used by COT staff as a T&O control strategy. The biocide is sprayed onto the water's surface via boat near the intake to control algal growth seasonally and subsequent T&O compounds. The biocide is typically deployed in the spring when algal blooms are most common in the HR. Figure 11 shows the amount of copper sulfate applied and the duration. This strategy works very well to control T&O in the river but contributes significant amounts of sulfate to the RW. During pilot testing, copper sulfate was routinely sprayed from April 5, 2021-June 1, 2021.

[1] The pilot RW is shown bolded in red, which includes the start of the pilot (11/30/2020-12/31/2020).

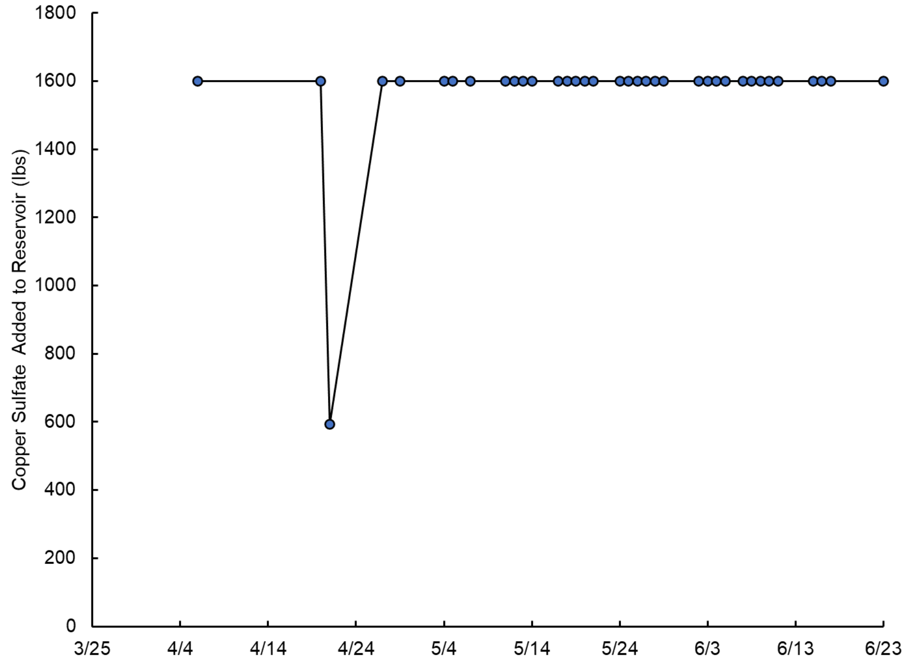


Figure 11 Application Copper Sulfate Biocide to Reservoir

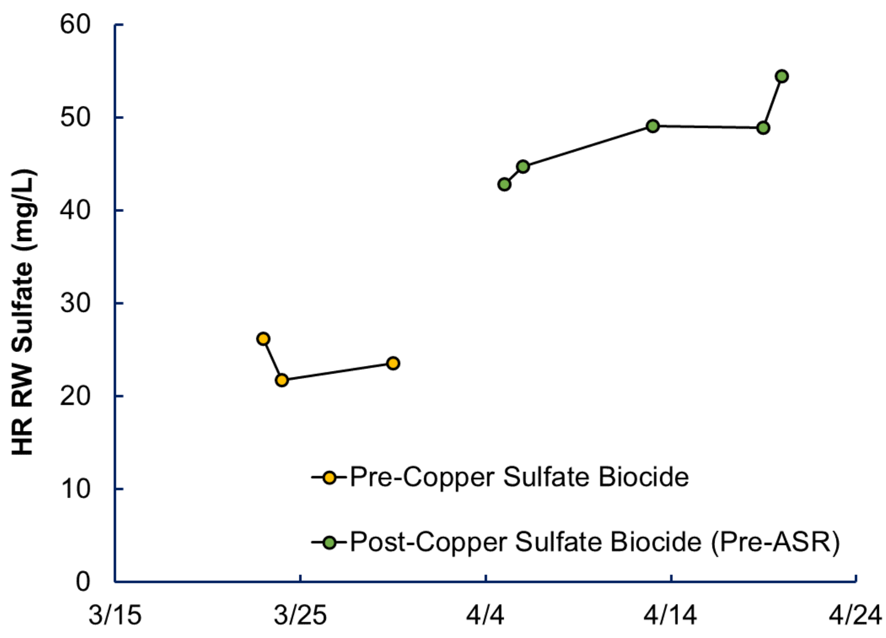


Figure 12 HR RW Sulfate - Effects of Copper Sulfate Biocide

4.2.2 ASR

Flow from the Rome Ave wells were recovered during the pilot operations to test the system with this water source present. The wells are generally recovered annually to help meet demands during periods of low river flow (spring). All eight ASR wells were pumped from April 23, 2021-June 1, 2021; and then again, August 10, 2021-August 25, 2021, only wells 2-4 were recovered from. A summary of ASR water quality is provided in Table 4. Of note, this water is relatively high in TDS, chloride, and sulfate - which affect anion equivalence of the RW and subsequently ion exchanges processes with SIX®. Figure 13 shows the effect of ASR on HR RW sulfate; it is important to note that ASR flows overlapped with additional augmented flow from the Harney Canal, which could account for the initial drop in sulfate. ASR sulfate remained relatively stable while recovering (Figure 14).

Table 4 ASR Wells 1-8 WQ Summary

		N data	Max	Min	Avg
Arsenic	µg/L	21	25.1	1.0	7.3
Chloride	mg/L	46	458.1	27.9	234
Dissolved Oxygen (field)	mg/L	46	2.69	0.02	0.35
Oxidation Reduction Potential (field)	mV	46	231	-230	-7.5
pH (Field)		46	7.6	7.1	7.3
Specific Conductivity (field)	mmhos/cm	46	2140	627	1320
Sulfate	mg/L	46	185	94	140
Temperature (field)	Degree C	46	26.8	21.2	24.1
Solids, Total Dissolved TDS	mg/L	9	1041	615	831
Turbidity	NTU	21	3.7	0.077	0.57
Iron Total	mg/L	9	0.35	0.07	0.21
Fluoride	mg/L	46	0.6	0.24	0.45
Gross Alpha	pCi/L	8	9.4+/-0.7 T	1.3+/-0.5 T	
TTHM	µg/L	8	23.87	< 0.45	4.34

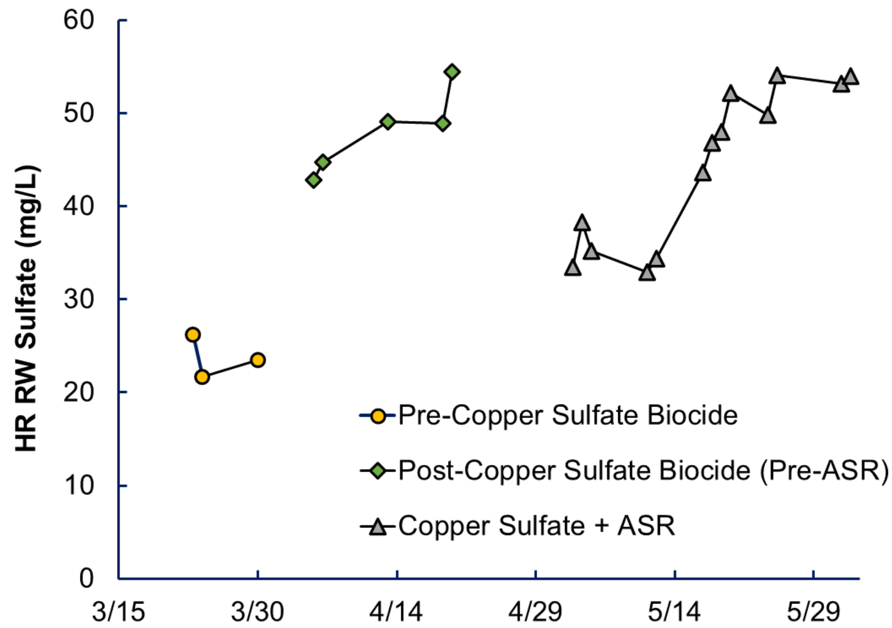


Figure 13 HR RW Sulfate - Effect of Copper Sulfate Biocide + ASR

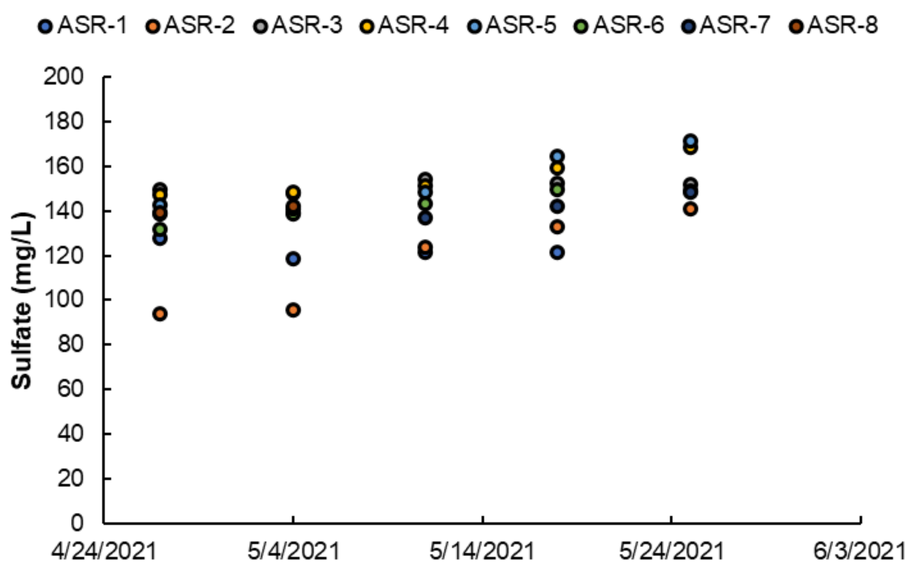


Figure 14 ASR Well Sulfate

4.2.3 Augmented Flow - Harney Canal

As previously mentioned, DLTWTF augments influent flow from one of its secondary source waters, the Harney Canal, as needed to meet demands. Typically, this is during the spring - early summer when river flows are lowest. This year, flow was augmented with this flow March 24, 2021-June 22, 2021. Figure 15 provides an overview of relative flow during that period.

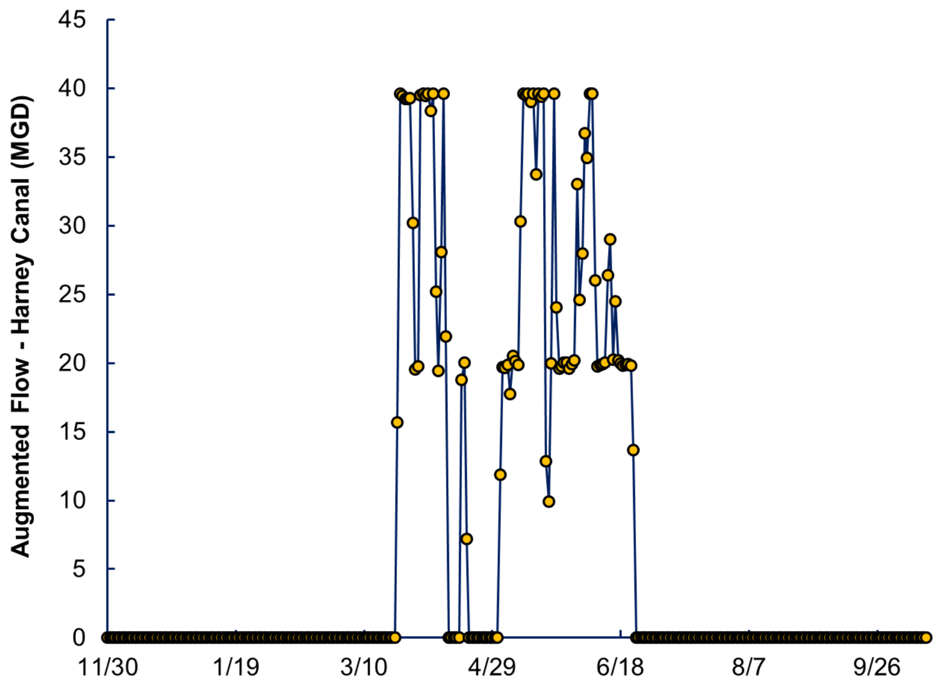


Figure 15 DLTWTF Augmented Flow - Harney Canal

4.2.4 RW Versus RW at Pilot

The DLTWTF is a zero-liquid discharge plant, and with that, does not discharge any liquid waste streams to sewer. All liquid waste streams generated at the plant are returned to the intake and retreated. Return flows include gravity thickener overflow, stormwater from the Solids Processing Facility (SPF) lagoons and the site, filtrate from the SPF belt presses, and the Rome Ave ASRs. Reported RW water quality is referring to that of the Hillsborough River. During piloting, a 'RW at the pilot' sampling location was incorporated to capture the changes in RW WQ due to these return flows. When operating, flows from the SPF are relatively stable throughout the year and vary hourly with peak flows occurring 7 am-3 pm (Figure 16). ASR flows vary seasonally and are dictated by the City's ability to recharge and recover flow from the various wells (relative impact of on return flows through Reclaim Pipes 1 and 2 shown in Figure 17). These streams vary in WQ and were noted to affect pilot performance.

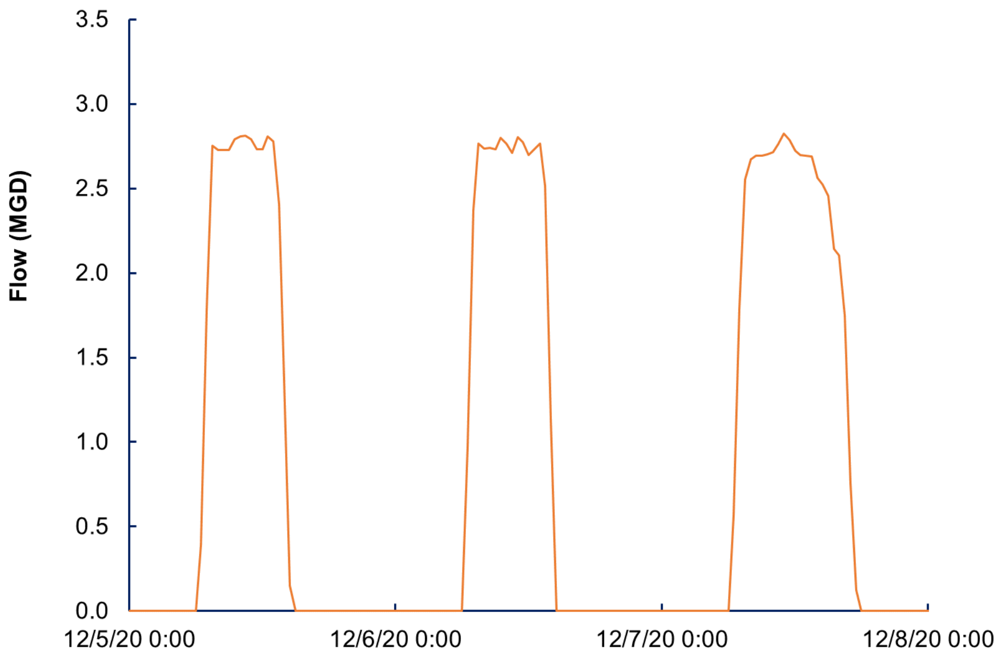


Figure 16 SPF Return Flow - Daily Fluctuations

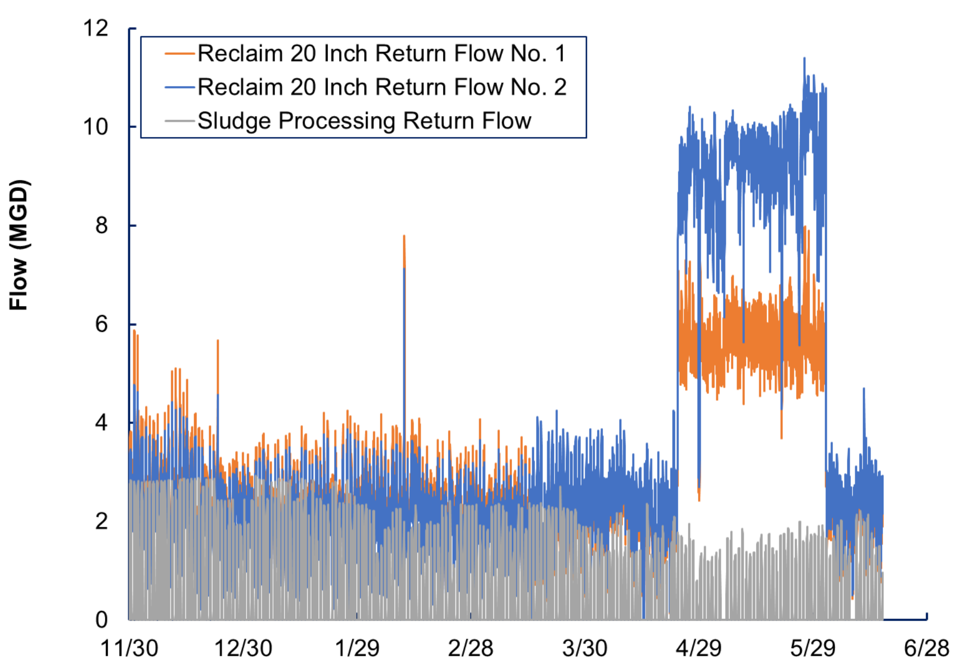


Figure 17 DLTWTF Return Flows

4.3 Pilot Operations

Due to the variability of the HR WQ, this pilot was operated in an adaptable manner to accommodate these changes. For this report, baseline operations were established based on the operations the majority of the time. With that, many operational changes were made from baseline to fully test the pilot (e.g., ASR turned on to assess bromide removal and impacts on bromate formation) and to understand the optimal operating ranges to achieve the best performance under these varying conditions. For ease of analysis, this testing has been broken down into three phases, and operational changes made are outlined for each.

4.3.1 Phases of Pilot Testing

To best analyze and report the results of this pilot testing, the pilot report is broken down into three distinct phases: SIX® optimization, Coagulation Optimization with Zeta Potential (ZP), and High TOC Season. A summary of these three phases and the associated testing period is provided in Table 5.

Table 5 Pilot Test Phases

Phase	Description	Start	End
Phase 1	SIX® Optimization	11/30/2021	3/15/2021
Phase 2	Coagulation Optimization with Zeta	3/16/2021	6/27/2021
Phase 3	High TOC Season	6/28/2021	10/16/2021
Low TOC	<15 mg/L	11/30/2021	6/27/2021
High TOC	>15 mg/L	6/28/2021	10/16/2021

4.3.1.1 Baseline Operations and Figure Overlays

Baseline conditions are those operating conditions that occur the majority of the time. Changes from these baseline conditions are highlighted in this report and the data. Figure 18 highlights significant operational changes throughout the pilot. Various versions of this figure are used as an overlay for other figures in this report where appropriate to understand better how these changes affected pilot data.

Table 6 Summary of Baseline Operations and Conditions

Process		Value	
SIX®	Flow	30.8	gpm
	Resin	20	mL/L
	Brine Range	40	mS/cm
		55	mS/cm
Floc Sed	Coagulant	ferric sulfate	-
Pilot Ozone	ON, Dose	1.0-4.15	mg/L
Filter 1	LR	4.6	gpm/sq ft
Filter 2	LR	8	gpm/sq ft
Filter 3	LR	4.6	gpm/sq ft
	Media	31	inches of GAC
Filter 4	LR	3.7	gpm/sq ft
COT Ops	Augment Flow	0	-
	Ozone	ON	-
	ASR	OFF	-
Microfloc Control	None		-
WQ	Hi TOC	15	mg/L and above
	Low TOC	15	mg/L and below
	Good Alk	80	mg/L and above
	Low Alk	80	mg/L of below

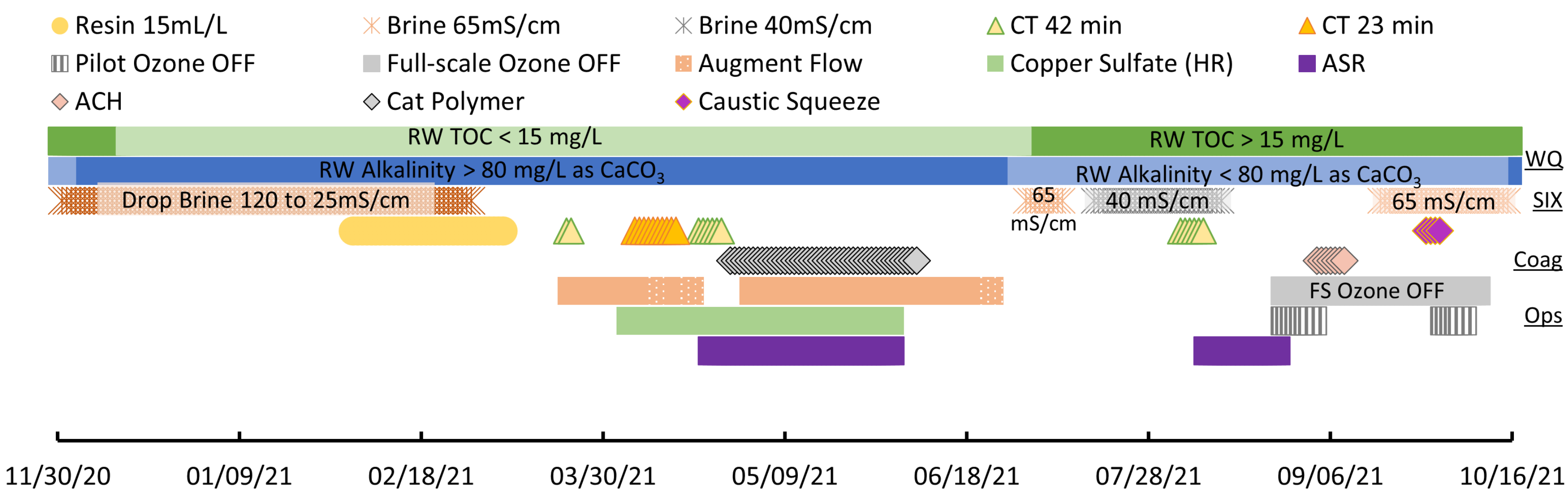


Figure 18 Summary of Operational Changes from Baseline and Figure Overlay. CT = SIX contact time

4.3.2 SIX®

This pilot testing intended to assess a range of operations to understand SIX® performance at various RW WQ. Initial SIX® bench-testing of the Tippin RW established starting points for SIX® operations. The SIX® process has historically utilized an anionic exchange resin, Lewatit S5128 (Lanxess Engineering Chemistry, Germany). This is a strong base, acrylic resin gel. The gellular resin allows for faster regeneration and reduced salt concentrations than traditional microporous resins due to the adsorptive kinetics. A bench-scale study was performed to assess the potential for alternative resins. The results from that study are summarized in Appendix D of this report. At the pilot scale, the same resin was used throughout. A summary of operational changes made to the SIX® pilot is provided in Table 7.

Table 7 Overview of SIX® Pilot Operational Ranges Tested

Parameter	Value
Brine Concentration	18-123 mS/cm (10,400-81,200 mg/L TDS)
Resin Concentration	15 & 20 mL/L
Contact Time	23 min, 30 min, 42 min

4.3.3 Floc/Sed

This pilot testing intended to assess a range of operations to understand SIX® downstream effects. Initial bench-testing of the SIX® effluent established starting points for coagulation chemistry. A summary of operational changes made to the coagulation chemistry tested is provided in Table 8.

Table 8 Overview of Floc/Sed Pilot Operations Tested

Chemical	Type
Coagulants	Ferric sulfate, ACH, cationic polymer
Floc Aid Polymer	Cationic: Polydyne Clarifloc C-308P Anionic: Hydrex 3511 (low charge) Hydrex 3521 (mid charge)

4.3.4 Ozone

The ozone unit was operated to match full-scale residual goals. The pilot ozone generator was automatically adjusted to maintain a residual of 0.5 mg/L at this 5.5 min CT sample location. The unit utilized ambient ait and an oxygene concentrator at the start of the pilot; the system was converted to pure oxygen the week of January 18th to improve reliability. A summary of ozone operations is provided in Table 9.

Table 9 Overview of Ozone Pilot Operations Tested

Parameter	Value
Ozone Flowrate	6.24 gpm
Detention Time to First Sample	5.5 min
Residual at First Sample Point	0.5 mg/L

4.3.5 Filters

The four filter configurations tested were designed and operated to provide a wide range of operational data to use for full-scale now and in the future. An overview of the filter configurations tested is provided in Table 10. New filters will be built as part of MP; various new configurations were tested as part of the new filter design work. Filter 1 was designed and operated to mimic current-full-scale filters. Pilot filter operations and media were adjusted, as needed, to determine effects on headloss over time and optimize performance with the various media configurations. This report details results from Filter 1 & 2; additional data for Filters 3 & 4 can be found in Appendix C.

4.3.5.1 Filter Media

Virgin GAC media was used for Filters 2-4. The GAC for these filters was added while the pilot was being commissioned. RW was plumbed directly to the filters for one week in an attempt to exhaust the adsorptive capacity prior to the start of the pilot. A summary of this exhaustion can be found in Appendix A.

Table 10 Overview of Pilot Filter Media Configurations and Operations

	Filter 1 "Existing Filter Control"	Filter 2 "New Filter"	Filter 3 "New Filter, Match L/D, Low Headloss"	Filter 4 "Modified Existing Filter, Less Headloss"
GAC depth (in)	22	63	40	34
Sand depth (in)	12	9	12	9
ES, GAC (mm)	1.05 (F830)(1)	1.40 (F816)	1.40 (F816)	1.1 (F820)
ES, sand (mm)	0.5	0.6	0.6	0.5
L/D	1075	1495	1234	1242
Loading rate (gpm/sq ft)	3.25-6.0	6.0-10.0	4.0	3.7
EBCT, GAC (min)	4.3-2.33	2.33-1.4	6.23	5.73
Allowable Headloss (ft)	6	12	12	6

Note:
(1) Full-scale GAC was originally F830 media. Sieve analysis of this GAC at the end of the pilot resulted in D_{10} ES 1.05 mm.

4.3.5.2 Filter 1 Control

For the control filter, Filter 1, sand and GAC were pulled directly from full-scale Filter 24. This allows for a better comparison of the pilot to the full-scale, which is critical considering the challenges associated with headloss and filter loading rate. A representative sample of media was collected by City staff and provided to the TWT to be loaded into the filter. Due to the age of the control media, sieve analysis of this media was performed at the end of the piloting and can be found in Appendix A. Full-scale Filter 24 data was collected throughout the pilot and is herein presented as a representative for comparison to full-scale filter performance.

Section 5

PHASE 1: SIX® OPTIMIZATION (NOVEMBER 30, 2021-MARCH 15, 2021)

5.1 Phase 1 WQ

A summary of pilot RW WQ is provided in Table 11. For seasonal RW WQ, this phase began at the very end of the high TOC season, with TOC quickly falling into the median range (10-15 mg/L) and staying there. Generally speaking, this RW was the easiest to treat relative to the other testing phases, achieving high filter UFRVs and meeting the TOC goal <2 mg/L consistently.

Table 11 Phase 1 RW at Pilot Water Quality(1)

Parameter	N Data	Raw		
	(#)	Max	Min	Avg
Alkalinity (mg/L as $CaCO_3$)	71	136	79	121
pH	71	7.91	7.2	7.5
TOC (mg/L)	47	20.6	8.5	11
Color (apparent, PCU)	69	150	50	77
T&O (Geosmin, ng/L)	11	4.2	<1.0	2.5
T&O (MIB, ng/L)	11	1	<1.0	0.1
Iron (total, mg/L)	15	0.234	0.1	0.1
Manganese (dissolved)	10	0.057	<0.001	<0.001
Calcium Hardness (mg/L as $CaCO_3$)	68	140	84	125
Bromide (µg/L)	15	74.3	58	66

Notes:
(1) Data summarized from pilot Phase 1 11/30/21-3/15/21.

5.1.1 Time Series Plots

Figure 19 through Figure 23 provide overviews of key WQ parameters during Phase 1 of testing. Phase 1 included start-up periods for each of the pilot processes. After all of the processes were started up and stable, the optimization of SIX® began with lowering brine concentration in order to determine the best range for operations and where the low limit occurs where performance declines. This low brine point is highlighted on relevant Phase 1 WQ graphs.

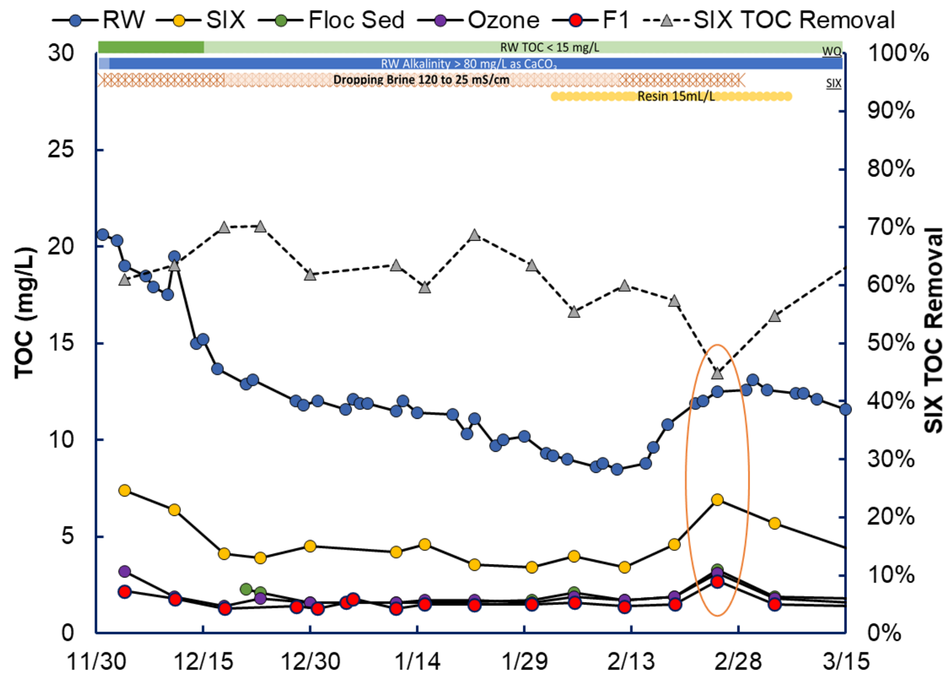


Figure 19 Phase 1 Pilot TOC and SIX® TOC Removal
Low removal point highlighted coincides with purposefully low SIX® brine concentration (25 mS/cm).

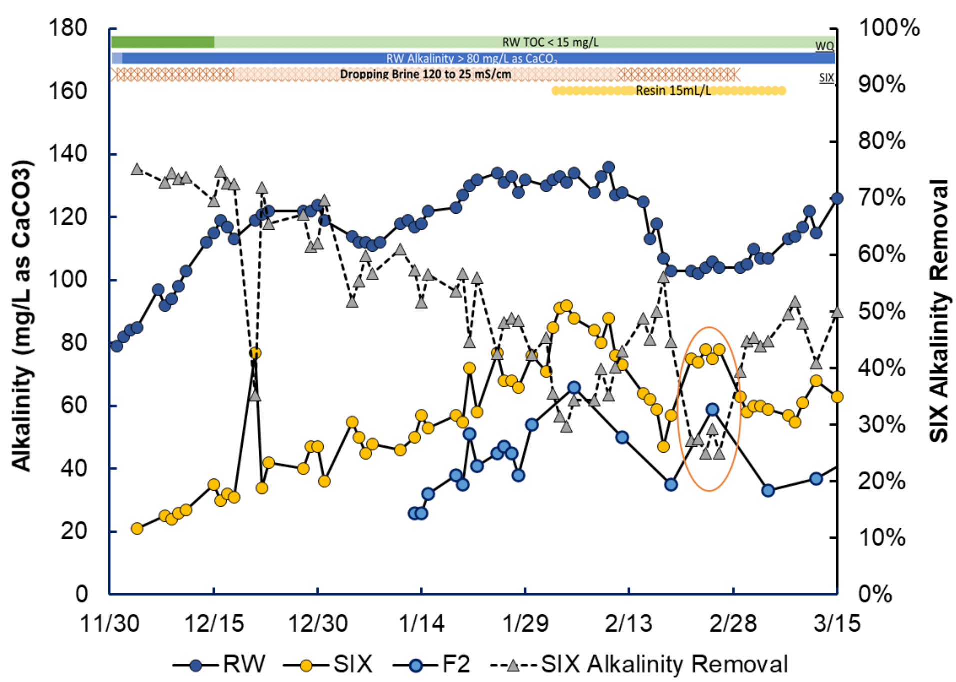


Figure 20 Phase 1 Pilot Alkalinity and SIX® Alkalinity Removal
Low removal point highlighted coincides with purposefully low SIX® brine concentration (25 mS/cm).

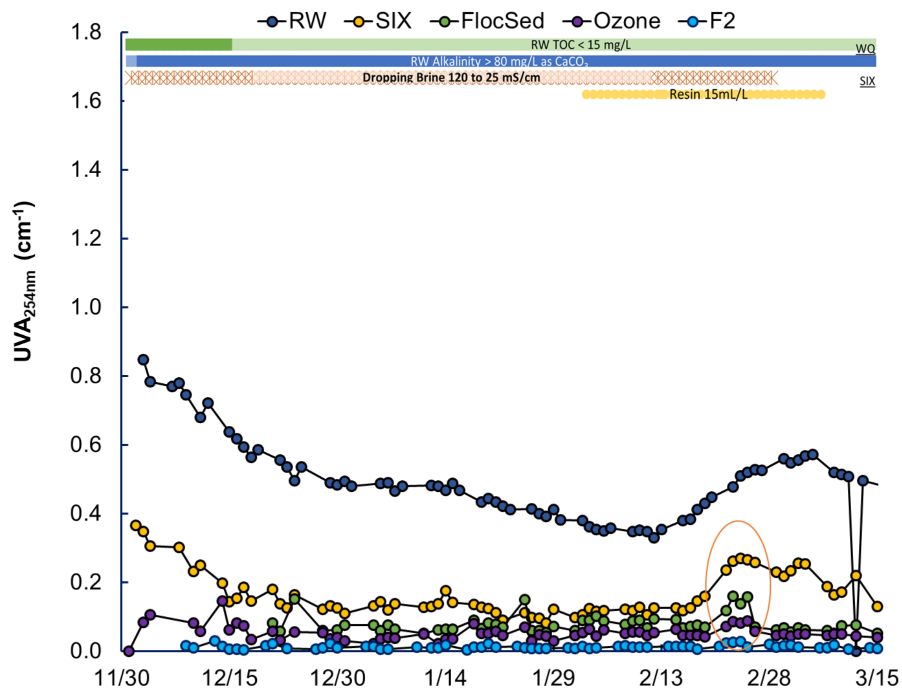


Figure 21 Phase 1 Pilot UVA
Low removal point highlighted coincides with purposefully low SIX® brine concentration (25 mS/cm).

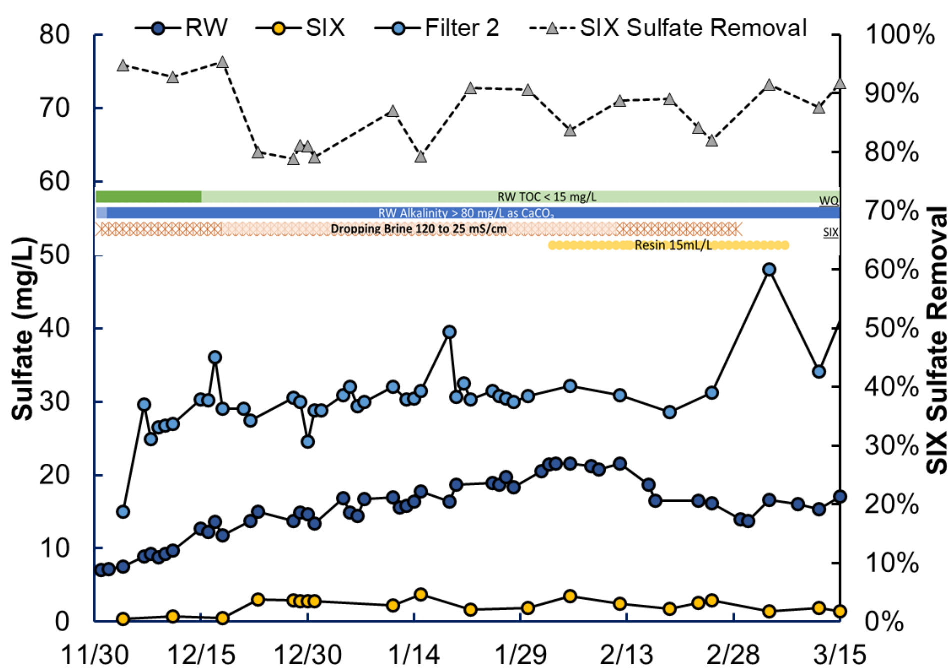


Figure 22 Phase 1 Pilot Sulfate and SIX® Sulfate Removal

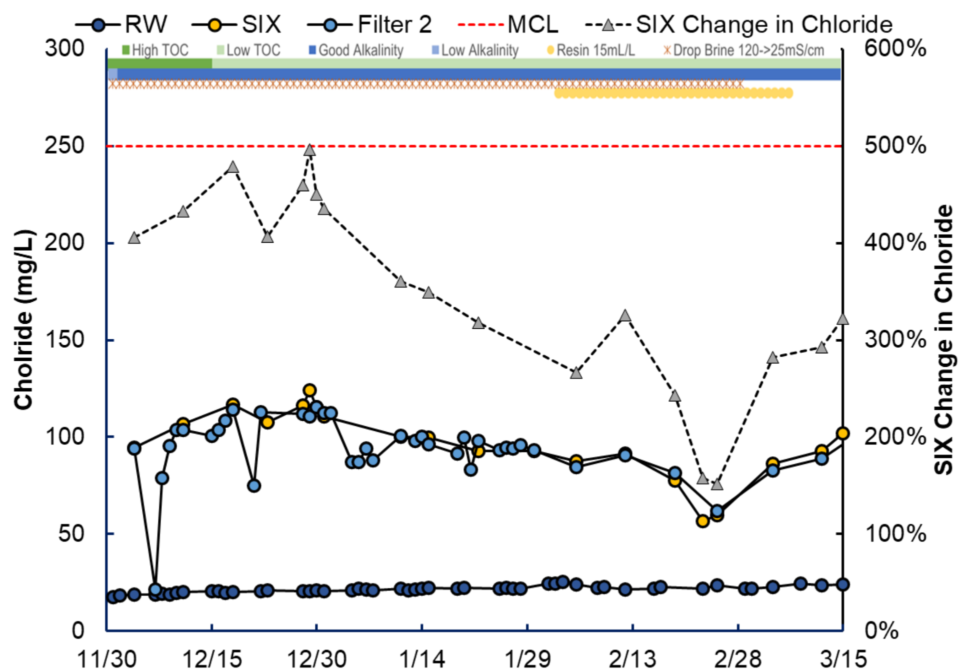


Figure 23 Phase 1 Pilot Chloride and SIX® Effect on Chloride

5.2 Phase 1 Operations

Table 12 Phase 1 Operational Timeline

Process	Element	Date	Details
SIX®	Brine	11/30-2/20	Gradually dropped brine concentration
	Resin	2/2-3/8	15mL/L dose
FlocSed	pH	1/12	Control Floc Sed effluent to pH 7 with caustic trim
Filter 1	LR	11/30/20 12/10/20 3/9/21	5.2 gpm/sq ft 3.3 gpm/sq ft 4.6 gpm/sq ft
Filter 2	LR	11/30/20	6 gpm/sq ft
Filter 3	LR	11/30/20	4 gpm/sq ft
Filter 4	LR	11/30/20	3.6 gpm/sq ft

Table 13 Phase 1 Operations

Parameter		Range	
SIX	Resin Dose	15 & 20	mL/L
	CT	30	min
	Brine Concentration	135-18	mS/cm
Coagulation	Ferric sulfate Dose	16.5-63.3	mg/L
	Floc aid polymer Dose	0.12-0.58	mg/L
	Caustic Dose	2.7-22.3	mg/L
Ozone	Dose	1.1-2.7	mg/L
Filter 1	LR	3.3-5.3	gpm/sq ft
	UFRV	6763-19610	gal/sq ft
Filter 2	LR	6.0	gpm/sq ft
	UFRV	9728-35910	gal/sq ft
Filter 3	LR	4.2	gpm/sq ft
	UFRV	7608-23610	gal/sq ft
Filter 4	LR	4.0	gpm/sq ft
	UFRV	7270-18459	gal/sq ft

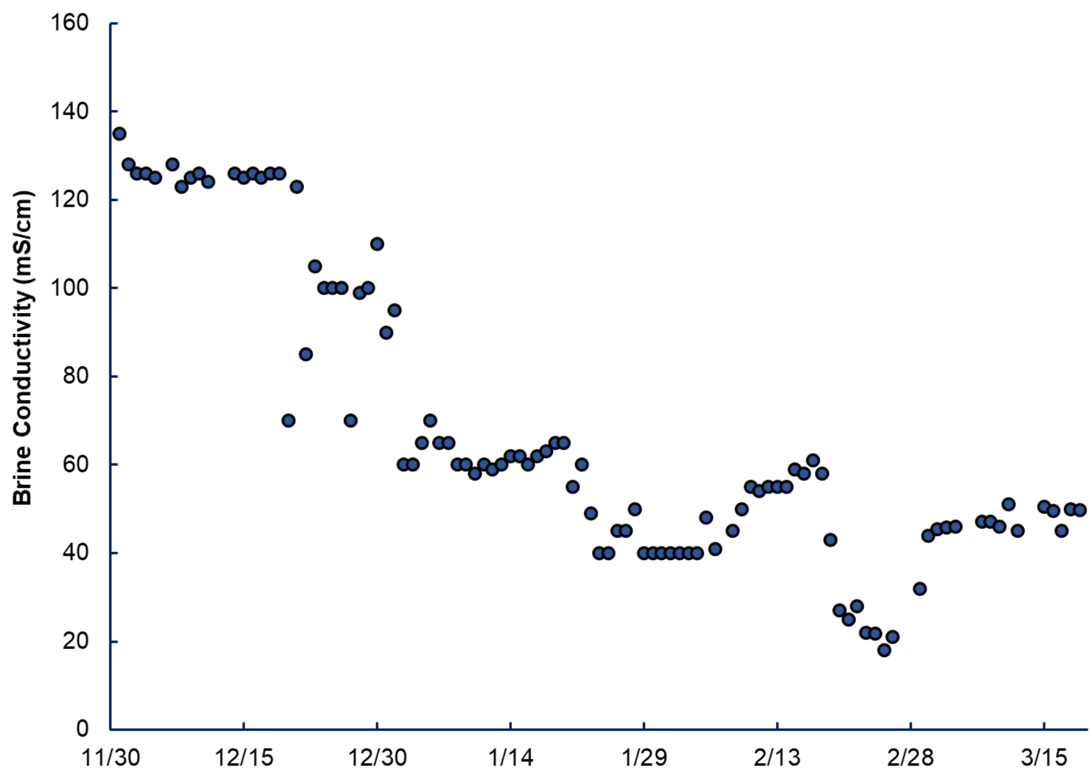


Figure 24 Phase 1 Brine Conductivity (1x Brine Setpoint)

Section 6

PHASE 2: COAGULATION OPTIMIZATION WITH ZETA POTENTIAL (MARCH, 16, 2021-JUNE 27, 2021)

6.1 Phase 2 WQ

This phase of the pilot testing was focused on coagulation optimization. Neutral ZP was found to be a practical test for coagulant demand based on filter performance during Phase 1 of testing. In March, the zeta meter was lent by Carollo for onsite rapid zeta testing. Table 14 summarizes RW WQ during this period of testing.

Table 14 Phase 2 RW at Pilot Water Quality[(1)]

Parameter	N Data	Raw		
	(#)	Max	Min	Avg
Alkalinity (mg/L as $CaCO_3$)	68	155	113	139
pH	68	8.38	7.4	8.1
TOC (mg/L)	36	11.9	3.5	6.4
Color (apparent, PCU)	65	80	35	55
Turbidity (NTU)	73	5.73	1.0	2.85
T&O (Geosmin, ng/L)	58	99.3	<1.0	8.9
T&O (MIB, ng/L)	58	11.6	<1.0	2.2
Iron (total, mg/L)	15	0.096	0.007	0.072
Manganese (dissolved)	13	0.082	0.001	0.035
Calcium Hardness (mg/L as $CaCO_3$)	62	180	126	162
Bromide (µg/L)	15	147	58	88.4

Notes:
(1) Data summarized from pilot Phase 2 3/16/21-6/27/21.

6.1.1 Time Series Plots

The figures below provide an overview of key WQ trends during Phase 2 of testing.

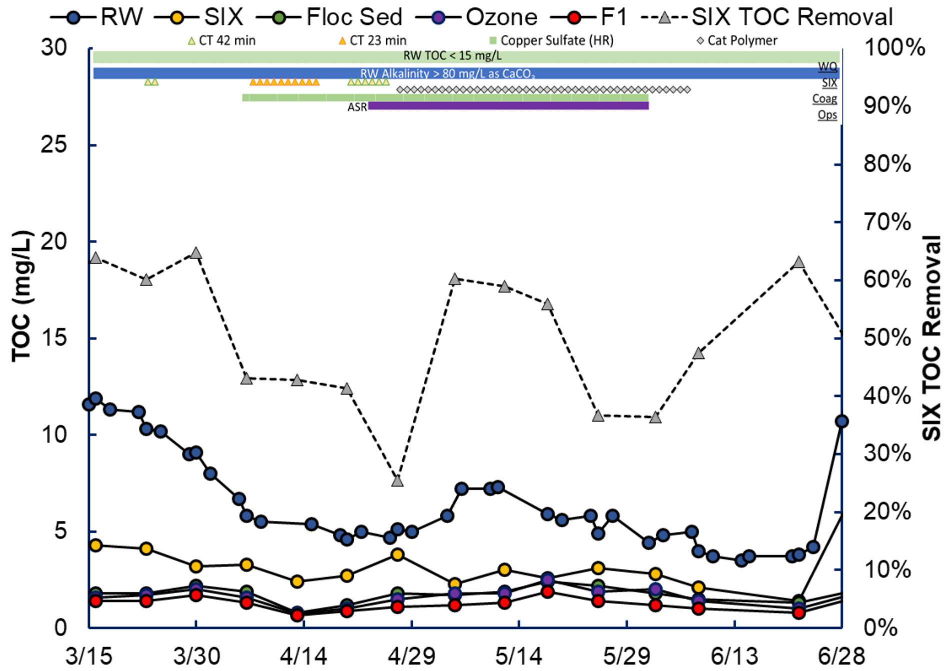


Figure 25 Phase 2 Pilot TOC and SIX® TOC Removal

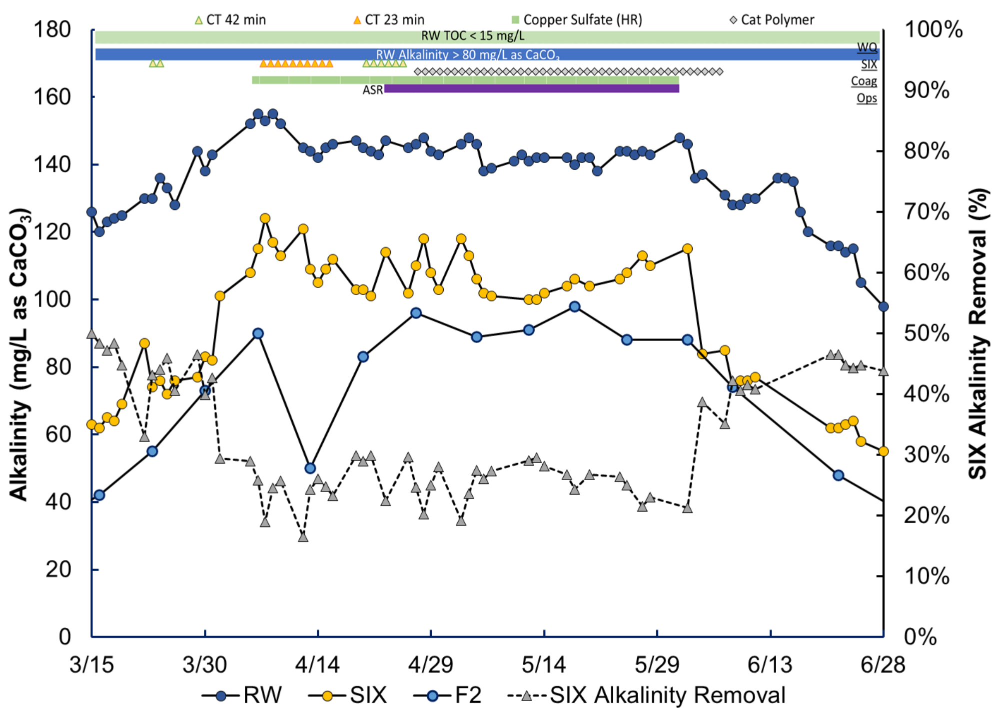


Figure 26 Phase 2 Pilot Alkalinity and SIX® Alkalinity Removal

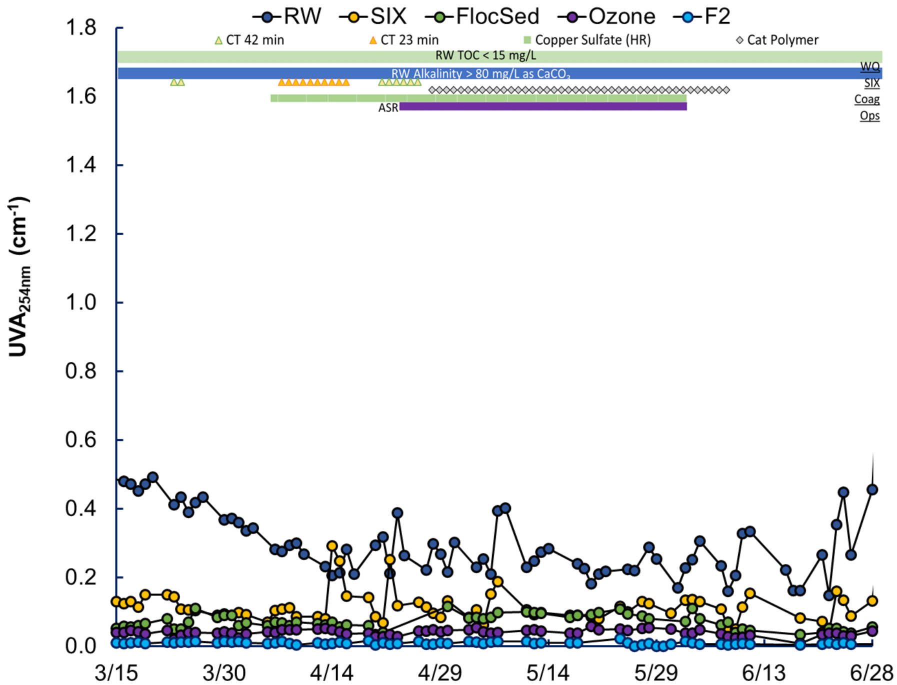


Figure 27 Phase 2 Pilot UVA

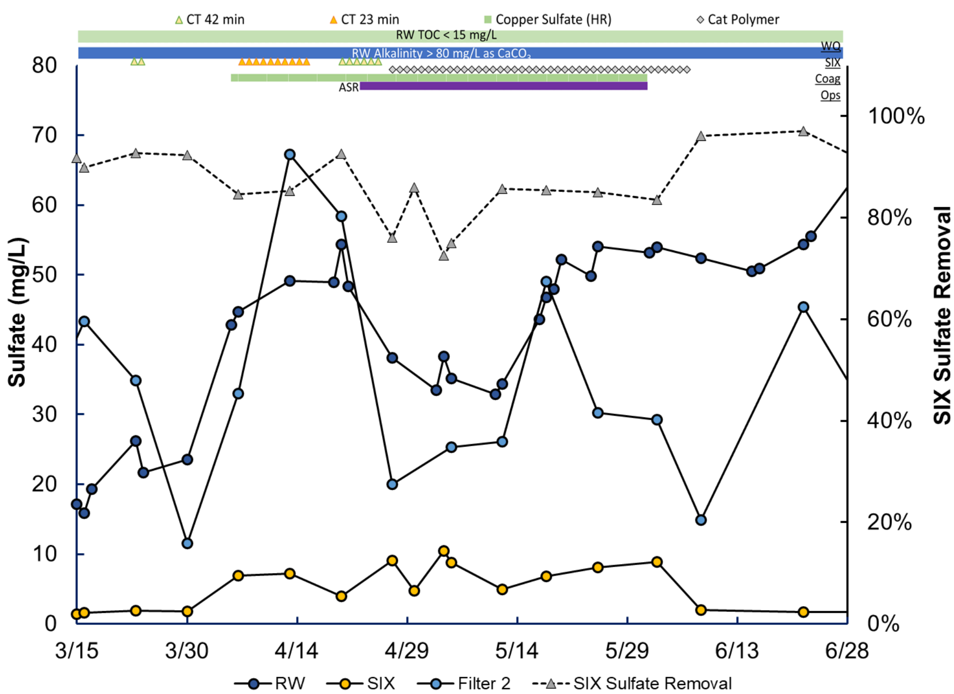


Figure 28 Phase 2 Pilot Sulfate and SIX® Sulfate Removal

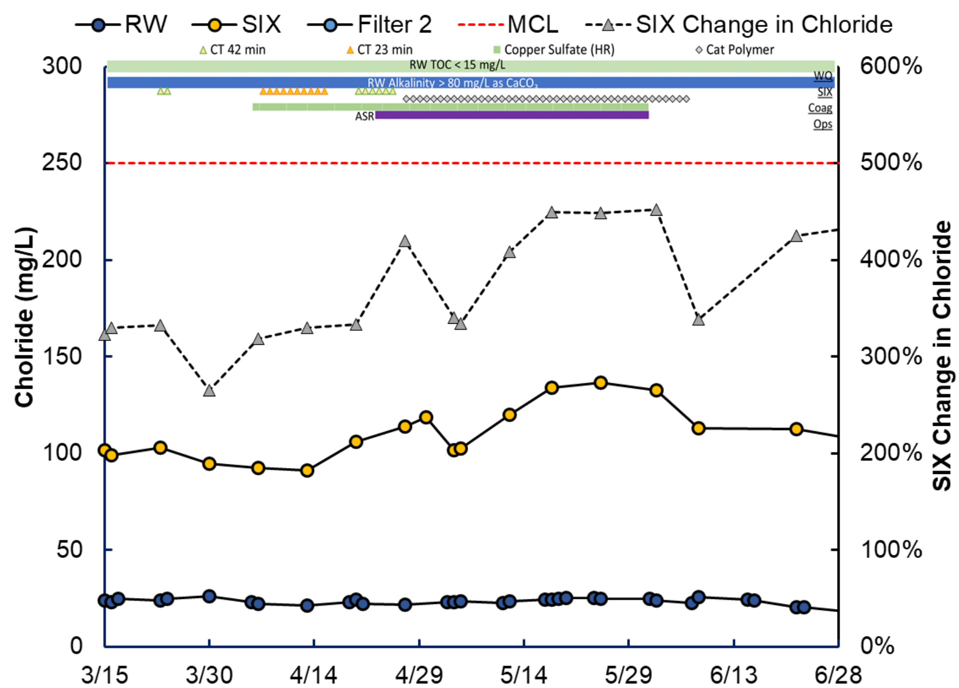


Figure 29 Phase 2 Pilot Chloride and SIX® Effect on Chloride

6.2 Phase 2 Operations

Table 15 Phase 2 Operational Timeline

Parameter		Date	Change
COT Ops	T&O control	4/5-6/1	Copper sulfate biocide to HR
	ASR	4/23-6/1	Recovering Rome Ave Wells 1-8
SIX®	Flow(1)	4/6-16	23 min CT (39.6 gpm)
		4/19-23	42 min CT (22 gpm)
Coagulation	ZP Online	3/18	Neutral ZP for Coagulant demand
	Cationic polymer with ferric sulfate	4/26-6/7	Testing new coagulant
Filter 2	LR	3/31	8 gpm/ sq ft
Filter 3	LR	3/29	4.6 gpm/sq ft
	Media	3/29	removed 9" of GAC

Notes:
(1) SIX® CT 30 min during all other times (30 gpm).

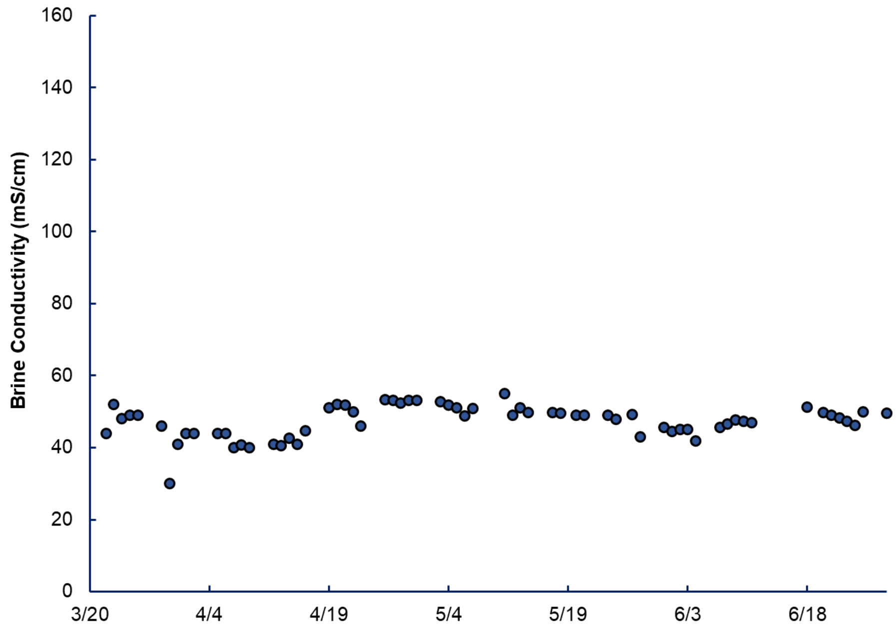


Figure 30 Phase 2 SIX Brine Conductivity (1x Brine Setpoint)

Table 16 Phase 2 Operations

Process	Parameter	Range	
SIX	Resin Dose	20	mL/L
	CT	23, 30, 42	min
	Brine Concentration	30-55	mS/cm
Coagulation	Ferric sulfate Dose	5.3-91.0	mg/L
	Floc aid polymer Dose	0.0-0.63	mg/L
	Cationic polymer Dose(1)	1.36-3.8	mg/L
	Caustic Dose	0.3-44.1	mg/L
Ozone	Dose	1.0-3.6	mg/L
Filter 1	LR	4.6	gpm/sq ft
	UFRV	4567-20826	gal/sq ft
Filter 2	LR	6.0-8.0	gpm/sq ft
	UFRV	7940-38500	gal/sq ft
Filter 3	LR	4.6	gpm/sq ft
	UFRV	6412-22813	gal/sq ft
Filter 4	LR	4.0	gpm/sq ft
	UFRV	3940-16989	gal/sq ft

Notes:
(1) Cationic polymer dosed along with 15-20 mg/L ferric sulfate and 0.1-0.2 mg/L floc aid polymer

Section 7

PHASE 3: HIGH TOC SEASON (JUNE 28, 2021-OCTOBER 15, 2021)

This phase of the pilot testing was focused on high TOC season (>15 mg/L), which was combined with low hardness/alkalinity (<80 mg/L as $CaCO_3$). These two combinations yielded low UFRV due to headloss. Table 17 summarizes RW WQ during this period of testing.

At the end of the pilot, a chemical cleaning of the resin was tested. The caustic squeeze consisted of a robust, high pH regeneration cycle. Resin was soaked in pH 12 brine (50 g/L NaCl + 2% (w/v) NaOH) solution for ~24 hours, thoroughly rinsed, and returned to process. This cleaning took place September 27, 2021-September 30, 2021; effects were observed until the end of the pilot October 15, 2021.

7.1 Phase 3 WQ

Table 17 Phase 3 RW at Pilot Water Quality(1)

Parameter	N Data	Raw		
	(#)	Max	Min	Avg
Alkalinity (mg/L as $CaCO_3$)	15	79	46	62
pH	14	7.13	6.86	7
TOC (mg/L)	16	28.7	16.6	21.2
Color (apparent, PCU)	15	500	200	279
T&O (Geosmin, ng/L)	5	<1	<1	<1
T&O (MIB, ng/L)	5	<1	<1	<1
Iron (total, mg/L)	16	0.494	0.124	0.39
Manganese (dissolved)	12	0.14	0.04	0.085
Calcium Hardness (mg/L as $CaCO_3$)	70	146	56	69.9
Bromide (µg/L)	16	91.7	33.9	54.8

Notes:
(1) Data summarized from pilot Phase 3 6/28/21-10/15/21.

7.1.1 Time Series Plots

Figure 31 through Figure 35 provide an overview of key WQ trends during Phase 3 of testing.

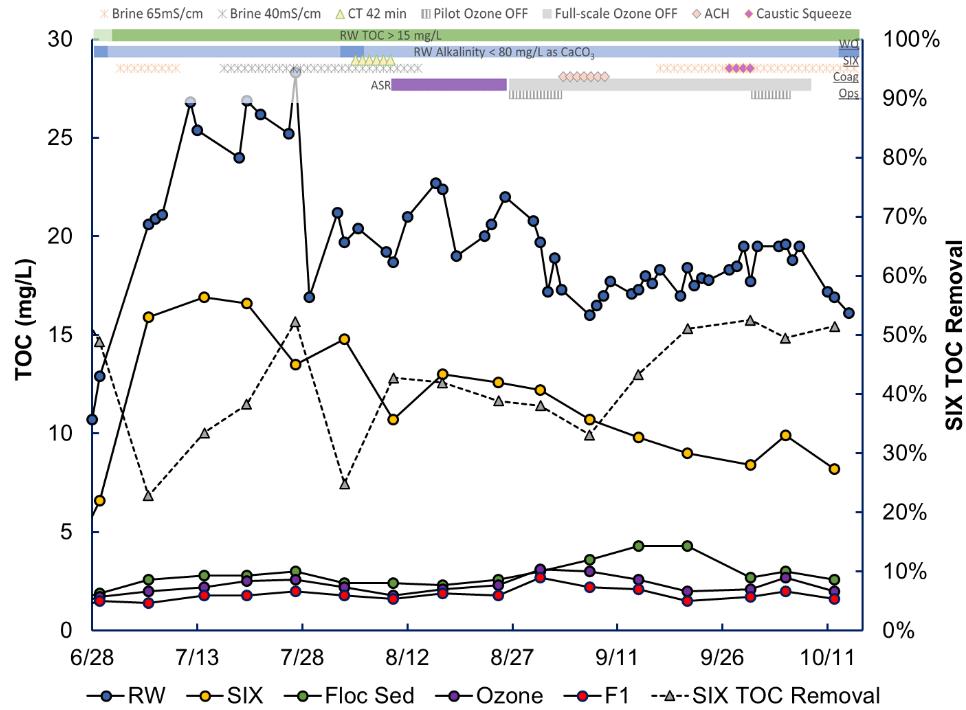


Figure 31 Phase 3 Pilot TOC and SIX® TOC Removal

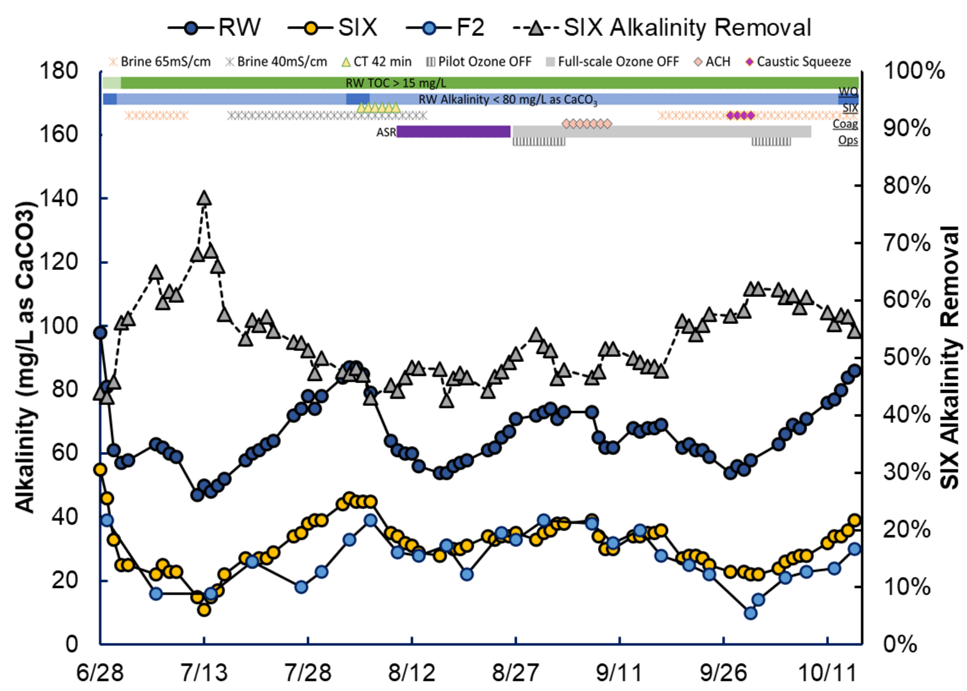


Figure 32 Phase 3 Pilot Alkalinity and SIX® Alkalinity Removal

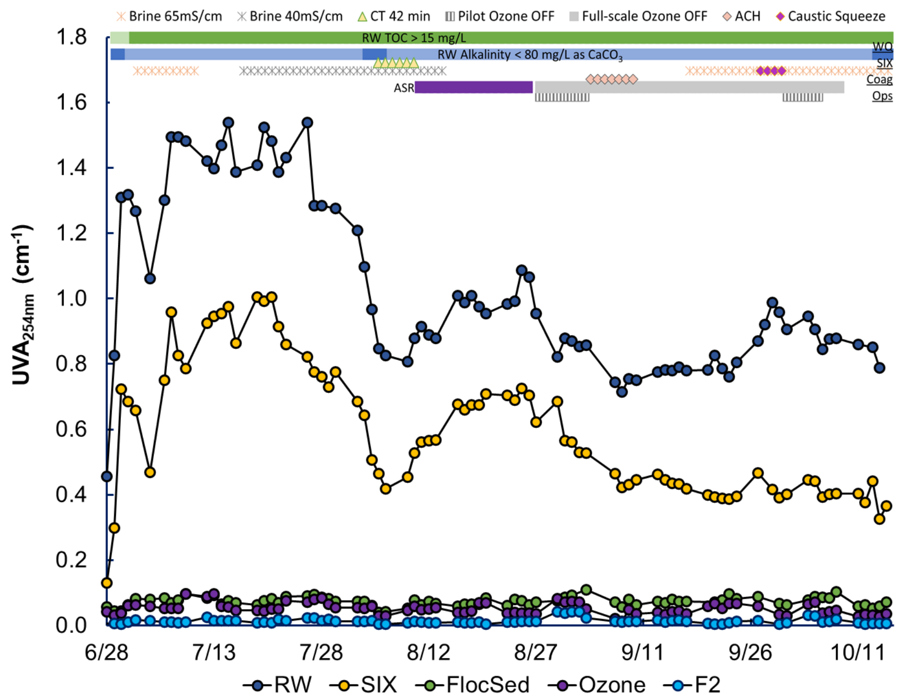


Figure 33 Phase 3 Pilot UVA

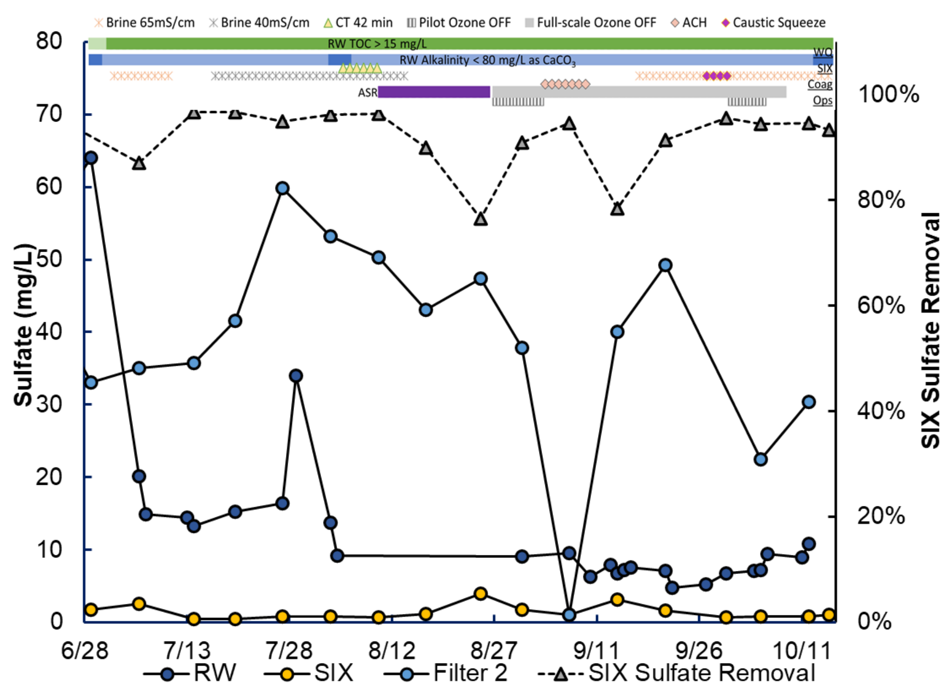


Figure 34 Phase 3 Pilot Sulfate and SIX® Sulfate Removal

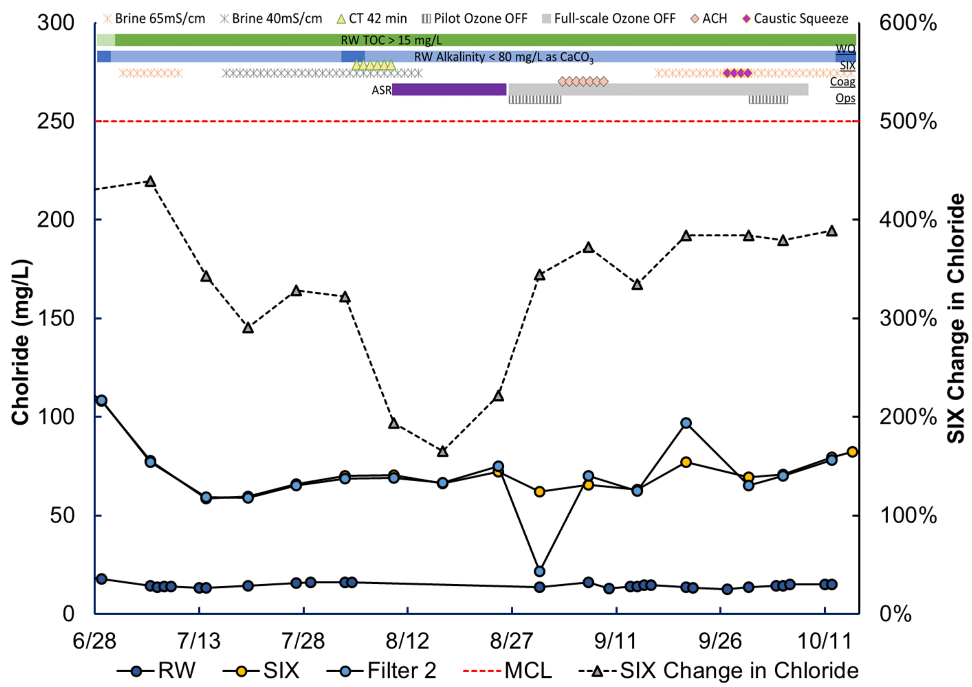


Figure 35 Phase 3 Pilot Chloride and SIX® Effect on Chloride

Table 18 Phase 3 Operational Timeline

Parameter		Date	Change
COT Ops	ASR	8/10-8/25/21	Rome Ave Wells 2-4
	Ozone OFF	8/27-10/8/21	LOX shortage
SIX®	Flow(1)	8/4-8/9	42 min CT (22 gpm)
	Caustic Squeeze	9/27-10/1/21	Resin cleaning
Coagulation	ACH	9/3-9/9	New coagulant
	Anionic (mid charge)	9/16-9/17	New FA polymer
	Anionic (low charge)	9/17-9/20	
Filter 1	LR	9/21/21 9/22/21 9/25/21 10/13/21 10/15/21	2.3 gpm/sq ft 4.6 gpm/sq ft 6 gpm/sq ft 2.3 gpm/sq ft 8 gpm/sq ft (bump test)
Filter 2	LR	10/14/21	10 gpm/sq ft
Filter 4	LR	9/21-22/21 9/22/21 9/25/21 10/13/21	6 gpm/sq ft 3.6 gpm/sq ft 2.2 gpm/sq ft 8 gpm/sq ft (bump test)
Microfloc Control	Alkalinity	7/15-9/4	Dosed sodium bicarbonate
	Peroxide	9/9-9/12	Ozone quench
	Chlorine	9/22-end	Pre-filter

Notes:
(1) SIX® CT 30 min during all other times (30 gpm).

Table 19 Phase 3 Operations

Process	Parameter	Range	
SIX	Resin Dose	20	mL/L
	CT	30, 42	min
	Brine Concentration	37-70	mS/cm
Coagulation	Ferric sulfate Dose	16.1-76.1	mg/L
	Floc aid polymer Dose	0.0-0.5	mg/L
	ACH Dose	24.5-28.6	mg/L
	Caustic Dose	1.4-50.1	mg/L
Ozone	Dose	1.1-5.2	mg/L
Filter 1	LR	2.3-6.0	gpm/sq ft
	UFRV	3124-18710	gal/sq ft
Filter 2	LR	6.0-10.0	gpm/sq ft
	UFRV	6879-44862	gal/sq ft
Filter 3	LR	4.6	gpm/sq ft
	UFRV	5391-25718	gal/sq ft
Filter 4	LR	2.3-6.0	gpm/sq ft
	UFRV	3315-16143	gal/sq ft

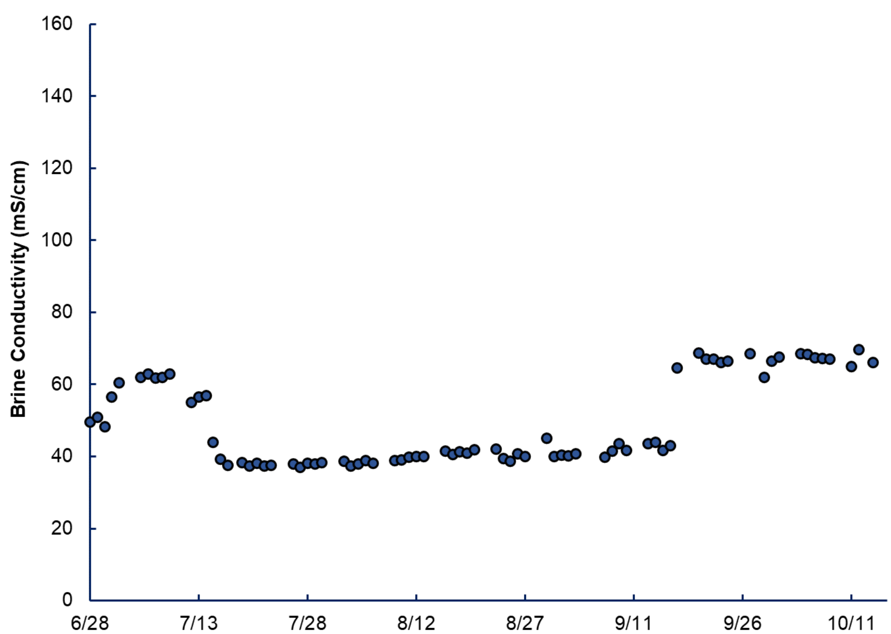


Figure 36 Phase 3 SIX Brine Conductivity (1x Brine Setpoint)

Section 8

SUMMARY OF OBJECTIVES AND RESULTS

Pilot objectives are broken down by each of the pilot skids, respectively.

8.1 Suspended Ion Exchange (SIX®)

Objective 1:

Assess and determine the optimum resin dose and contact time and corresponding required contactor size.

Results: **MET WITH EXCEPTIONS**

A design resin dose of 20 mL/L and 30 minutes contact time was selected based on Ramboll experience, review of available water quality data, and preliminary jar tests. These settings were used for most of the pilot testing period.

The primary objective was to achieve improved organics removal, where ion exchange is complementary to the existing treatment processes. Table 20 shows a summary of the organics removal performance, measured as TOC or via UV-absorbance. Data is shown as mean weekly values, with standard deviation shown in parentheses.

The trial demonstrated that the proposed design resin dose and contact time can achieve a filtered water TOC of less than 2 mg/L in all seasons. UV absorbance at 254 nm (UVA) is used as a surrogate for TOC for process monitoring. It is understood that the portion of TOC that absorbs UV light at 254 nm is more reactive, and more likely to form disinfection by-products. Daily UVA measurements were taken for the duration of the trial. These showed that the entire process train could reduce UVA by 95-99 percent.

Table 20 Pilot TOC and UVA Removal

	Raw	Filtered	SIX®	Floc/Sed	Ozone/Filters(1)
TOC	*mg/L*	*mg/L*	*% Removal*	*% Removal*	*% Removal*
Phase 1	12.5 (3.2)	1.4 (0.4)	61% (8%)	82% (4%)	88% (4%)
Phase 2	6.2 (2.4)	1.2 (0.3)	49% (12%)	71% (9%)	81% (7%)
Phase 3	19.7 (3.5)	1.8 (0.3)	41% (8%)	85% (5%)	91% (2%)
UVA	*/cm*	*/cm*	*% Removal*	*% Removal*	*% Removal*
Phase 1	0.52 (0.16)	0.028 (0.053)	67% (7%)	82% (5%)	95% (7%)
Phase 2	0.29 (0.08)	0.009 (0.002)	59% (12%)	74% (10%)	97% (1%)
Phase 3	1.07 (0.27)	0.014 (0.008)	44% (10%)	93% (2%)	99% (1%)

Notes:
(1) Filtered water data is based on Filter 2.

In general, we are comfortable with the range of operations tested and resulting SIX® performance over the range of RW WQ tested. A summary of the performance on the major anions and color is provided in Table 21, Table 22, and Table 23. It is important to note the following when analyzing SIX performance:

- Phase 2 Apparent color removal data is skewed due to limited data and operational effects (SIX® RW tank began accumulating solids and increasing the influent Apparent Color, once this was realized, regular cleaning of the RW tank occurred).
- Phase 2 Bromide data is likely low in part due to operational challenges during this time (eductor clogging and inconsistent resin dosing) as well as the effect of other anions (in particular sulfate in the ASR and copper sulfate biocide that was sprayed on the HR for algae control).
- CT 42 min data is also limited by the amount of data collected at this longer CT. Theoretically, SIX® anion removal performance should increase with more contact time. Figure 39 below shows UVA removal through the SIX® contactor at various CTs. It was found that SIX® effluent UVA correlated strongly with TOC (Figure 37).

Table 21 Average SIX® Percent Removal at Various Pilot Test Periods, SIX® Resin Doses and CT

	Alkalinity	TOC	Chloride	Apparent Color	Sulfate	Bromide	UVA
Phase 1	51%	61%	+349%	41%	86%	15%	67%
Phase 2	32%	49%	+371%	17%	86%	3%	59%
Phase 3	53%	41%	+321%	29%	92%	29%	44%
Low TOC	42%	56%	+358%	11%	86%	5%	64%
High TOC	53%	41%	+321%	29%	92%	29%	43%
CT 30 min	47%	51%	+348%	20%	88%	13%	57%
CT 42 min	37%	41%	+333%	ND	93%	7%	52%
CT 23 min	23%	43%	+324%	6%	85%	16%	43%
15mL/L	39%	55%	+238%	36%	87%	19%	61%
20 mL/L	47%	50%	+362%	15%	88%	13%	56%

Table 22 Average SIX® Removal (mg/L) at Various Pilot Test Periods, SIX® Resin Doses and CT

	Alkalinity	TOC	Chloride	Apparent Color	Sulfate	Bromide	UVA
	mg/L as $CaCO_3$	mg/L	mg/L	PCU	mg/L	µg/L	cm^{-1}
Phase 1	58.04	6.99	+77.84	27.00	10.90	8.75	0.31
Phase 2	43.73	3.39	+87.98		34.72	0.61	0.18
Phase 3	31.20	9.46	+55.16	84.38	15.14	17.54	0.43
Low TOC	50.88	5.05	+82.91	10.17	22.81	2.09	0.24
High TOC	31.20	9.46	+55.16	84.38	15.14	17.54	0.43
CT 30 min	50.46	7.31	+73.94	41.27	18.44	7.02	0.33
CT 42 min	40.50	1.90	+81.60	ND	50.40	4.80	0.27
CT 23 min	34.67	2.80	+70.15	2.50	39.85	12.60	0.11
15mL/L	45.13	5.76	+57.67	28.33	12.97	11.10	0.27
20 mL/L	50.31	7.14	+76.02	39.21	20.78	7.32	0.33

Table 23 Average SIX® Removal as Ionic Equivalence at Various Pilot Test Periods

	Alkalinity	TOC	Sulfate	Bromide	Chloride	Sum of RW Anions
	mEq/L	mEq/L	mEq/L	uEq/L	mEq/L	mEq/L
Phase 1	1.22	0.12	0.29	0.09	2.02	3.07
Phase 2	0.87	0.05	0.76	-0.50	2.46	4.37
Phase 3	0.71	0.12	0.30	0.21	1.66	2.34
Low TOC	1.15	0.09	0.50	-0.43	2.22	3.68
High TOC	0.71	0.12	0.30	0.21	1.66	2.34

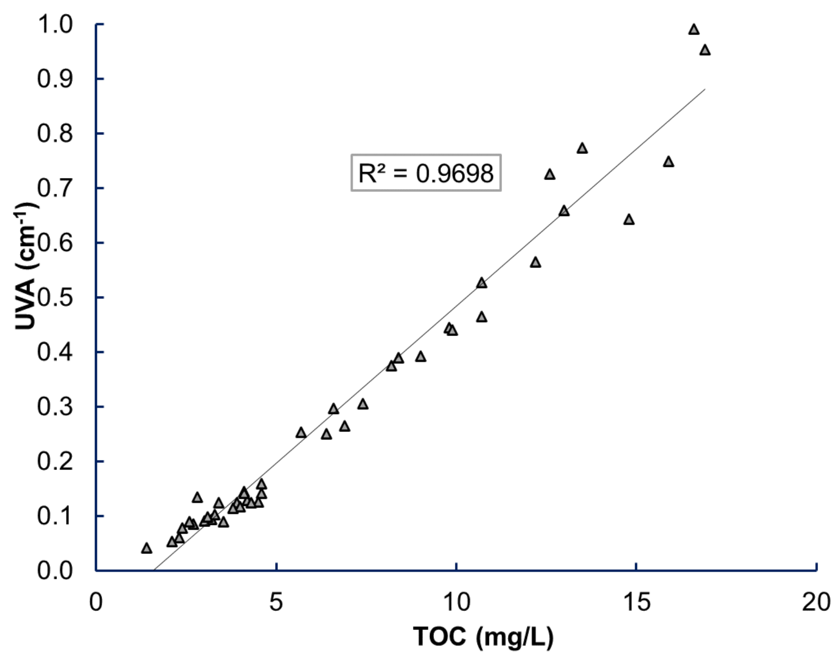


Figure 37 SIX® Effluent UVA vs. TOC

It may be possible that Improved performance would be achieved with a higher resin dose (30 mL/L) and effectively reduce the required contactor size. Although it will be reviewed in further detail during preliminary design with Ramboll and PWNT, the initial recommendation is a resin concentration of 30 mL/L and a contact time of 20 minutes.

As part of the piloting effort, alternate resins were evaluated to determine the potential for a different resin to be bid as part of the procurement process. As part of this evaluation, similar resins were identified (with respect to resin type and physical properties). Resins from Lanxess (original SIX® resin), Du Pont, and Purolite were tested and examined. The Du Pont resin resulted in lower UV absorbance removal than the Lanxess resin (30 percent less). Both Purolite resins removed more UV absorbance (6-17 percent more), but these resins are riskier concerning resin attrition. It also should be noted that the pH of all alternate resins were lower (pHs of 6.0 to 6.4 as compared to th Lanxess pH of 6.8) which denotes higher alkalinity removal. This could have cost implications with respect to the requirement for the addition of caustic/carbon dioxide required as well as salt use. This information will be reviewed in further detail during the preliminary design. More information on this resin evaluation is shown in Appendix D.

Objective 2:

Understand the implications of contactor size on brine use, and volume of waste stream. Assess impact of alternative operational setpoints.

Results: **MET IN FULL**

When the bench testing is examined, it was noted that the reduction of UV absorbance was correlated to the product of the resin concentration times the contact time. This shows that removing anions is proportional to the amount of resin the contactor. Below in Table 24is a summary of the relationship between resin concentration and contact time. Note that the same shaded colors are proportional to the same amount of resin in the contactor.

Table 24 SIX Percent UV Absorbance Removal vs. Contact Time and Resin Dose. (Data from Ramboll bench testing-1/7/2020)

CT (min)	Resin Dose (mL/L)				
	10	20	30	40	60
10	14%	47%	63%	71%	78%
20	48%	70%	78%	80%	82%
30	63%	77%	80%	81%	82%
40	71%	80%	81%	82%	82%
240	81%	81%	82%	82%	83%

The green shaded cells are equivalent to the same resin inventory used during piloting. Note that the contact time during piloting was 21 minutes. To provide some conservatism, the orange cell equivalent inventory is recommended to be used with 30 mL/L resin concentration and a 20 minute contact time at 140 mgd flow. This assumption will be reviewed during the preliminary design.The brine use is proportional to the anions removed by the resin. Assuming the same resin inventory is used, the brine use will remain the same and contactor sizing will not impact brine use.

The pilot was operated with resin dose of 20 mL/L and contact time of 30 minutes for ~80 percent of the trial. However during full scale operations, resin dose and contact time may vary depending on production requirements, plant availability and water quality. The following additional scenarios were trialed:

- 15 mL/L resin dose at 30 minutes contact time, representing a lower resin dose during low TOC season.
- 20 mL/L resin dose at 23 minutes contact time, representing a higher flow rate if several trains were offline due to planned or unplanned maintenance.
- 20 mL/L resin dose at 42 minutes contact time, representing more typical average flows rather than peak design flow.

Theoretically organics removal through SIX® should be lower if resin dose or contact time is reduced, although this will also vary depending on the raw water UVA and other process settings. Total UVA removal through the entire treatment train is relatively consistent, with greater than 97 percent removal in all scenarios.

Figure 38 shows the UVA removal through SIX® plotted against raw water UVA. Figure 39 shows UVA removal plotted against time, based on grab samples through the SIX® contactor. The figure shows that under most conditions there is minimal addition UVA removal past 20 minutes.

The conclusions that we can draw from this data are:

1. During low TOC seasons, a lower resin dose would produce acceptable process outcomes.
2. During most seasons, the plant can be operated with shorter contact time (~20 min) if required with minimal negative impacts on operation.
3. If contact time is longer (e.g., due to lower plant flows) then organics removal may be higher through SIX®, but this may not make a measurable difference on final water TOC.

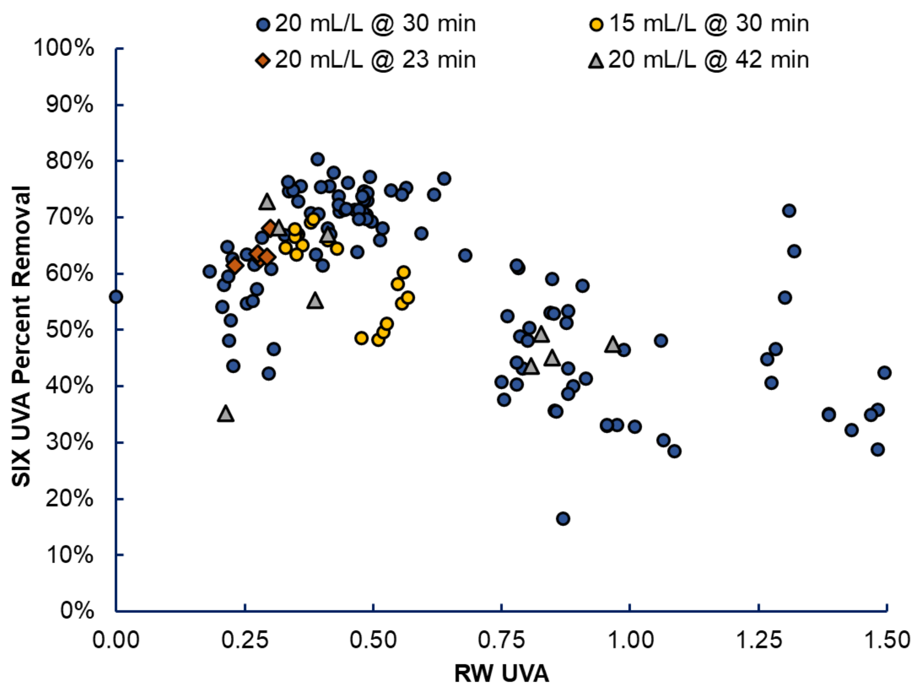


Figure 38 SIX® UVA Removal vs RW UVA at various resin doses and CT.

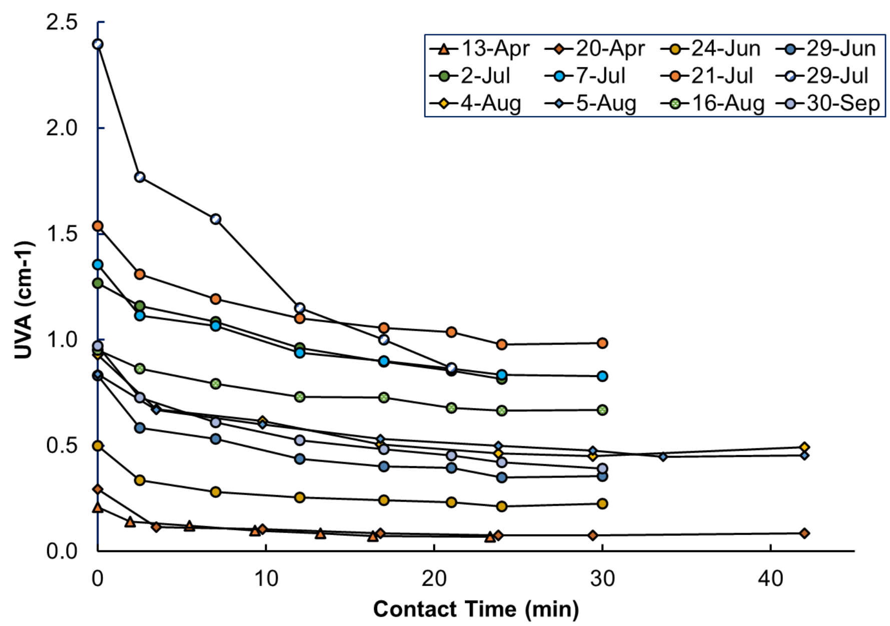


Figure 39 UVA through the SIX® Contactor. All resin doses 20 mL/L. Triangle markers designate 23 min CT, circles designate 30 min CT, diamonds designate 42 min CT.

<u>Objective 3</u>:

Demonstrate the TOC and color removal during different seasons and the impact of other anions on TOC removal.

<u>Results</u>: **MET IN FULL**

SIX® is an anion exchange process, where negatively charged ions such as bicarbonate, sulfate and organic acids are exchanged for chloride. Therefore the performance of SIX® will depend on the relative concentrations of other anions.

Figure 42 illustrates a profile of the raw water quality over the trial period, based on relative ionic equivalence concentrations of the major anions. The figure illustrates that the most significant competing anion concentration is bicarbonate. The spraying of copper sulfate on the HR for algae control resulted in significantly higher sulfates (a SIX®-competing anion) in the RW. (Note that ASR was turned on during these periods as well contributing to the increased RW sulfate). TOC appeared to be negatively correlated with anion concentration. This is because the highest TOC concentrations come after rainfall events which flush high organic water into the source waters while diluting raw water anions. It was found that SIX® removed 20-50 percent of apparent color from the RW (Figure 40). Similarly, SIX® removed 30-70 percent of RW TOC varying with seasonal RW fluctuations and was influenced by operational changes (Figure 41).

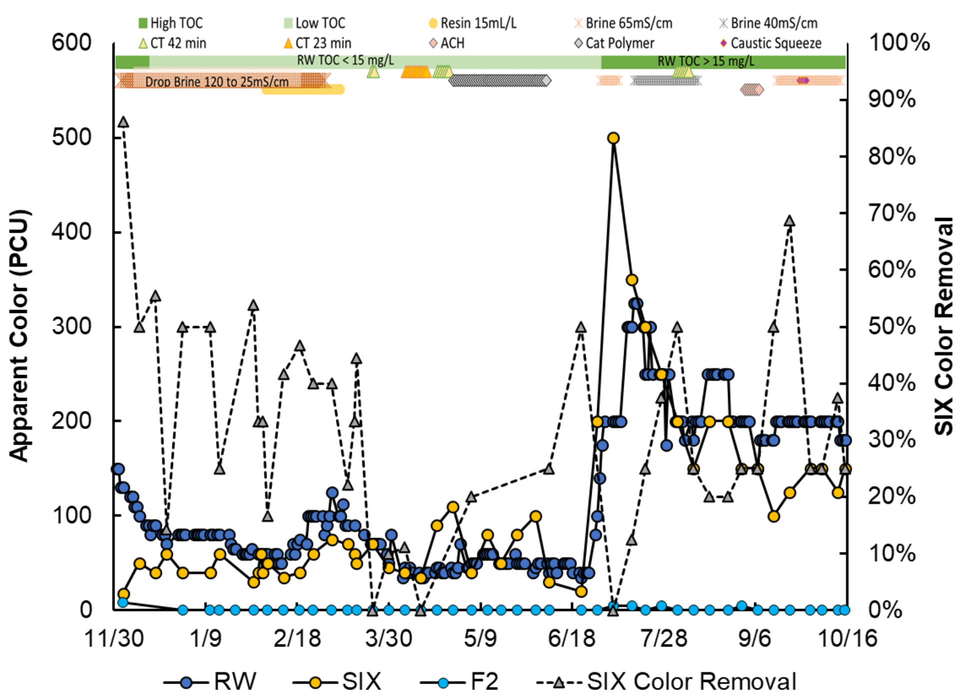


Figure 40 SIX® Apparent Color Removal

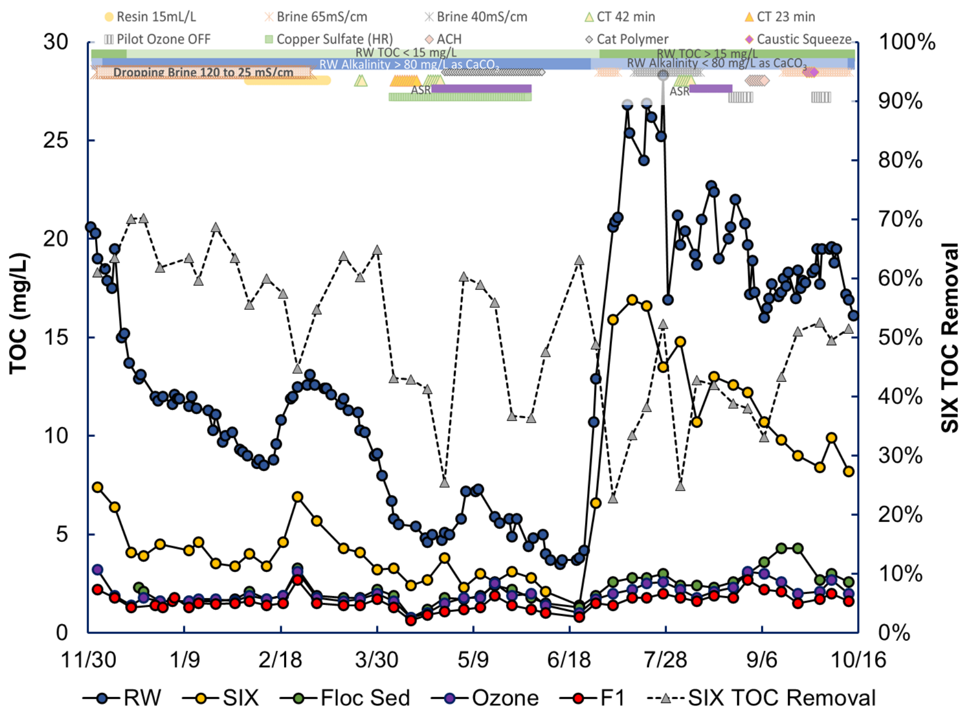


Figure 41 SIX® TOC Removal

Table 21 summarizes SIX® TOC and color removal during the various operational test periods and conditions.

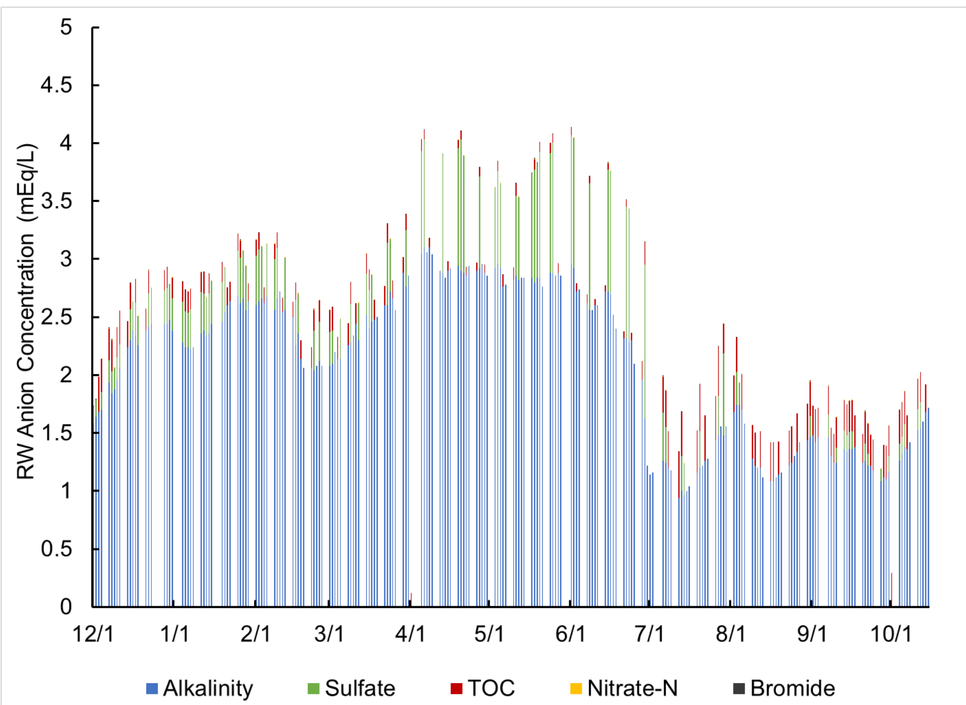


Figure 42 Anionic Equivalence of RW at Pilot (excluding chloride)

Table 25 shows a summary of this data by phase. As for previous sections, there is some variability in process settings that will impact the analysis, but for about 80 percent of the time the pilot was operated at the same resin dose and contact time.

The selectivity of anion exchange resins for different anions is typically: SO_4^{2-} > NO_3^- > Cl^- > HCO_3^- > OH^-. This is born out by the data that shows that sulfate removal is relatively consistent, at 87-88 percent. The resin has high affinity for sulfate (relative to bicarbonate). Chloride increases in the treated water due to ion exchange with target and non-target anions. Chloride increase was highest when raw water anion concentration is highest. Figure 43 plots chloride increase against raw water anions. Organics removal does not appear to have a strong correlation to raw water anion concentration. Other factors such as resin dose, TOC concentrations, and TOC fractions are more significant.

Table 25 Anions and TOC Data(1)

	Chloride	Alkalinity	Sulfate	TOC
Raw	mg/L	mg/L as $CaCO_3$	mg/L	mg/L
Phase 1	21.7 (1.6)	115 (14)	15.5 (3.9)	12.5 (3.2)
Phase 2	23.5 (1.5)	138 (10)	41.8 (12.4)	6.2 (2.4)
Phase 3	14.6 (1.4)	66 (9.3)	15.5 (15.6)	19.7 (3.5)
SIX®	mg/L	mg/L	mg/L	mg/L
Phase 1	94 (15)	56 (18)	2.1 (1.1)	4.8 (1.4)
Phase 2	111 (15)	95 (18)	5.2 (3.0)	2.9 (0.8)
Phase 3	69 (17)	31 (7)	1.3 (1.1)	11.8 (3.2)
SIX® Removal	Increase mg/L	% Removal	% Removal	% Removal
Phase 1	73 (16)	52%	87%	82%
Phase 2	88 (15)	32%	87%	52%
Phase 3	54 (18)	53%	88%	41%

Notes:
(1) Values shown are average weekly data, SD values in brackets.

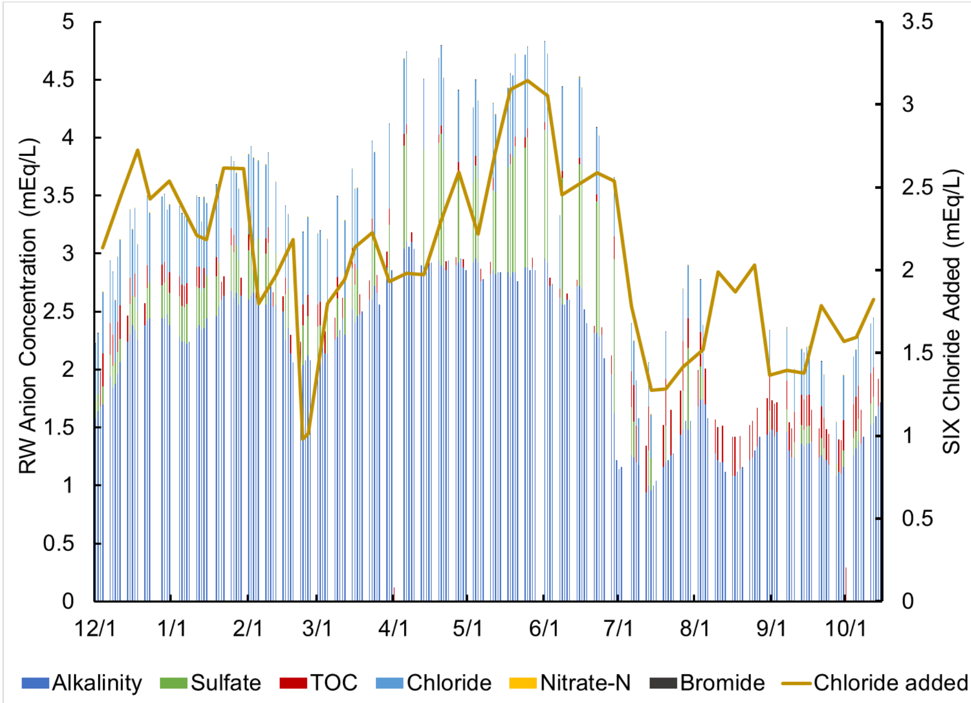


Figure 43 RW Anionic Equivalence and SIX® Chloride Equivalence Adeed

As shown in Figure 44, TOC removal decreased by 30 percent when the copper sulfate was applied. These effects were mitigated slightly by increasing the brine concentration for the SIX® regeneration step. An alternative biocide to replace the copper sulfate with a non-sulfate-based biocide may prove beneficial for SIX® performance. It may also be possible to add ASR downstream of SIX® to avoid sending the higher sulfates in that stream to SIX® (depending on the TOC of the ASR wells).

It is recommended that additional testing of the ASR water occur to quantify the sulfate, TOC and bicarbonate contributions from these wells.

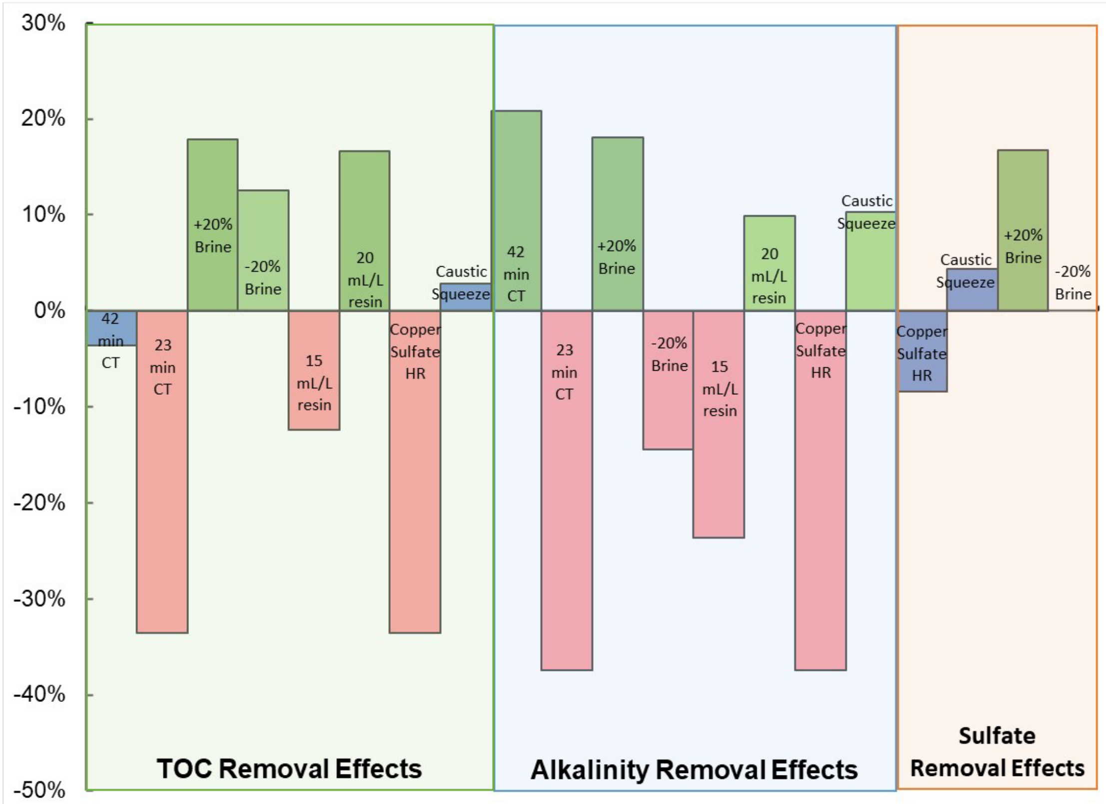


Figure 44 Operational Changes and Effects on SIX® Anion Removal Performance

Liquid chromatography using an organic carbon detector (LC-OCD) can be used to fractionate TOC, based on size exclusion. Figure 45 illustrates this, based on samples taken from July 2021. The existing sedimentation basins are able to remove biopolymers and humic substances. SIX® is able to remove a portion of humic substances and also smaller building blocks. Fractions can be quantitatively estimated based on the area under the curves. Table 26 illustrates how total TOC removal is lower for the piloted process train, primarily due to the increased removal of the building block fraction.

Table 26 TOC Fractionation by Process (all units mg/L)

	TOC	Biopolymers	Humic Substances	Building Blocks	Lower MW Substances
Raw Water	27.3	2.55	19.80	2.54	2.41
SIX® (Pilot)	17.0	1.35	12.35	1.70	1.60
SIX® + Coag (Pilot)	2.6	0.03	0.06	0.78	1.70
Sed Basins (Full Scale)	4.6	0.10	0.62	1.85	2.05

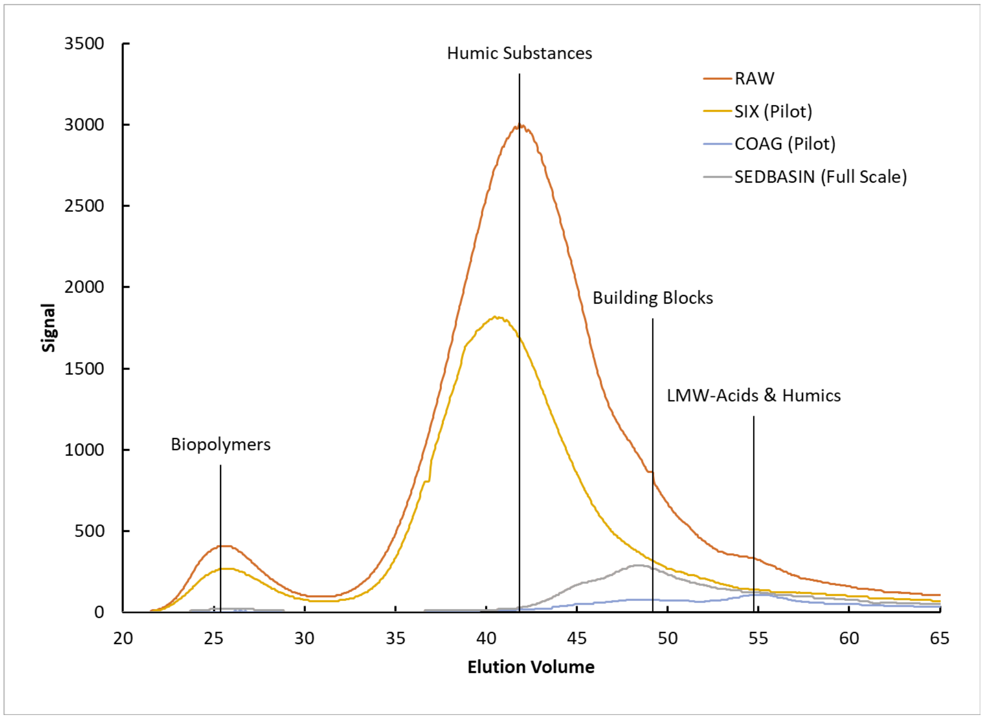


Figure 45 LC-OCD Results - SIX® vs. Full-Scale (sample date July 2021)

Objective 4:

Understand the long-term fouling characteristics of the suspended ion exchange resin (limited to 10.5-month study period).

Results: **MET IN FULL**

No biological fouling of SIX® resin was observed during the pilot. However, it is important to note the use of chloraminated water for brine dilution, resin rinsing and full resin volume (FRV) slurry. Using a non-chloraminated water may result in different effects and flexibility should be included in the full-scale (to use either SIX® effluent or plant water). It also should be remembered that there are periods when the plant uses free chlorine in the distribution system and these impacts on the resin. Currently, the SIX® design scope assumes the use of either chloraminated water or water from the SIX® effluent for brine dilution.

When a caustic squeeze was completed towards the end of the pilot (i.e., pH 12 with caustic brine soak for resin cleaning), the overall TOC removal did not increase significantly. This demonstrates that long-term fouling was not an issue. It should be noted that other anion removal (bicarbonate did increase significantly) and a significant amount of organics were removed by the caustic squeeze along with a decrease in microflocculation was observed, so the capability to do a caustic squeeze will be included in the full-scale design.

Objective 5:

Understand potential biological fouling's impact on settleability (resin).

Results: **MET WITH EXCEPTIONS**

No biological fouling of SIX® resin was observed during the pilot; therefore resin settleability was not affected. See the discussion above regarding the source water for brine dilution and the ability to do a caustic squeeze.

Objective 6:

Understand the removal of bromide from the SIX® process.

Results: **MET WITH EXCEPTIONS**

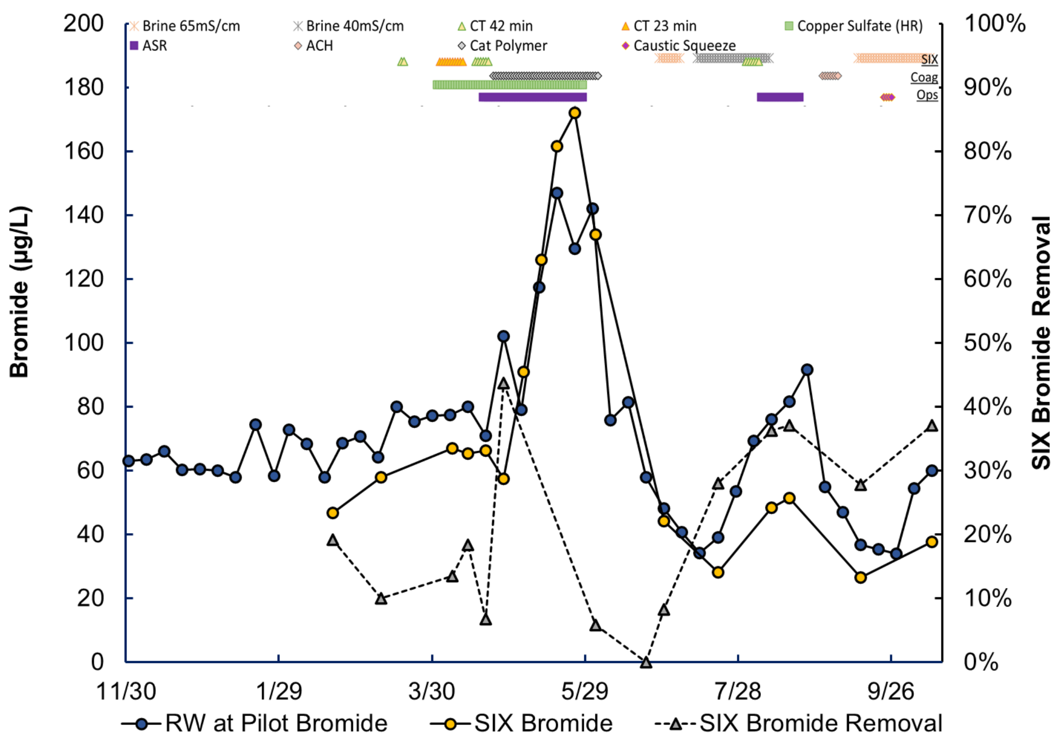


Figure 46 SIX® Bromide Removal

In general, it was found that SIX® removes 15-40 percent of the RW bromide. The most critical time of year for bromide removal is while the ASR recovery is occurring - this water carries high bromide levels. The ASR was purposefully turned on to test the SIX® performance under these conditions. Unfortunately, operational issues (eductor clogging) resulted in non-representative removal data. During the ASR recovery period, there were a few weeks where the SIX® effluent bromide was higher than the RW bromide, implying that SIX® was leaching bromide back out into the water - this is likely instead due to poor resin dosing and uncharacteristic/nonrepresentative removal data. Table 21 summarizes SIX® bromide removal during the various operational test periods and conditions.

Objective 7:

Understand the removal of bicarbonate from the SIX® process.

Results: **MET IN FULL**

Alkalinity was closely monitored during the pilot and proved to be a highly critical parameter affecting pilot performance. As an anion, bicarbonate is removed through the SIX® process; however, its relatively low removal affinity results in variable removal depending on the presence of other anions. It was anticipated that SIX® would remove bicarbonate and may require alkalinity to be added back in downstream and some alkalinity addition occurred during the pilot. Bicarbonate was the most sensitive anion with respect to brine concentration and might be the constituent that is utilized full-scale for operations.

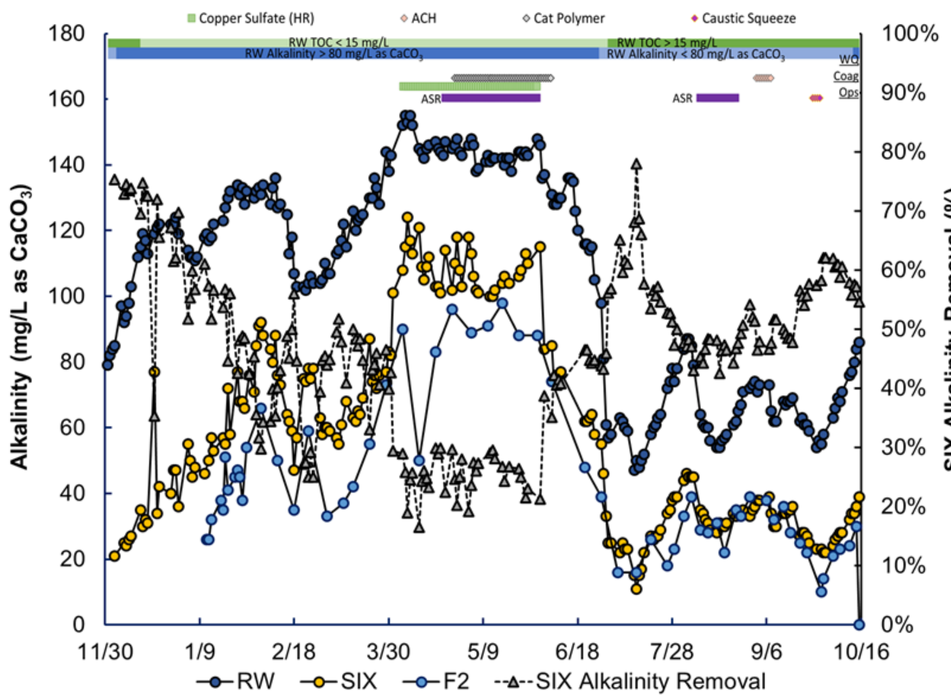


Figure 47 SIX® Alkalinity Removal

At the start of the pilot, SIX® alkalinity removal mimicked TOC removal, in that it started high with the conservative brine concentration and declined with the lowering of the brine concentration/use (Figure 47). During this time, it was realized that this alkalinity removal (pH buffer) resulted in lower coagulation pH, achieving higher TOC removal with less ferric than the previous MIEX® piloting. This effect remained constant throughout the pilot, but the alkalinity removal varied due to RW WQ shifts and operational changes.

During Phase 2 of the pilot, the ASR and Copper Sulfate caused a significant shift in the RW anion concentrations. Due to its lower affinity for removal versus sulfate and TOC, alkalinity removal dropped (Figure 48). During Phase 3, alkalinity was observed to influence the severity of microflocculation and filter headloss issues. It was observed that with the addition of 20 mg/L of bicarbonate, there was a 200 percent improvement of UFRVs on the the subsequent filter run (Figure 49).

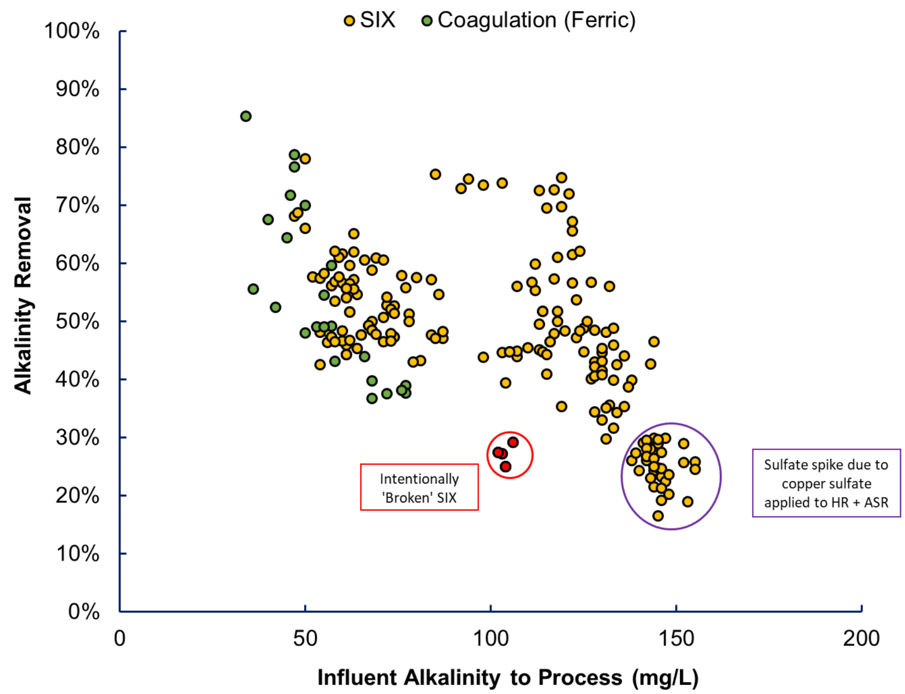


Figure 48 Pilot Alkalinity Removal (effect of sulfate)

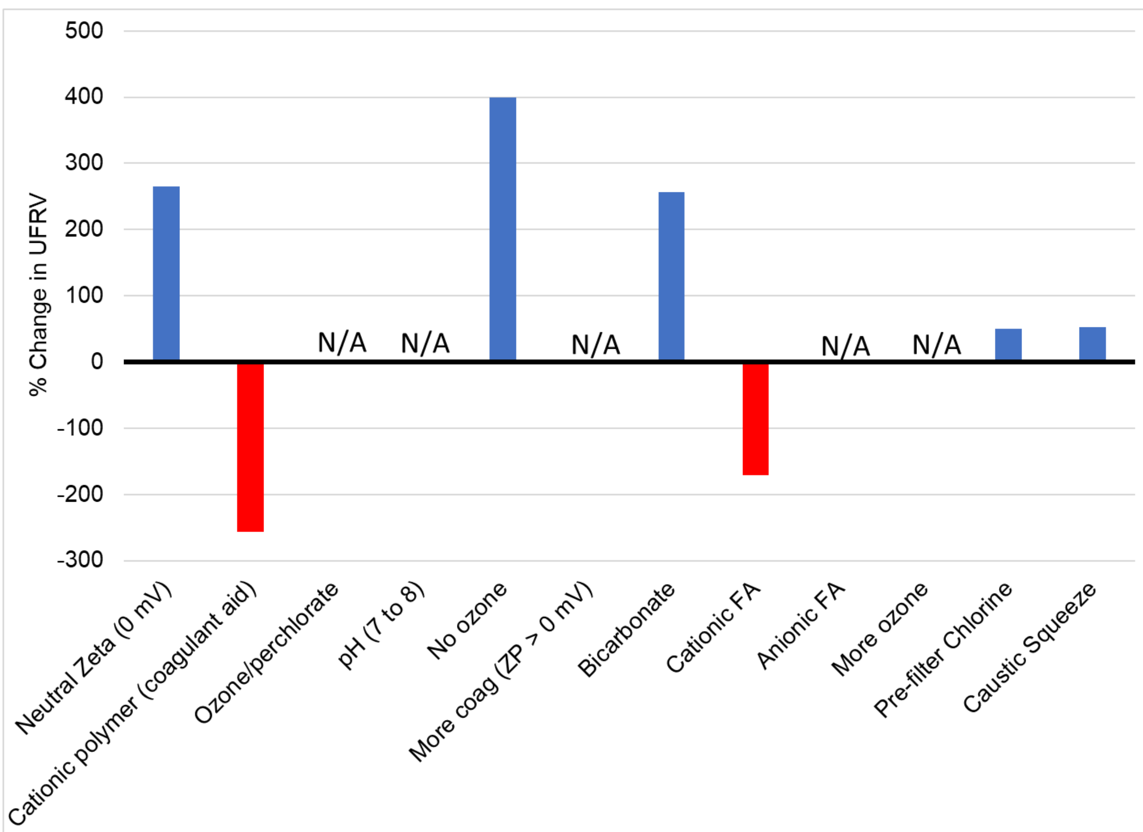


Figure 49 Microflocculation Control Technique Effects on UFRV. N/A means no significant change.

SIX® Alkalinity removal, at first a concern, was observed to be instead in a tool for monitoring performance and managing operations. Depending on seasonal RW alkalinity, SIX® could be operated to achieve desired effects based on the effluent alkalinity. This is a significant differentiating factor between the SIX® process and MIEX® process, whose resin has very high affinity for TOC, but very low affinity for other anions (Figure 50).

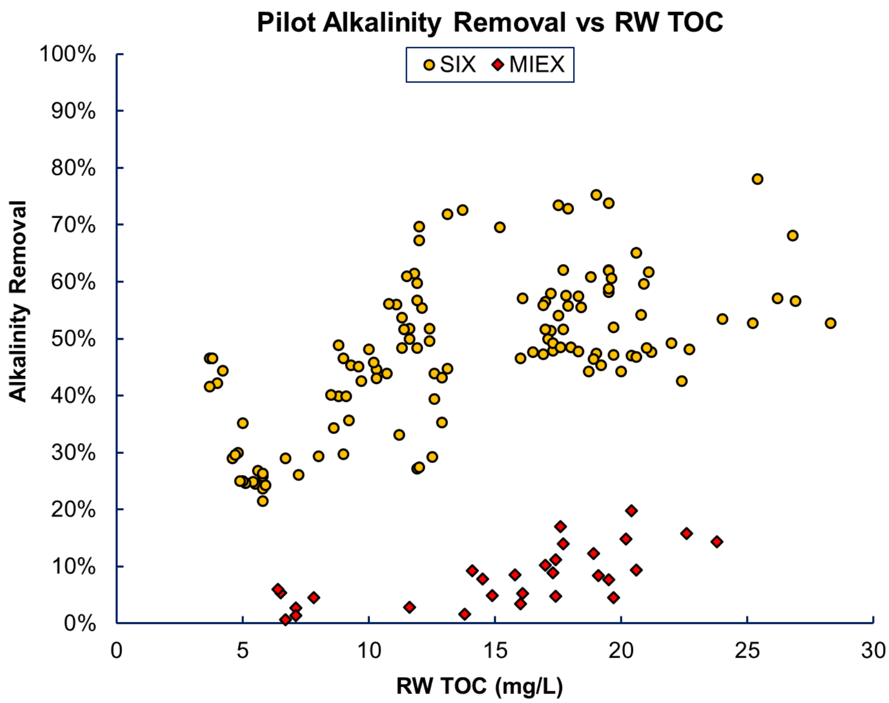


Figure 50 SIX® and MIEX® Pilot Alkalinity Removal vs. RW TOC

Based on the alkalinity removal observed by SIX®, it is expected that alkalinity will be required to be added back in at full-scale, but only certain times of the year. It is recommended that a combination of carbon dioxide and caustic be added downstream of floc/sed to maintain Finished alkalinity above 46 mg/L as $CaCO_3$, based on plant historic lows.

The RTW model for water process and corrosion chemistry was used to estimate required carbon dioxide and caustic doses to achieve the desired finished WQ (CCPP 0-13 mg/L, pH < 8.5, finished alkalinity >46 mg/L as $CaCO_3$). The range of CCPP that AWWA targets as a goal is 4-10 mg/L as $CaCO_3$. With the range of water quality that the City experiences, this range was widened to above 0 to below 13 mg/L as $CaCO_3$. This would be similar to the ranges that the City currently experiences. Table 27 provides a summary of these chemical requirements. It was found that RW alkalinity ranges strongly correlate to ranges of required chemicals. When RW alkalinity is greater than 100 mg/L as $CaCO_3$, it is not anticipated that any chemical addition be required to meet the FW alkalinity goals.

Table 27 Required Chemical Dosing to Achieve Desired Finished Alkalinity (RTW findings)

	RW Alk < 100	RW Alk < 85	RW Alk < 65
Carbon Dioxide Dose (mg/L)	0	18	27
Caustic Dose (mg/L)	3	20	28
Anticipated FW pH	8.2	8.4	8.5
Approx. Number of Days	20	58	72

8.2 Conventional Treatment (Coagulation, Flocculation, Sedimentation)

Objective 8:

Understand the impact of the SIX® process on the charge demand of the raw water seasonally.

Results: **MET IN FULL**

At the start of the pilot, initial ferric sulfate demand was determined based on dose required to achieve neutral zeta potential (0 mV). It was quickly realized that this approach provided good filter performance (especially when compared to full-scale filters). Carollo provided an onsite Zeta meter in March for routine zeta titration jar tests. Zeta titrations were performed approximately weekly, or as needed with shifts in RW WQ. The resulting ferric dosing represents the results of these titrations Figure 51.

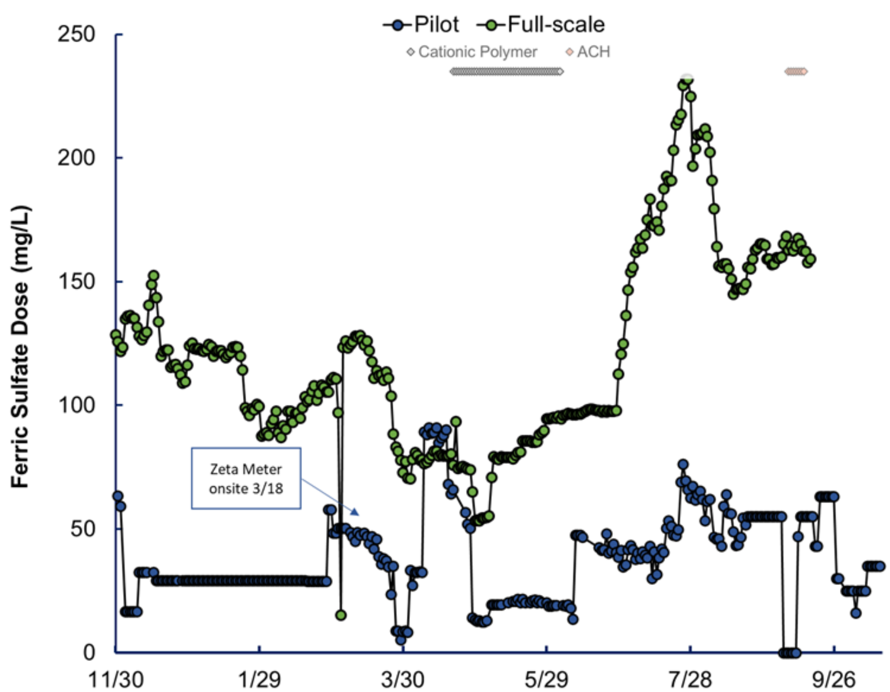


Figure 51 Pilot Ferric Sulfate Dose. Note the testing of alternate coagulants and subsequent lower Ferric dose during those times.

Objective 9:

Establish the impact of pH adjustment versus metal salt coagulants on additional TOC removal and ozone demand.

Results: **MET IN FULL**

Caustic dosing of pH control was brought online pre-ozone January 12, 2021. The caustic dose was controlled by the demand to achieve pH 7 (note that pH 8 was briefly tested September 13). Figure 52 shows the pilot caustic dosing generally trending inversely with coagulation pH and the resulting finished pH. The caustic dose in this figure is corrected to assume a ferric sulfate coagulant (coagulation pH was much higher during the testing of Cationic polymer and ACH coagulant alternatives, and so, caustic dose was low during that time and not representative). As previously discussed, SIX® alkalinity removal aided in overall pilot TOC removal due to improved ability to depress pH during coagulation (Figure 53). These effects are not available with the use of a coagulant that does not depress the pH (cationic polymer and ACH). Theoretically, lower incoming TOC will result in a lower ozone demand; that was observed to be the case during the pilot (Figure 54).

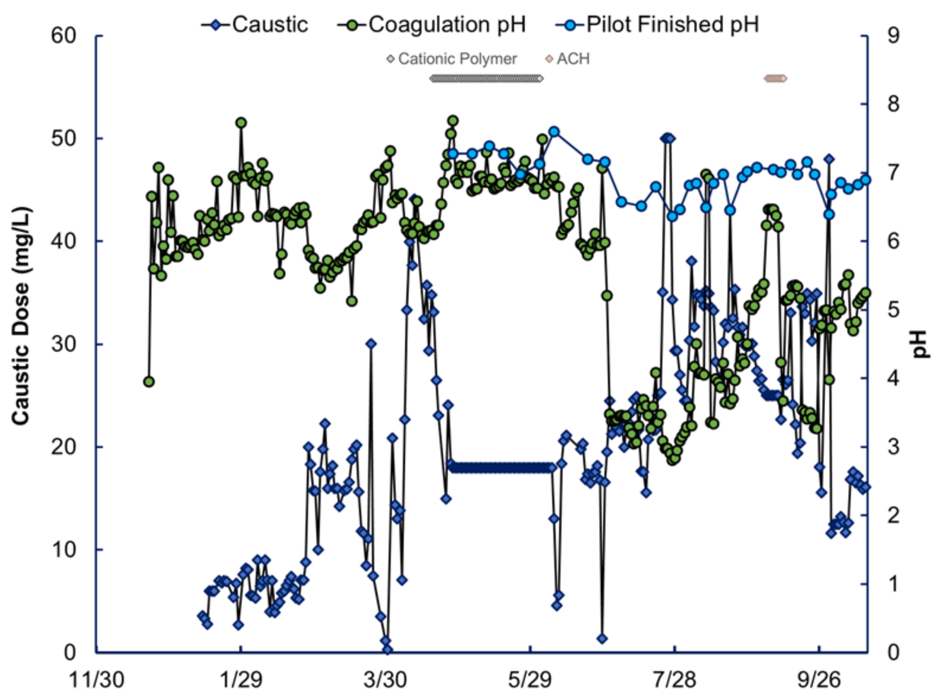


Figure 52 Caustic Dose to Achieve Neutral pH with Various Coagulants

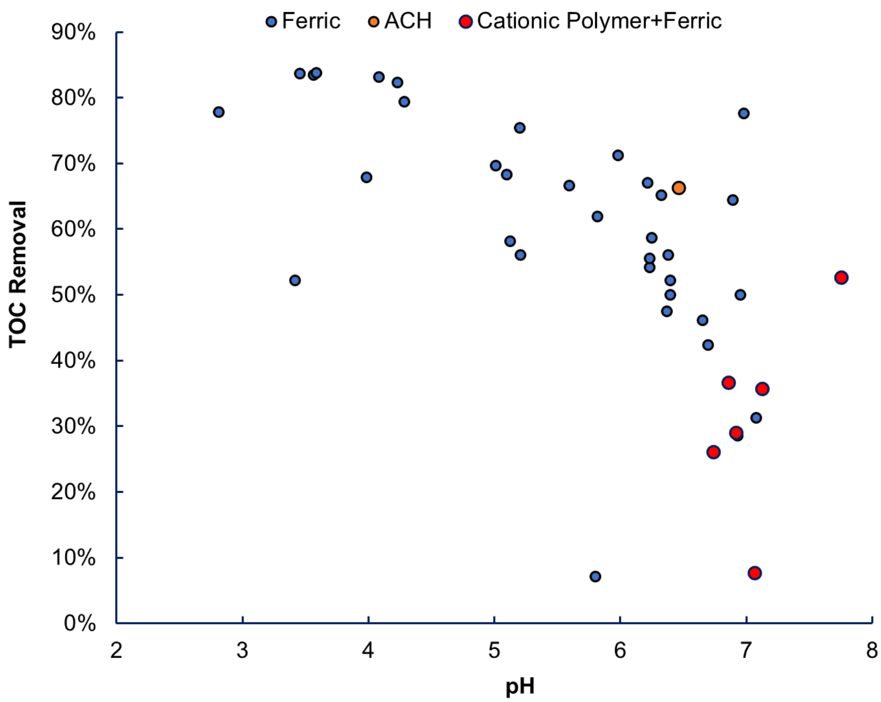


Figure 53 Conventional Treatment TOC Removal vs. Coagulation pH

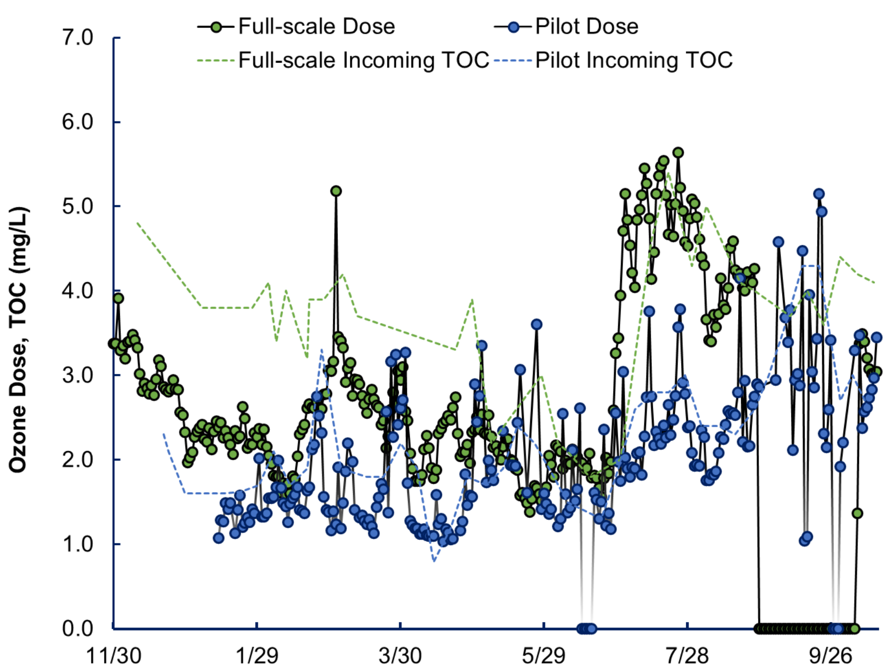


Figure 54 Full-Scale vs. Pilot Ozone Dose and Pre-Ozone TOC

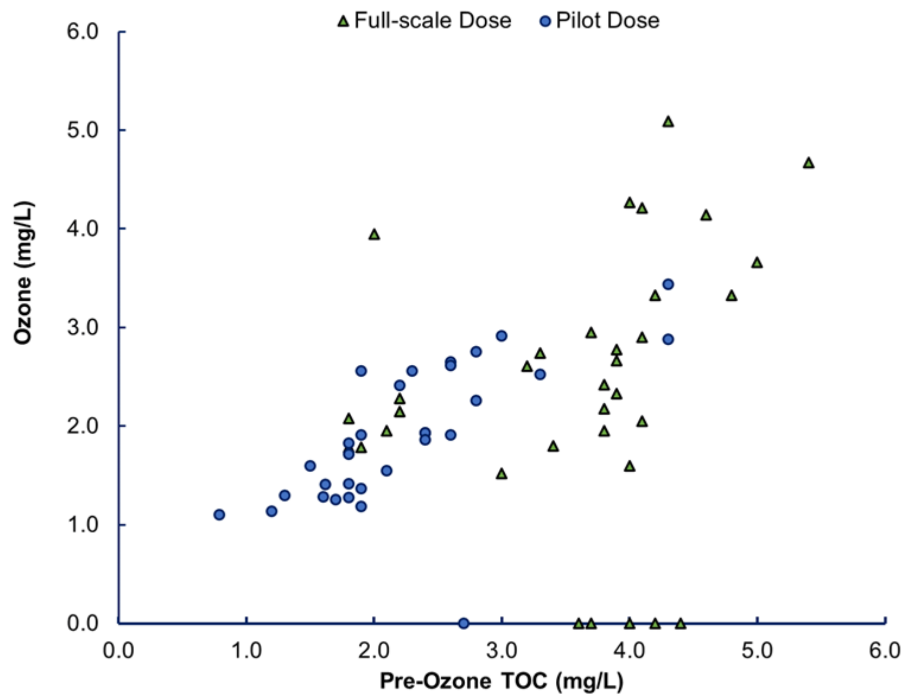


Figure 55 Ozone Dose vs. Pre-Ozone TOC

Objective 10:

Establish the impact of pH adjustment versus metal salt coagulants on the settleability and dewaterability.

Results: **MET IN FULL - more data would be better**

Based on Table 28, better settleability occurred at lower coagulation pH. Dewaterability was tested once during the pilot while using the ferric sulfate coagulation scheme and two different floc aid polymers. Pilot coagulation chemistry at the time of sampling was 60 mg/L ferric sulfate and 0.5 mg/L FA polymer (Polydyne C3223), resulting in a coagulation pH of 3.7. Upon arrival to external testing facility, solids sample pH was 6-6.5. The subsequent Belt Press and Centrifuge dewatering results are summarized in Table 28. These results are comparable to full-scale solids data from the same test period (July/August 2021) resulting in 25.6 % average solids cake.

Table 28 Pilot Solids Bench Test- Dewatering Expected Performance

	Belt Press 2 Belt Extended Klampress		Belt Press 3 Belt KPZ (8 roller)		Centrifuge-Aldec 125	
Hydraulic Loading (gpm/m)	100-110 @ 0.79%	100-110 @ 0.79%	160-180 @ 0.79%	160-180 @ 0.79%	250 gpm @ 0.79%	250 gpm @ 0.79%
Solids Loading	395-435	395-435	633-712	633-712	988 lbs/hr	988 lbs/hr
Cake Solids	18-19%	19-20%	18-19%	19-20%	20-21%	21-22%
Capture (lbs/hr/m)	94-95%	94-95%	94-95%	94-95%	93-95%	93-95%
Polymer Manufacturer	**Plant Polydyne C3223**	**Polydyne C6266PWG (Cationic, Emulsion, Potable)**	**Plant Polydyne C3223**	**Polydyne C6266PWG**	**Plant Polydyne C3223**	**Polydyne C6266PWG**
Polymer Dosage (neat lb/ton)	14-19	46-51	17-22	53-58	25-35	68-78
Activity of Polymer	100%	41%	100%	41%	100%	41%
Active Polymer Dosage (lbs/ton)	14-19	19-21	17-22	22-24	25-35	28-32

<u>Objective 11</u>:

Determine the potential for using or supplementing with a cationic polymer and the impacts on TOC, ozone demand, settleability, and dewaterability.

<u>Results</u>: **MET IN FULL**

The use of a cationic polymer for supplementing ferric sulfate was tested during April and May of the piloting. From Figure 56 and Figure 57, it was determined that coagulation performance and subsequently filter performance declined. It is important to note that during this time period, ASR and Copper Sulfate to the HR was also occurring. It is likely that these streams caused additional challenges (SIX® performance was negatively affected by the higher RW sulfate concentrations), which contributed to the poor results when testing the Cationic Polymer. It may be the case that the cationic polymer would work better during different times of the year. Figure 58 and Figure 59 show filter performance while normal cationic polymer coagulation chemistry was in use (1.5-4.0 mg/L + 15-20 mg/L ferric sulfate) and just after the cationic polymer was shut off with ferric kept at the low dose. These figures demonstrate that the cationic polymer was not helping as far as filter performance in addition to TOC removal. Due to the sub-par performance using the cationic polymer, solids dewaterability was not tested under this condition.

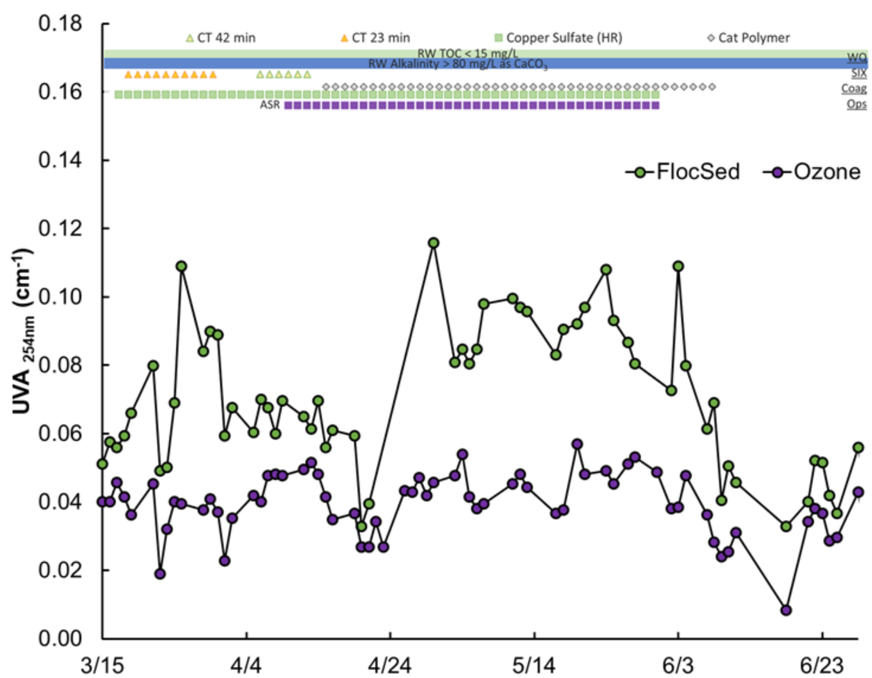


Figure 56 Floc/Sed and Ozone UVA during Cationic Polymer Test Period

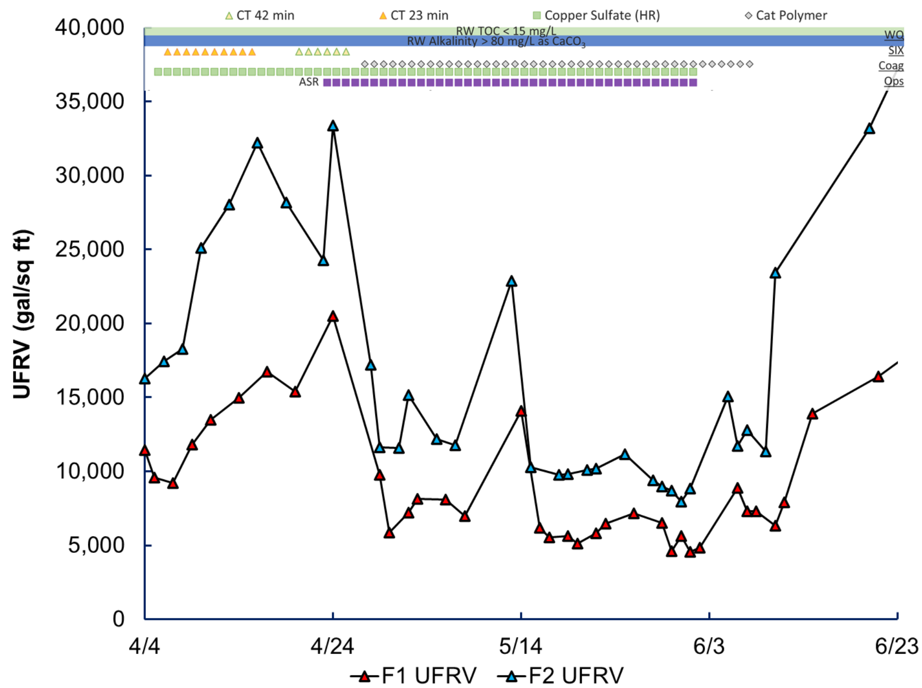


Figure 57 Filter UFRV during Cationic Polymer Test Period

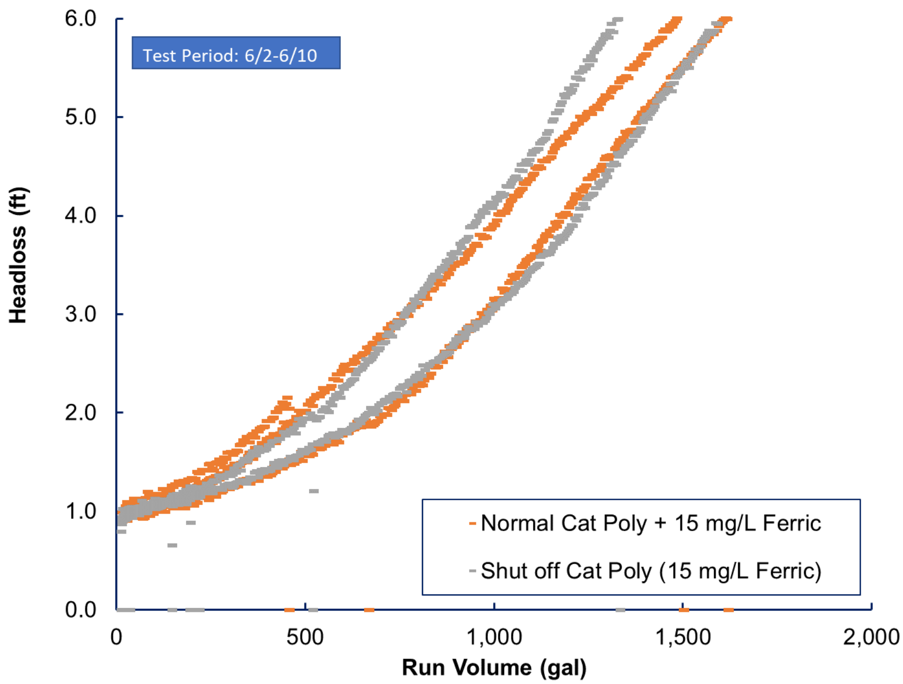


Figure 58 Filter 1 Headloss with and without Cationic Polymer Coagulant

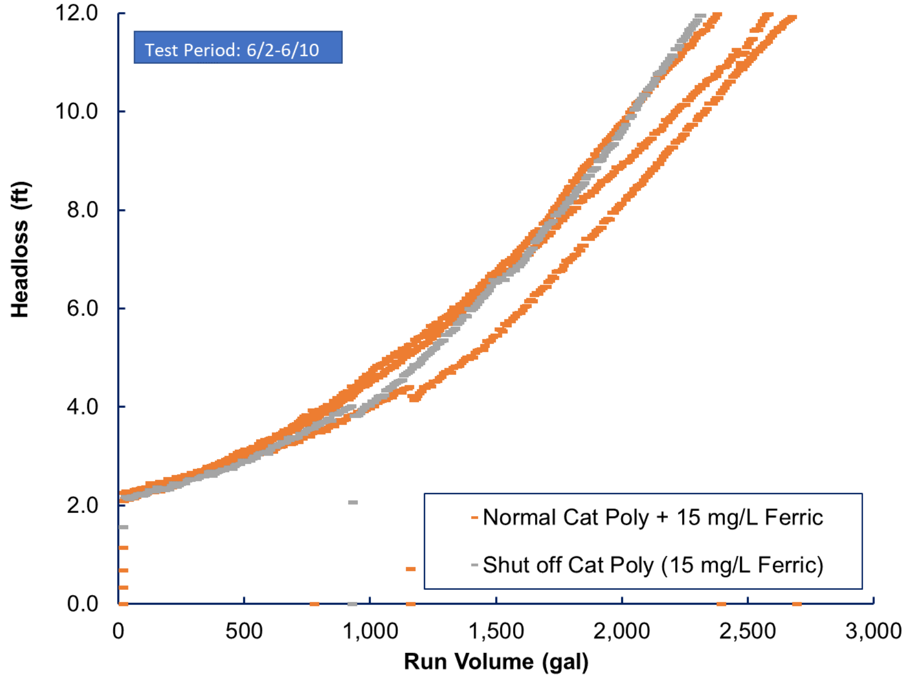


Figure 59 Filter 2 Headloss with and without Cationic Polymer Coagulant

Objective 12:

Determine the best floc aid polymer for the different coagulation schemes. Evaluate potential impacts of conventional floc/sed versus ballasted flocculation.

Results: **MET WITH EXCEPTIONS**

Three different floc aid polymers were tested at the pilot scale (Table 29). For most of the pilot, the current plant polymer was used and worked well. Because this polymer works well at the full-scale, alternative floc aid polymers were not tested until poor filter performance was observed during Phase 3 of the pilot. During periods of observed Microflocculation and low coagulation pH, it was observed that floc aid polymer had negative effects on filter performance (Figure 60 and Figure 61). Based on the headloss profiles of these filter runs, it appears that the Polydyne floc aid polymer was contributing to additional headloss on the filters and is likely not removed after one backwash.

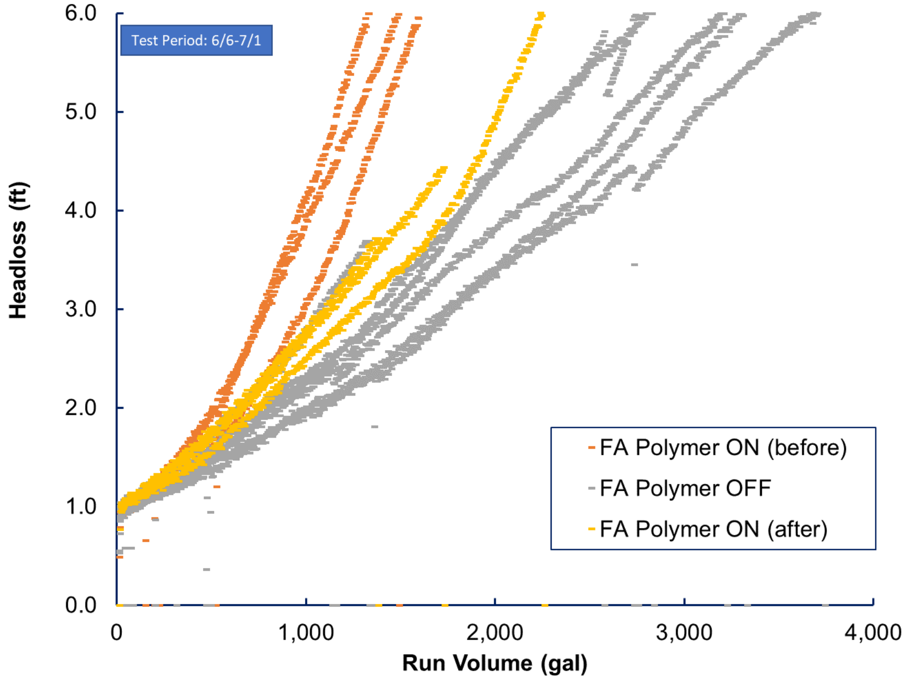


Figure 60 Filter 1 Headloss Curves with and without Floc Aid Polymer during Microflocculation

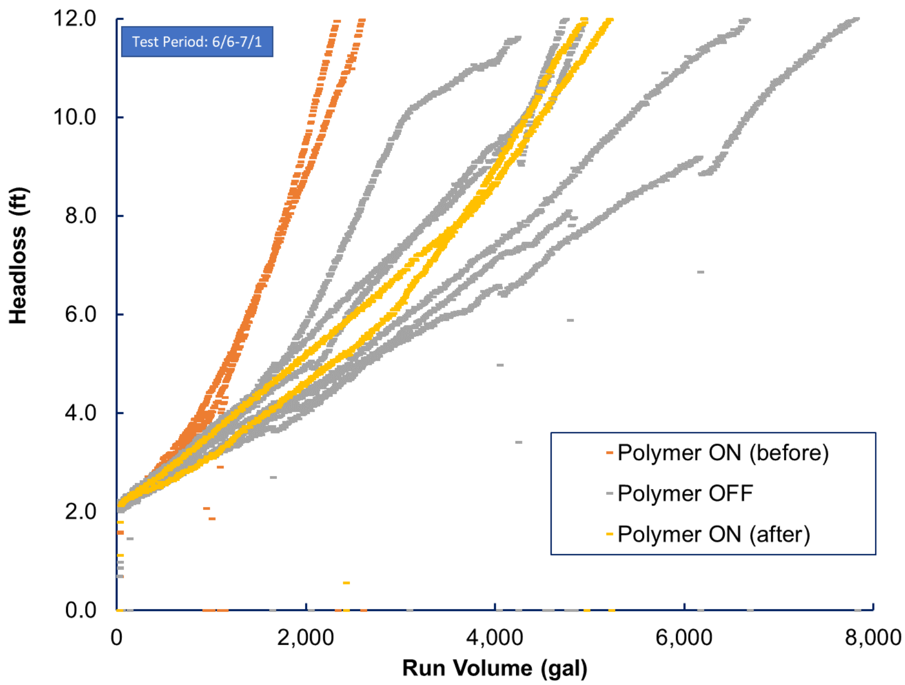


Figure 61 Filter 2 Headloss Curves with and without Floc Aid Polymer during Microflocculation

In reaching out to Actiflo® technical staff, anionic polymers were recommended in an attempt to mitigate these headloss issues. During this test period, alkalinity was very low and the resulting coagulation pH was consistently below pH 4. Based on coagulation pH, the anionic polymers theoretically perform better. With that, two alternate anionic floc aid polymers were tested (Table 29). These polymers did not improve filter runs, and so testing continued with the Polydyne cationic floc aid polymer.

Table 29 Tested Floc Aid Polymers

Floc Aid Polymer	
Polydyne C3223 (current plant poly)	Cationic
Hydrex 3511	Anionic
Hydrex 3521	Anionic

Although ballasted flocculation was not tested at the pilot scale, the current full-scale floc aid polymer (Polydyne C3223) was heavily relied upon for testing due to the fact that we know it works well with the current Actiflo® at the plant.

8.3 Ozone

Objective 13:

Determine the overall ozone demand and dose with both the ion exchange and coagulation/flocculation/sedimentation.

Results: **MET IN FULL**

Due to the lower pre-ozone TOC at the pilot compared to full-scale, ozone demand was also lower (Table 30). The amount by which the ozone demand was lower varied seasonally with shifts in RW WQ and pilot operations. Table 30 provides a summary of the average reduction in ozone demand at the various phases of testing.

Table 30 Reduction in Ozone Demand at Pilot vs. Full-Scale

	Ozone Dose Reduction	Avg Pilot Pre-Ozone TOC	Avg Full-Scale Pre-Ozone TOC
Phase 1	40%	2.0	3.9
Phase 2	24%	1.7	2.5
Phase 3	41%	2.9	4.2
Pilot Avg	30%	2.2	3.6

Objective 14:

Determine the approach to contact time based on the demand curves for each of the ion exchange and coagulation approaches.

Results: **MET IN FULL**

Through pilot testing of three different coagulant chemistries, ferric sulfate was found to be the only coagulant that worked well achieving the pilot goals (<2 mg/L TOC).

Based on the literature, ozone:TOC ration and hardness:TOC ration have a significant impact on microflocculation (Figure 62). During low TOC/high hardness season (typically winter and spring), the ozone:TOC ratio is in a range that avoids particle instability, but with a sharp increase in TOC and drop in hardness, the ozone:TOC ratio shifts (in combination with a shift in alkalinity), that results in more particle instability. During observed microflocculation, low ozone residual was tested in an attempt to reduce particle instability. Based on the headloss profile shown in Figure 63, it likely will not be possible to mitigate microfloc headloss effects by only reducing ozone doses. Microflocculation is further discussed under Objective 20.

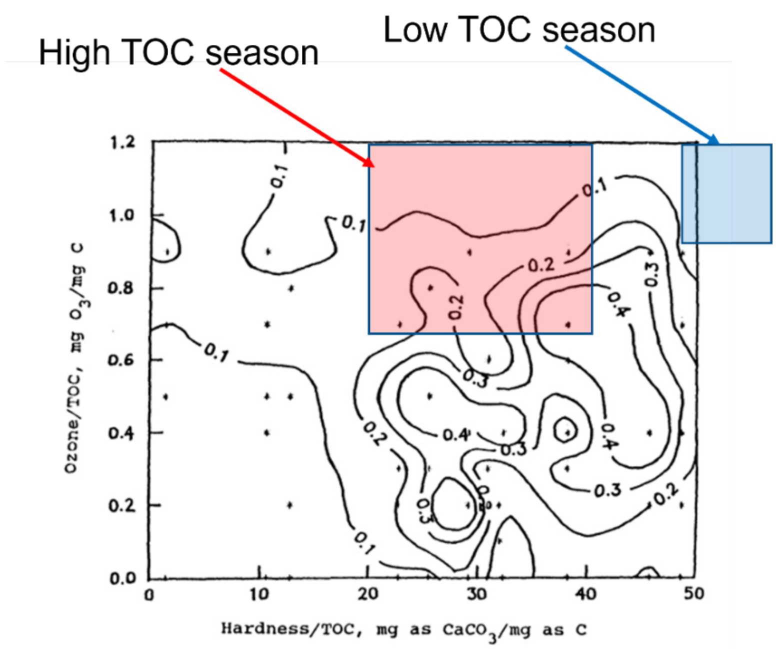


FIGURE 37. Effect of Hardness/TOC and Ozone/TOC Ratios on Particle Stability in Ozonated Waters. (Contours show different α values; the asterisks (*) show the actual experimental data points.)

Figure 62 Literature Findings of Ozone:TOC Ratio and Hardness:TOC Ration on Particle Stability and Microflocculation Potential. Alpha values signify particle collision efficicency; higher collision efficiency means floc will be stickier and cause more filter headloss.

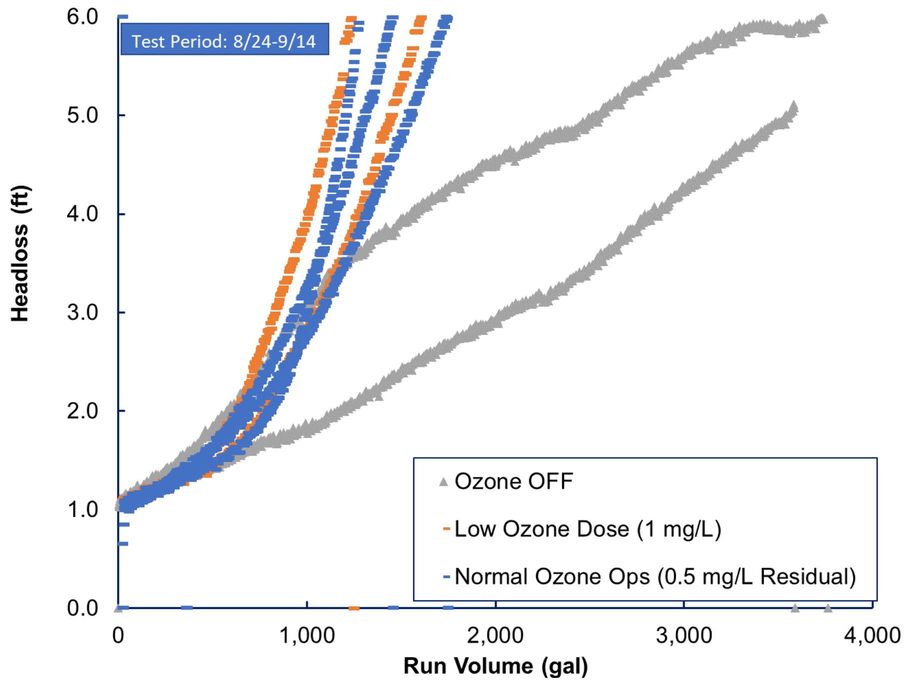


Figure 63 Filter 1 Headloss Curve during Microflocculation - Low Ozone Dose

Objective 15:

Determine the potential for bromate formation and associated mitigation measures based on the overall ozone demand and the selected pretreatment approaches. (This analysis shall include the impact of the ASR well if the City is running the well during piloting).

Results: **MET IN FULL**

Bromate formation at the pilot-scale was monitored throughout testing; more frequent sampling occurred while ASR was on with higher RW Bromide. Although bromate control strategies were not implemented at the pilot, the reduced ozone demand reduced bromate formation. In addition to the reduced ozone demands at the pilot,SIX® removes bromide resulting in less bromate formation potential. Figure 64 shows bromate concentration in the full-scale finished water and pilot effluent; of note, neither exceeded the MCL of 10 µg/L at any time. Based on the data from the ASR period, full-scale bromate control strategies will be successful at mitigating the additional bromate formation seen at the pilot during this time although the ability to mitigate bromate formation should be maintained.

The bromide concentrations tested during this pilot period were slightly below annual average based data since 2014 (Table 31). Figure 65 shows historic bromide concentrations and the tendency to spike when ASR is on, which has varied annually.

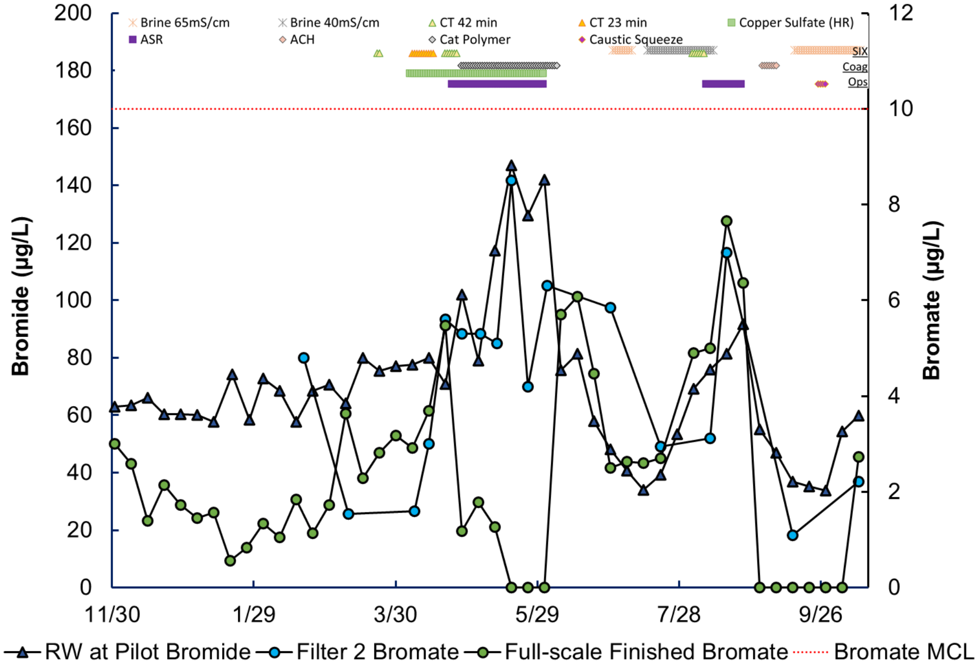


Figure 64 Bromate Formation at the Pilot and Full-Scale

Table 31 Average and Maximum Historic Full-Scale Bromide (all units in µg/L)

	HR RW		Pre Ozone	
	Avg	Max	Avg	Max
2014	62.0	184	63.5	139
2015	71.8	221.5	75.7	120.7
2016	56.3	165.2	60.7	140.5
2017	167.9	83.0	151.7	927.1
2018	83.5	82.3	84.9	289.4
2019	66.5	72.2	69.9	181.2
2020	70.2	79.2	71.1	250.9
2021	66.2	84.4	66.6	147.0
Avg	**80.6**	**121.5**	**80.5**	**274.5**

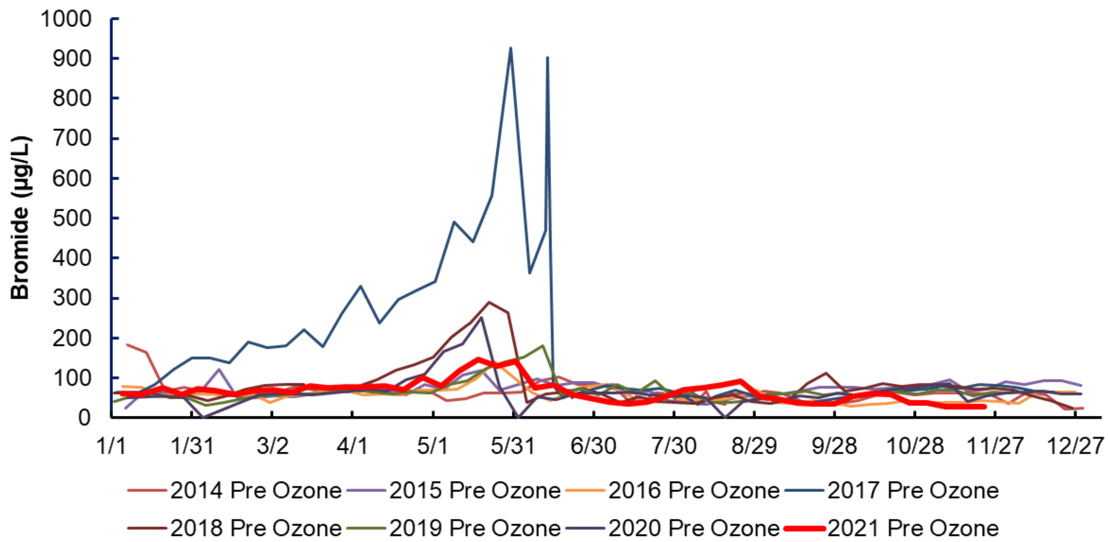


Figure 65 Historic Full-Scale Pre-Ozone Bromide (includes ASR flows)

Objective 16:

Determine the chlorine demand when ozone is not operational or if ozone is being used for oxidation only and the approach to CT.

Results: **MET WITH EXCEPTIONS**

Chlorine demand was measured during three rounds of demand/decay and SDS testing. Instantaneous chlorine demand for those samples when ozone was on is summarized in Table 32. Instantaneous demand data was collected after 10 min reaction time. It was found that pilot bench-scale chlorine demand testing was similar to full-scale; however it is expected that with the lower finished TOC, there will be lower chlorine demand with SIX® at the full-scale long-term.

Table 32 Chlorine Demand Summary

	Date Sampled	TOC (mg/L)	Instantaneous Chlorine Demand (mg/L)
Pilot	7/20/2021	1.7	0.90
	8/17/2021	1.7	1.40
	10/12/2021	1.5	0.55
Full-scale	7/20/2021	2.9	0.90
	8/17/2021	2.4	0.90
	10/12/2021	3.3	1.05

Objective 17:

Determine the impacts of the different pretreatment methods on the potential for sidestream injection (in terms of getting CT with one application point).

Results: **NOT MET**

Sidestream ozone injection may still be possible but was not tested at the pilot-scale. With the lower ozone demand and lower TOC experienced at the pilot, a reduction in the requirement to add ozone across the contactor to maintain an ozone residual is expected.

Objective 18:

Determine the impacts and approach to quenching (hydrogen peroxide only).

Results: **MET IN FULL**

Ozone quenching with hydrogen peroxide was tested as a potential microflocculation mitigation strategy. Hydrogen peroxide was dosed with two different approaches: at low dose (0.5 mg/L) at the end of the ozone contactor and also to at the front of the contactor to quench ozone residual (approx. 0.5 mg/L H_2O_2 per mg/L O_3 dose). The resulting effects on filter performance were insignificant or resulted in worse performance (Figure 66).

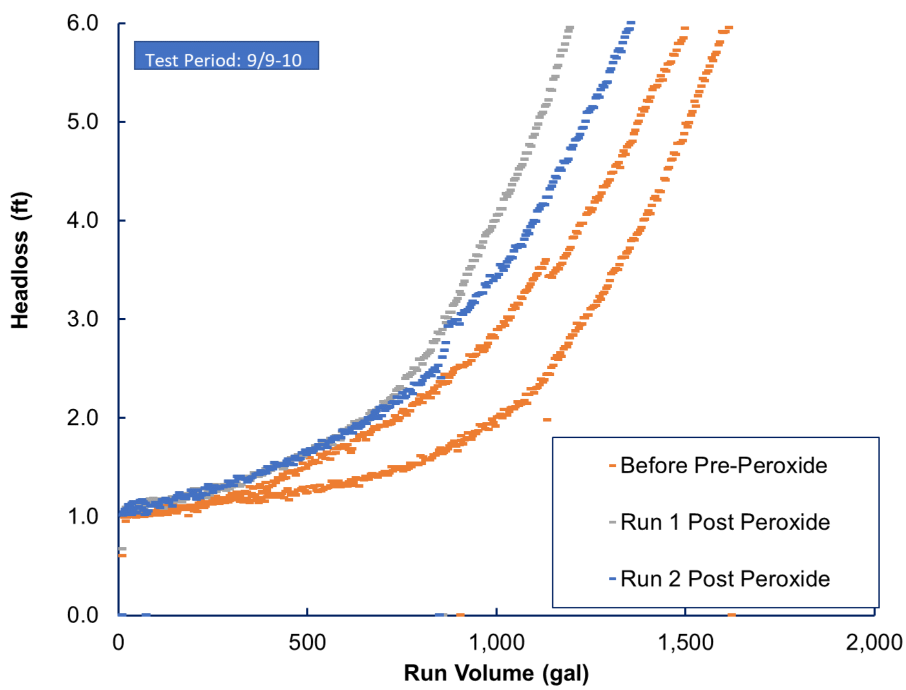


Figure 66 Filter 1 Headloss Curves with and without Peroxide

Objective 19:

Impact of ozone dose and pretreatment on TOC removal through biological filtration.

Results: **MET IN FULL**

Figure 67 shows the pilot and full-scale filter performance versus TOC removed by the filters. On average, the amount of TOC removed by the pilot filters was lower than full-scale, predominantly due to the lower TOC going on to the filters. Theoretically, it is assumed that with higher TOC removal through the filter, the biology on the filter media is more active, and will therefore contribute to higher headloss and lower filter UFRVs. It is interesting to note that full-scale filter performance does not follow this trend, with relatively consistent UFRV regardless of TOC removed; this implies that headloss issues at full-scale are likely due to non-biological factors, at least in part.

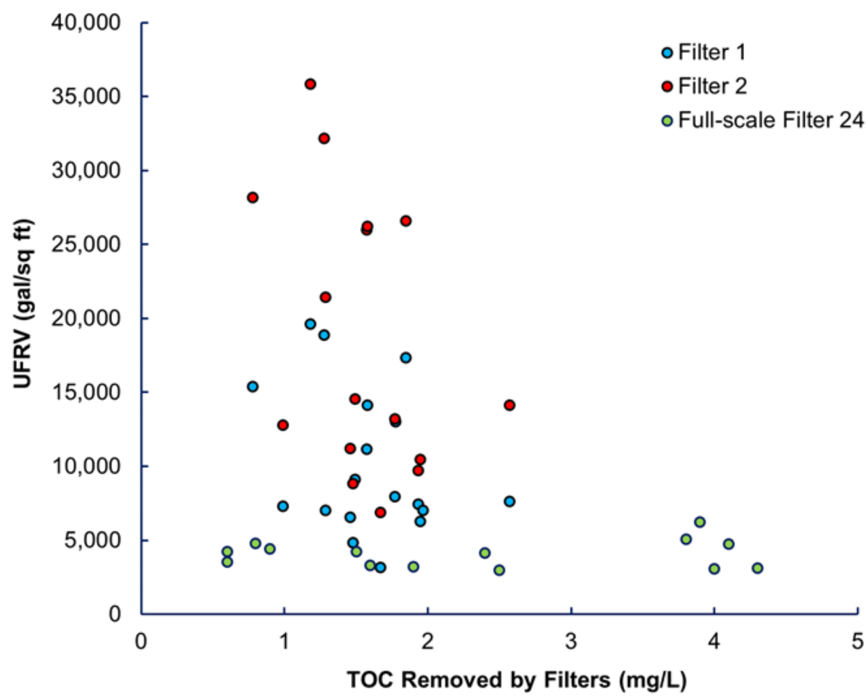


Figure 67 Pilot and Full-Scale Filter Performance vs. TOC Removed by Filter

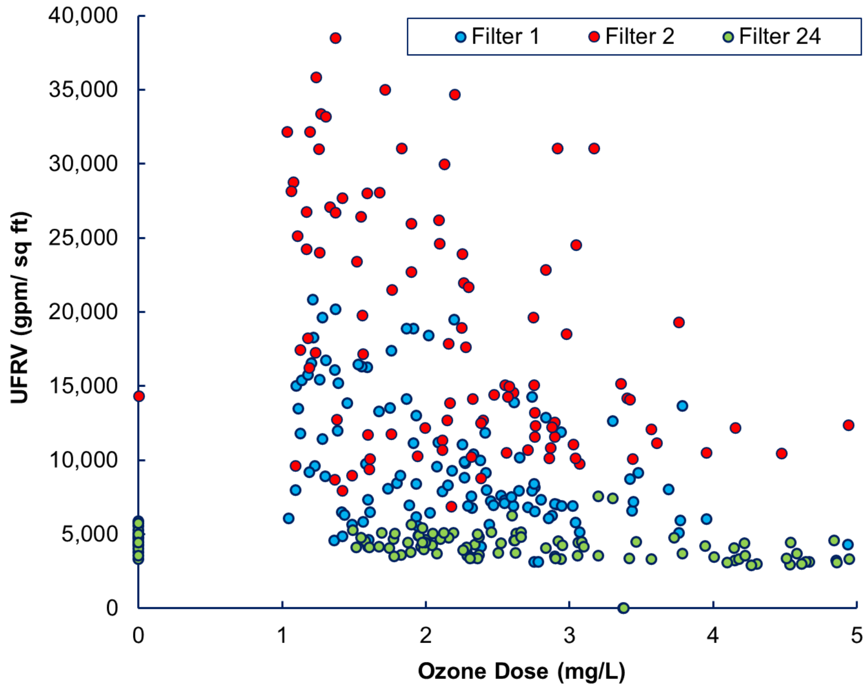


Figure 68 Pilot and Full-Scale Filter Performance vs. Ozone Dose

New Objective 20:

Understand the implications of ozone on Microflocculation and filter headloss.

Results: **MET IN FULL**

During high TOC season and Phase 3 of pilot testing, a significant increase in filter headloss accumulation rates was observed. Through literature review of pre-ozonation and its impacts on coagulation/flocculation, it was determined that these changes in headloss accumulation were likely due to the presence of microflocculation with intermediate ozone (Figure 63). There are many factors involved in the formation of microfloc (largely studied with pre-ozone, but not for intermediate ozone). These factors include ozone:TOC, hardness:TOC (Figure 62), calcium concentration, and alkalinity concentration. During a unique WQ test period (highest RW TOC, fluctuating alkalinity), dramatic effects on filter performance were observed with changing alkalinity (Figure 69 and Figure 70). At alkalinity below 80 mg/L, headloss curves take on an exponential shape (as opposed to the linear headloss curve that we would expect). It was also during this time that filters began washing on turbidity (assumed due to very high TOC and fragile floc) - this was the only time during pilot testing that filters backwashed on turbidity. Figure 49 summarizes the control strategies tested and the corresponding results on filter performance. With the addition of alkalinity, UFRVs improved; however this improvement was not consistent over time. The addition of pre-chlorine to meet the chlorine demand did, however, result in improved filter performance throughout the rest of the pilot (approximately one month of testing). Figure 71 and Figure 72 show the shift towards flatter headloss curves in the filters with the addition of pre-chlorine.

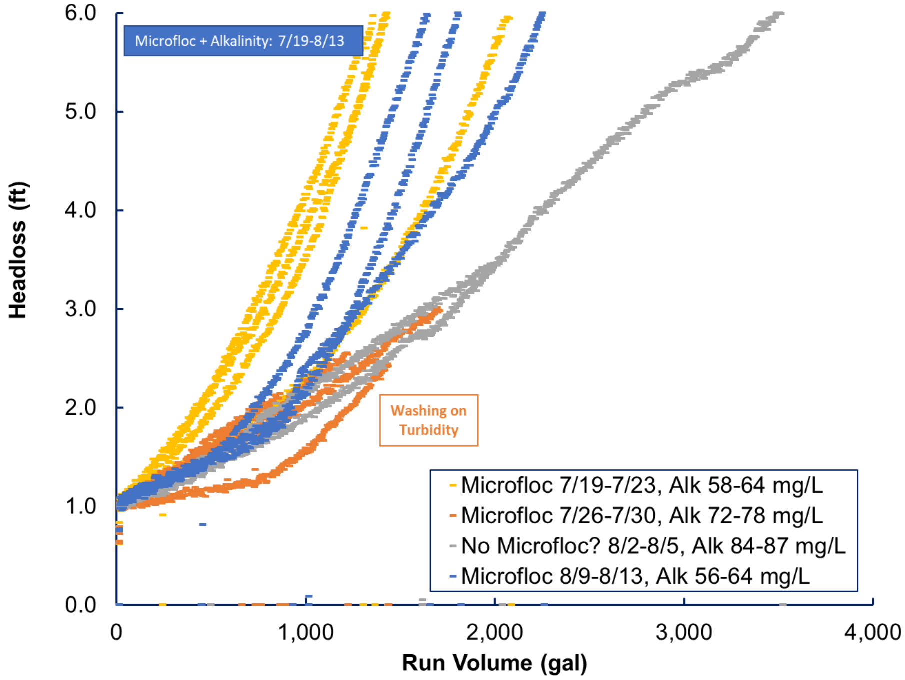


Figure 69 Filter 1 Headloss - Observed Microflocculation and Alkalinity Effects

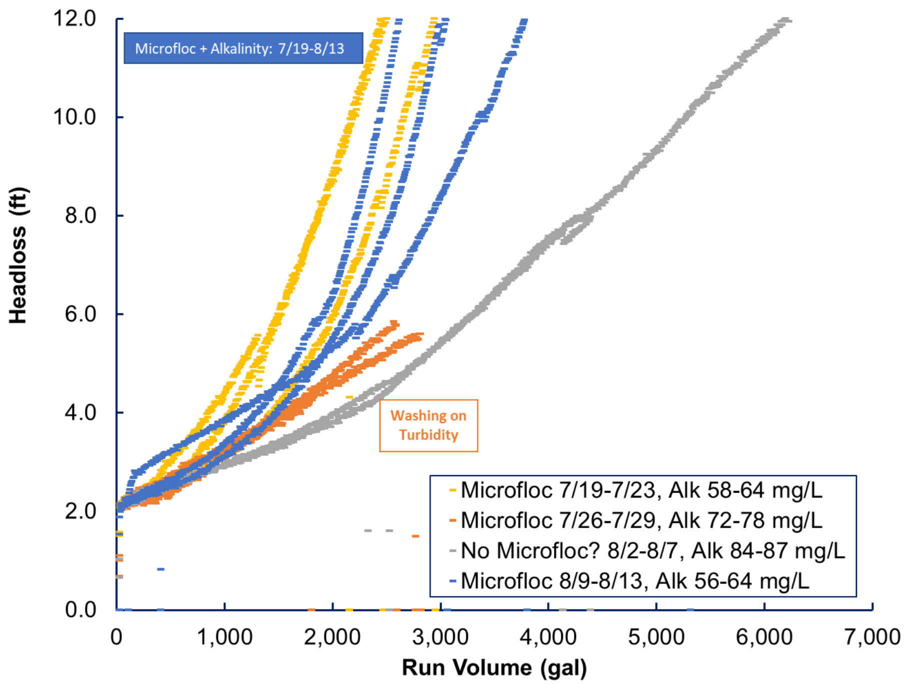


Figure 70 Filter 2 Headloss - Observed Microflocculation and Alkalinity Effects

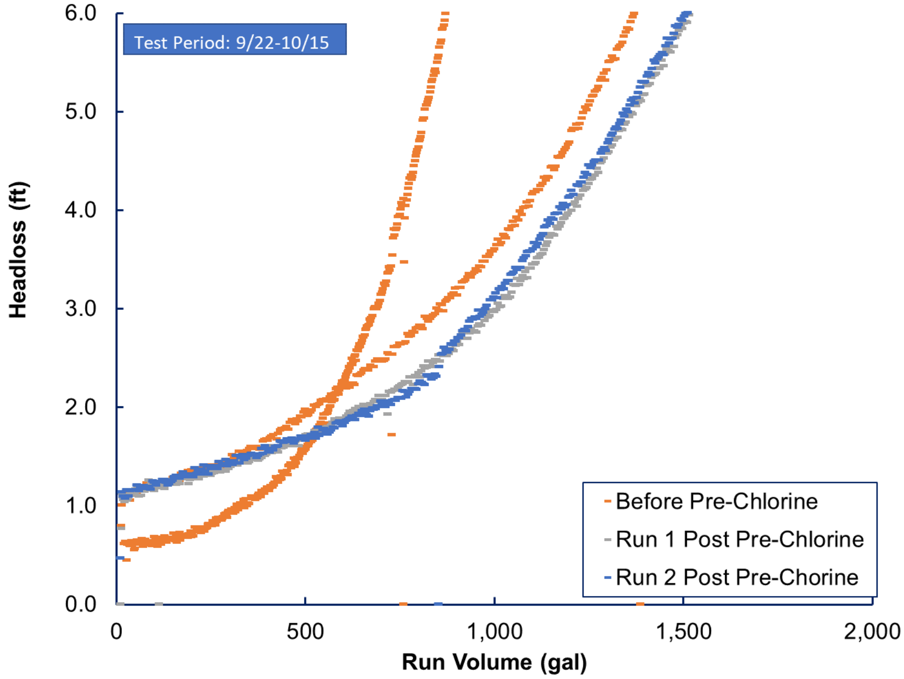


Figure 71 Filter 1 Headloss vs. Run Volume - Pre-Chlorine Effects during Microflocculation
LR changed from 4.6 to 6.0 gpm/sq ft between the two 'pre-chlorine' runs.

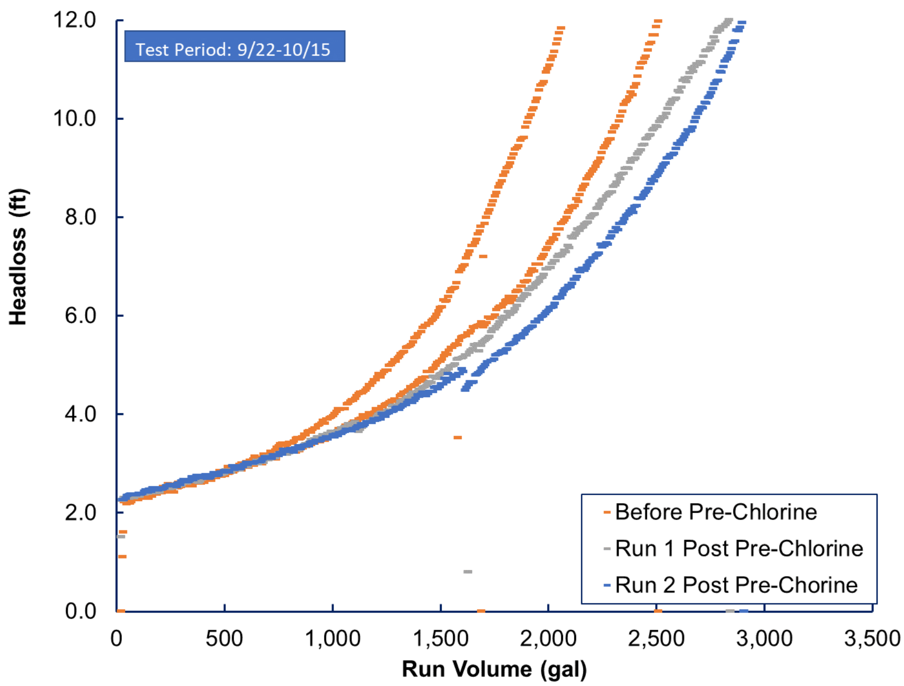


Figure 72 Filter 2 Headloss vs. Run Volume - Pre-Chlorine Effects during Microflocculation

In August, a new tool allowed for the measuring of head pressure incrementally through the filter media bed. This data seems to corroborate microflocculation at the filters. With microflocculation, pressure accumulates exponentially at the very top of the filter media, with minimal headloss occurring just 10 inches below. When chlorine was added to meet demand, an improvement was observed in the headloss at the surface of the filter bed, and although minimal, resulted improved UFRV by 25 percent. (Figure 73)

As mentioned, the SIX® resin underwent chemical cleaning at the end of September. The caustic squeeze also resulted in improved filter runs. Figure 73 and Figure 74 show filter runs just before caustic cleaning (at LR 4.6) and just after caustic cleaning (LR 6.0); even at the higher loading rate, it was observed that headloss accumulation at the top of the media bed improved and the curve flattened out. These effects were short-lived and initial improvements diminished after a few runs.

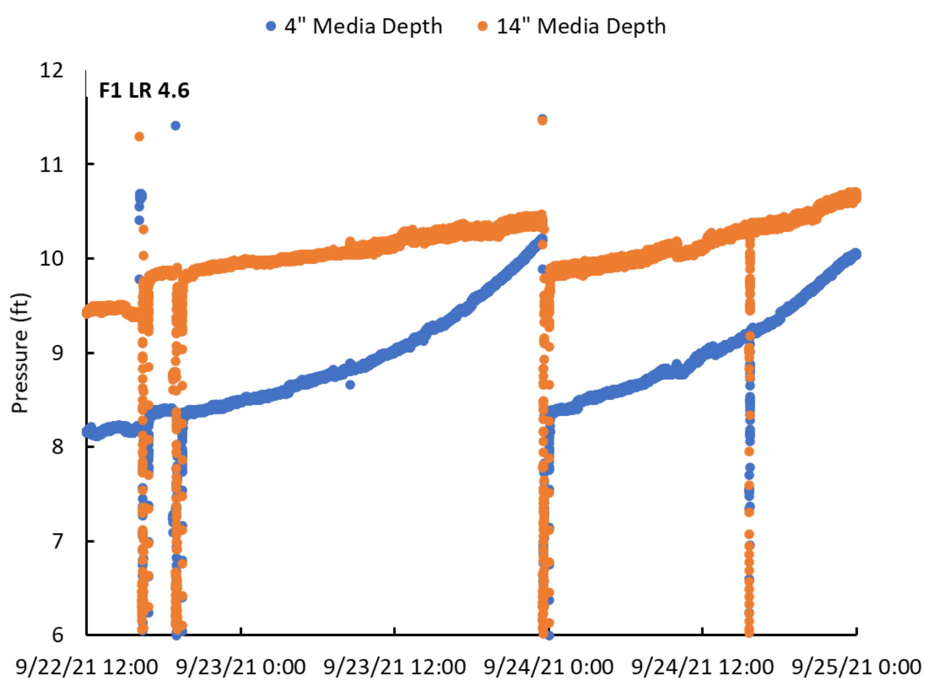


Figure 73 Filter 1 Incrememntal Headloss - Observed Microflocculation with Headloss Curves at the Top of the Media Bed
F1 LR = 4.6 gpm/sq ft. Run 1: 1ppm Chlorine, Run 2: 2ppm chlorine (meeting demand).

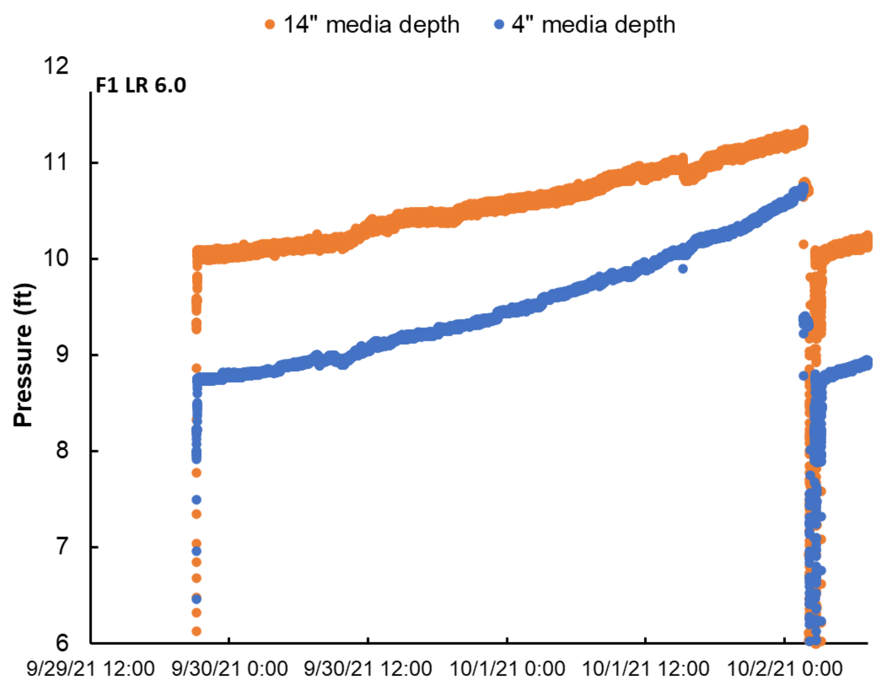


Figure 74 Filter 1 Incrememntal Headloss - Minimal Microflocculation with First Run Post-Caustic Squeeze
F1 LR = 6.0 gpm/sq ft.

With the observation of microflocculation and headloss accumulation at the surface of the media bed, a 'bump' test was performed to gradually ramp up filter loading rate and observe effects. It was observed that at higher loading rates, there is a shift in particles deeper into the bed. This was confirmed by taking grab turbidity samples with the ramping LR; Figure 75 shows the spiking of turbidity at higher LRs, which then seems to stabilize. This shift in particle distribution is reinforced when the LR is returned (see head pressure at both LR 6.0 steps), the head pressure is lower, effectively shifting these particles and utilizing more capacity of the filter bed and achieving higher UFRVs. UFRVs were observed to increase in both Filter 1 and Filter 2 with increased LR up to the LRs tested.

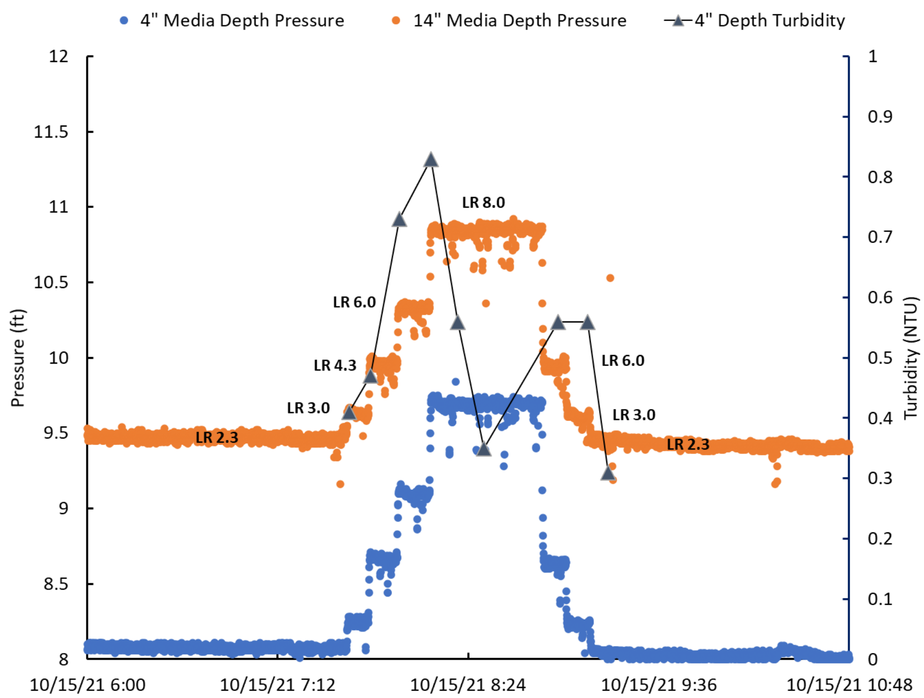


Figure 75 Filter 1 Incrememntal Headloss with 4 inch Turbidity
F1 LR = 2.3-8.0 gpm/sq ft.

8.4 Filters

<u>Objective 21</u>:

Evaluate different filter loading rates and media configurations (sizes and depth) based on pretreatment approaches.

<u>Results</u>: **MET IN FULL**

Filter loading rates did not remain constant throughout the pilot. In general, filter loading rates were raised over the pilot test period to bracket performance and understand filter performance at varying loading rates. Filter 1 (control) operated at loading rates up to 6 gpm/sq ft (with LR bump tests up to 8 gpm/sq ft with no effect on turbidity) (Figure 76 and Figure 77). Similarly, Filter 2 was operated at loading rates up to 8-10 gpm/sq ft with no effect on turbidity (Figure 70 and Figure 72).

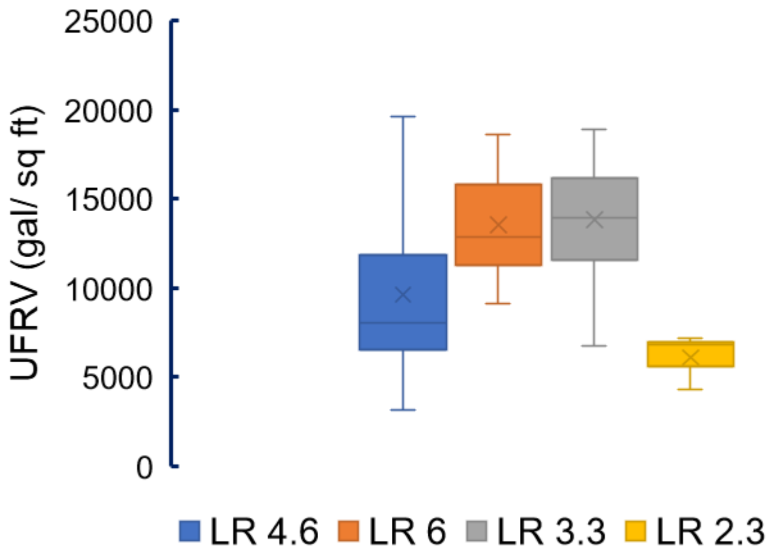


Figure 76 Filter 1 UFRV vs. Filter Loading Rate

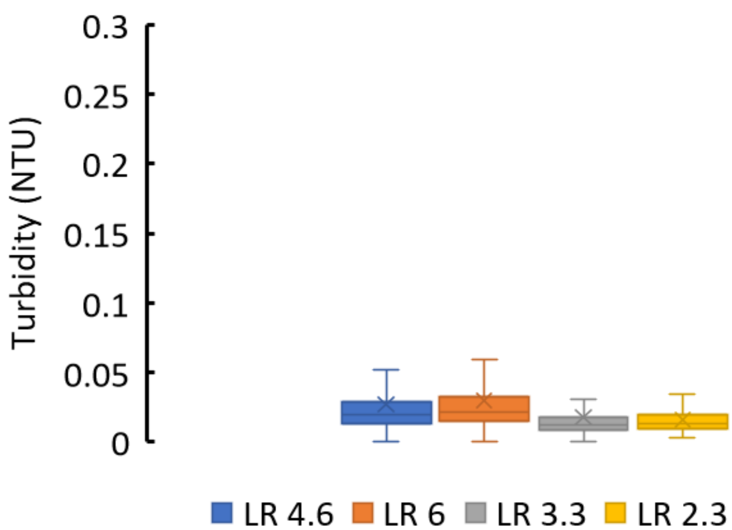


Figure 77 Filter 1 Turbidity vs. Run Volume at Various Loading Rates (LR gpm/sq ft).

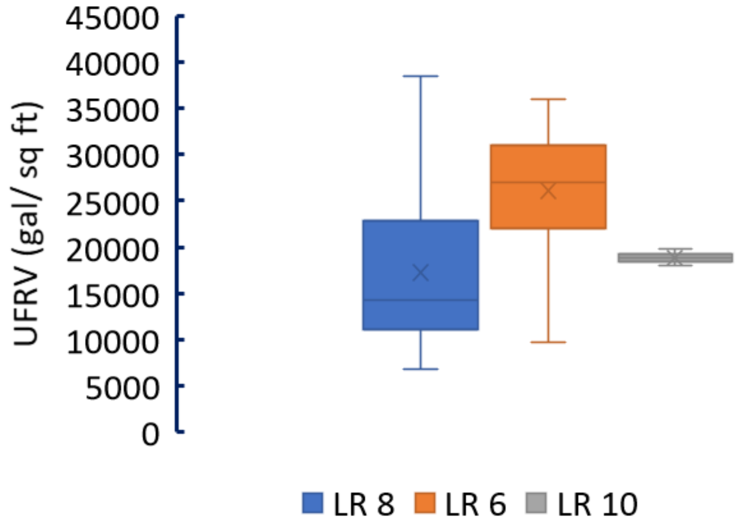


Figure 78 Filter 2 Headloss vs. Run Volume at Various Loading Rates (LR gpm/sq ft).

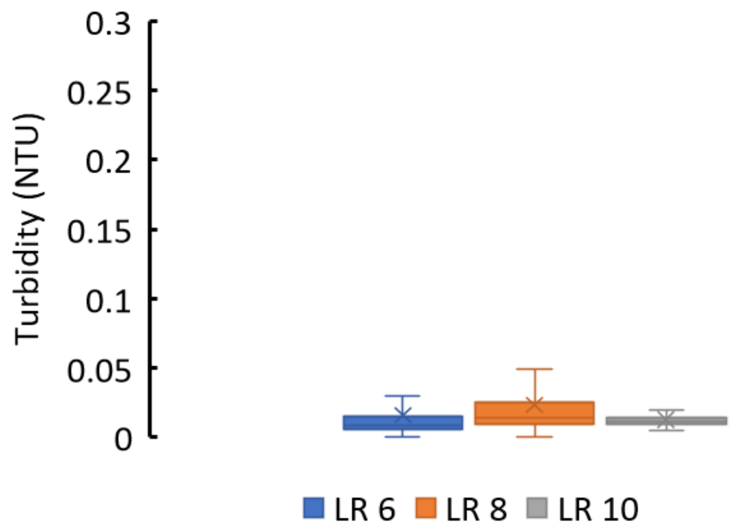


Figure 79 Filter 2 Turbidity vs. Run Volume at Various Loading Rates (LR gpm/sq ft).

Objective 22:

Evaluate the combined use of hydrogen peroxide and phosphorus addition (if needed) in combination with pH adjustment to improve filter loading rates.

Results: **MET IN FULL**

- As previously discussed, hydrogen peroxide was tested to quench ozone during microflocculation periods; it was not found to improve performance.
- Similarly, based on Phos-Gly enzyme analysis, filters were not found to be phosphorus-limited and so phosphorus was not applied to the filters. To note, the City has also experimented with phosphorus and hydrogen peroxide addition and has found no effect on the filters.
- Filters were briefly operated at pH 8 to observe effects; no significant effects were observed on filter performance or headloss accumulation rates (Figure 80).

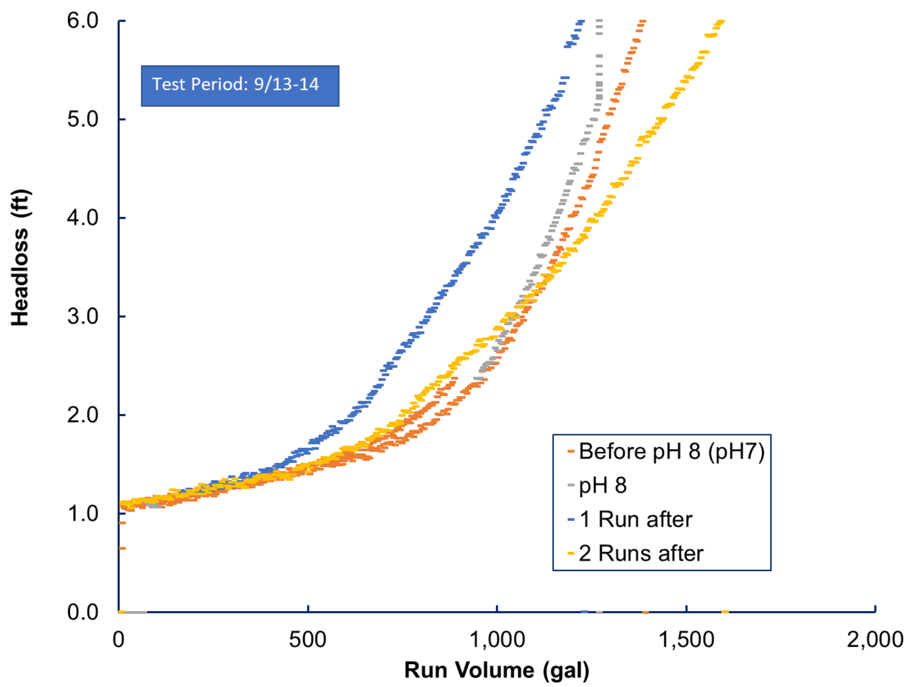


Figure 80 Filter 1 Headloss at pH 7 vs. pH 8

Objective 23:

Evaluate the impacts of improved backwash protocol, different media configurations, and potential filter design changes (additional headloss).

Results: **MET IN FULL**

Filter backwash protocol was updated September 5 to shift from FTW to a RTW protocol. This RTW procedure requires less BW water and may improve filter turbidity during transitions from BW to service. Table 33 shows a summary of UBV and UBWV based on these changes. It was observed that this change in BW regime to RTW did not impact clean bed headloss (CBHL) (Figure 81).

Table 33 Filter UBWV and UBV with FTW and RTW Backwash(1)

	UBWV (gal)		URV (gal/sq ft)	
	RTW	FTW(2)	RTW	FTW(2)
F1	39.2	115.8	199.7	589.6
F2	54.2	109.6	275.9	558.0
F3	51.7	96.6	263.5	492.2
F4	46.0	83.0	234.4	422.5

Notes:
(1) FTW was tested 12/17/20-9/5/21; RTW was tested 9/5/21.
(2) FTW assumes FTW step F1: 20 min, F2: 10 min, F3: 15 min, F4: 16 min and LR F1: 4.6, F2: 8, F3: 4.6, F4: 3.7 gpm/sq ft (does not acct for ramping).
Both scenarios assume refill duration: 3 min.

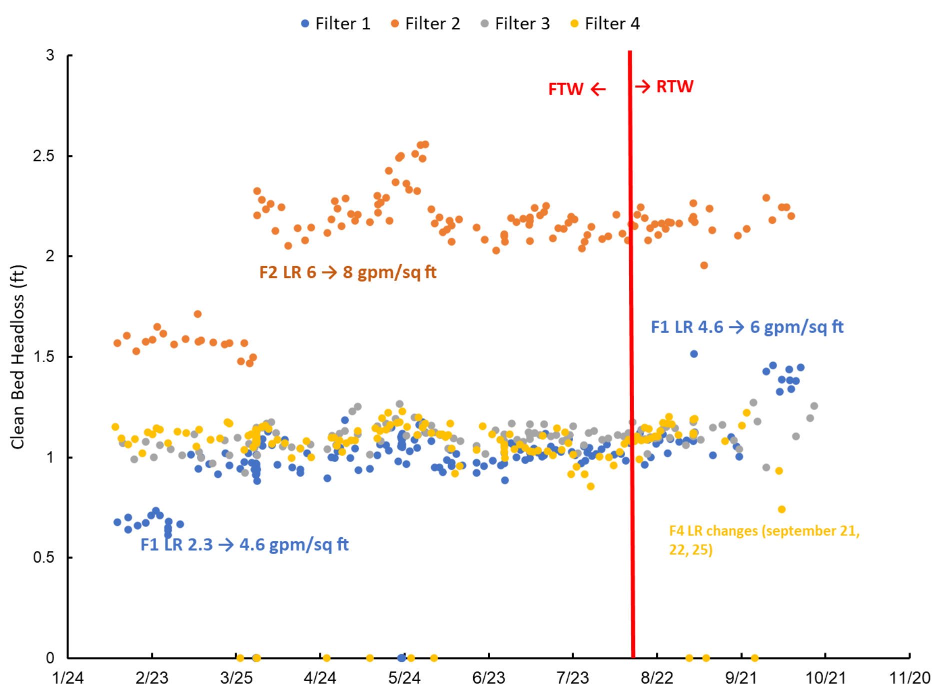


Figure 81 Filter CBHL with FTW and RTW

Objective 24:

Perform analysis of biological growth with different pretreatment (ability to handle T&O, TOC removal).

Results: **MET IN FULL**

In general, the filters during pilot testing did not receive as high TOC or T&O as with full-scale (a result of effective upstream process operations), and so the removal burder on the filters was low. As previously discussed, nutrient supplementation was investigated but not tested due to the measured lack of nutrient deprivation. The use of peroxide and chlorine (bleach) pre-filters was tested as a microflocculation control (to mitigate high headloss issues). However, these pre-treatment schemes were tested during Phase 3 of testing when there was negligible T&O compounds to determine filter removal performance.

T&O compounds were controlled well by COT operators with the spraying of the HR with copper sulfate during algae season. MIB and Geosmin were detected in the RW during the pilot as seen in Figure 82; all of the detectable T&O occurred during Phase 2 of pilot testing. Due to short time frame with T&O was in the RW, it is difficult to assess filter T&O removal capabilities; Figure 83 shows the pre-filter T&O levels and subsequent finished T&O. Finished T&O was consistently below the level of detection (1 µg/L) throughout the pilot.

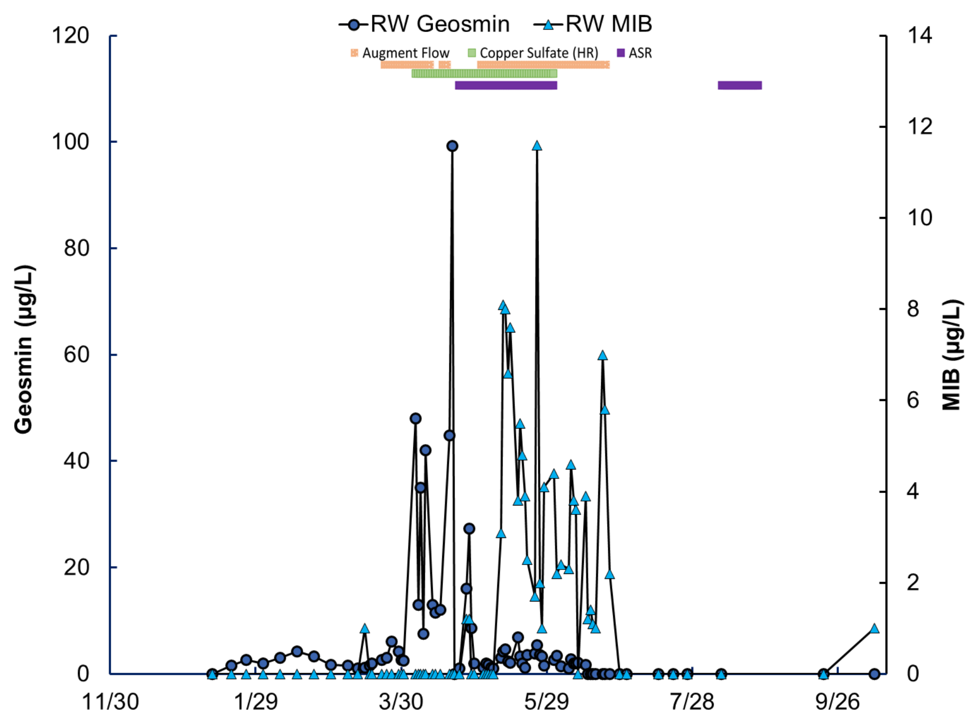


Figure 82 RW Geosmin and MIB

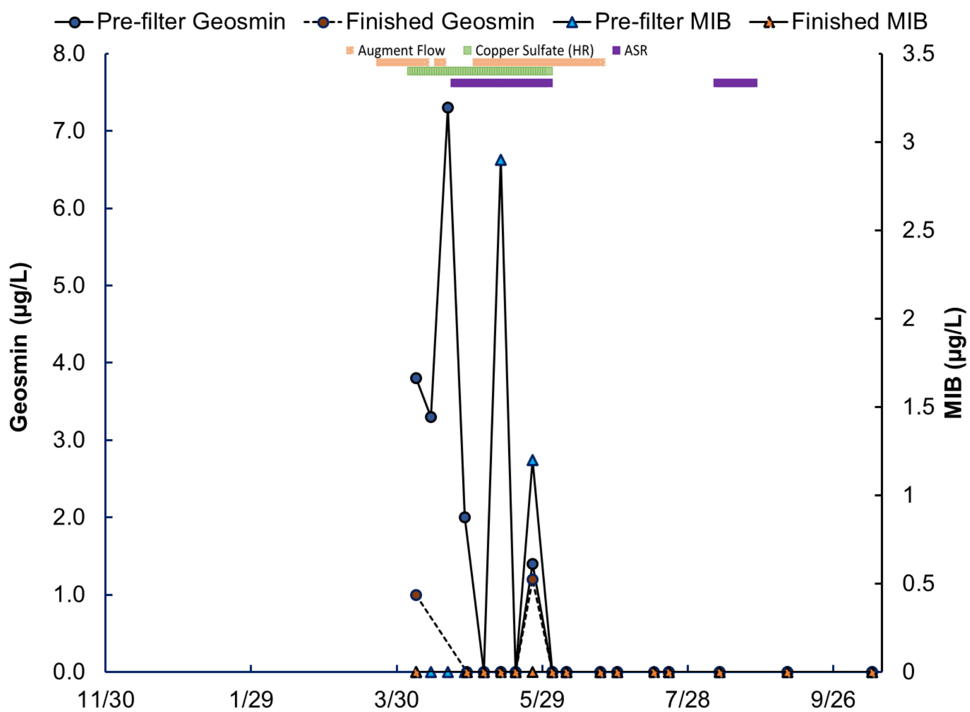


Figure 83 SIX® Pre-Filter and Finished T&O

The ability of SIX® to remove both organics and alkalinity resulting in more effective coagulation and lower finished water TOC. The average finished water TOC from the SIX® pilot was 1.4 mg/L as compared to the full-scale TOC 2.4 mg/L. The lower TOC results in lower ozone demand. This lower ozone demand and competing reactions provide more ability to oxidize taste and odor compounds while minimizing bromate formation (due to lower ozone demand).

Section 9

FULL-SCALE EC, MIEX®, AND SIX® COMPARISON

9.1 Ion Exchange

The SIX® and MIEX® pilots sought to understand better ion exchange performance with the seasonably variable water quality at DLTWTF. The MIEX® pilot was run for a much shorter duration (October 4,2017-February 5, 2018). It is also important to note that the MIEX® pilot was run intermittently during that time. An overview of the differences between the SIX® and MIEX® process can be found in Section 1.2.1 Piloting Ion Exchange at DLTWTF - MIEX® and SIX®. A comparison summary is provided in Table 34.

Table 34 Ion Exchange Pilot Comparison: SIX® and MIEX®

	SIX®		MIEX®	
	High TOC	Low TOC	High TOC	Low TOC
Salt Use	1545 lb/ MG		650 lb/MG(1)	
Resin Fouling	none observed		required chlorine	
TOC Removal(2) (%)	43%	65%	67%	55%
Alkalinity Removal (%)	53%	42%	11%	4%

Notes:
(1) MIEX® salt usage from MIEX® pilot report, assumed based on reference from IXOM, not collected pilot data.
(2) SIX® TOC removal from UVA data.

Resin regeneration frequency is much higher with SIX®, which results in the resin less heavily loaded. With lightly loaded resin, SIX® regeneration is quicker and uses lower brine concentration but removes other anions. The more frequent regeneration and less heavy loading results in higher salt use than MIEX®. A generic, off-the-shelf SBA resin was used during the SIX® pilot; MIEX® utilizes a proprietary magnetic resin with a particularly high affinity for NOM removal, resulting in higher TOC removal than SIX®. Due to the generic affinity properties of the SIX® resin along with less heavily loading of the resin, a significant amount of anions will be removed; this is evident in the alkalinity removal by SIX®.

It should be noted that some investigation of the potential for salt supply from the Tampa Bay Seawater Desalination project was investigated. Both the seawater feed and reverse osmosis streams were analyzed. Although the brine concentration covered an extensive range, the anticipated chloride concentration once optimized ranged from 14,700 to 18,350 mg/L. The chloride concentration of the seawater feed was 14,000 mg/L and the reverse osmosis concentrate was 36,000 mg/L. To provide 1,285 lbs per million gallons of water treated at 140 mgd, a flowrate of 328 gpm of reverse osmosis would be required and the net present value of the salt savings would be approximately $31.7 million (assuming an average demand of 90 mgd and no salt cost escalation). The only anion in the seawater that could interfere with the anion exchange process is sulfate which is 4,800 mg/L in the reverse osmosis concentrate stream. The sulfate concentration in other SIX® projects has been as high as 7,500 mg/L, so problems with sulfate would not be anticipated. Additional water quality from these samples is included in Table 35.

Table 35 TBW Desal Feed and Concentrate Stream WQ

Analyte	Units	Desal Feed	Desal Concentrate
pH		7.9	7.7
Alkalinity	mg/L as $CaCO_3$	120	270
Total Hardness	mg/L as $CaCO_3$	4800	12000
TOC	mg/L	2.3	4.9
TDS	mg/L	25000	65000
Chloride	mg/L	14000	36000
Sulfate	mg/L	1800	4800
Bromide	mg/L	46	120
Sodium	mg/L	7700	18000
Calcium	mg/L	320	780

The TBW Desal plant typically operates six or seven months per year (early-December through early-June/July). While in operation, the plant typically processes 20 MGD, producing 10 MGD of concentrate (monthly average December 2021). Future flows at this plant are not expected to be reduced; if brine concentrate can be used for an IX regenerant, the desal plant could process more flow. Regardless of whether the plant is operating, raw seawater could still be sent to DLTWTF, offsetting some of the regenerant needs.

9.2 Coagulation

Coagulation will remain the second treatment process at DLTWTF through the MP improvements. As expected, with roughly half of the TOC removed by upstream ion exchange along with alkalinity removal (resulting in lower coagulation pHs), downsteam coagulation chemical usage is lower. A significant difference in SIX® and MIEX® coagulation was observed due to the lower alkalinity in the SIX® effluent. Currently, full-scale operations require sulfuric acid most of the year to achieve the necessary low coagulation pH to remove adequate TOC. With lower alkalinity in the SIX® effluent, coagulation pH was lower and more TOC was removed with less ferric sulfate than MIEX®. It is important to note that the SIX® pilot coagulation was operated to achieve neutral ZP. In contrast, the MIEX® pilot coagulation was operated to achieve color removal (same as full-scale). Table 36 provides a comparison summary of coagulation operations and performance during both the SIX® and MIEX® pilots, as well as full-scale performance during the SIX® pilot test period.

Table 36 Coagulation Comparison: Full-Scale, SIX®, and MIEX®

	SIX®		MIEX®		Full-Scale(1)	
	High TOC	Low TOC	High TOC	Low TOC	High TOC	Low TOC
Ferric Sulfate Dose (mg/L)	48	41	109	72	167	100
Sulfuric Acid Dose (mg/L)	N/A	N/A	N/A	N/A	15	85
Coagulation pH	4.32	6.43	6.5	7.2	4.47	4.81
Avg RW TOC (mg/L)	21	9.8	19	9.6	21	9.8
Avg FW TOC (mg/L)	1.8	1.2	2.9	2.0	3.0	2.4
TOC Removal (%)	74%	46%	54%	20%	87%	58%

Notes:
(1) Full-scale data collected during SIX® pilot.

9.3 Ozone

Ozone dose correlates strongly with pre-ozone TOC. With the lowest pre-ozone TOC, the SIX® pilot ozone resulted in the lowest ozone demand. Generally, ozone was operated full-scale to achieve 0.5 mg/L residual at 5.5 min CT; the SIX® pilot followed this closely, full-scale regularly must lower the ozone dose to avoid residual carry over to the filters. MIEX® ozone operations targeted a residual of 0.3 mg/L at 5.0 minute CT to match full-scale operations at that time and the ozone equipment was not as reliable as the ozone system used during the SIX® pilot. Table 37 provides a comparison summary of ozone operations during both the SIX® and MIEX® pilots, as well as full-scale performance during the SIX® pilot test period.

Table 37 Ozone Comparison: Full-Scale, SIX®, and MIEX®

	SIX®		MIEX®		Full-Scale(1)	
	High TOC	Low TOC	High TOC	Low TOC	High TOC	Low TOC
Ozone Dose (mg/L)(2)	2.54	1.60	4.8	1.78	4.30	2.37
Pre-Ozone TOC (mg/L)	2.89	1.84	3.87	2.44	4.11	3.28
O_3:TOC ratio(3)	0.89	0.87	1.24	0.73	1.05	0.72
Caustic Dose (mg/L)(4)	50	11	21	6	22	54

Notes:
(1) Full-scale data collection during SIX® pilot.
(2) Lower confidence in MIEX® ozone dose data.
(3) Typical O_3:TOC for pre-ozonation is between 0.5-1.0 mg O_3 per mg of carbon
(4) SIX® caustic dose adjusted for alkalinity control as shown in Table 47.

As previously described, with significant alkalinity removal from SIX®, the SIX® pilot did not always meet the finished WQ goal of 46 mg/L alkalinity during low RW alkalinity periods. Based on RTW findings, caustic and carbon dioxide doses were determined to achieve the goal.

9.4 Filters

Filter LRs during SIX® piloting were adjusted during the pilot to understand the limitations of the filter performance. Data presented in Table 38 for the SIX® pilot summarizes data from Filter 1 (control filter media), full-scale data is from Filter 24, MIEX® pilot filters were run similarly and the data averaged. Table 38 provides a comparison summary of filter operations and performance during both the SIX® and MIEX® pilots, as well as full-scale performance during the SIX® pilot test period. Compared with full-scale and MIEX pilot filter performance, SIX filter performance was significantly higher; the ability to operate filters at much higher loading rates is attributed to achieving reduced headloss with neutral coagulation ZP.

Table 38 Filter Comparison: Full-Scale, SIX®, and MIEX®(1)

	SIX®		MIEX®		Full-Scale	
	High TOC	Low TOC	High TOC	Low TOC	High TOC	Low TOC
Avg UFRV (gal/sq ft)	9208	11371	4411	3990	4040	4387
Avg LR (gpm/sq ft)	4.88	4.12	2.2	2.3-4.0	2.32	2.27
Max LR (gpm/sq ft)	6	4.6	2.2	4.0	2.71	2.85

Notes:
(1) Table data from the following: SIX® Filter 1 (control), full-scale Filter 24, and MIEX® range and average of the four filters.

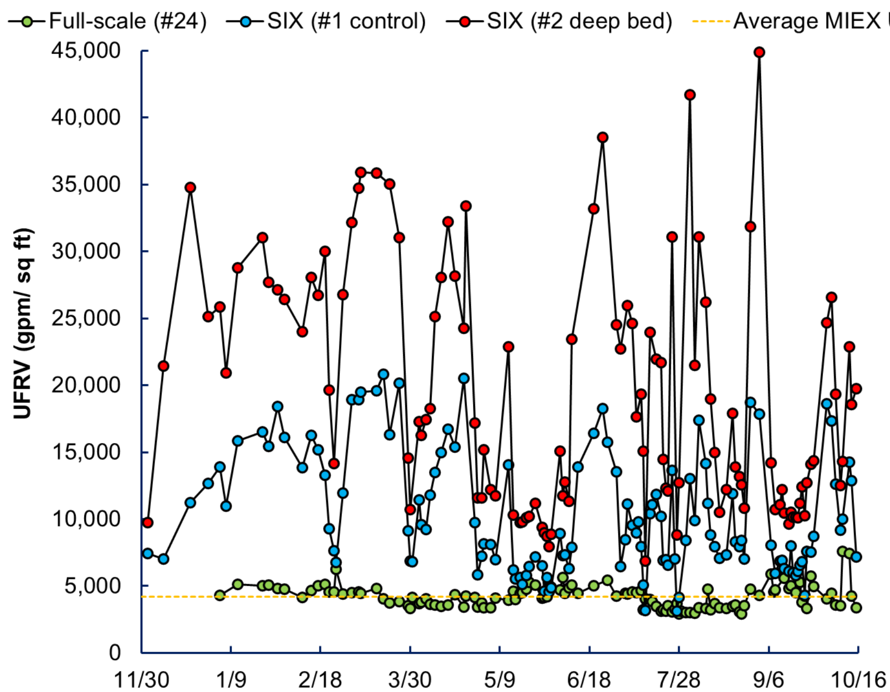


Figure 84 Full-Scale, SIX®, and MIEX® Pilot Filter UFRV Comparison

9.5 Water Quality

Full-scale water quality data is summarized from the SIX® pilot test dates. Three particular parameters highlight the major differences in performance between SIX®, MIEX®, and current full-scale operations: TOC, alkalinity, and chloride (a byproduct of ion exchange resin regeneration). A summary of these WQ parameters for RW and finished is provided in Table 39.

Table 39 WQ Comparison: Full-Scale, SIX®, and MIEX®(1)

WQ Parameter		SIX®		MIEX®		Full-Scale	
		High TOC	Low TOC	High TOC	Low TOC	High TOC	Low TOC
RW	Avg TOC	same as full-scale		19	9.6	21	9.8
	Avg Alkalinity			97	141	62	127
	Avg Chloride			17	21	17	22
	Avg pH			7.3	7.8	7.0	7.7
Finished	Avg TOC	1.8	1.2	2.9	2.0	3.0	2.4
	Avg Alkalinity	27	57	85	123	61	94
	Avg Chloride	73	100	44	46	4.6	4.4
	Avg pH	6.8	7.3	7.4	7.4	7.87	7.88

Notes:
(1) Table data is from the following: SIX® and full-scale data from 11/30/20-10/15/21 and MIEX® from 10/11/17-1/22/18.

9.5.1 TOC

Figure 85 provides an overview of finished water TOC with respect to the overall finished water goal of meeting below 2 mg/L. Generally, full-scale can only meet this goal during very low RW TOC periods. The MIEX® pilot struggled to achieve the goal during higher RW TOC periods, but was successful during low TOC conditions. With the SIX® pilot and targeting neutral ZP for coagulation, the 2 mg/L goal >95 percent of the time was met.

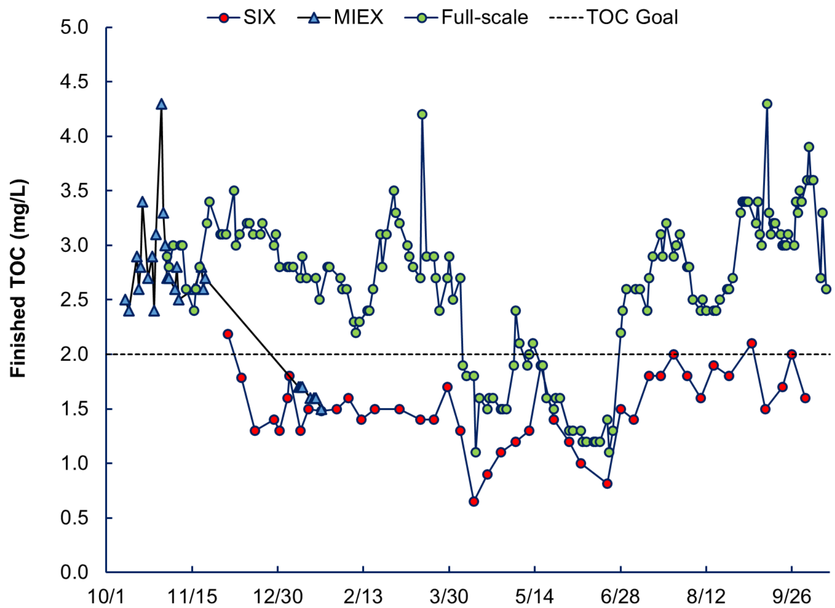


Figure 85 Finished TOC - SIX®, MIEX®, Full-Scale

9.5.2 Alkalinity

Figure 86 highlights another key difference between SIX®, MIEX®, and current full-scale concerning alkalinity. Alkalinity shifts significantly seasonally inversely to TOC; when TOC is low, alkalinity is high, and vice versa. With minimal alkalinity removal of MIEX® (due to the TOC-specific affinity of the resin and heavily loaded resin), finished alkalinity remained above the WQ goal of 46 mg/L as $CaCO_3$ throughout the testing. With SIX®, however, the generic SBA resin removes alkalinity (HCO_3^- and CO_3^{2-}). During periods of low RW alkalinity it is anticipated that alkalinity, in the form of carbon dioxide and caustic, be added back into the sedimentation basin effluent to meet this goal and avoid any issues in the DS.

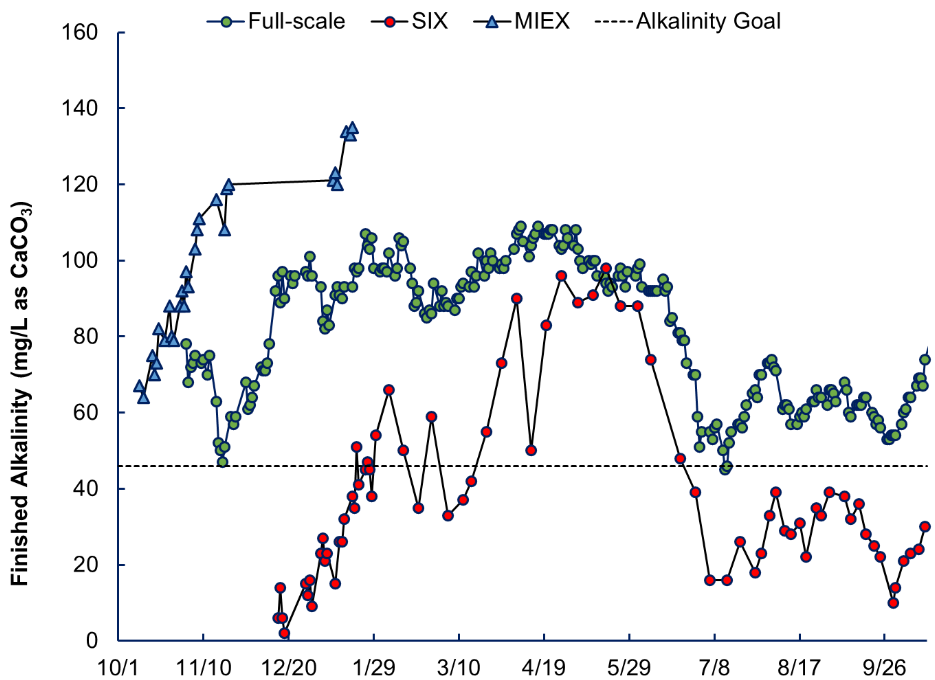


Figure 86 Finished Alkalinity - SIX®, MIEX®, Full-Scale

9.5.3 Chloride

Figure 87 highlights the significant increase in chloride that is expected of the finished WQ with a full-scale ion exchange technology installation. Due to the higher regeneration frequency, SIX® effluent chloride is higher than that of MIEX®. It is possible that full-scale SIX® chloride will be lower with further optimization. It is important to note; neither process resulted in chloride levels exceeding the MCL (250 mg/L).

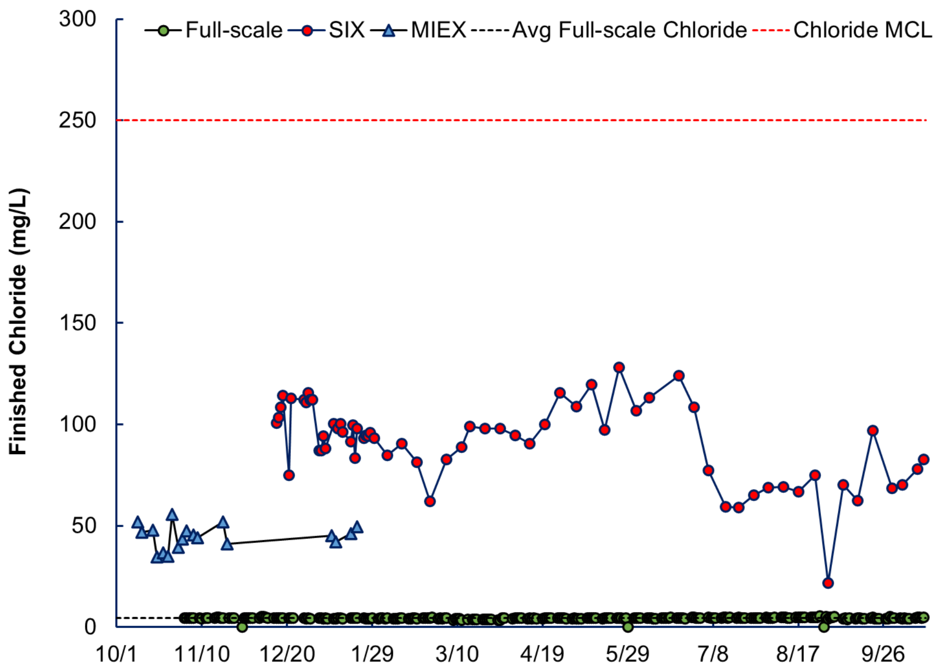


Figure 87 Finished Chloride - SIX®, MIEX®, Full-Scale

9.5.3.1 Chloride-to-Sulfate Mass Ratio (CSMR)

As previously discussed in the MIEX® Pilot Study Report, the CSMR will change with incorporating an ion exchange process at the DLTWTF. With the additional chloride byproduct of the ion exchange resin regeneration process and removal of sulfate, finished water quality will have higher CSMR. The CSMR is calculated as follows.

$$CSMR = \frac{[Cl^-]}{[SO_4^{2-}]} \qquad \text{Eq. 1}$$

According to the EPA guidelines summarized in Table 40, CSMR and lead leaching is not a concern if there is no lead in the distribution system (DS). City staff has confirmed that there is no lead in the DS, and so there is no concern; however if lead pipe existed, there is a risk of contamination regarding the installation of an ion exchange process. Based on the finished WQ at both the SIX® and MIEX® pilot, CSMR ranges were calculated compared to full-scale and summarized in Table 41.

Table 40 EPA Recommended Level of Lead Concern Relative to CSMR of Water

CSMR	Concern Level
No lead solder or lead pipe in distribution	No Concern
CSMR < 0.2	No Concern
0.2 < CSMR <0.5	Significant Concern
CSMR > 0.5, and alkalinity <50 mg/L as $CaCO_3$	Serious Concern

Table 41 Summary of CSMR of Finished Water

	High TOC	Low TOC
Current Full-Scale(1)	1.1	0.88
SIX®	1.8	3.0
MIEX®	1.3	1.8

Notes:
(1) Note full-scale data from SIX® pilot time period. Sulfate data is needed to calculate this parameter. Will be updated in final draft.

It should be noted that the increase of chlorides combined with the drop in sulfate will increase the rate of corrosion of carbon steel and could result in potential attack of 304 stainless steel. Due to this potential, all stainless steel downstream of the SIX® process will standardize on 316 stainless steel as a part of future projecs.

Section 10

ECONOMIC ANALYSIS

With the results of this pilot study, additional economic analysis was required to update net present values and overall economic feasibility compared to existing operations (Refer to baseline Alternative 1B, DLTWTF Expansion without IX in the Original Master Plan completed in 2018) and SIX® operations. Capital costs for implementation of SIX® are greater than existing facility modifications; however, if chemical costs can be reduced enough, then the payback period could justify the capital expense. This section details the results of the economic analysis, including comparisons to existing operations and the MIEX® economic analysis completed in 2018.

Due to the significant seasonal variations in water quality and subsequent treatment and dosing scheme, the economic analysis conducted considered low and high TOC seasons and costs associated with each. High TOC season and low TOC season were quantified as any days where raw water TOC is consistently above 15 mg/L or below 15 mg/L, respectively. Full-scale and SIX® pilot-scale chemical doses were used in conjunction with the full-scale raw water flow rate of 80 mgd to calculate a pound per day chemical usage.

Using the assumed chemical costs below, an average total cost for chemicals per day could be determined (based on chemical costs reported by the City in 2018).

- Ferric sulfate: $0.08 per pound.
- Lime: $0.11 per pound.
- Caustic: $0.26 per pound.
- Sulfuric Acid: $0.06 per pound.
- Chlorine: $0.26 per pound.
- Polymer: $1.38 per pound.
- Chlorine: $0.26 per pound.
- Ozone: $0.84 per pound (including power).
- Carbon dioxide: $0.06 per pound.
- Salt: $0.06 per pound.

Costs for all other plant chemicals like fluoride, ammonia, and hydrogen peroxide were not included in this analysis since they are not expected to differ (on average) between SIX® pretreatment and the existing enhanced coagulation treatment processes.

Operating and maintenance costs were developed for the alternatives evaluation only and were based on knowledge of the DLTWTF's existing power and chemical costs in addition to annual costs incurred specific to each alternative. Solids handling was assumed to cost $0.02 per pound of sludge produced and power was $0.08 per kWh. It was assumed that chemicals and power costs will increase at a rate of 3 percent per year, while sludge disposal costs will increase at a rate of 6 percent per year due to the reduction in land availability as the population in the area grows. Operating costs were evaluated at average annual daily flows for each year based on the B&V 2018 Master Plan Report flow projections. Life cycle costs were developed to determine the 20-year and 30-year net present value of SIX®. The operating costs were discounted at a rate of 3 percent to net present value. A reoccurring yearly cost of $200,000 per year was used for SIX® resin replacement.

10.1 Results

Table 42 shows the seasonal chemical costs in dollars per million gallons treated comparing existing full-scale operations to SIX® pilot operations. SIX® was a significantly lower cost for treatment during low TOC season, at $153/MG compared to the existing system cost of $271/MG, but surprisingly higher during high TOC season, $263/MG versus $222/MG, respectively (although anions in the water during high TOC season did drop and it is believed that salt use was not fully optimized during this time frame like it was for MIEX®). This difference is lessened when considering the SIX® pilot removed more TOC than full-scale, as shown in Table 43 and was able to meet the City's finished water quality goals (while current operation and the MIEX® pilot were not able to meet the goals). When normalized for the added TOC removal by SIX® (91 percent in high TOC season and 86 percent in low TOC season), the differential in high TOC season is reduced and benefit in low TOC season is increased. Over the course of the year, SIX® will have lower chemical and operational costs.

When comparing this to the previously completed MIEX® study, which resulted in a high TOC season cost of $176/MG and low TOC cost of $117/MG, the greatest differing factors are (1) higher salt usage in SIX®, (2) use of caustic for alkalinity recovery post coagulation. Salt use in the SIX® pilot was 4.7 times more than the assumed salt use in MIEX®. Salt and caustic in the SIX® pilot alone make up $205/MG of the $263/MG in high TOC and $113/MG of the $153/MG in the low TOC season. Non-cost benefits of alkalinity reduction have been summarized in previous sections of this report and options for salt costs reduction are detailed herein.

Table 42 Seasonal Total Chemical Costs

Operation(1)	Units	High TOC Season(2)	Low TOC Season(3)
Existing, Full-Scale	$/MG	$222	$271
SIX® Pilot	$/MG	$263	$153
Differential		+$41	-$118
% Difference		18.5% increase	43.5% decrease

Notes:
(1) During pilot operations from November 30, 2020 - October 15, 2021.
(2) High TOC occurred from December 15, 2020 - July 1, 2021.
(3) Low TOC season occurred from July 1, 2021 - October 15, 2021.

Table 43 Seasonal Differential Chemical Costs Normalized for TOC Removal

Operation	Units	High TOC Season	Low TOC Season	
Existing, Full-Scale	%	84%	72%	TOC Removed
SIX® Pilot	%	91%	86%	TOC Removed
Differential Normalized		+$22	-$171	
% Difference Normalized		9.3% increase	52.9% decrease	

The seasonal unit costs developed in Table 42 were used in the overall economic and net present worth analysis. SIX® Power usage at a future average day flowrate of 90 mgd was provided and assumed to be 125 kWh per million gallons per day treated. This power includes instrument air, process water pumping, fresh brine pumping, waste brine pumping, resin pumping, and the SIX® blowers. Solids production with SIX® would be reduced by 63 percent which was accounted for in the capital and O&M costs.

Capital costs developed for the existing full-scale alternative (1B-Expanded Conventional Treatment) have been maintained and escalated (using ENR Indices = ~12.2 percent increase) from the Original Master Plan completed in 2018. Those costs include new plate settlers and flocculators, concrete construction, demolition, and repair (for expansion of basin treatment capacity to 100 mgd), expanded chemical systems, 48 mgd of new filters, and sludge processing facility upgrades. In summary, the capital cost of Alternative 1B from the original master plan is shown in Figure 88. This value was multiplied by the November 2021 ENR value of 12,467 and divided by the July 2018 ENR value of 11,116 to get to today's total capital cost dollar value of $86M.

Table 5.7 Alternative 1B Capital Costs
David L. Tippin Water Treatment Facility Master Plan
City of Tampa

Item	Cost
Plate Settlers	$5,400,000
Flocculators	$720,000
Concrete Demolition	$725,000
Concrete	$1,545,000
Concrete Coating	$1,907,000
Chemical Systems Expansion	$2,104,000
New Filters (22 new, 48 mgd)	$24,960,000
Sludge Processing Facility Upgrades	$1,656,000
Site Work (5 percent)	$1,950,000
Piping, Valves, Appurtenances (15 percent)	$5,850,000
EI&C (20 percent)	$7,800,000
Total Direct Cost	**$54,617,000**
Contingency (25 percent)	$13,660,000
GC OH&P (12 percent)	$6,555,000
Sales Tax (7 percent)	$1,910,000
Total	**$76,742,000**

Figure 88 Alternative 1B Capital Cost Assumption from Chapter 5 of 2018 Master Plan

Capital cost assumptions were presented in Task Order 2 - Master Plan Update, Workshop 3 and are shown in Figure 89. Cost of additional filters was not included in the SIX® capital costs since increased loading rates of 6-8 gpm/sqft, made possible by SIX®, do not require additional filtration capacity at the plant (existing operations and the MIEX® option would require additional filters). Additional capacity in the filter is still recommended; however, due to the increased ability to retire old filters, take filters out of service, and maintain filter effluent flumes without impacting DLTWTF production. It was assumed SIX® would require one less belt filter press at the solids handling facility, which was incorporated into the costs. SIX® capital costs including expanding the existing conventional basins to 100 mgd and maintaining the existing Actiflo® system, a 2021 cost of $27M, for better comparison to the baseline Alternative 1B, for a total capital cost of $122M for SIX® implementation.

Process/MEICA	$32,370,000
Civil/Structural	$22,960,000
Subtotal	$55,330,000
Contingency (30%)	$16,599,000
Engineering (15%)	$10,789,350
GC O&HP (12%)	$8,631,480
Total Construction	**$91,349,830**
Resin (ODP)	$4,500,000
Total	**$95,849,830**

Figure 89 SIX® Capital Cost Assumptions from Master Plan Update

Table 44 shows the life cycle cost comparison when considering O&M costs. The existing conventional basin rehabilitation in 15 and 30 years was removed from the comparison since the SIX® process will still employ a low pH coagulation process. With an annual O&M savings of $1.6M, the SIX® process has a little over a 20-year payback period and becomes more economically favorable after 30 years.

Table 44 Economic Analysis Summary (in millions)

	Baseline 1B Expansion of Conventional System	SIX®
Capital Cost	$86.1	$122
Annual O&M Cost	$8.50	$6.90
Net Present Value (20-Year)	$256	$263
Net Present Value (30-Year)	$354	$342

10.2 Sensitivity Analysis

As previously discussed, the major cost implication of SIX® is related to salt usage. If alternative or supplemental means for salt supply could be considered, the payback period and annual O&M savings with SIX® implementation could be significant. This sensitivity analysis considers the use of Tampa Bay Water's desalination concentrate water for 100 percent salt supply. The project would include a ~20 mile, 6 inch ductile pipeline from TBW's desalination facility to DLTWTF at an approximate capital cost of $27M (assumed cost for urban construction). As shown in Table 45, elimination of the cost of purchased salt would result in an annual O&M savings of $4.6M compared to existing full-scale operations. This would result in a payback period for the desal pipeline of less than 15 years.

Table 45 Economic Analysis Summary (in millions)

	Baseline 1B Expansion of Conventional System	SIX®	SIX® with Desal Salt Supply
Capital Cost	$86.1	$122	$149
Annual O&M Cost	$8.50	$6.90	$3.90
Net Present Value (20-Year)	$256	$263	$231
Net Present Value (30-Year)	$354	$342	$277

Section 11

REGULATORY

This section contains an overview of the collected pilot data to assist the regulators, including FDOH, in understanding the SIX® process and implications downstream, particularly the filters. In addition to a preliminary design report, manufacturer technical information and operations and maintenance requirements will be developed during the design phase of the SIX® project (to occur in 2022/2023). This section of the report will provide the supporting information as required by the F.A.C. stated below.

The City of Tampa Water Department falls under the Hillsborough County Florida Department of Health (FDOH) jurisdiction for matters related to enforcement of the Florida Administrative Code (F.A.C.) Chapter 62. The pilot study required the Florida Department of Environmental Protection (FDEP) form 62-555.520 and received a permit to operate under Permit Number 0168017-1608 WC/MM. The operation of the pilot study was conducted by and under the requirements of the permit.

Regarding full-scale implementation, the F.A.C. address design and construction of public water systems, per Rule 62-55.320(2)(a) through (c):

> *(2) Innovative or Alternative Processes and Equipment. The Department encourages the development of new treatment processes and equipment. However, construction permits for innovative or alternative treatment processes or equipment (i.e., treatment processes or equipment not covered in the engineering references listed in Rule 62-555.330, F.A.C.) shall not be issued unless construction permit applicants include in the preliminary design report or design data accompanying their permit application supporting information demonstrating to the Department that the process or equipment is capable of consistently and reliably producing drinking water meeting applicable standards in Chapter 62-550, F.A.C., and requirements in this chapter. Supporting information shall include the following:*
>
> *(a) The manufacturer's technical information;*
>
> *(b) Data and reports from full-scale or pilot-plant installations that are operated under conditions comparable to those for which the process or equipment is being proposed and that are operated for a sufficient time to verify satisfactory performance of the process or equipment; and,*
>
> *(c) Operation and maintenance requirements and availability of technical support.*

11.1 SIX®

TOC is on the list of target containments to be removed at DLTWTF since TOC is a precursor to regulated disinfection by-products (DBPs). The City strives to produce treated water with a low TOC content. Therefore, although only a specific TOC removal percentage ranging from 25 percent to 50 percent is regulated, the pilot study set forth an effluent TOC goal of 2.0 mg/L (in addition to overall removal percentages). As shown in Figure 90, the pilot resulted in consistently meeting this goal for over 10.5 month test period (November 30, 2020-October 15, 2021), which is a significant improvement compared to existing full-scale operations, as shown in green. The SIX® process removed 30-70 percent of the raw water TOC, as shown in Figure 91.

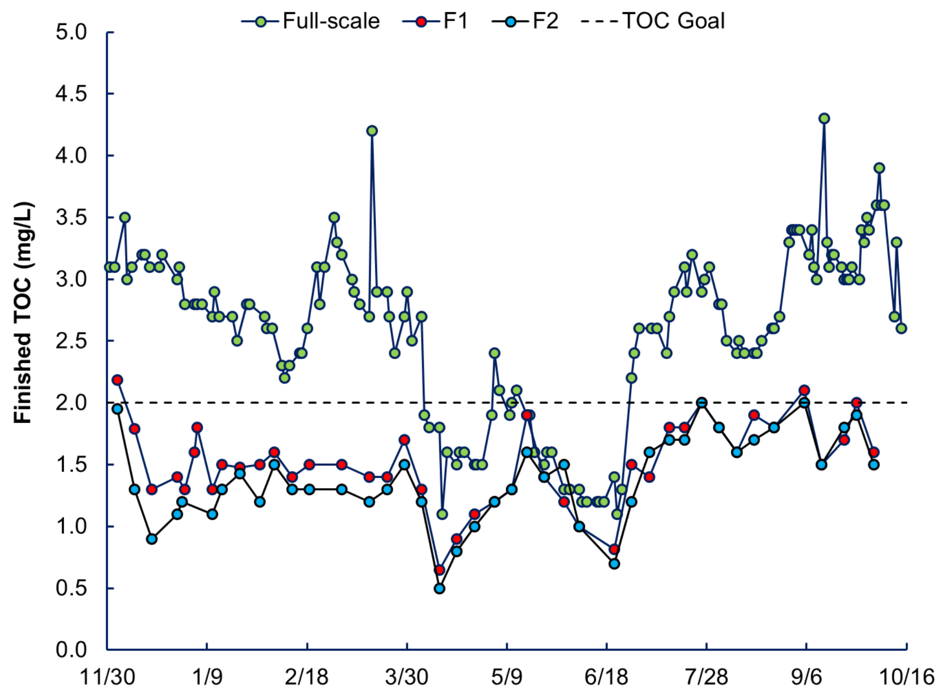


Figure 90 Finished TOC - Full-Scale and SIX® Pilot Filters 1 and 2

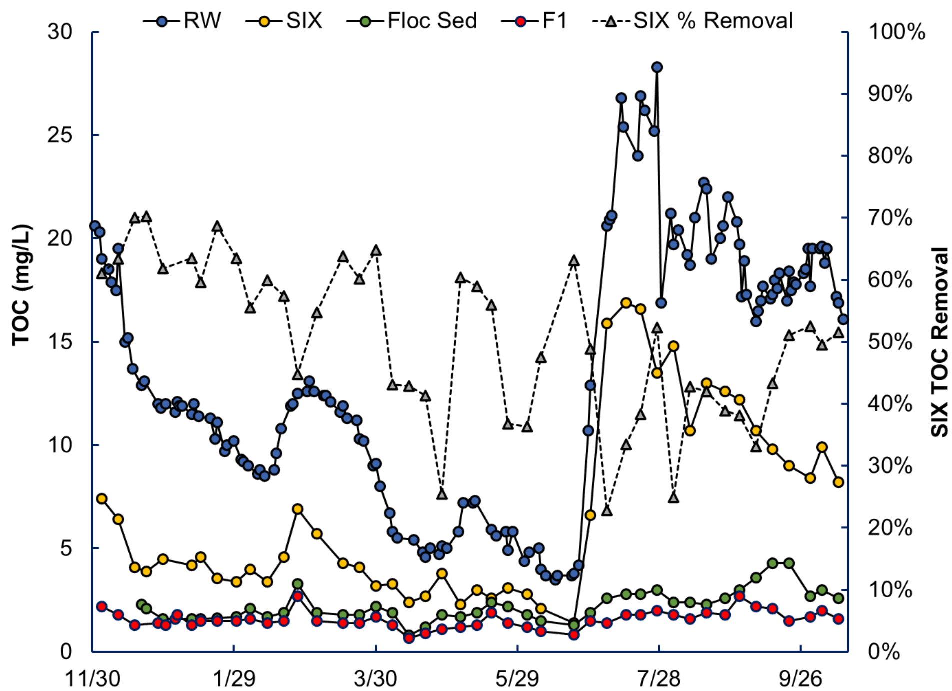


Figure 91 Pilot TOC and SIX® TOC Removal

The SIX® process offers significant savings on downstream coagulant use due to the lower alkalinity and TOC removal burden. Figure 92 shows full-scale chemical usage over the piloting period. Compared to Figure 93, the pilot chemical usage, there is an excellent reduction in ferric use. On average, the pilot-treated water required 20-40 percent of the ferric sulfate dose used by full-scale during the test period. Further, the pilot showed the elimination of the need for lime and sulfuric acid. Removing sulfuric acid from the DLTWTF will increase safety and reliability at the plant.

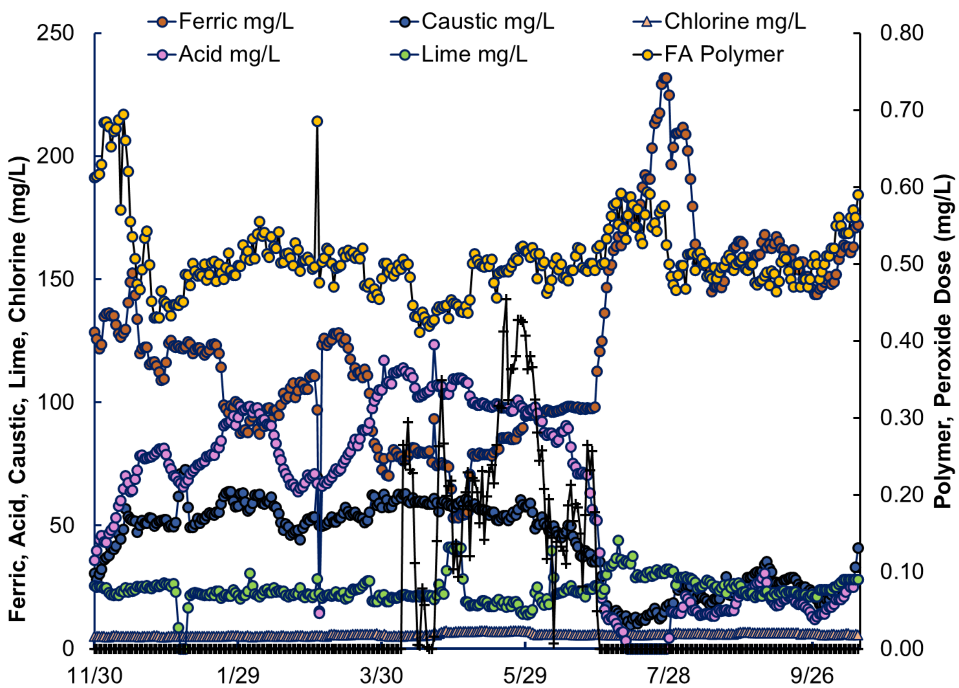


Figure 92 Full-Scale Chemical Dosing

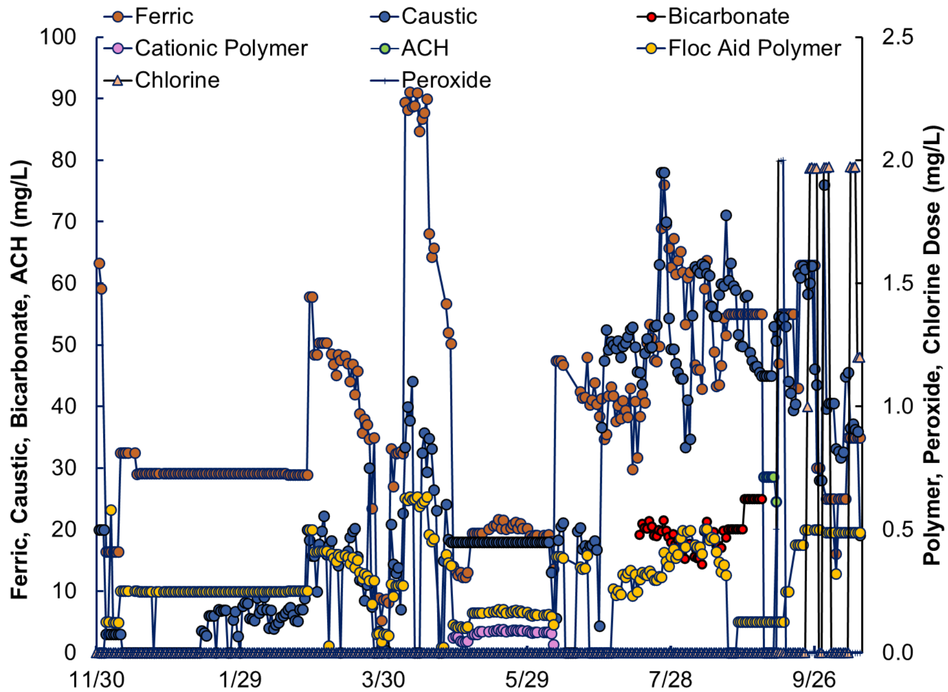


Figure 93 SIX® Pilot Chemical Dosing

Although beneficial to the coagulation process, SIX®'s ability to reduce alkalinity (between 30-70 percent), can impact treated water pH and stability. Therefore, to avoid corrosive waters and undesirable CCPP, carbon dioxide in combination with caustic will likely be required at certain times of the year. Carbon dioxide is a commonly employed chemical used at water treatment plants. To quantify the required doses during seasonal variations in water quality throughout the year, key pilot dates were looked at to bracket chemical requirements based on modeling of the chemistry (RTW model).

Table 46 summarized those findings based on anticipated ranges of RW alkalinity.

Table 46 RTW Findings for Alkalinity Control Based on Pilot Data

Pilot Data								RTW Findings				
Pilot Data Date	RW Alk (mg/L as $CaCO_3$)	RW TDS (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Ca Hardness (mg/L as $CaCO_3$)	Cl (mg/L)	SO4 (mg/L)	CCPP (mg/L) Target 4-10	pH	Carbon Dioxide Dose (mg/L)	Caustic Dose (mg/L)	Resulting Alkalinity (mg/L as $CaCO_3$)
2/4/2021	131	280	7.66	92	163	88	32.1	6.71	8	0	1	93
12/4/2020	85	200	7	21	108	94.5	15	2.16	8.41	18	20	46
4/7/2021	153	280	7.9	124	185	91	35	12.56	7.51	0	0	124
6/25/2021	105	230	7.45	58	160	110	45.4	4	8.21	0	3	62
6/28/2021	98	180	7.4	55	96	110	33.1	1.45	8.12	0	3	80
7/13/2021	50	150	6.8	11	80	59	35.8	2.23	8.5	27	28	46
Pilot Average	105	217	7	58.6	137	92.3	32.6	2.66	8	0	8	69

Table 47 Summary of RTW Dose Requirements for Corrosion Control

	RW Alk < 100	RW Alk < 85	RW Alk < 65
Carbon Dioxide Dose (mg/L)	0	18	27
Caustic Dose (mg/L)	3	20	28
Anticipated FW pH	8.2	8.4	8.5
Approx. Number of Days	20	58	72

The pilot study also showed a favorable impact on the ozone demand with SIX® in place, with lower ozone doses required by SIX® treated water, as shown in Figure 94.

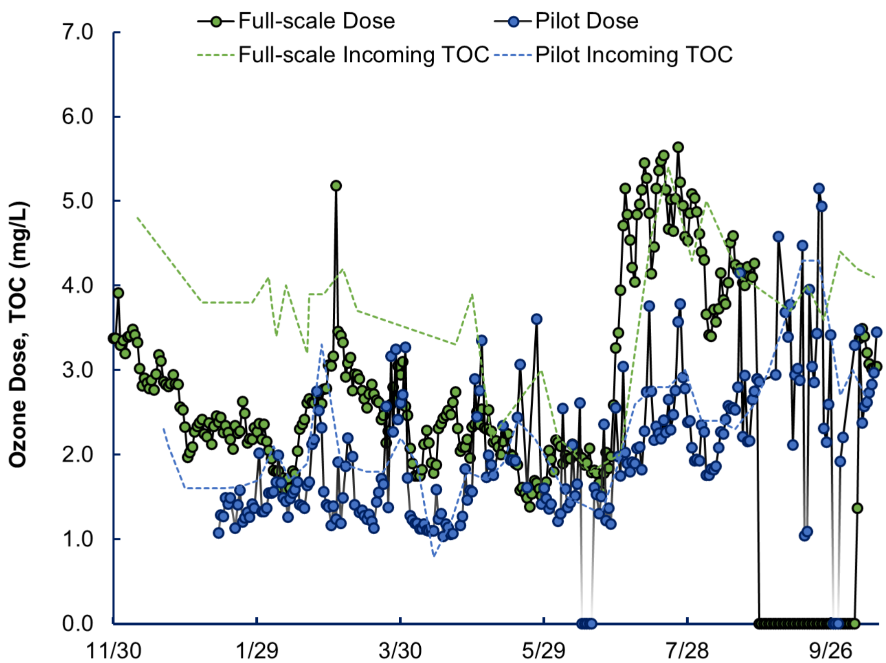


Figure 94 Full-Scale and SIX® Ozone Dose and Pre-Ozone TOC

The SIX® Process produces a waste brine solution that requires disposal. During the pilot, the volume of brine produced was inconsequential to full-scale and sent to the head of the plant. The waste brine consists of organics, sodium, and chloride but did not adversely impact full-scale operations during the pilot period. For full-scale implementation at DLTWTF, the volume of brine will be significant enough that it cannot be recycled to the head of the plant. Instead, the waste brine will be sent to deep well injection for disposal.

Currently, the City is in the process of applying for a Class I Injection Well with a permit application being submitted to FDEP via form 62-528.900(1) to permit three deep injection wells to be located at the DLTWTF facility. The full-scale SIX® system will include waste brine pumps that will serve the deep injection wells. Data from three waste brine samples over the pilot period and resulting water quality information are shown in Table 48 and Table 49. The requirements for permitting and constructing the wells will be followed in accordance with the F.A.C. and under the jurisdiction of FDEP.

Table 48 General WQ of SIX® Brine Waste

Sample	Date Sampled	pH (SU)	Conductivity (uS/cm)	Alkalinity (mg/L as $CaCO_3$)	TOC (mg/L)	TDS (mg/L)	Nitrate (mg/L - N)	Chloride (mg/L)	Sulfate (mg/L)	Bicarb (mg/L)
Brine Waste	1/25/21	8.7	26,100	760	350	20,000	2.2	6,000	2,000	920
Brine Waste	9/16/21	8.6	NT	2,700	730	13,000	3.7	4,200	2,600	NT
Caustic Brine Waste	10/1/2021	10	NT	NT	NT	110,000	NT	50,000	NT	NT

Notes:
(1) NT= not tested.

Table 49 Additional WQ Data of SIX® Brine Waste

Analyte	Units	Brine Waste (1/25/21)	Brine Waste (9/16/21)
Total Hardness	mg/L as $CaCO_3$	NT	47
Nitrite	mg/L -N	NT	0.62
TKN	mg/L - N	NT	21
Orthophosphate	mg/L - P	5.6	NT
Total Phosphate	mg/L - P	5.1	NT
Total P	mg/L - P	NT	7.1
Bromate	mg/L	NT	1
Bromide	ug/L	3,100	2,100
Silica	mg/L	4.4	7.7
Sodium	mg/L	6,800	4,000
Calcium	mg/L	36	17
Aluminum	mg/L	NT	2,000
Iron	mg/L	1	9.9
Magnesium	mg/L	3	1.2
Manganese	ug/L	NT	200
Fluoride	mg/L	4.3	7
Sulfide	mg/L	NT	0.25
Potassium	mg/L	8.5	10
Sp Conductance	umho/cm	NT	19,000
Gross Alpha	pCi/L	NT	3
Radium 226	pCi/L	NT	1
Radium 228	pCi/L	NT	1

Notes:
(1) NT= Not tested.

11.2 Filters

The introduction of SIX® and downstream processes will change the speciation and concentration of organic material in the water so that it will affect the biology in the biological filters. This was observed during the pilot study and is expected to occur full scale. The effect of this destabilization may be a change in biological activity that allows for modifications to system operations in combination with alternate filter media configurations that will reduce headloss in the filters. Current full-scale operations are limited by the headloss of the existing filters, which impacts plant capacity and efficiency. These headloss limitations may be caused by media configuration, the biofiltration process, and/or the backwash process. Implementation of the SIX® process is expected to positively impact the DLTWTF filters by increased run times and the ability to increase filter loading rates.

Pilot loading rates (LR) began within the 10 State Standards recommended range of 2.0-4.0 gpm/sq ft aside from Filter 2, a deep bed and this filter started at a LR of 6.0 gpm/sq ft. It was only after an initial satisfactory performance that filter LR was increased to determine ranges of operation and sensitivity of turbidity removal and headloss with loading rate.

Pilot Filter 1 was used as a control for the existing full-scale media configuration. The pilot study results showed successful operation at 6 gpm/sqft; therefore, once SIX® is implemented it will be requested that the full-scale filters be allowed to operate at a maximum filter loading rate of 6 gpm/sqft. A summary of Pilot Filter 1 performance at the various loading rates tested is provided in Figure 95.

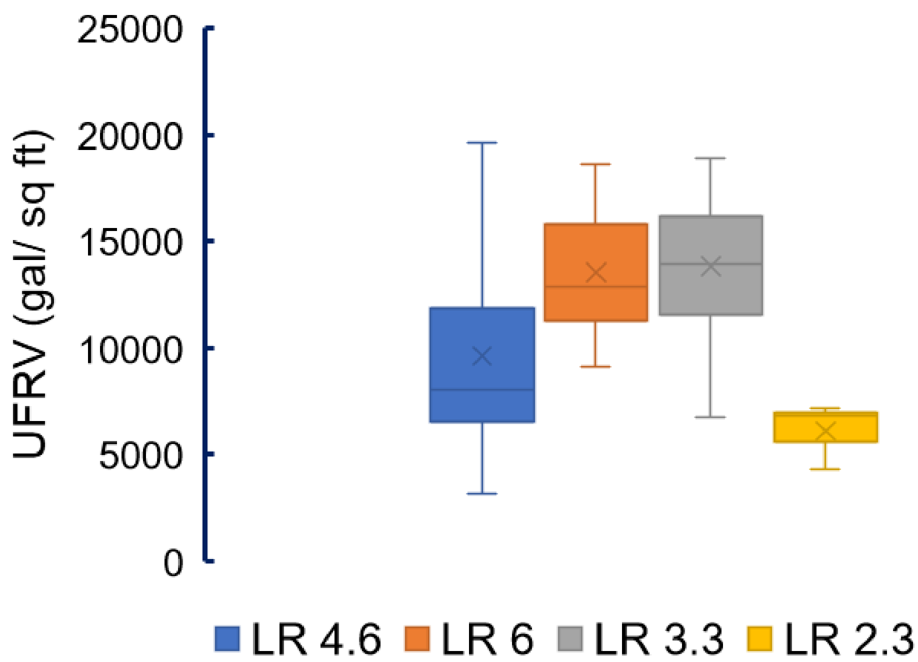


Figure 95 Filter 1 UFRV Performance vs. Loading Rate

Further, the City is in the process of designing six new dual-bay filters at the northwest end of the site. Pilot Filter 2 was determined to be the most appropriate filter configuration that the new filters should be designed to based on outstanding performance compared to the other pilot filters. In this case, the new filters would be operated at a maximum filter loading rate of 8 gpm/sqft in full-scale application (after SIX® process commissioning) based on the pilot study results. Details on Pilot Filter 1 and 2 are shown in Table 50 and Table 51. A summary of Pilot Filter 2 performance at the various loading rates tested is provided in Figure 96.

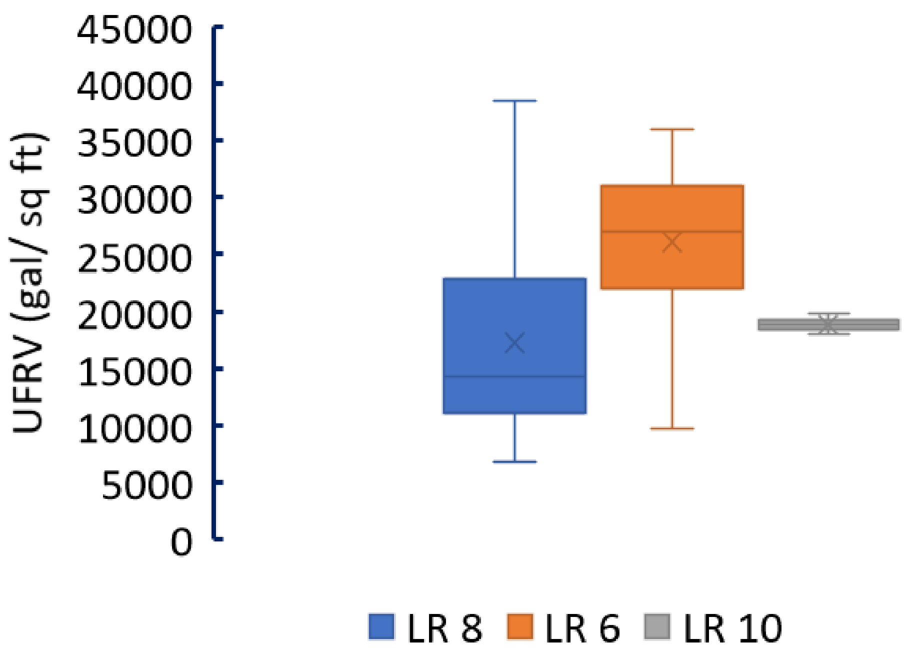


Figure 96 Filter 2 UFRV Performance vs. Loading Rate

Table 50 Existing Filter Control (Pilot Filter 1) Media Configuration and LR Request

Pilot Filter 1 "Existing Filter Control"	
GAC Depth (in)	22
Sand Depth (in)	12
ES, GAC (mm)	0.90
ES, Sand (mm)	0.50
L/D	1230
Allowable Headloss (ft)	6
Tested Loading Rates (gpm/sq ft)	3.25-8
Average Filter Run Turbidity (NTU)	0.02
Loading Rate Request (gpm/sq ft)	**6**

Table 51 New Filter Design (Pilot Filter 2) Media Configuration and LR Request

Pilot Filter 2 "New Filter"	
GAC Depth (in)	63
Sand Depth (in)	9
ES, GAC (mm)	1.40
ES, Sand (mm)	0.65
L/D	1495
Allowable Headloss (ft)	12
Tested Loading Rates (gpm/sq ft)	6-10
Average Filter Run Turbidity (NTU)	0.02
Loading Rate Request (gpm/sq ft)	**8**

Section 12

CONCLUSION

Through this pilot test, the following global results were achieved and herein described:

1. Characterize treatment performance over a range of raw water quality conditions.
2. Confirm that the selected treatment processes can reliably and continuously produce treated water that meets the City's finished water quality goals under the range of raw water quality conditions experienced from the Hillsborough River/ASR wells.
3. Establish preliminary operating criteria and range of chemical doses and waste streams that can be used to estimate project life cycle costs.

Appendix A

TEST EQUIPMENT

1.1 SIX

SIX skid specifications are summarized in Table 1.

Table 1 SIX Pilot Skid Specifications

Parameter	Value
Supplier	Ramboll
Assembled Dimensions	19' H x 16' W x 20' L
Maximum Flow Rate	50 gpm
Resin Regen Capacity	1700 gpd
Contactor Detention Time (at 30 gpm flow)	20-30 min
Feed Tank Volume	264 gal (1000 L)
Contactor Volume	924 gal (3500 L)
Lamella Settler Hopper Volume	37 gal (140 L)
Regeneration Tank Volume	37 gal (140 L)
Fresh Resin Tank Volume	74 gal (360 L)

1.2 MRI Floc/Sed

The specifications for the floc/sed skid are shown in Table 2.

Table 2 Floc/Sed Pilot Skid Specifications

Parameter	Value
Manufacturer	MRI, Inc.
Assembled Dimensions	8' H x 7' W x 18' L
Maximum Flow Rate	110 gpm
Rapid Mix	Komax in-line Mixer
3-stage Flocculator	70-20 GT
Flocculation time at 50 gpm	38 minutes
Available Settling Plates (quantity/size each)	28 @ 4.5' x 4.5'
Number of plates at 0.3 gpm/sq ft plate loading rate (at 80% efficiency) at 50 gpm	18
Available Chemical Feed Pumps (quantity/size)	5 @ 0.01 - 21.7 gpd
Sludge Collector Blowdown Rate	26 gpm

Notes:
Not all settling plates were used. A summary of plate LR is provided in section 1.2.1.2 below.

1.2.1 Coagulation/Flocculation/Sedimentation

1.2.1.1 Flocculation mixing

A mixing speed of 6 RPM was selected for the flocculator. Corresponding G values for mixing in each of the three stages is summarized in *Table 3*.

Table 3 G Values for MRI Flocculator

RPM	G (s^{-1})		
	1st stage	2nd stage	3rd stage
8	52.6	31.5	16.5
7	43.4	26.0	13.6
6	**34.2**	**20.5**	**10.7**
5.6	30.0	18.1	9.5

1.2.1.2 Sedimentation - Plate Loading Rarte

The MRI FlocSed unit used for this pilot is sized to 110 gpm and has a series of plates for settling. To achieve adequate settling and minimal solids carry-over at the operating flow of 30 gpm, additional settling plates were plugged. A summary of this is provided in Table 4 below.

Table 4 MRI Plate Loading Rate Details

	Start of pilot- Jan 28	Jan 28 - End of pilot
Floc tank (gal)	1908	1908
Flow (gpm)	30	30
Floc HRT (min)	63.6	63.6
Effective Area (ft^2)	158.0	176.5
Settling Area (ft^2/plate)	9.3	9.3
# of plates	17	19
Plate LR (gpm/ft^2)	0.19	0.17

1.3 Ozone

The specifications for the unit are shown in Table 5. The feed flow is controlled automatically. Contact chambers have 25 volumetrically-spaced ports for sampling dissolved ozone. The ozone generator is air-cooled with an integral oxygen concentrator for creating ozone from ambient air and shuts down automatically if a leak is detected.

Table 5 Ozone Pilot Skid Specifications

Parameter	Value
Manufacturer	Intuitech
Assembled Dimensions	75.5" H x 50" W x 122" L
Flow Rate Range, per contactor	2.0-9.0 gpm
Contactors	2 @ 133 gal
Flowrate through one contactor at 21.4 minutes (equivalent to full plant flow)	6.2 gpm
Ozone Delivery Range	0.1-6.5 g/h
Ozone Dose Range for one contactor at 6.3 gpm	0.07-4.5 mg/L
Chemical Feed Pumps Range	3 @ 0.01 - 21.7 gpd
Minimum flowrate required for filters	3.36 gpm

1.4 Biofiltration

The filter skid used was provided by Carollo and manufactured by Intuitech. Each filter operates using automatic PID flow control. The module can be operated as four independent filters, or two sets of two filters in series. The air scour and backwash systems are shared by all filters and utilize automatic PID flow control. Chemical feed pumps are flow paced with direct entry of chemical dosage. Each chemical pump can be selectively paced to any of the filter feed flows, the combined filter feed flow, or the backwash flow.

Backwashing is initiated manually by an operator in the manual mode, or on runtime, run volume, head loss, or effluent turbidity in the automatic mode (it is anticipated that head loss will control on this project based on historical plant operations). Only one filter may be backwashed at a time. The equipment is monitored and controlled by an HMI that communicates with the on-board PLC, which monitors and controls various instruments and components. The specifications for the skid are shown in Table 6.

Table 6 Biofiltration Pilot Skid Specifications

Parameter	Value
Manufacturer	Intuitech
Assembled Dimensions	136" H x 146" W x 50" D
Flow Rate	0 - 12.0 gpm
Filters	4 @ 6" internal diameter
Maximum Media Depth	72"
Filtration Rate Range	2.55 - 15.3 gpm/sq ft
Backwash Rate Range	5.10 - 30.6 gpm/sq ft
Backwash Tank Capacity	150 gal
Air Scour Rate Range	2.55 - 10.2 scfm/sq ft
Chemical Feed Pumps Range	5 @ 0.01 - 21.7 gpd
Chemical Feed Tanks	5 @ 4 gal

1.4.1 BW protocol

Filter BW protocols began with a FTW regime, summarized in Table 7. On 9/5/21, all four filter BW protocols were changed to follow a RTW regime, summarized in Table 8.

Table 7 FTW (Filter to Waste) Regime (start of pilot – 9/5/21)

Step	Filter 1	Filter 2	Filter 3	Filter 4
Drain Level	34 inches	6 inch	0 inch	0 inch
Air Scour	1 scfm for 90 sec	0	0	0
Air Scour/BW	1.1 gpm/0.5 scfm	1.88 gpm/0.8 scfm	1.88 gpm/0.8 scfm	1.61 gpm/0.8 scfm
BW 1	1.1 gpm for 30 sec	1.1 gpm for 30 sec	1.1 gpm for 30 sec	1.1 gpm for 30 sec
BW 2	3.53 gpm for 330 sec	4.57 gpm for 420 sec	4.22 gpm for 420 sec	3.52 gpm for 420 sec
BW 3	1.1 gpm for 30 sec	1.1 gpm for 30 sec	1.1 gpm for 30 sec	1.1 gpm for 30 sec
FTW	25 min or 0.2 NTU	13.8 min or 0.2 NTU	20.7 min or 0.2 NTU	22.4 min or 0.2 NTU

Table 8 RTW (Rinse to Waste) Regime (as of 9/5/21)

Step	Filter 1	Filter 2	Filter 3	Filter 4
Drain level	34 inches	6 inch	0 inch	0 inch
Air Scour	1 scfm for 90 sec	0	0	0
Air Scour/BW	1.1 gpm/0.5 scfm	1.88 gpm/0.8 scfm	1.88 gpm/0.8 scfm	1.61 gpm/0.8 scfm
BW 1	1.1 gpm for 30 sec	1.1 gpm for 30 sec	1.1 gpm for 30 sec	1.1 gpm for 30 sec
BW 2	3.53 gpm for 330 sec	4.57 gpm for 420 sec	4.22 gpm for 420 sec	3.52 gpm for 420 sec
RTW	1.0 gpm for 960 sec	1.0 gpm for 960 sec	1.0 gpm for 960 sec	1.0 gpm for 960 sec

1.4.2 Summary of Virgin GAC Exhaustion at Start of Pilot

During pilot commissioning, raw water was fed to the filter columns in order to exhaust adsorptive capacity of the virgin GAC in Filters 2-4. Filter 1 was loaded with exhausted media from the full-scale filter #24. Pilot Filter 1 was used as a control to gauge the exhaustion of the virgin GAC. After the first week of exhaustion, UVT % removal was still higher in Filters 2-4, compared to Filter 1, suggesting that the adsorptive capacity was not fully exhausted (Figure 1 and Figure 2). The subsequent week, while getting the ozone pilot commissioned, it can be noted that UVT % removal was about the same for all four filters (12/10) (Figure 3 and Figure 4).

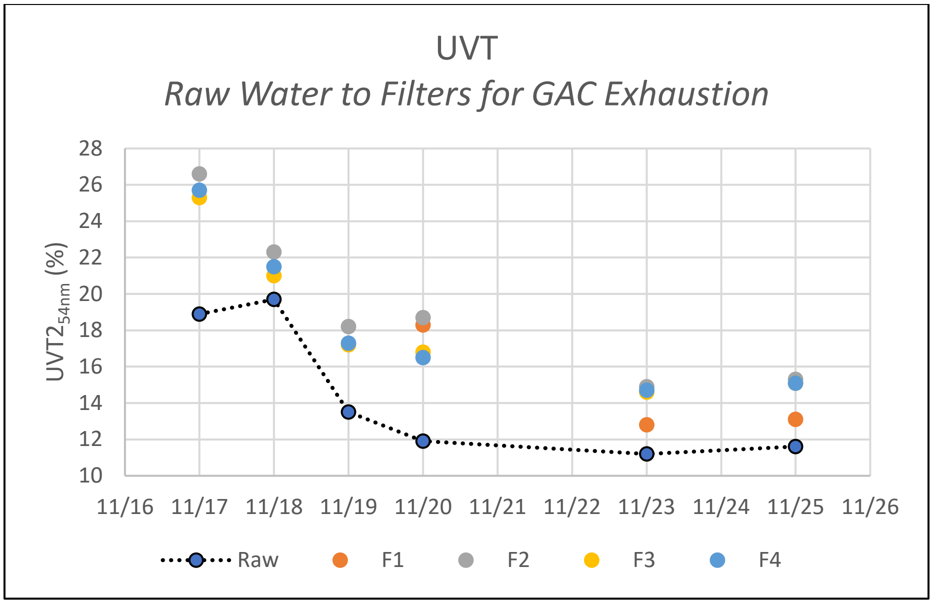


Figure 1 Filter Virgin GAC Exhaustion Pre-Pilot - UVT

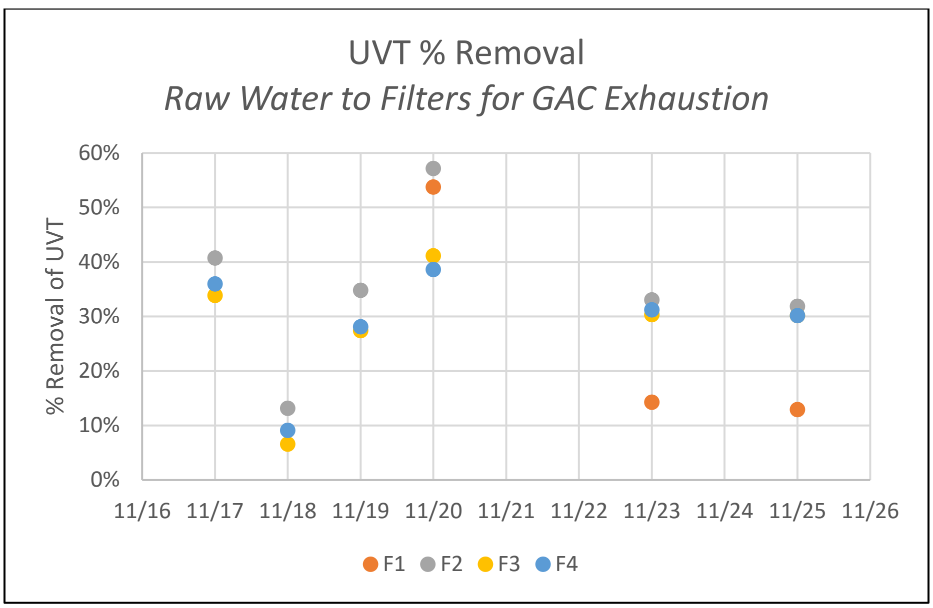


Figure 2 Filter Virgin GAC Exhaustion Pre-Pilot – UVT % Removal

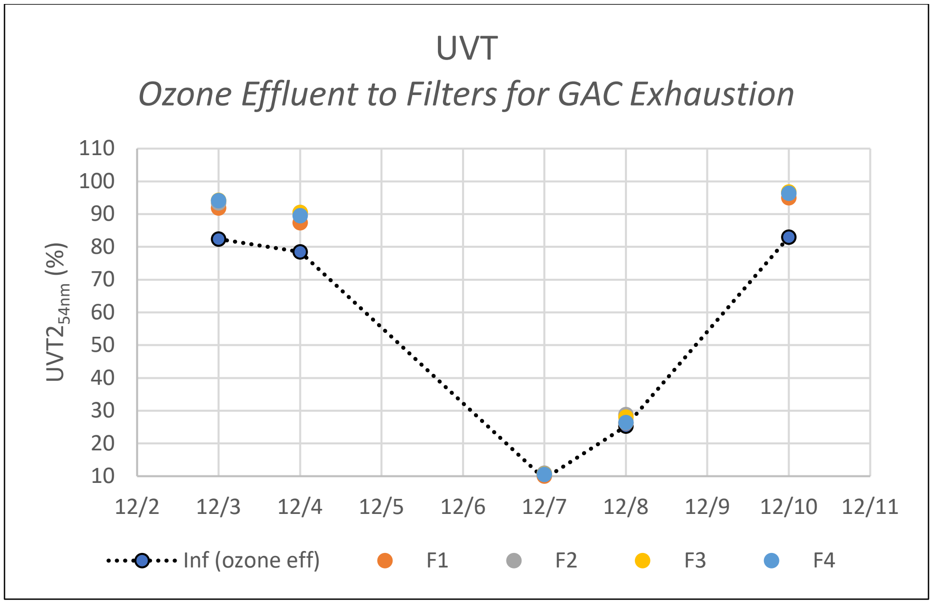


Figure 3 Filter GAC UVT – Pilot first two weeks

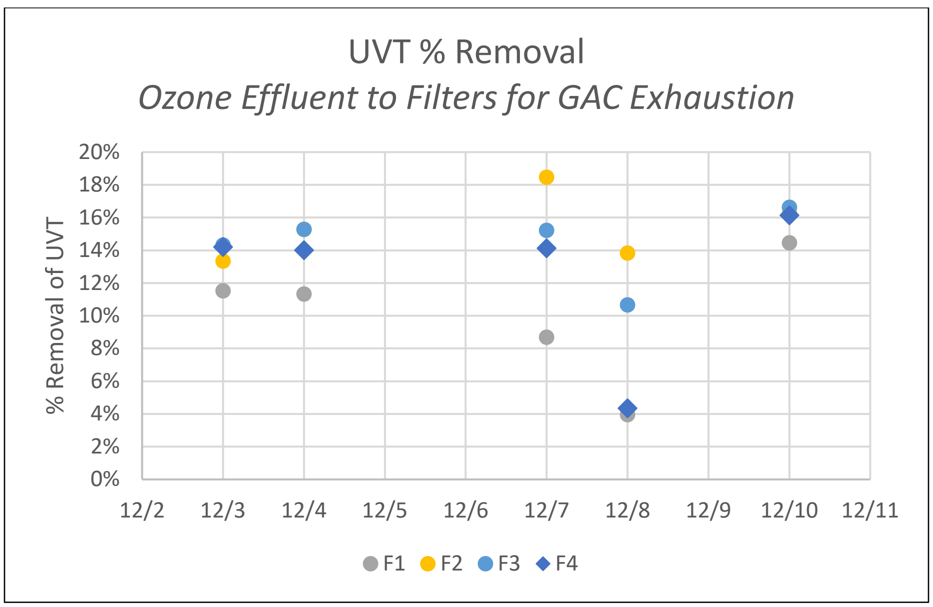


Figure 4 Filter GAC UVT % Removal– Pilot first two weeks

1.4.3 Pilot Filter 1 GAC Sieve Analysis and Abrasion Testing (Full-scale Filter #24)

At the end of the pilot test period, pilot filter 1 GAC was sampled and analyzed. The original GAC media loaded was an F830 media (X mm).Media size and abrasion resistance was performed per ASTM C136 and ANSI*AWWA B604-12. The same tests were run on a virgin Calgon F820 GAC for comparison. Test results are summarized below in Table 9. Figure 5 shows a visual of the resulting sieve analyses from this testing. It is recommended that GAC media retain 75% of original media size post-abrasion testing; adhering to this GAC spec for future filter media would help to avoid media attrition, washout, headloss due to excess fines, and replacement frequency.

Table 9 GAC Sieve Analysis and Abrasion Test Results

	COT GAC	Calgon F820
D_{10} (mm) [(1)]	1.05	1.01
Post- Abrasion D_{10} (mm)	0.5	0.96
% Retention [(2)]	58%	97%

Notes:

(1) D_{10} is media size where 10% is retained (90% passing).

(2) % Retention = Final D_{avg} / original D_{avg}.

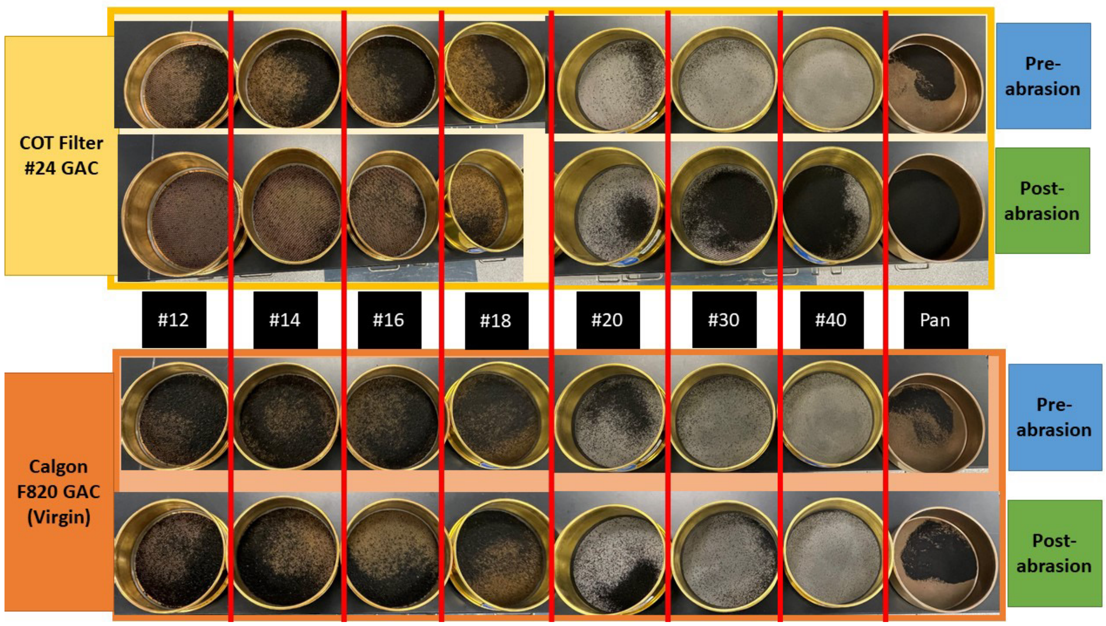


Figure 5 GAC media samples post-sieve analysis before and after abrasion testing.

1.4.4 Pilot Testing Location, Supply Source, and Pilot Waste

At the DLTWTF, raw water is pumped from the Hillsborough River to the existing conventional basins 5 – 8 as well as to the Actiflo® basins 1 and 2. The pilot-testing equipment will be located at Building #9, also called the Parts Building, and noted in Figure 6. For the pilot study, water was supplied directly from the Actiflo® raw water pipe (Figure 8) via an existing two inch supply tap (Figure 9), prior to any chemical addition, but after raw water screening, and is highlighted in Figure 7.

Treated water from the pilot system as well as waste streams for all treatment trains was collected and pumped to Junction Box 4, highlighted in Figure 7, which directs flows back to the plant intake. Figure 12 and Figure 13 provide closer visuals of Junction Box #4.

Figure 6 DLTWTF and Hillsborough River, Tampa, FL.

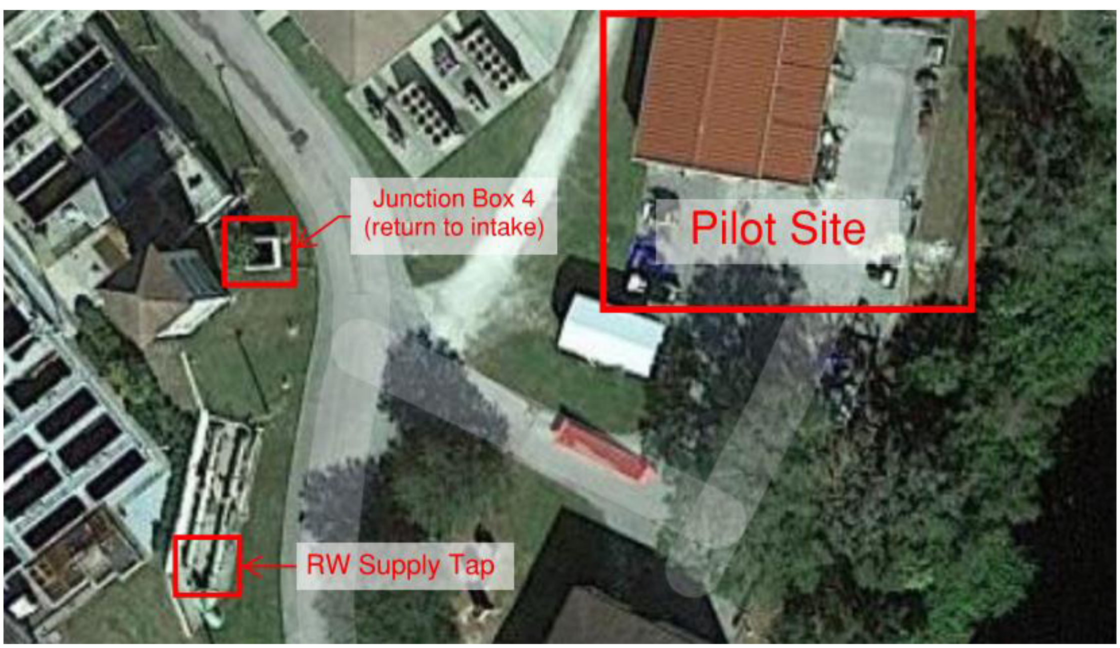


Figure 7 DLTWTF Pilot Location, RW supply, and Waste Discharge Locations

Figure 8 DLTWTF Actiflo® Piping

Figure 9 DLTWTF Pilot Raw Water Tap

Figure 10 DLTWTF Pilot Raw Water Pump and Pre-filtration Setup

Figure 11 DLTWTF Pilot Waste/Overflow Collection Tank. Sump pumps sending water to Junction Box #4.

Figure 12 DLTWTF Junction Box #4

Figure 13 DLTWTF Junction Box #4 (internal)

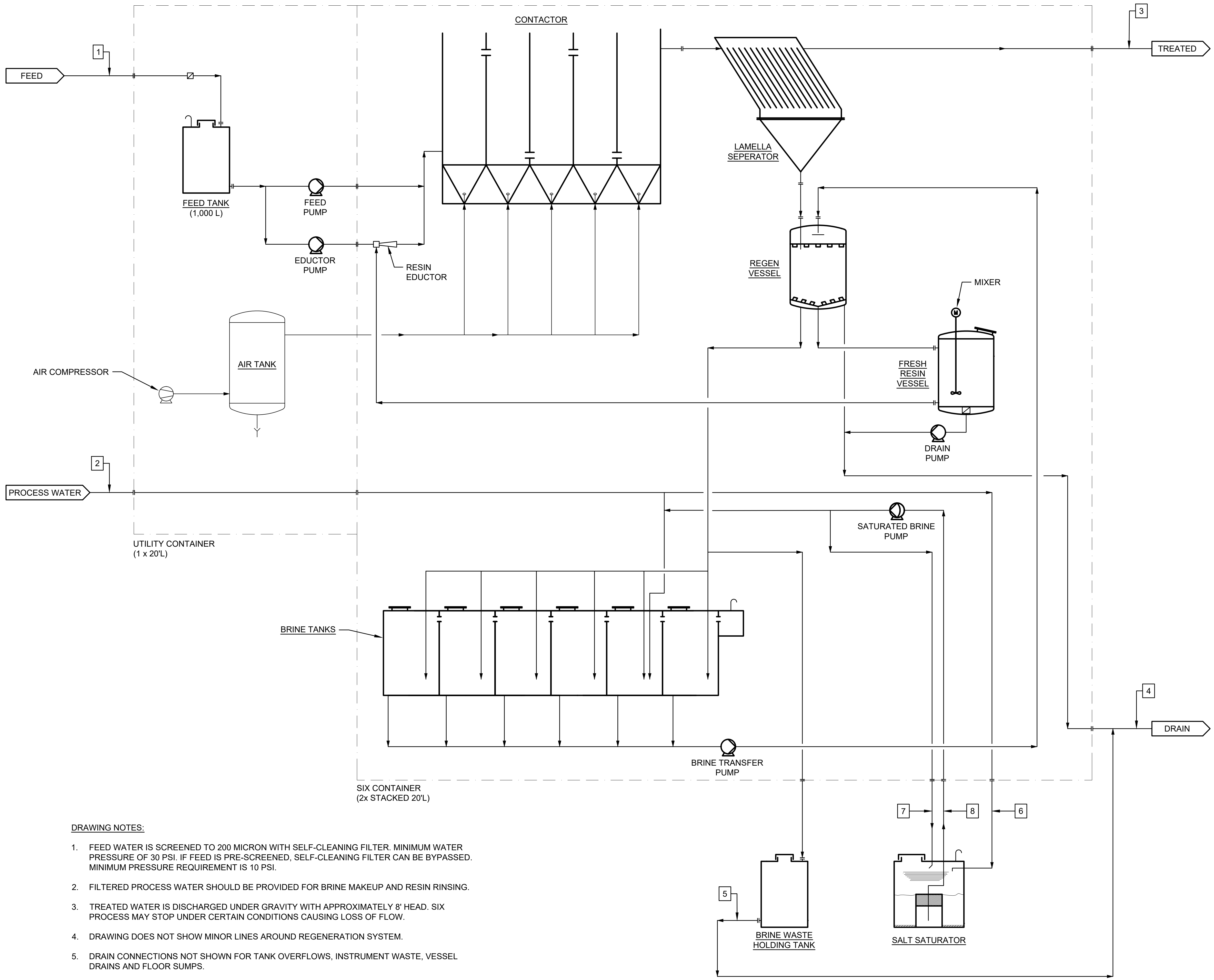
SKID MANUALS

1.1. SIX- Ramboll
1.2. Floc/Sed- MRI
1.3. Ozone – Intuitech
1.4. Filters - Intuitech

SIX - RAMBOLL

I:\Carollo.24678\75777.Tampa-Wtp-Upgra\Docs\DWG\Sheets\FIGURES\75777-FIG1_SIX PILOT PFD.dwg

PROJECT: SIX PILOT DATED: 10/12/2020 DESIGNER: TWL



DRAWING NOTES:

1. FEED WATER IS SCREENED TO 200 MICRON WITH SELF-CLEANING FILTER. MINIMUM WATER PRESSURE OF 30 PSI. IF FEED IS PRE-SCREENED, SELF-CLEANING FILTER CAN BE BYPASSED. MINIMUM PRESSURE REQUIREMENT IS 10 PSI.
2. FILTERED PROCESS WATER SHOULD BE PROVIDED FOR BRINE MAKEUP AND RESIN RINSING.
3. TREATED WATER IS DISCHARGED UNDER GRAVITY WITH APPROXIMATELY 8' HEAD. SIX PROCESS MAY STOP UNDER CERTAIN CONDITIONS CAUSING LOSS OF FLOW.
4. DRAWING DOES NOT SHOW MINOR LINES AROUND REGENERATION SYSTEM.
5. DRAIN CONNECTIONS NOT SHOWN FOR TANK OVERFLOWS, INSTRUMENT WASTE, VESSEL DRAINS AND FLOOR SUMPS.

LEGEND

1	RAW WATER INLET (2")
2	SERVICE WATER
3	TREATED WATER (4")
4	DRAIN (4")
5	BRINE WASTE DRAIN (4")
6	SALT SATURATOR MAKEUP (3/4" PROCESS WATER)
7	CONCENTRATED BRINE RETURN (3/4")
8	CONCENTRATED BRINE SUPPLY (3/4")

MAIN PLANT ITEMS

TAG	NAME	CAPACITY	NOTES
INT_OT_51	FEED TANK	1 m3	ATMOSPHERIC
IW_OR_0x	CONTACTOR	3.5 m3	5x CELLS
LS_OS_51	LAMELLA SEPARATOR	140 L (CONE)	
HG_OV_51	REGEN VESSEL	140 L	
HG_OV_53	FRESH RESIN VESSEL	360 L	
RB_OV_xx	BRINE TANKS	400 L	6x CELLS
RB_OT_10	SALT SATURATOR	1000 kg SALT	
IL_T_12	AIR TANK	500 L	

MECHANICAL

TAG	NAME	CAPACITY	POWER
IW_OP_10	FEED PUMP	3 - 12 m3/h	0.75 kW
IW_OP_20	EDUCTOR PUMP	1 m3/h	0.37 kW
IW_OJ_10	RESIN EDUCTOR		
HG_OP_10	DRAIN PUMP	1 m3/h	0.37 kW
HG_OM_10	MIXER		0.25 kW
RB_OP_20	SATURATED BRINE PUMP	300 L/h	0.37 kW
RB_OP_10	BRINE TRANSFER PUMP	0.5 - 2 m3/h	0.75 kW
IL_OK_10	AIR COMPRESSOR	12 cfm	3.7 kW

PROCESS FLOW DIAGRAM
SIX PILOT PLANT

DAVID L. TIPPIN WTP UPGRADE
7125 N. 30th STREET
TAMPA, FLORIDA 33610

FIGURE 1

RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

RAMBOLL

FLOC/SED - MRI

Meurer Research, Inc.

16133 W 45th Drive
Golden, Colorado 80403
Tel (303) 279-8373 Fax (303) 279-8429

Plate Settler Pilot Pre-Treatment Package

MRI Contact: **Dan May**
Phone: **(720) 287-5606**

Meurer Research, Inc. Plate Settler Pilot Unit Protocol

MRI
meurer research

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1.0 Introduction

The Meurer Research, Inc. Plate Settler Pilot Unit is a self-contained plate settler unit complete with inline mixer, 3-stage flocculator, Inlet Diffusers, plate settlers and sludge removal. Each unit is provided for the use of the client to establish the feasibility of plate settlers as an effective settling enhancement for their particular application.

2.0 Chemical Feed

The chemical feed may be provided by the plant, which is established and in place.

Should experimentation with chemicals be in the scope of the pilot test, MRI will provide up to two (2) chemical feed pumps of the peristaltic type, two (2) 35 gallon mixing tanks can be provided as well. (See the chemical feed pump manual at the end of this document)

3.0 In Line Mixer

With the Plate Settler Pilot Unit MRI will provide a Komax in line mixer in place of the rapid mix. The mixer will be a 3" mixer incorporated into the 4 inch inlet line. No adjustments are required for the in-line mixer. (See the attached spec sheets for the Komax mixer at the end of this document).

4.0 Three Stage Flocculator

Each Plate Settler Pilot Unit will include a three stage flocculator. The stages are engineered to produce from 70 to 20 GT. Each set of flocculator paddles are attached to a common shaft. The flocculator drive has a 1 HP 90 VDC variable speed motor.

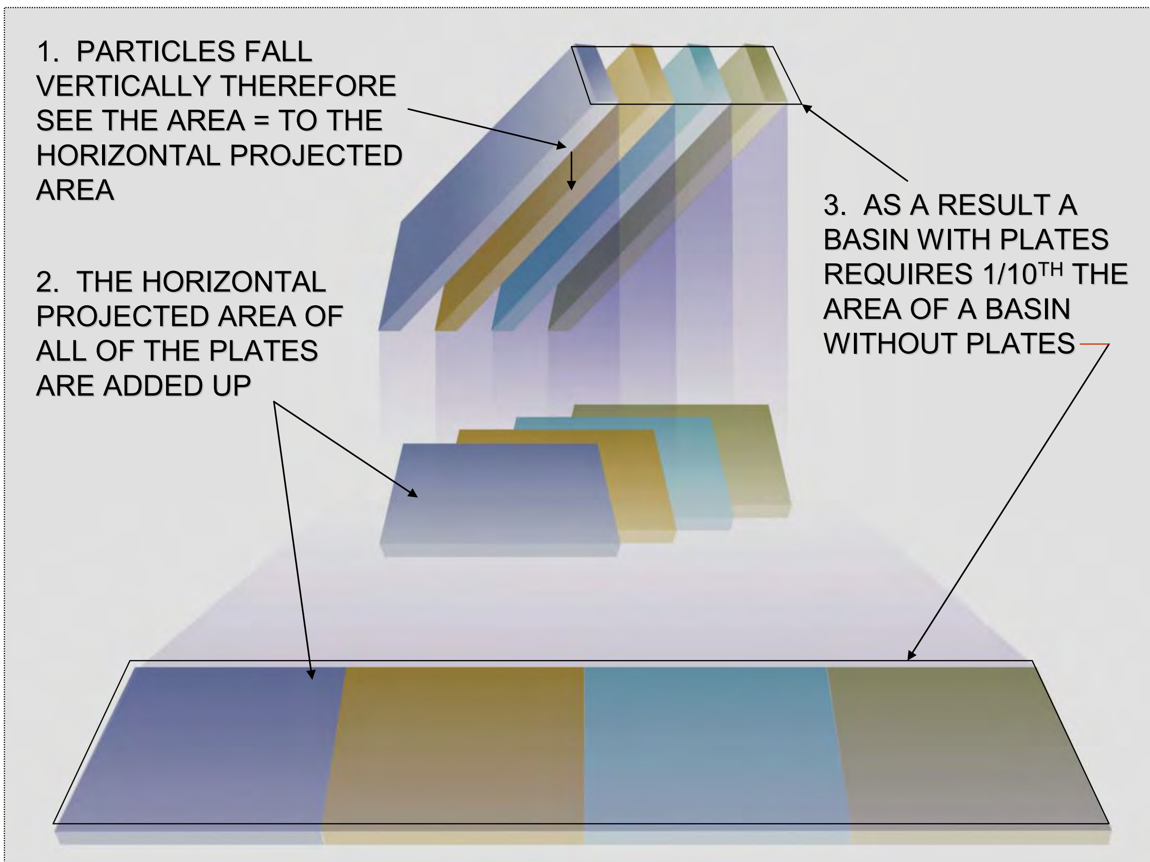
Each stage of the flocculator is separated by a stainless steel baffle wall with openings that create an over and under flow pattern.

5.0 Inlet Diffusers

As the flow exits the flocculator and enters the settling area it passes though an Inlet Diffuser which slows the velocity to <.5 fps and aligns the flow with the feed channels on either side of the plate settlers. The Inlet Diffusers are designed to allow the incoming flow to gently rotate as it homogenizes into the settling area maintaining the floc structure.

6.0 Plate Settlers

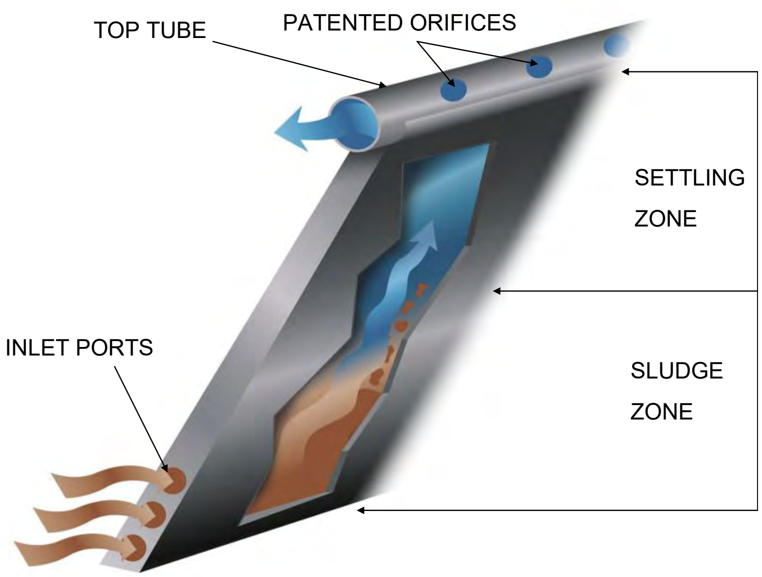
The plate settlers are positioned on 55^0 and spaced 2 inches apart. The settled solids see the projected area of each plate as a settling surface. The projected areas overlap which results in higher flows in a smaller footprint.



The plate settlers consist of individual plates set two inches apart forming a plate pack. Each plate is equipped with a top tube that strengthens the plate, distributes the flow and with adjacent top tubes forms a grating that can be walked on and easily cleaned.

Each plate is equipped with inlet ports located at the bottom of the plate on each side where the flow enters the plate and then travels up to the top tube. The flow exits between the plates and then enters the top tube through the orifices that removes the flow evenly across the entire width of the plate.

ANATOMY OF THE MRI PLATE SETTLER



7.0 Effluent Troughs

The effluent troughs are located adjacent to the plate settlers on both sides. Each trough is equipped with an effluent weir. The flow exits the top tubes and flows over the effluent weirs.

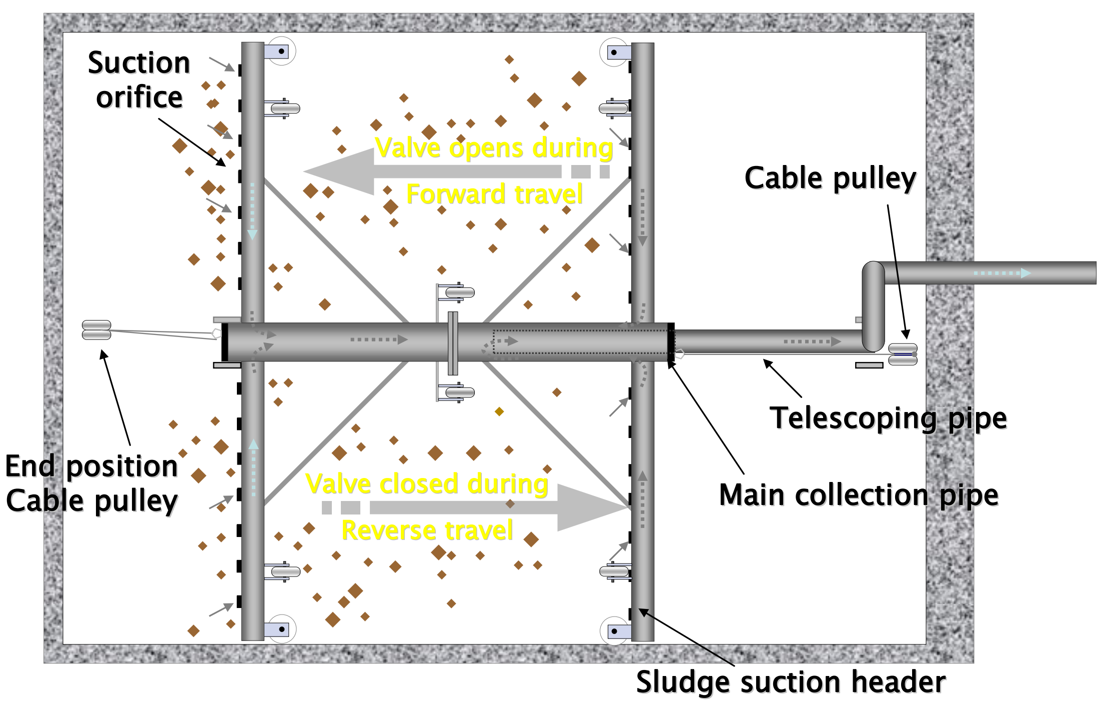
8.0 Sludge Collector

Each pilot unit is equipped with an automated sludge collector that removes the settled solids from the settling area.

When called on by the control panel the Hoseless Sludge Collector will make one pass across the settling area floor removing all settled solids.

The underflow is discharged through the end of the pilot unit which is equipped with a sludge valve that starts and stops the flow. The flow rate is controlled by a 2” manual butterfly valve. The normal flow setting for the Sludge collector is between 25-30 GPM. This will be calibrated by a 5 gallon bucket test during start-up.

Hoseless Cable-Vac™ System



8.1 HOSELESS SLUDGE COLLECTOR CONTROLS

SEQUENCE OF OPERATION

FOR COLLECTION (HCV) SYSTEM
(INCLUDES COLLECTOR AND VALVE ONLY)

16133 West 45th Drive.
Golden, CO 80403
Phone: 303-279-8373
Fax: 303-279-8429

Hose-Less Cable-Vac™ and Control Panel Operation
MRI Pilot Unit: MRI-1502
(HCV Sludge Collector and Valve Only)

Control of the Sludge Collector unit (collector and valve) will be from the Local Control Panel (LCP-MRI-01) located on the side of the packaged pilot-unit tank. Operation of the Sludge Collector unit will either be through automated PLC sequencing, the Plant Control System (SCADA), the HMI Touch Screen Terminal located on the face of the Local Panel enclosure door, or the VFD Keypad and drive potentiometer located inside the Local Panel. These controls will allow the operator to control the following parameters, and will display the following information.

Remote/Auto & Local/Auto Operation–
In **REMOTE/AUTO** mode (system LOR switch in remote and unit HOA switch in auto), a call to run will allow the sludge collector unit to run a normal sequence of operation.

Which is as follows:
When the sludge collector unit is called to run, the sludge valve will open. Once the sludge valve has been proven fully open, the collector unit will run to the far end of the basin, collecting sludge along the way. When the collector has reached its end limit position (opposite end of the drive in most cases), the sludge valve will remain open for 60-120 seconds (field adjustable) and then close. This is to assure that no sludge build-up will occur at the end, as well as flushing out the collector system. The collector knows which end it has reached due to inductive proximity sensors located on the drive unit. The sensors sense the cable position on the grooved drum pre-set by our Field Engineers. Once the valve has been proven fully closed, the unit will return to its home position and then stop once the home sensor limit is initiated (in most occasions under the drive and about 6-12 inches from the end stops). Since the valve is closed, running the unit back to the contracted position evacuates water from the collection chamber through the collection pipe orifices. Therefore, it acts as a self-back flushing system. Once the unit reaches its fully contracted position, the unit will wait for another call to run.

A call to run can be accomplished these ways when the system/unit are set in **REMOTE/AUTO** mode respectively:

1. By a communication control point via plant control system (Ethernet/IP).
2. By a momentary contact closure from a remote source (Dry Contacts).

A call to run can be accomplished these ways when the system/unit are set in **LOCAL/AUTO** mode respectively:

1. By setting a time to run on a 24hr time clock in the Local Panel Touch Screen.
2. By depressing the **MANUAL START** button on the Local Panel Touch Screen.

The unit sequencing is performed by a pre-programmed PLC.

Auto Operation Notes:

- Note that 'system selector switch' and 'LOR' refer to the Local/Off/Remote selector switch and 'unit selector switch' and 'HOA' refer to the Hand/Off/Auto selector switch. Also note that REMOTE/AUTO, LOCAL/AUTO, or any combination of the two refers to the system and unit selector switches respectively.
- When a remotely initiated cycle is executed in Local/Auto or Local/Hand mode, the collector unit will not respond.
- If at any time the sludge collector unit is set in Hand mode at the LCP during an automated cycle sequence, the collector unit sequence will be skipped until its next cycle is scheduled to begin.
- Note that the sludge valve actuator must be set in Remote mode to obtain control of it through the local control panel.
- Note that the system selector switch must be set in Remote mode and the unit selector switch set in Auto mode to enable automatic cycling from SCADA.
- Note that the system selector switch must be set in Local mode and the unit selector switch set in Auto mode to enable control of the collector unit from the Local Panel HMI touch screen terminal.
- Placing the system selector switch from Local to Remote or from Remote to Local when the unit is running will discontinue the collector run sequence until re-issued a run command. (Valve will close if not already)
- Placing the unit selector switch from Hand to Auto or from Auto to Hand when the unit is running will discontinue the collector run sequence until re-issued a run command. (Valve will close if not already)
- Run timers may be initiated through the Plant Control System (SCADA) if the Local Panel HMI 24hr time clock is not used. When a collector unit is scheduled to run, a remote start sequence may be sent to the Local Control Panel via Ethernet/IP or Dry Contacts from SCADA (whichever is preferable).
- Start time set-points for the collector unit may be selectable from the plant control system (SCADA). Whenever a start time is initiated, the collector unit shall operate in sequence until one complete cycle has been completed. Start times and cycle frequencies are modifiable via SCADA.
- PLC I/O tags and IP addresses shall be coordinated with MRI's field start up engineer and integrator.

Local/Hand Operation. (For PLC Bypass)–

In **LOCAL/HAND** mode (system LOR switch in local and unit HOA switch in hand), the Cable Drive (sludge collector) and Sludge Valve can be controlled independently of each other from the Local Control Panel.

Recommended control is as follows:

Before the sludge collector unit is called to run forward, the sludge valve for the corresponding unit shall be commanded open by the operator. When the sludge valve opens, the operator may then initiate a run forward command. When the operator selects forward, the unit will run to the far end of the basin, collecting sludge along the way. Once the sludge collector reaches its end sensor limit position, the operator shall wait approximately one to two minutes and then close the valve (manual valve closure may be done at operators discretion). The sludge collector will wait at its end position until it is commanded to run in reverse by the operator. When the sludge collector is commanded to run in reverse, the unit will run to the home end of the basin until it has reached its home sensor limit position. Once the unit reaches its fully contracted position, it will wait for another call to run by the operator.

Independent operation of the sludge collector and sludge valve can be accomplished these ways when the system/unit are set in **LOCAL/HAND** mode respectively:

1. ***Sludge Collector, Forward*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. When open, push the **FORWARD** button on the VFD keypad and depress the **ENTER** button. The cable drive will run and pull the sludge collector unit until it has either reached its end sensor limit position, a fault occurs, the sensor trips out on its torque set point, or is turned **OFF** on either the system switch, unit switch, or VFD keypad.
2. ***Sludge Collector, Reverse*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. When open, push the **REVERSE** button on the VFD keypad and depress the **ENTER** button. The cable drive will reverse and pull the sludge collector unit until it has either reached its home sensor limit position, a fault occurs, the sensor trips out on its torque set point, or is turned **OFF** on either the system switch, unit switch, or VFD keypad.
3. ***Sludge Collector, Speed Control*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. After a run forward or reverse command has been executed, turn the drive potentiometer on the VFD clockwise or counterclockwise. This will adjust the speed of the sludge collector unit to its desired speed set point. (Recommended speed is 1-3 fpm)
4. ***Sludge Collector, Stop*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. When open, depress the **OFF** button on the VFD keypad or depress the Emergency Stop Button found at the Cable Drive Junction Box. The system and unit selector switches may also be used to stop the unit. *(Note: The cable drive E-Stop will work in any mode at any time)*
5. ***Sludge Valve, Open*** - In **LOCAL/HAND** mode, place the valve Open/Close selector switch to **OPEN.** This will open the Sludge Valve.
6. ***Sludge Valve, Close*** - In **LOCAL/HAND** mode, place the valve Open/Close selector switch to **CLOSE.** This will close the Sludge Valve.

All PLC sequencing logic is bypassed in Local/Hand mode

Hand (Local) Operation Notes:

- Independent operation and all of the parameters described above may be initiated through the Local Panel HMI touch screen terminal when the system switch is set in Local mode and the unit switch set in Auto mode. Refer to MRI's field start-up engineer for the HMI sequence of operation and command parameters.

- When in Auto mode, the sludge valve will not respond when selecting Open or Close at the valve selector switch. Thus, the valve selector switch will only work when the system switch is set in Local mode and the unit selector switch is set in Hand mode (PLC bypass).
- Note that the system selector switch must be set in Local mode to obtain control of the sludge collector unit at the Local Control Panel.
- Note that the system selector switch must be set in Local mode and the unit selector switch set in Hand mode to bypass the PLC and obtain control of the collector via the VFD drive.
- The HMI touch screen terminal is the only means of starting the collector unit and valve when the system/unit are set in Local/Auto mode respectively. The HMI is disabled in Local/Hand mode.
- To manually execute a "Full System Cycle at the Local Control Panel," set the system Local/Off/Remote selector switch to Local mode and the unit Hand/Off/Auto selector switch to Auto mode, then depress the designated icon buttons displayed on the HMI touch screen terminal. This will run the sludge collector unit at one full cycle described in Auto Operation. Note that when using the VFD to control the collector, the valve Open/Close selector switch is the only means of controlling the valve at the Local Control Panel.

Alarming–

An alarm will be generated on the following conditions:

1. *Over Torque (Drive Fault)* – This is generated by a signal sent from a current monitor system inside the VFD drive measuring the amperage draw from the cable drive's AC motor.
2. *Time Out (Trip Fail)* – When running, if the collector unit has not reached either of its home or end sensors in an allotted time. (Depends on the size of basin)
3. *Valve Failure* – The sludge valve has either failed to open or failed to close.
4. *Under or Over voltage (Drive Fault)* – This is generated by the VFD drive sensing the incorrect voltages being applied to the VFD or taken in from the motor.
5. *E-Stop Engaged* – This is generated by depressing the emergency stop button at the Cable Drive Junction Box.
6. *General Drive Fault* – This is generated by the drive sensing a motor failure or other related condition that may exist at the VFD, motor, or Local Control Panel.
7. *Mode Conflict* – This is generated when the system selector switch is set in Remote mode and the unit selector switch is not set in Auto mode.

In an alarm condition, the run sequence will be stopped immediately and an alarm indication will be generated. This indication will be displayed by a red graphic **ALARM** icon light displayed on the Local Panel touch screen terminal. The unit will not run again until the alarm has been reset. Resetting the alarm can be achieved by depressing the red graphic **ALARM RESET** icon button displayed on the Local Panel touch screen terminal. Once the alarm has been reset, the unit will wait for a call to run, and then continue its sequence.

Alarming Notes:

- The Hose-Less Cable-Vac™ sludge collector drive can endure an indefinite stall by means of an over current shutdown condition. The control system senses excessive current loading on the motor, issues a stop command, and generates an alarm. The unit can be started only after the alarm state is acknowledged and reset.

- All alarming may be password protected through the Local Panel touch screen terminal (may be assisted by MRI's field technician).
- Over Torque is plausible in Hand mode. (Contacts will open on VFD to stop the drive)
- Alarms are intended to be reset at the Local Control Panel. Conditional alarms such as 'Power Fail' or 'Com/Link Fail' may be resettable via the SCADA network. Refer to MRI's field start-up engineer for more information.
- Drive Fault Alarms are also viewable at the VFD keypad. If a drive fault condition occurs, the VFD will display a fault code corresponding to its specific failure or fault condition (fault codes begin with the letter F followed by numbers; example: F7 = Motor Overload). To identify the drive fault by its fault code, refer to the VFD user manual. **See VFD user Manual below for more information.** ***(Rockwell publication 22F-UM001D-EN-E)***

Communications–

The Local Control Panel shall communicate to a Remote Control System or Master Control Panel (SCADA) via Ethernet Communications ***OR*** Dry Contacts.

A Remote Control System (SCADA) can ***RECIEVE*** the following information via ***ETHERNET/IP.***

1. System in Local/Remote Mode
2. Unit in Hand/Auto Mode
3. Sludge Collector Unit Run Status
4. Sludge Collector Unit Travel Status
5. Sludge Collector Unit Timers and Cycle Frequency Status
6. Sludge Collector Unit Common Fail/Fault Alarm
7. Sludge Valve Position Status
8. Sludge Valve Failure Alarms

A Remote Control System (SCADA) can ***RECIEVE*** the following information via ***DRY CONTACTS.***

1. System in Remote Mode
2. Sludge Collector Unit Run Status
3. Sludge Valve Position Status
4. Common Fail/Fault Alarm

The following parameters and status points can be viewable or adjustable via the Operator Interface located on the Local Control Panel HMI Touch Screen Terminal.

1. System Local/Off/Remote
2. Unit Hand/Off/Auto
3. Run Status indication for all equipment
4. Sludge Collector Travel Control & Status
5. Sludge Collector Timers and Cycle Frequency
6. Sludge Collector Speed Control & Status
7. Sludge Valve Position Control and Status
8. Failure/Fault alarms identifying cause of equipment failure
9. Alarm Set Points
10. Alarm History Log

11. Security Passwords

The following is an ***EXAMPLE*** list of commands located on the Local Control Panel HMI Touch Screen Terminal.

1. Run/Start Sequence
2. Run Forward/Reverse
3. Sludge Valve Open/Close
4. Alarm Indication/Reset
5. Configure Timers or Cycle Frequency
6. Set/Reset Security Passwords

A Remote Control System (SCADA) may ***SEND*** the following commands via ***ETHERNET/IP.***

1. Initiate a Run/Start Sequence
2. Initiate a Stop Sequence
3. Initiate a Collector Run Forward Command
4. Initiate a Collector Run Reverse Command
5. Adjust Collector Speed
6. Initiate a Sludge Valve Open Command
7. Initiate a Sludge Valve Close Command
8. Configure Timers or Cycle Frequencies
9. Reset Alarm (See notes below)

A Remote Control System (SCADA) may ***SEND*** the following commands via ***DRY CONTACTS.***

1. Initiate a Run/Start Sequence

Communication Notes:

- For an actual list of HMI commands, please refer to MRI's Field Engineer at system start-up. System training is also available if needed.
- HMI sequence of operation and screen shots shall be coordinated with MRI's Field Start-up Engineer.
- Alarms are intended to be reset at the Local Control Panel**.** Only conditional alarms such as 'Power Fail' or 'Com/Link Fail' that do not inhibit the units ability to run while the alarm is annunciated but recovered, can be reset from the SCADA network. Refer to MRI's field start-up engineer for more information.
- PLC I/O tags and IP addresses shall be coordinated with MRI's field start up engineer and integrator.

Provisions–

The Provisions for running single or concurrent units depend upon the free discharge piping. If the discharge piping is individually installed, then each unit can be run concurrently. You cannot dump sludge into a common Discharge Header unless appropriate pumps are supplied. Each unit must be able to evacuate at least 100-200gpm every sequence. Electrically, there are no issues to running 1 or 10 units at a time. GPM issues will arise if the units are ran concurrently with minimal discharge. *Meurer Research advises upon running one unit at a time with each having its own free discharge.*

SEQUENCE OF OPERATION

FOR FLOCCULATION (FLOCC) SYSTEM
(FLOCCULATOR ONLY)

meurer research

16133 West 45th Drive.
Golden, CO 80403
Phone: 303-279-8373
Fax: 303-279-8429

Flocculator and Control Panel Operation
MRI Pilot Unit: MRI-1502
(Flocculator unit Only)

Control of the Flocculator unit will be from the Local Control Panel (LCP-MRI-01) located on the side of the packaged pilot-unit tank. Operation of the Flocculator unit will be either through automated PLC sequencing, the Plant Control System (SCADA), the HMI Touch Screen Terminal located on the face of the Local Panel enclosure door, or the VFD Keypad and drive potentiometer located inside the Local Panel. These controls will allow the operator to control the following parameters, and will display the following information.

Remote/Auto & Local/Auto Operation–
In **REMOTE/AUTO** mode (system LOR switch in remote and unit HOA switch in auto), a call to run will allow the Flocculator unit to run a normal sequence of operation.

Which is as follows:
When the Flocculator unit is called to run, the Flocculator shaft and paddles will begin to rotate forward (the forward direction is indicated by the direction the face of the Flocculator paddles are pointed). The unit will continue to rotate until the cycle is over or until it is commanded off by the operator.

A call to run can be accomplished these ways when the system/unit are set in **REMOTE/AUTO** mode respectively:

1. By a communication control point via plant control system (Ethernet/IP).
2. By a momentary contact closure from a remote source (Dry Contacts).

A call to run can be accomplished these ways when the system/unit are set in **LOCAL/AUTO** mode respectively:

1. By setting a time to run on a 24hr time clock in the Local Panel Touch Screen.
2. By depressing the **MANUAL START** button on the Local Panel Touch Screen.

The unit sequencing is performed by a pre-programmed PLC.

Auto Operation Notes:
- Note that 'system selector switch' and 'LOR' refer to the Local/Off/Remote selector switch and 'unit selector switch' and 'HOA' refer to the Hand/Off/Auto selector switch. Also note that REMOTE/AUTO, LOCAL/AUTO, or any

combination of the two refers to the system and unit selector switches respectively.

- When a remotely initiated cycle is executed in Local/Auto or Local/Hand mode, the Flocculator unit will not respond.
- Note that the system selector switch must be set in Remote mode and the unit selector switch set in Auto mode to enable automatic cycling from SCADA.
- Note that the system selector switch must be set in Local mode and the unit selector switch set in Auto mode to enable control of the flocculator unit from the Local Panel HMI touch screen terminal.
- Placing the system selector switch from Local to Remote or from Remote to Local when the unit is running will discontinue the Flocculator run sequence until re-issued a run command.
- Placing the unit selector switch from Hand to Auto or from Auto to Hand when the unit is running will discontinue the Flocculator run sequence until re-issued a run command.
- Run timers may be initiated through the Plant Control System (SCADA) if the Local Panel HMI 24hr time clock is not used. When the Flocculator unit is scheduled to run, a remote start sequence may be sent to the Local Control Panel via Ethernet/IP or Dry Contacts from SCADA.
- PLC I/O tags and IP addresses shall be coordinated with MRI's field start up engineer and integrator.

Local/Hand Operation. (For PLC Bypass)–
In **LOCAL/HAND** mode (system LOR switch in Local and unit HOA switch in Hand), the Flocculator unit can be controlled independently at the Local Control Panel.

Independent operation of the flocculator can be accomplished these ways when the system/unit are set in **LOCAL/HAND** mode respectively:

1. ***Flocculator, Forward*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. When open, push the **FORWARD** button on the VFD keypad and depress the **ENTER** button. The chain drive will run and rotate the Flocculator unit forward until either a fault occurs, the sensor trips out on its torque set point, or is turned to the **OFF** position on either the system, unit, or VFD Keypad.
2. ***Flocculator, Reverse*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. When open, push the **REVERSE** button on the VFD keypad and depress the **ENTER** button. The chain drive will run and rotate the Flocculator unit in reverse until either a fault occurs, the sensor trips out on its torque set point, or is turned to the **OFF** position on either the system, unit, or VFD Keypad.
3. ***Flocculator, Speed Control*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. After a run forward or reverse command has been executed, turn the drive potentiometer on the VFD clockwise or counterclockwise. This will adjust the speed of the Flocculator unit to its desired speed set point.
4. ***Flocculator, Stop*** - In **LOCAL/HAND** mode, open the Local Control Panel door to access the drive. When open, depress the **OFF** button on the VFD keypad or depress the Emergency Stop Button found at the Flocculator Chain Drive E-Stop Junction Box. *(Note: The E-Stop button will work in any mode at any time)*

All PLC sequencing logic is bypassed in Local/Hand mode

Hand Operation Notes:

- Independent operation and all of the parameters described above may be initiated through the Local Panel HMI touch screen terminal when the system switch is set in Local mode and the unit switch set in Auto mode. Refer to MRI's field start-up engineer for the HMI sequence of operation and command parameters.
- Note that the system selector switch must be set in Local mode to obtain control of the sludge collector unit at the Local Control Panel.
- Note that the system selector switch must be set in Local mode and the unit selector switch set in Hand mode to bypass the PLC and obtain control of the flocculator unit via the VFD drive.
- The HMI touch screen terminal is the only means of starting the Flocculator unit when the system/unit are set in Local/Auto mode respectively. The HMI is disabled in Local/Hand mode.

Alarming–

An alarm will be generated on the following conditions:

1. *Over Torque (Drive Fault)* – This is generated by a signal sent from a current monitor system inside the VFD drive measuring the amperage draw from the cable drive's AC motor.
2. *Under or Over voltage (Drive Fault)* – This is generated by the VFD drive sensing the incorrect voltages being applied to the VFD or taken in from the motor.
3. *E-Stop Engaged* – This is generated by depressing the emergency stop button at the Flocculator Chain Drive E-Stop Junction Box.
4. *General Drive Fault* – This is generated by the drive sensing a motor failure or other related condition that may exist at the VFD, motor, or Local Control Panel.
5. *Mode Conflict* – This is generated when the system selector switch is set in Remote mode and the unit selector switch is not set in Auto mode.

In an alarm condition, the run sequence will be stopped immediately and an alarm indication will be generated. This indication will be displayed by a red graphic **ALARM** icon light displayed on the Local Panel touch screen terminal. The unit will not run again until the alarm has been reset. Resetting the alarm can be achieved by depressing the red graphic **ALARM RESET** icon button displayed on the Local Panel touch screen terminal. Once the alarm has been reset, the unit will wait for a call to run, and then continue its sequence.

Alarming Notes:

- The Hose-Less Cable-Vac™ sludge collector drive can endure an indefinite stall by means of an over current shutdown condition. The control system senses excessive current loading on the motor, issues a stop command, and generates an alarm. The unit can be started only after the alarm state is acknowledged and reset.
- All alarming may be password protected through the Local Panel touch screen terminal (may be assisted by MRI's field technician).
- Over Torque is plausible in Hand mode. (Contacts will open on VFD to stop the drive)

- Alarms are intended to be reset at the Local Control Panel. Conditional alarms such as 'Power Fail' or 'Com/Link Fail' may be resettable via the SCADA network. Refer to MRI's field start-up engineer for more information.
- Drive Fault Alarms are also viewable at the VFD keypad. If a drive fault condition occurs, the VFD will display a fault code corresponding to its specific failure or fault condition (fault codes begin with the letter F followed by numbers; example: F7 = Motor Overload). To identify the drive fault by its fault code, refer to the VFD user manual. **See VFD user Manual below for more information.** ***(Rockwell publication 22F-UM001D-EN-E)***

Communications–

The Local Control Panel shall communicate to a Remote Control System or Master Control Panel (SCADA) via Ethernet Communications ***OR*** Dry Contacts.

A Remote Control System (SCADA) can ***RECIEVE*** the following information via ***ETHERNET/IP.***

1. System in Local/Remote Mode
2. Unit in Hand/Auto Mode
3. Flocculator Unit Run Status
4. Flocculator Unit Timers and Cycle Frequency Status
5. Flocculator Unit Common Fail/Fault Alarm

A Remote Control System (SCADA) can ***RECIEVE*** the following information via ***DRY CONTACTS***.

1. System in Remote Mode
2. Flocculator Unit Run Status
3. Common Fail/Fault Alarm

The following parameters and status points can be viewable or adjustable via the Operator Interface located on the Local Control Panel HMI Touch Screen Terminal.

1. System Local/Off/Remote
2. Unit Hand/Off/Auto
3. Run Status indication for all equipment
4. Flocculator Timers and Cycle Frequency
5. Flocculator Speed Control & Status
6. Failure/Fault alarms identifying cause of equipment failure
7. Alarm Set Points
8. Alarm History Log
9. Security Passwords

The following is an ***EXAMPLE*** list of commands located on the Local Control Panel HMI Touch Screen Terminal.

1. Run/Start Sequence
2. Run Forward/Reverse
3. Alarm Indication/Reset
4. Configure Timers or Cycle Frequency
5. Set/Reset Security Passwords

A Remote Control System (SCADA) may ***SEND*** the following commands via ***ETHERNET/IP.***

1. Initiate a Run/Start Sequence
2. Initiate a Stop Sequence
3. Initiate a Flocculator Run Forward Command
4. Initiate a Flocculator Run Reverse Command
5. Adjust Flocculator Speed
6. Configure Timers or Cycle Frequencies
7. Reset Alarm (See notes below)

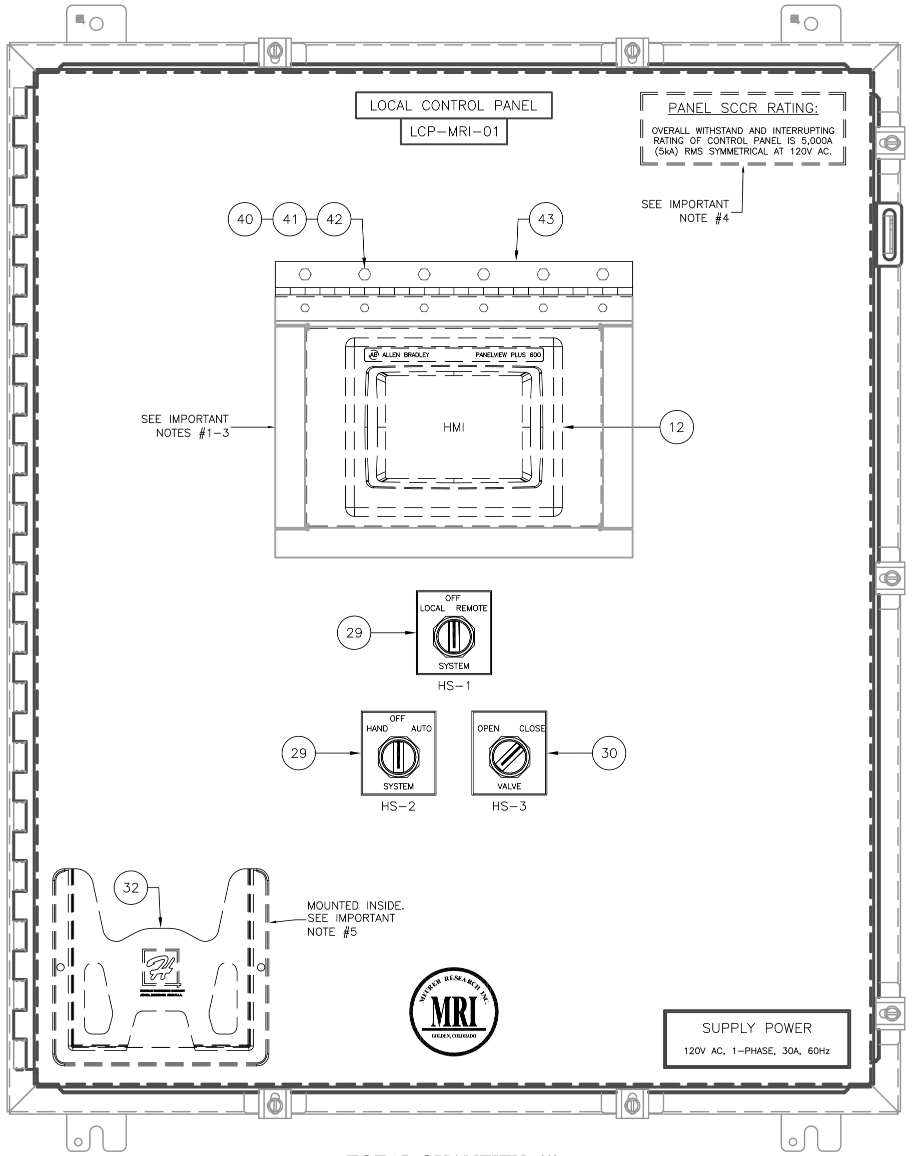
A Remote Control System (SCADA) may ***SEND*** the following commands via ***DRY CONTACTS***.

1. Initiate a Run/Start Sequence

Communication Notes:

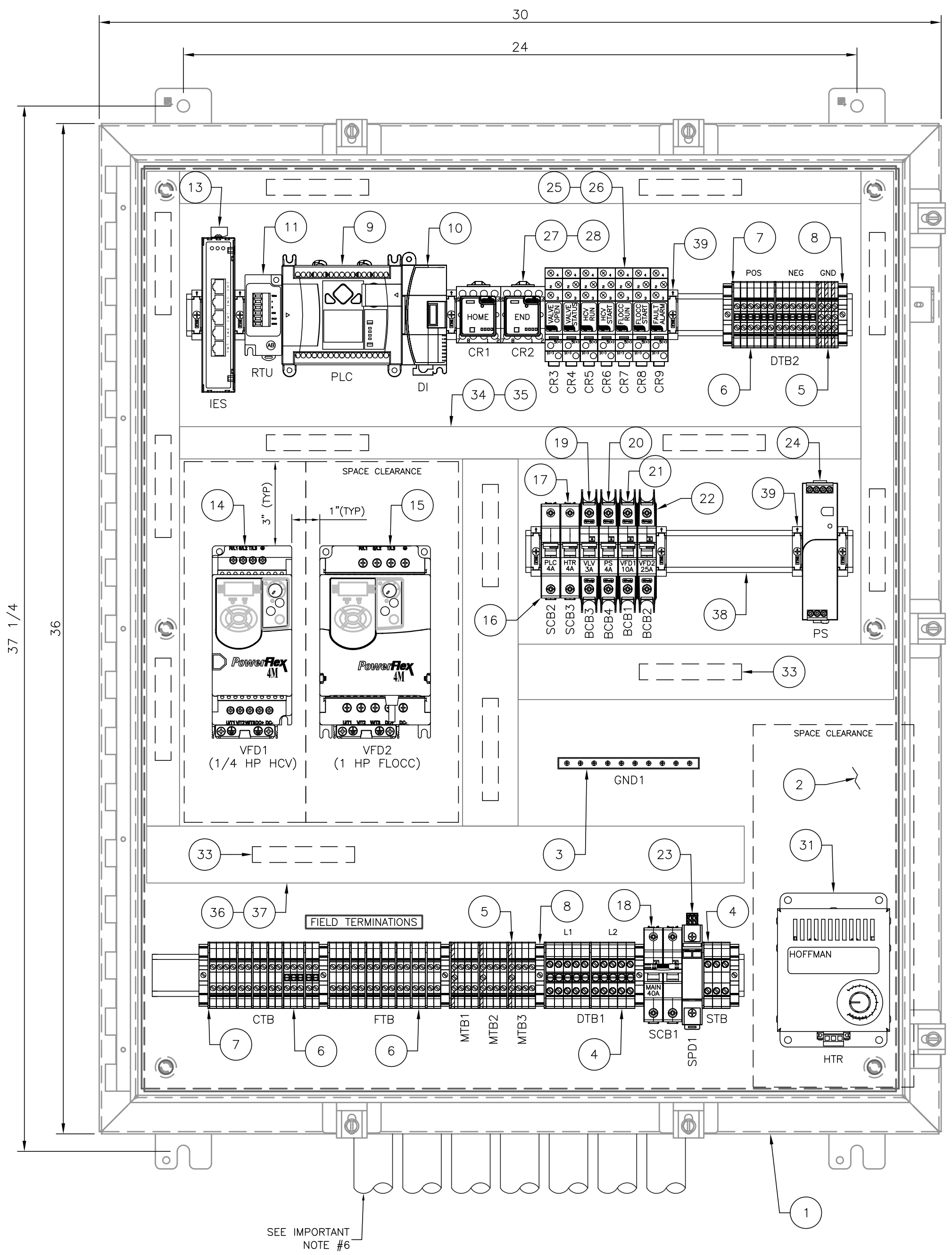
- For an actual list of HMI commands, please refer to MRI's Field Engineer at system start-up. System training is also available if needed.
- HMI sequence of operation and screen shots shall be coordinated with MRI's Field Start-up Engineer.
- Alarms are intended to be reset at the Local Control Panel**.** Only conditional alarms such as 'Power Fail' or 'Com/Link Fail' that do not inhibit the units ability to run while the alarm is annunciated but recovered, can be reset from the SCADA network. Refer to MRI's field start-up engineer for more information.
- PLC I/O tags and IP addresses shall be coordinated with MRI's field start up engineer and integrator.

LOCAL CONTROL PANEL GENERAL ARRANGEMENT
(PACKAGED PILOT-UNIT ASSEMBLY)



TOTAL QUANTITY: (1)
SUPPLY POWER - 120V AC, 1-PHASE, 30A, 60Hz
LINE-TO-NEUTRAL VOLTAGE
(FROM PLANT POWER UTILITY SOURCE)

EXTERIOR VIEW: ENCLOSURE FACE



INTERIOR VIEW: SUB PANEL & COMPONENTS

BILL OF MATERIALS

ITEM #	QUANTITY	DESCRIPTION	MANUFACTURER	MODEL/PART #
1	1	36" X 30" X 08" NEMA 4X PAINTED ALUMINUM ENCLOSURE	HOFFMAN	A36H3008ALLP
2	1	36" X 30" SUB BACK-PANEL	HOFFMAN	A36P30
3	1	GROUND BUS BAR 10-POINT	ILSCO	D167-10
4	13	8mm POWER TERMINAL BLOCK	ALLEN BRADLEY	1492-J6
5	6	6mm GROUND TERMINAL BLOCK	ALLEN BRADLEY	1492-JG4
6	51*	5mm CONTROL TERMINAL BLOCK	ALLEN BRADLEY	1492-J3
7	22	TERMINAL BLOCK END PARTITION COVER	ALLEN BRADLEY	1492-EBJ3
8	8	TERMINAL BLOCK END STOP ANCHOR	ALLEN BRADLEY	1492-EAJ35
9	1	MICROLOGIX 1100 PLC CONTROLLER	ALLEN BRADLEY	1763-L16BWA
10	1	MICROLOGIX 1100 PLC 8PT. DC DIGITAL INPUT EXP. MODULE	ALLEN BRADLEY	1762-IQ8
11	1	MICROLOGIX 1100 DH-485/MODBUS RTU ADAPTER	ALLEN BRADLEY	1763-NC01
12	1	PANELVIEW PLUS COMPACT 600 HMI TOUCH SCREEN TERMINAL	ALLEN BRADLEY	2711PC-T6C20D8
13	1	5-PORT UNMANAGED INDUSTRIAL ETHERNET SWITCH	ANTAIRA	LNX-500A
14	1	POWERFLEX 4M AC HCV VFD DRIVE (120VAC, 1/4 HP)	ALLEN BRADLEY	22F-V1P6N103
15	1	POWERFLEX 4M AC FLOCC VFD DRIVE (120VAC, 1 HP)	ALLEN BRADLEY	22F-V4P5N103
16	1	SUPPLEMENTARY CIRCUIT BREAKER 1-POLE 4A (CRV C)	ALLEN BRADLEY	1492-SPM1C040
17	1	SUPPLEMENTARY CIRCUIT BREAKER 1-POLE 4A (CRV B)	ALLEN BRADLEY	1492-SPM1B040
18	1	SUPPLEMENTARY CIRCUIT BREAKER 1-POLE + N 40A (CRV C)	ALLEN BRADLEY	1492-SPM1C400-N
19	1	MINIATURE BRANCH CIRCUIT BREAKER 1-POLE 3A	ALLEN BRADLEY	1489-M1C030
20	1	MINIATURE BRANCH CIRCUIT BREAKER 1-POLE 4A	ALLEN BRADLEY	1489-M1C040
21	1	MINIATURE BRANCH CIRCUIT BREAKER 1-POLE 10A	ALLEN BRADLEY	1489-M1C100
22	1	MINIATURE BRANCH CIRCUIT BREAKER 1-POLE 25A	ALLEN BRADLEY	1489-M1C250
23	1	SURGE PROTECTOR 120VAC 1-POLE	ALLEN BRADLEY	4983-DS120-401
24	1	DC POWER SUPPLY (80W, 3.3A OUTPUT)	ALLEN BRADLEY	1606-XLE80E
25	7	1-POLE 24VDC CONTROL RELAY	ALLEN BRADLEY	700-HK36Z24-3-4
26	7	1-POLE RELAY BASE-SOCKET	ALLEN BRADLEY	700-HN121
27	2	2-POLE 24VDC CONTROL RELAY	ALLEN BRADLEY	700-HA32Z24-3-4
28	2	2-POLE RELAY BASE-SOCKET	ALLEN BRADLEY	700-HN125
29	2	3 POSITION SELECTOR SWITCH (2N.O. & 2N.C. CT BLOCK)	ALLEN BRADLEY	800H-JR2B
30	1	2 POSITION SELECTOR SWITCH (1N.O. & 1N.C. CT BLOCK)	ALLEN BRADLEY	800H-HR2A
31	1	ELECTRIC PANEL HEATER 200W	HOFFMAN	DAH2001A
32	1	THERMOPLASTIC DATA POCKET 6" X 6"	HOFFMAN	ADP1
33	1*	CORROSION INHIBITOR TAPE (4" STRIP PER SQ. FT.)	HOFFMAN	AHCI60R
34	2*	1" X 3" X 6' WIRE DUCT (AS NEEDED)	PANDUIT	F1X3LG6
35	2*	1" X 6' DUCT COVER (AS NEEDED)	PANDUIT	C1LG6
36	1*	2" X 3" X 6' WIRE DUCT (AS NEEDED)	PANDUIT	F2X3LG6
37	1*	2" X 6' DUCT COVER (AS NEEDED)	PANDUIT	C2LG6
38	2*	ALUMINUM DIN RAIL 3' (AS NEEDED)	IDEC	BNDN1000
39	8*	DIN RAIL STOP (AS NEEDED)	IDEC	BNL6
40	6	SELF-SEALING 1/4-20 X 1 18-8 S.S. HEX-BOLT	APM-HEXSEAL	ST1/4-20X1-2701
41	6	SELF-SEALING 1/4-20 18-8 S.S. HEX-NUT	APM-HEXSEAL	1/4-20-AJ-6-SS
42	6	SELF-SEALING 1/4 304 S.S. FLAT WASHER	APM-HEXSEAL	75082
43	1	HMI TOUCH SCREEN SUN SHIELD COVER (PAINTED BLUE)	MRI	N/A

WIRE COLOR KEY & SYSTEM NOTES:

1. SUPPLY POWER WIRING TO BE SIZED FOR LOAD (MIN. #10 AWG)
2. NTERNAL PANEL WIRING SHALL BE COLOR CODED AS FOLLOWS:
   BLUE (BLU) = +DC (POSITIVE) POWER/CONTROL CIRCUITS
   BLUE/WHITE (BLU/WHT) = -DC (NEGATIVE) POWER/CONTROL CIRCUITS
   PINK (PNK) = INTERNAL MISCELLANEOUS AUXILIARY INPUTS
   YELLOW (YEL) = VALVE CONTROL/STATUS CIRCUITS
   VIOLET (VLT) = DRY CONTACTS & FIELD CONTROL/STATUS CIRCUITS
   BLACK (BLK) = E-STOP CONTROL/STATUS CIRCUITS
   GRAY (GRY) = LOCAL/REMOTE/HAND/AUTO CONTROL/STATUS CIRCUITS
   ORANGE (ORG) = COLLECTOR/SYSTEM CONTROL/STATUS CIRCUITS
   BLACK (BLK) = AC POWER CIRCUITS (MIN. #14 AWG)
   RED (RED) = AC CONTROL CIRCUITS (MIN. #16 AWG)
   WHITE (WHT) = AC NEUTRAL CIRCUITS (MIN. #14 AWG)
   BLACK (BLK) = L1 LEAD OF 230V AC, 3ϕ MOTOR (MIN. #14 AWG)
   RED (RED) = L2 LEAD OF 230V AC, 3ϕ MOTOR (MIN. #14 AWG)
   BLUE (BLU) = L3 LEAD OF 230V AC, 3ϕ MOTOR (MIN. #14 AWG)
   GREEN (GRN) = EQUIPMENT GROUNDING CONDUCTORS
3. ALL CONTROL WIRING = MIN. #20 AWG (SEE DWGS B12-B14)
4. WIRES BEGINNING WITH SUFFIX 'P' INDICATE +DC (POSITIVE)
5. WIRES BEGINNING WITH SUFFIX 'N' INDICATE -DC (NEGATIVE)
6. WIRES BEGINNING WITH SUFFIX 'H' INDICATE HAND CONTROL
7. CONTROL CIRCUIT VOLTAGE IS 24V DC, 60Hz
8. POWER CIRCUIT VOLTAGE IS 120V AC, 1ϕ, 60Hz
9. MOTOR CIRCUIT VOLTAGE IS 230V AC, 3ϕ, 60Hz
10. PANEL DIMENSIONS ARE 36"H X 30"W X 08"D (NEMA 4X ALUMINUM)
11. RECOMMENDED AND MOST EFFICIENT SPEED IS 1-3 FT/MIN
12. PANEL IS PROVIDED PRE-WIRED AND MRI TESTED
13. (*) IN BOM DENOTES AN APPROXIMATION OR MAY VARY

IMPORTANT NOTES:

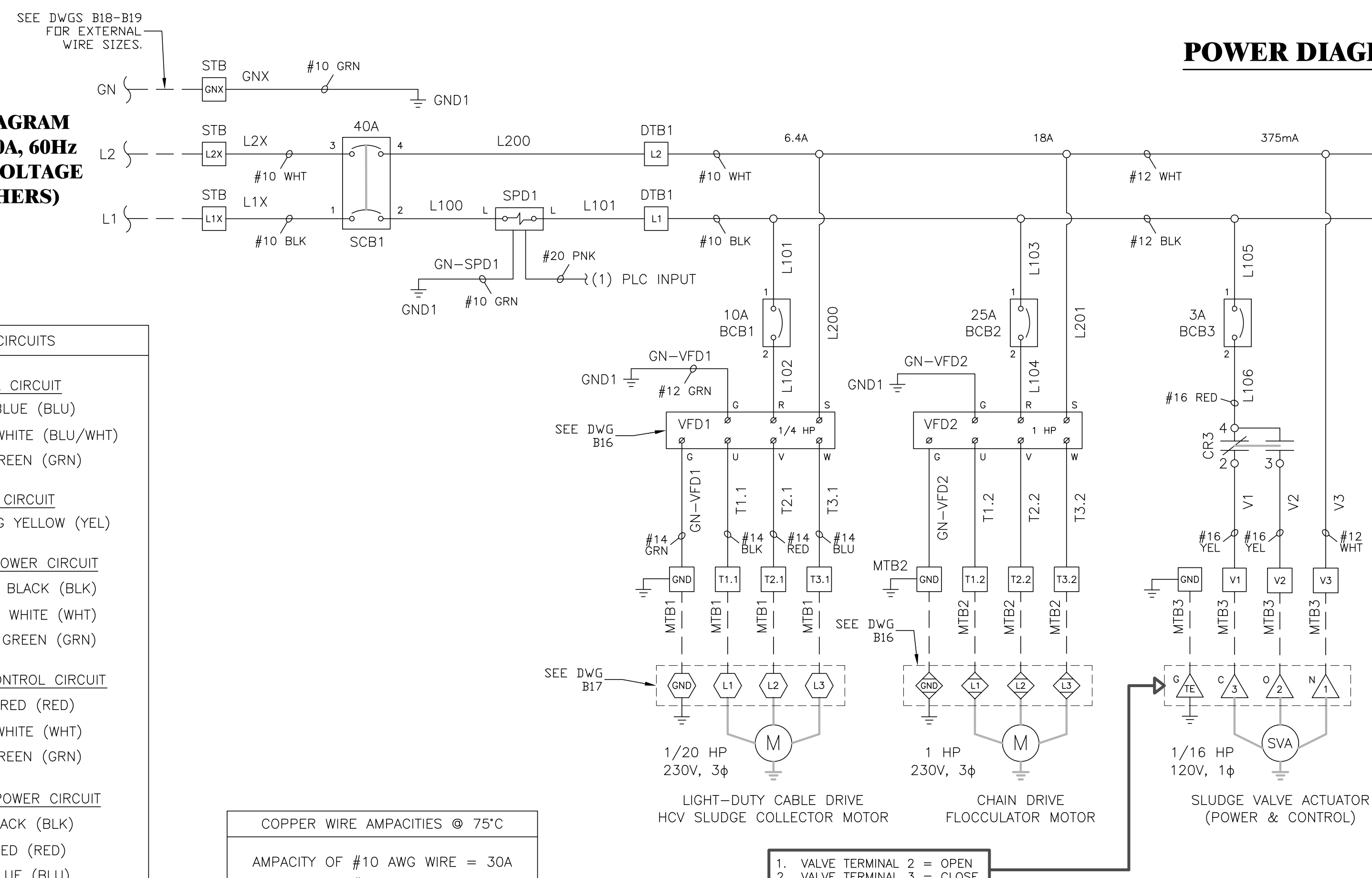
1. SELF-SEALING FASTENERS ARE USED TO MOUNT THE HMI TOUCH SCREEN COVER TO MAINTAIN THE PANEL'S NEMA RATING INTEGRITY.
2. THE HMI TOUCH SCREEN COVER IS PAINTED BLUE 304 STAINLESS STEEL.
3. SEE DRAWING B20 FOR HMI TOUCH SCREEN COVER DIMENSIONS, BOM, AND MOUNTING DETAILS.
4. THE SCCR RATING LABEL SHALL BE PLACED ON THE INTERIOR SIDE OF ENCLOSURE DOOR (INSIDE).
5. PANEL WILL BE PROVIDED WITH MRI ELECTRICAL DRAWINGS AND COMPONENT SPECIFICATION/INSTALL CUT SHEETS IN DATA POCKET.
6. CONDUIT IS TO BE MOUNTED ON THE BOTTOM SIDE OF THE ENCLOSURE CABINET. (DONE BY MRI & OTHERS)

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)	DRAWN BY: LGERBER	REV 1:	PILOT-UNIT LOCAL CONTROL PANEL
PROJECT NUMBER: MRI-1502	SCALE: N/A	REV 2:	GENERAL ARRANGEMENT & BOM
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:	CUSTOMER NUMBER N/A — DRAWING NUMBER 1502B10

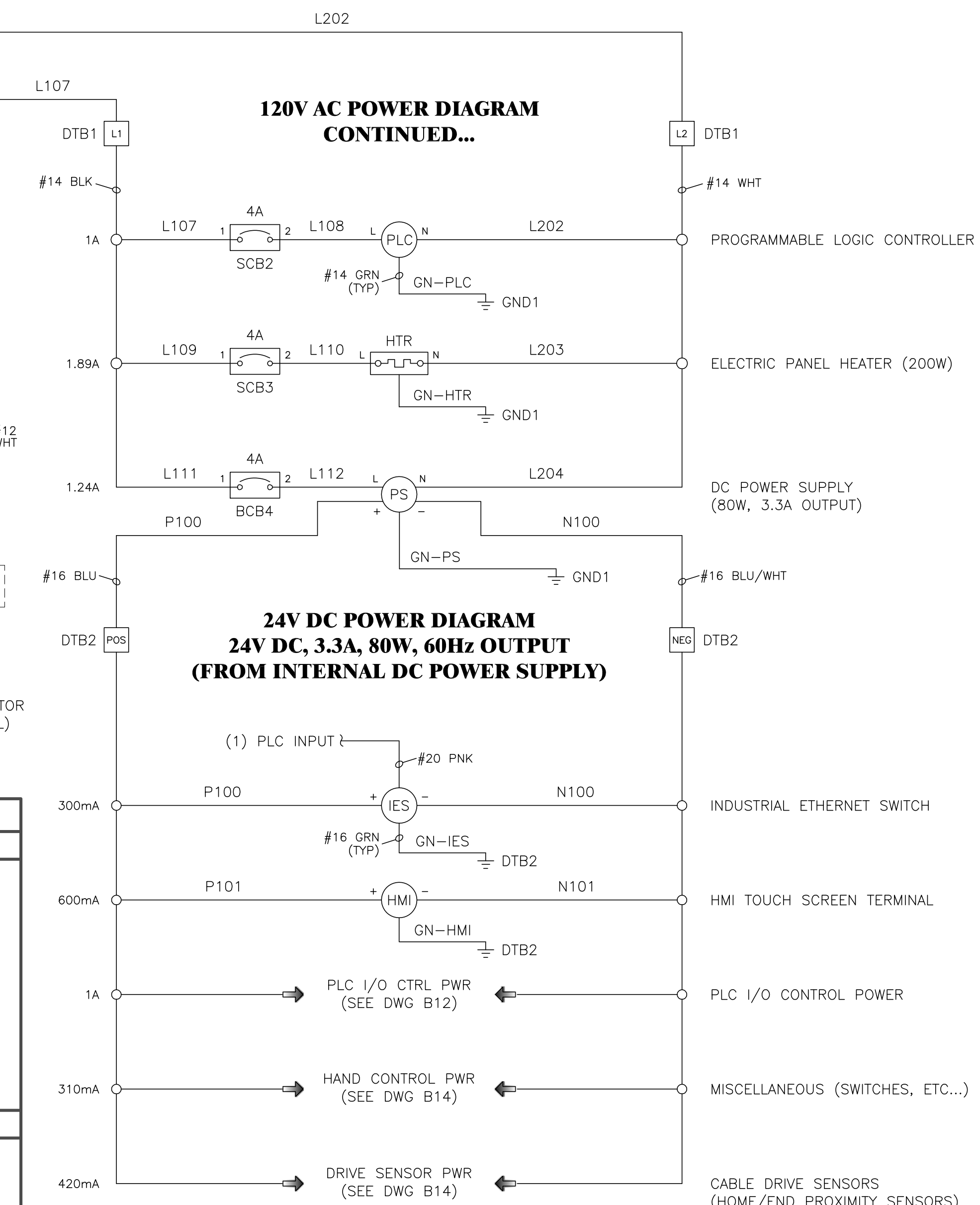
POWER DIAGRAM

120V AC POWER DIAGRAM
120V AC, 1-PHASE, 30A, 60Hz
LINE-TO-NEUTRAL VOLTAGE
(SUPPLIED BY OTHERS)



120V AC POWER DIAGRAM CONTINUED...

24V DC POWER DIAGRAM
24V DC, 3.3A, 80W, 60Hz OUTPUT
(FROM INTERNAL DC POWER SUPPLY)



INTERNAL WIRE CIRCUITS
24V DC CONTROL CIRCUIT
POS = #16 AWG BLUE (BLU)
NEG = #16 AWG BLUE/WHITE (BLU/WHT)
GND = #16 AWG GREEN (GRN)
VALVE CONTROL CIRCUIT
VALVE CTRL = #16 AWG YELLOW (YEL)
120V AC, 1ϕ PANEL POWER CIRCUIT
L1/L = #10-14 AWG BLACK (BLK)
L2/N = #10-14 AWG WHITE (WHT)
GND = #10-14 AWG GREEN (GRN)
120V AC, 1ϕ PANEL CONTROL CIRCUIT
L1/L = #16 AWG RED (RED)
L2/N = #16 AWG WHITE (WHT)
GND = #16 AWG GREEN (GRN)
230V AC, 3ϕ MOTOR POWER CIRCUIT
L1 = #14 AWG BLACK (BLK)
L2 = #14 AWG RED (RED)
L3 = #14 AWG BLUE (BLU)
GND = #14 AWG GREEN (GRN)

COPPER WIRE AMPACITIES @ 75°C
AMPACITY OF #10 AWG WIRE = 30A
AMPACITY OF #12 AWG WIRE = 20A
AMPACITY OF #14 AWG WIRE = 15A
AMPACITY OF #16 AWG WIRE = 10A
AMPACITY OF #18 AWG WIRE = 7A
AMPACITY OF #20 AWG WIRE = 5A

SYMBOL LEGEND
= RELAY CONTACT
= CIRCUIT BREAKER
= SURGE PROTECTOR
= HEATER
(XXX) = PANEL/FIELD COMPONENTS

WIRING/TERMINATION SCHEMATIC KEY
(00) = TERMINAL BLOCK IN HCV CABLE DRIVE J-BOX
[00] = TERMINAL BLOCK IN LOCAL CONTROL PANEL
△00 = TERMINAL IN SLUDGE VALVE ACTUATOR
——— = INTERNAL PANEL WIRING (DONE BY MRI)
— — = EXTERNAL FIELD WIRING (DONE BY OTHERS/MRI)
——— = INTERNAL DEVICE WIRING (DONE BY MFR. OR MRI)

SHORT CIRCUIT CURRENT RATING CALCULATION

ABBREVIATIONS & SCCR RATINGS @ 120VAC:

1. SCCR = SHORT CIRCUIT CURRENT RATING
2. SPD1 = SURGE PROTECTION DEVICE (SCCR = 100kA)
3. BCB1-BCB4 = BRANCH CIRCUIT BREAKERS 1-4 (SCCR = 10kA)
4. SCB1-SCB3 = SUPPLEMENTARY CIRCUIT BREAKERS 1-3 (SCCR = 10kA)
5. VFD1-VFD2 = VARIABLE FREQUENCY DRIVES 1-2 (SCCR = 65kA)
6. DTB1-DTB2 = DISTRIBUTION TERMINAL BLOCKS 1-2 (SCCR = 10kA)
7. MTB1-MTB3 = MOTOR TERMINAL BLOCKS 1-3 (SCCR = 10kA)
8. CTB = CONTROL TERMINAL BLOCKS (SCCR = 10kA)
9. STB = SUPPLY TERMINAL BLOCKS (SCCR = 10kA)
10. CR3 = CONTROL RELAY 3 (CONTACTS ONLY) = (SCCR = 5kA)
11. PS = POWER SUPPLY (SCCR = 10kA, INCLUDES PS INTERNAL FUSE)
12. HTR = HEATER (SCCR = NOT REQUIRED)
13. PLC = PROGRAMMABLE LOGIC CONTROLLER (SCCR = NOT REQUIRED)

NOTES:

14. COMPONENTS LISTED ABOVE WITHOUT SCCR RATING ARE NOT INCLUDED NOR REQUIRED IN PANEL SCCR CALCULATION PER UL 508A.
15. SEE UL 508A SB4.1-2 & MNF. SPECIFICATIONS FOR MORE INFO.

CONTROL PANEL SCCR RATING

16. OVERALL WITHSTAND AND INTERRUPTING RATING OR SCCR RATING OF CONTROL PANEL IS 5,000A (5kA) RMS SYMMETRICAL AT 120V AC.

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)	DRAWN BY: LGERBER	REV 1:	POWER DIAGRAM
PROJECT NUMBER: MRI-1502	SCALE: N/A	REV 2:	230VAC - 120VAC - 24VDC
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:	CUSTOMER NUMBER N/A — DRAWING NUMBER 1502B11

WIRE CONDUCTOR AMPACITIES
AMPACITY OF #16 AWG WIRE = 10A
AMPACITY OF #18 AWG WIRE = 7A
AMPACITY OF #20 AWG WIRE = 5A

INTERNAL WIRE CIRCUITS
24V DC CIRCUIT
POS = #16 AWG BLUE (BLU)
NEG = #16 AWG BLUE/WHITE (BLU/WHT)
GND = #16 AWG GREEN (GRN)
DIGITAL I/O CIRCUITS
INPUTS = #20 AWG CLR. VARIES
OUTPUTS = #18 AWG CLR. VARIES

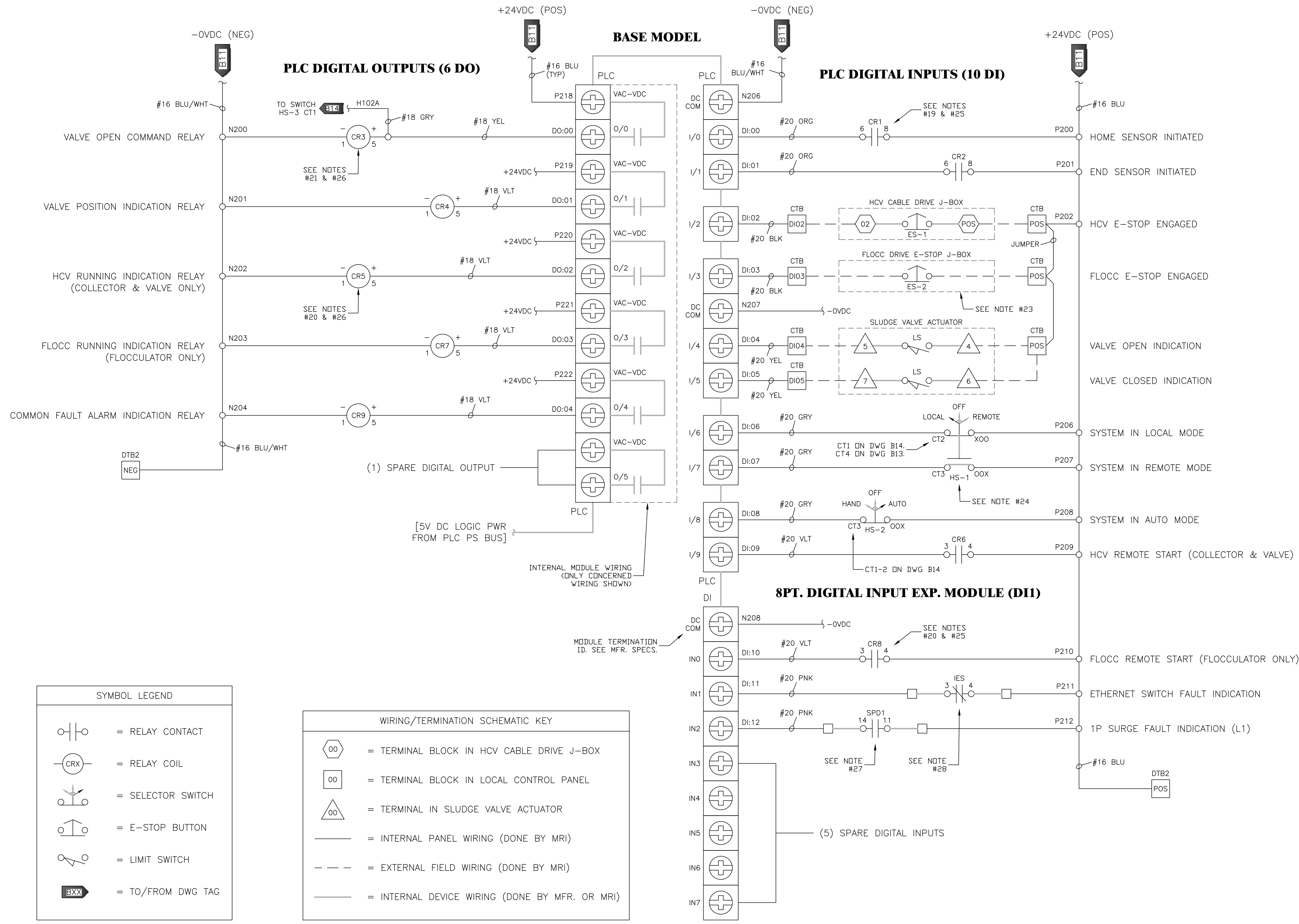
ABBREVIATIONS & NOTES:

1. CR = CONTROL RELAY
2. LS = LIMIT SWITCH
3. IES = INDUSTRIAL ETHERNET SWITCH
4. SPD = SURGE PROTECTION DEVICE
5. DTB = DISTRIBUTION TERMINAL BLOCK
6. CTB = CONTROL TERMINAL BLOCK
7. CT1 = CONTACT 1
8. CT2 = CONTACT 2
9. CT3 = CONTACT 3
10. N.O. = NORMALLY OPEN
11. N.C. = NORMALLY CLOSED
12. HS = HAND SWITCH
13. ES = EMERGENCY STOP (E-STOP)
14. DI = DISCRETE INPUT (DIGITAL)
15. DO = DISCRETE OUTPUT (DIGITAL)
16. (5) SPARE DC SINK/SOURCE DIGITAL INPUTS
17. (1) SPARE RELAY DIGITAL OUTPUT
18. (0) SPARE ANALOG VOLTAGE INPUTS (NOT SHOWN)
19. SEE HAND DIAGRAM ON DRAWING B14 FOR HOME & END SENSOR RELAY COIL CONFIGURATIONS.
20. SEE DRY CONTACTS ON DRAWING B13 FOR RUN, ALARM, & VALVE POSITION OUTPUT RELAY CONTACT CONFIGURATIONS AND FOR REMOTE START INPUT RELAY COIL CONFIGURATIONS.
21. SEE 120VAC POWER DIAGRAM ON DRAWING B11 FOR VALVE OPEN/CLOSE COMMAND RELAY CONTACT CONFIGURATIONS.
22. SEE DRAWING B10 FOR WIRE COLOR KEY.
23. THE FLOCCULATOR E-STOP J-BOX DOES NOT HAVE TERMINAL BLOCKS. WIRES ARE TERMINATED DIRECTLY TO THE E-STOP BUTTON'S CONTACT BLOCK. (DONE BY MRI)

CONTROL RELAY, SWITCH, & CONTACT RATINGS:

24. SWITCH CONTACT MAX. CONTROLLED LOAD: 2.5A @ 24VDC & 10A @ 120VAC
25. RELAY CONTACT MAX. CONTROLLED LOAD: 10A @ 24VDC & 16A @ 120VAC
26. RELAY COIL MAX. CONTROLLED LOAD: 21mA, 0.5W @ 24VDC
27. SPD CONTACT MAX. CONTROLLED LOAD: 1A @ 24VDC & 2A @ 120VAC
28. IES CONTACT MAX. CONTROLLED LOAD: 1A @ 24VDC

I/O CONTROL DIAGRAM



MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)	DRAWN BY: LGERBER	REV 1:	DIGITAL I/O CONTROL DIAGRAM (INCLUDES I/O EXPANSION MODULE)	CUSTOMER NUMBER N/A
PROJECT NUMBER: MRI-1502	SCALE: N/A	REV 2:		DRAWING NUMBER 1502B12
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:		

HARDWIRED CONTROLS DIAGRAM / DRY CONTACTS

INTERNAL WIRE CIRCUITS

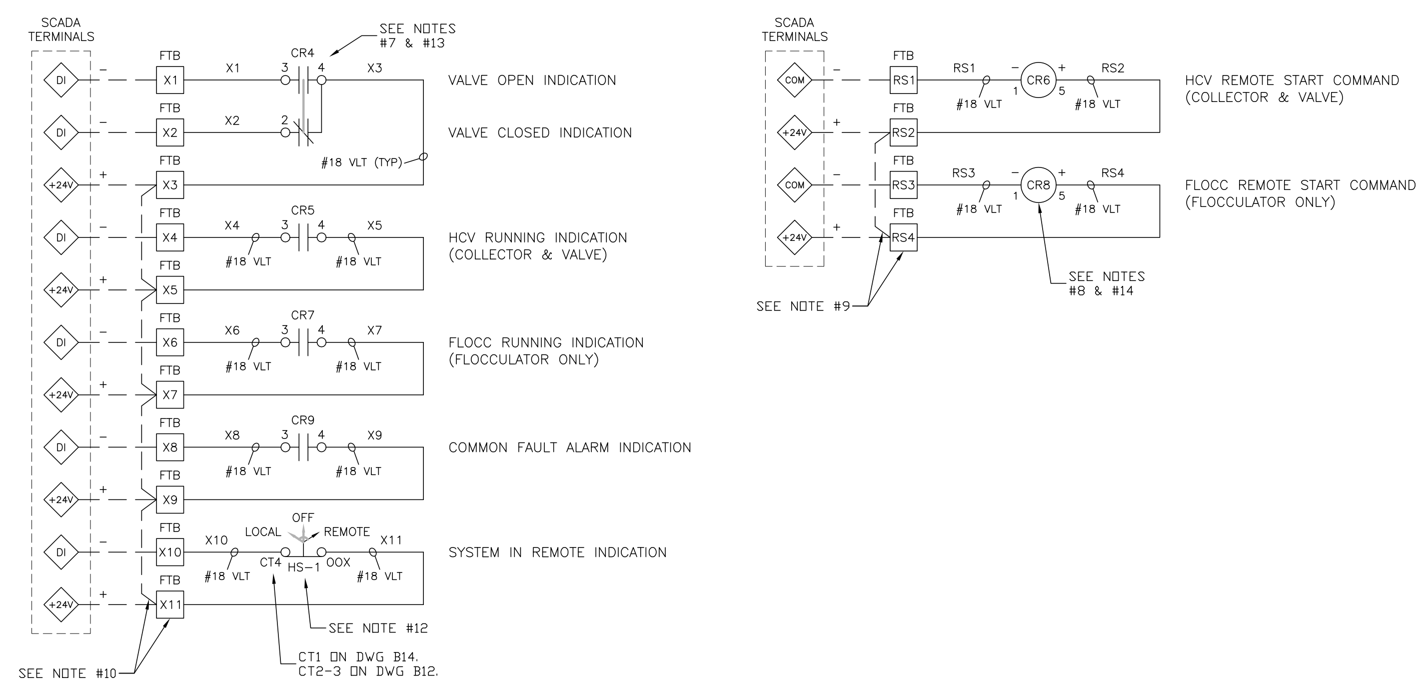
FIELD CONTROL/DRY CONTACTS
#18 AWG VIOLET (VLT)

ABBREVIATIONS & NOTES:

1. CR = CONTROL RELAY
2. HS = HAND SWITCH
3. DI = DISCRETE INPUT (DIGITAL)
4. CT4 = CONTACT 4
5. FTB = FIELD TERMINAL BLOCK
6. COM = COMMON (FOR +24VDC CONTROL POWER)
7. SEE OUTPUT DIAGRAM ON DRAWING B12 FOR RUN, ALARM, & VALVE POSITION RELAY COIL CONFIGS.
8. SEE INPUT DIAGRAM ON DRAWING B12 FOR REMOTE START RELAY CONTACT CONFIGURATIONS.
9. SITE INSTALLATION MAY JUMPER TERMINAL BLOCKS RS2 TO RS4 IF DESIRED TO REDUCE WIRE RUNS TO THE PLANT CONTROL SYSTEM (SCADA).
10. SITE INSTALLATION MAY JUMPER TERMINAL BLOCKS X3, X5, X7, X9, & X11 IF DESIRED TO REDUCE WIRE RUNS TO THE PLANT CONTROL SYSTEM (SCADA).
11. BOTH DRY CONTACTS AND ETHERNET COMMUNICATIONS ARE PROVIDED FOR FLEXIBILITY AND REDUNDANCY. PLANT MAY CHOOSE ONLY ONE OR THE OTHER.

CONTROL RELAY AND SWITCH RATINGS:

12. SEL. SWITCH CONTACT MAX. CONTROLLED LOAD: 2.5A @ 24VDC & 10A @ 120VAC
13. RELAY CONTACT MAX. CONTROLLED LOAD: 10A @ 24VDC & 16A @ 120VAC
14. RELAY COIL MAX. CONTROLLED LOAD: 21mA, 0.5W @ 24VDCC



SYMBOL LEGEND

- = RELAY CONTACT
- (CRX) = RELAY COIL
- = SELECTOR SWITCH

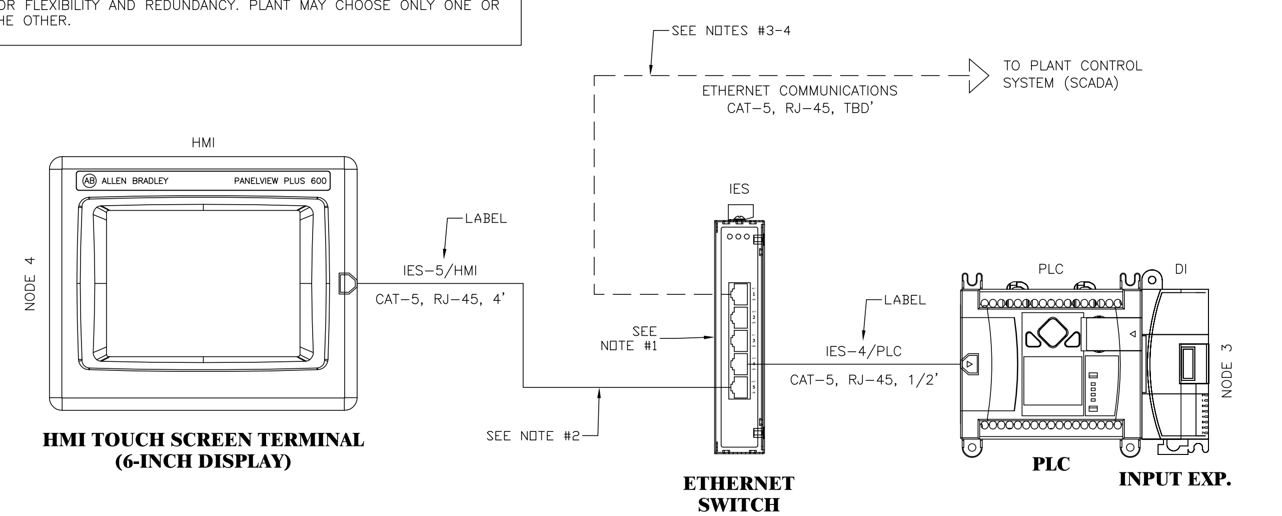
WIRING/TERMINATION SCHEMATIC KEY

- 00 = TERMINAL BLOCK IN LOCAL CONTROL PANEL
- ◇00 = TERMINAL IN PLANT CONTROL SYSTEM (SCADA)
- ——— = INTERNAL PANEL WIRING (DONE BY MRI)
- — — — = EXTERNAL FIELD WIRING (DONE BY OTHERS)

ETHERNET COMMUNICATIONS SETUP

NOTES:

1. (2) SPARE UNMANAGED ETHERNET [CU/TX] TP RJ-45 PORTS.
2. INTERNAL ETHERNET CABLES ARE TP RJ-45 CATEGORY-5 PATCH CORD.
3. EXTERNAL ETHERNET CABLE SHALL BE TP RJ-45 CATEGORY-5 CABLE.
4. BOTH DRY CONTACTS AND ETHERNET COMMUNICATIONS ARE PROVIDED FOR FLEXIBILITY AND REDUNDANCY. PLANT MAY CHOOSE ONLY ONE OR THE OTHER.



WIRING/CABLE SCHEMATIC KEY

- ——— = INTERNAL PANEL CABLE (DONE BY MRI)
- — — — = EXTERNAL FIELD CABLE (DONE BY OTHERS)

IP ADDRESS INFO

XXX.XXX.XXX.XXX = PROGRAMMABLE LOGIC CONTROLLER (PLC)
XXX.XXX.XXX.XXX = HMI TOUCH SCREEN TERMINAL (OIT)

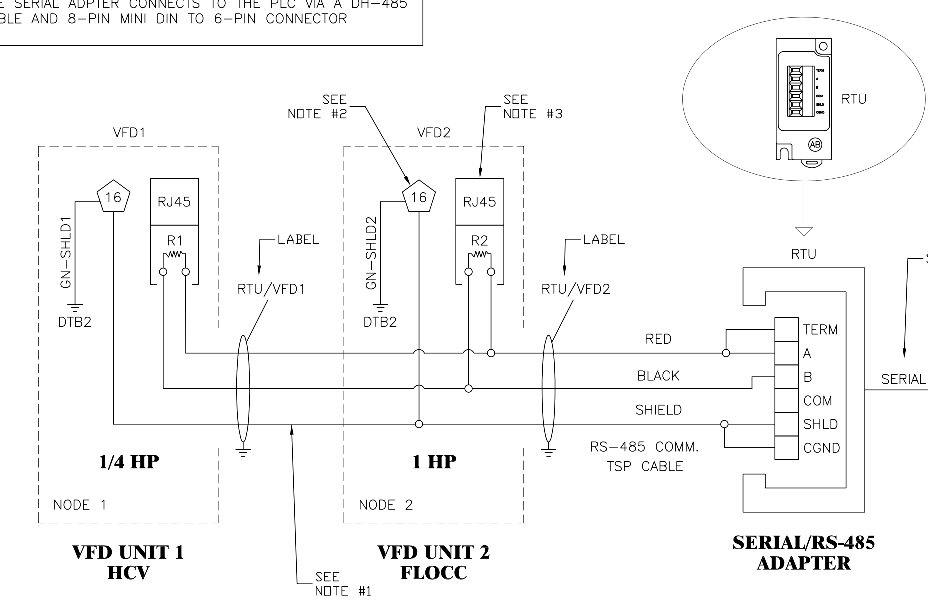
SERIAL/RS-485 MODBUS RTU SETUP

NOTES:

1. DAISY CHAIN RS-485 TSP CABLE BETWEEN VFD'S.
2. CONNECT RS-485 TSP SHIELD TO VFD TERMINAL 16.
3. PLACE A 4.1kΩ RESISTER ON EACH VFD RJ45 CONNECTOR.
4. THE SERIAL ADPTER CONNECTS TO THE PLC VIA A DH-485 CABLE AND 8-PIN MINI DIN TO 6-PIN CONNECTOR

INTERNAL RS-485 TSP CABLE

TWISTED SHIELDED CABLE (GRAY)
(+) POLE = #18 AWG RED
(−) POLE = #18 AWG BLACK
SHIELD = ALUMINUM

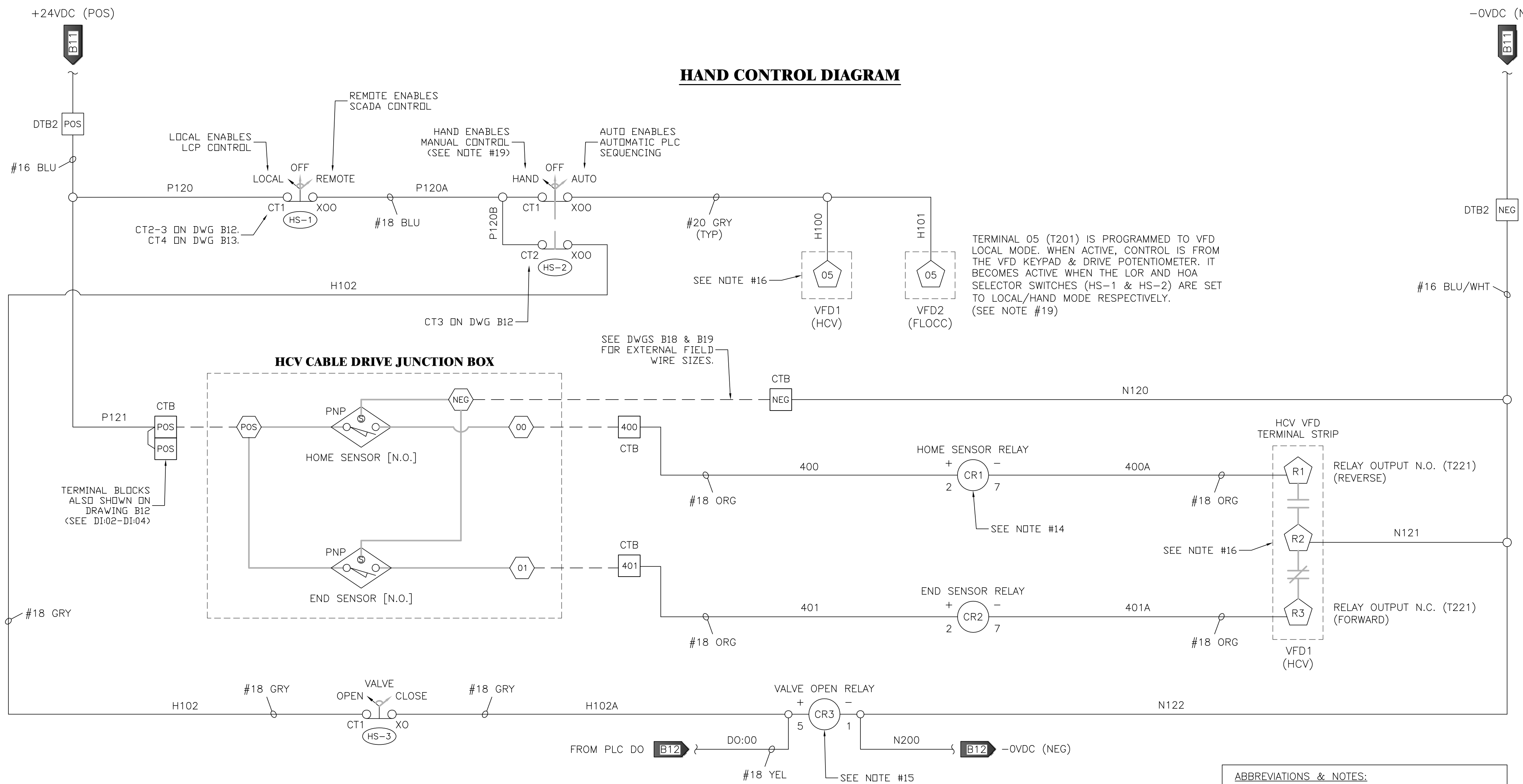


WIRING/TERMINATION SCHEMATIC KEY

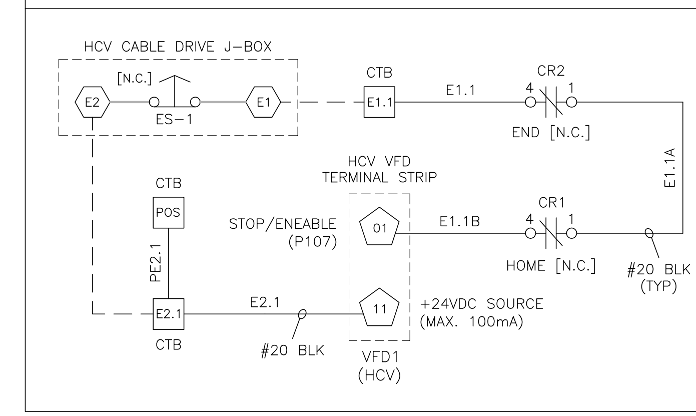
- ⬠00 = TERMINAL IN VARIABLE FREQUENCY DRIVE (VFD)

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)	DRAWN BY: LGERBER	REV 1:	MEURER RESEARCH, INC.
PROJECT NUMBER: MRI-1502	SCALE: N/A	REV 2:	COMMUNICATIONS SETUP WITH HARDWIRED CONTROL DIAGRAM / DRY CONTACTS
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:	CUSTOMER NUMBER N/A — DRAWING NUMBER 1502B13

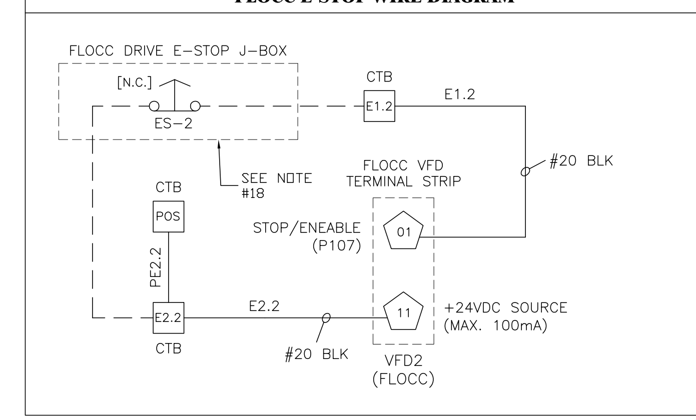
HAND CONTROL DIAGRAM



HCV E-STOP WIRE DIAGRAM



FLOCC E-STOP WIRE DIAGRAM



SYMBOL LEGEND	
—|├○	= RELAY CONTACT
(CRX)	= RELAY COIL
◇	= PROXIMITY SENSOR SWITCH
	= SELECTOR SWITCH
	= EMERGENCY STOP BUTTON
BXX	= TO/FROM DRAWING TAG

WIRING/TERMINATION SCHEMATIC KEY	
⬡ 00	= TERMINAL BLOCK IN HCV CABLE DRIVE J-BOX
□ 00	= TERMINAL BLOCK IN LOCAL CONTROL PANEL
⬠ 00	= TERMINAL IN VARIABLE FREQUENCY DRIVE (VFD)
———	= INTERNAL PANEL WIRING (DONE BY MRI)
— — —	= EXTERNAL WIRING (DONE BY MRI)
———	= INTERNAL DEVICE WIRING (DONE BY MFR. OR MRI)

INTERNAL WIRE CIRCUITS

24V DC CIRCUIT

POS = #16 AWG BLUE (BLU)
NEG = #16 AWG BLUE/WHITE (BLU/WHT)
GND = #16 AWG GREEN (GRN)

HAND CONTROL CIRCUITS

#18-20 AWG GRAY (GRY)

COLLECTOR CONTROL CIRCUITS

#18 AWG ORANGE (ORG)

E-STOP CONTROL CIRCUITS

#20 AWG BLACK (BLK)

ABBREVIATIONS & NOTES:

1. CR = CONTROL RELAY
2. CTB = CONTROL TERMINAL BLOCK
3. DTB = DISTRIBUTION TERMINAL BLOCK
4. VFD = VARIABLE FREQUENCY DRIVE
5. PNP = POSITIVE-NEGATIVE-POSITIVE
6. HCV = HOSE-LESS CABLE-VAC
7. FLOCC = FLOCCULATOR
8. CT1 = CONTACT 1
9. CT2 = CONTACT 2
10. N.O. = NORMALLY OPEN
11. N.C. = NORMALLY CLOSED
12. HS = HAND SWITCH
13. ES = EMERGENCY STOP (E-STOP)
14. SEE INPUT DIAGRAM ON DRAWING B12 FOR HOME/END SENSOR RELAY CONTACT CONFIG.
15. SEE POWER DIAGRAM ON DRAWING B11 FOR VALVE OPEN/CLOSE RELAY CONTACT CONFIG.
16. SEE DRAWINGS B15-B16 FOR VFD DRIVE PROGRAMMING PARAMETERS.
17. SEE DWG B10 FOR WIRE COLOR KEY.
18. THE FLOCC E-STOP J-BOX DOES NOT HAVE TERMINAL BLOCKS. WIRES ARE TERMINATED DIRECTLY TO THE E-STOP BUTTON'S CONTACT BLOCK. (DONE BY MRI)
19. WHEN THE HOA SWITCH IS SET IN HAND, THE PLC IS BYPASSED AND CONTROL OF EACH DRIVE UNIT IS OBTAINED FROM THE VFD KEYPAD AND POT. VALVE CONTROL IS OBTAINED FROM THE VALVE SEL. SWITCH.

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)
PROJECT NUMBER: MRI-1502
PROJECT LOCATION: N/A

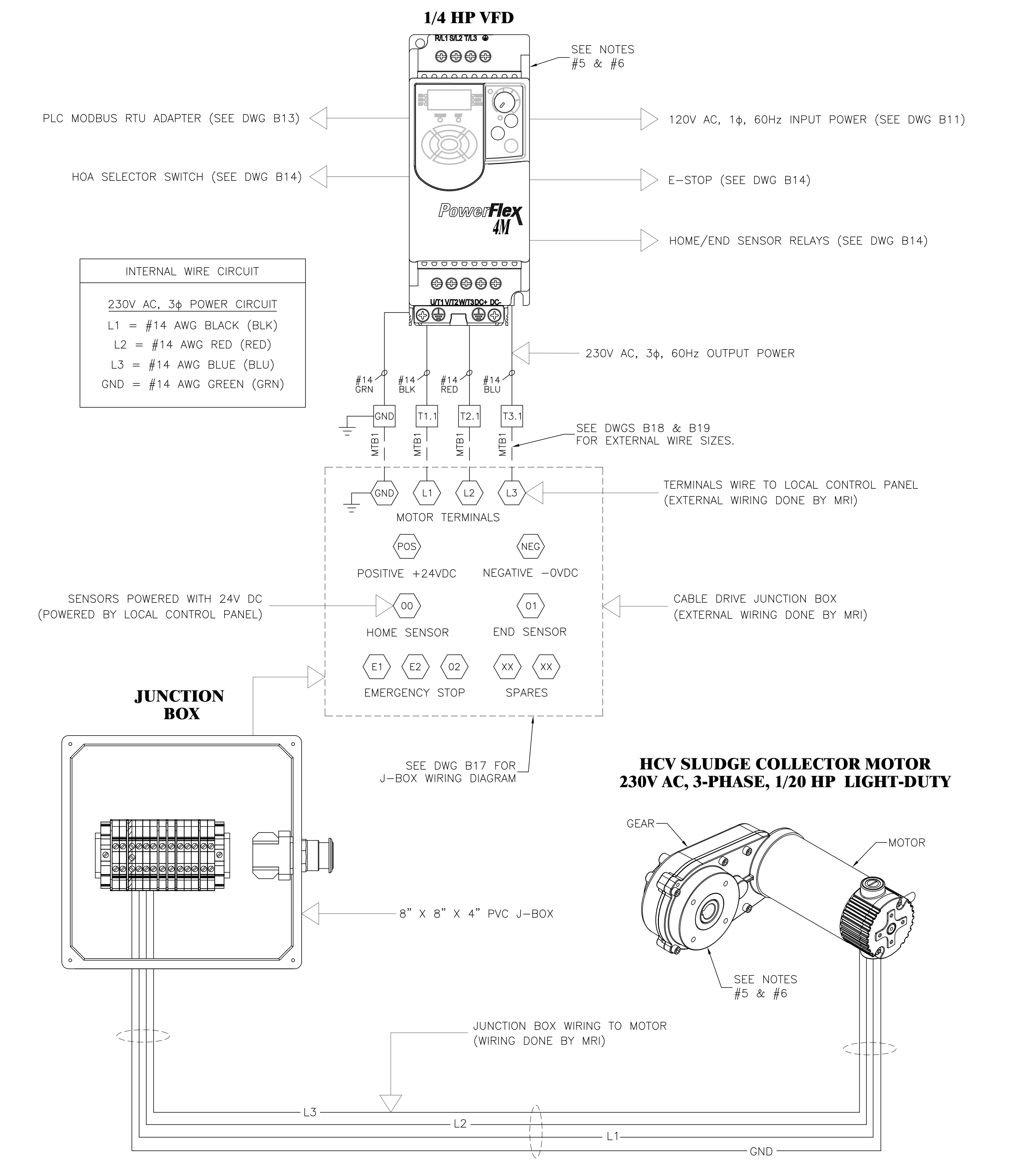
DRAWN BY: LGERBER
SCALE: N/A
DATE: 3/28/16

REV 1:
REV 2:
REV 3:

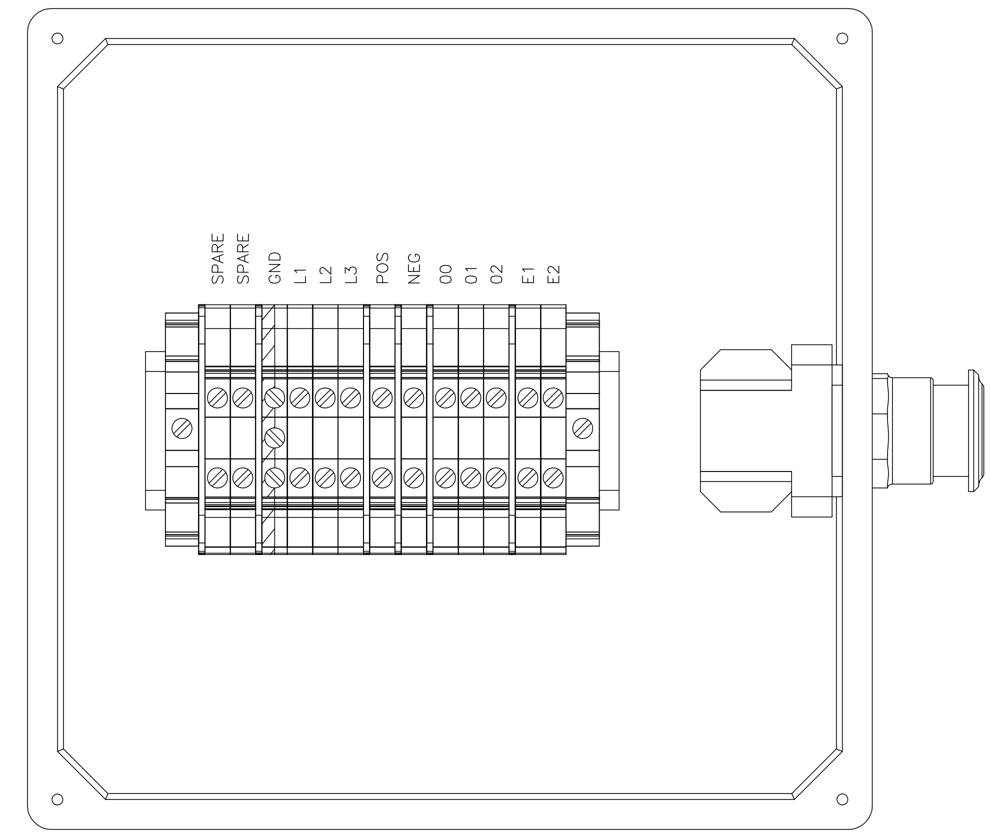
HAND CONTROL DIAGRAM
(PLC BYPASS)

CUSTOMER NUMBER N/A
DRAWING NUMBER 1502B14

HCV SLUDGE COLLECTOR VFD/MOTOR CONTROL DIAGRAM



JUNCTION BOX DETAIL (ENLARGED ILLUSTRATIVE VIEW)



ABBREVIATIONS & NOTES:

1. CTB = CONTROL TERMINAL BLOCK
2. MTB = MOTOR TERMINAL BLOCK
3. VFD = VARIABLE FREQUENCY DRIVE
4. HCV = HOSE-LESS CABLE-VAC
5. HCV COLLECTOR CORRESPONDS TO THE SLUDGE COLLECTOR 1/20 HP CABLE DRIVE MOTOR. IT IS POWERED BY A 1/4 HP VFD INSIDE THE LCP.
6. THE HCV COLLECTOR MOTOR IS RATED FOR AN INPUT VOLTAGE OF UP TO 230V AC, 1-PHASE AND WILL BE SUPPLIED BY THE VFD.

WIRING/TERMINATION SCHEMATIC KEY

(00) hexagon	= TERMINAL BLOCK IN HCV CABLE DRIVE J-BOX
[00] square	= TERMINAL BLOCK IN LOCAL CONTROL PANEL
———	= INTERNAL PANEL WIRING (DONE BY MRI)
— — —	= EXTERNAL FIELD WIRING (DONE BY MRI)

4M VFD PROGRAMMING PARAMETERS:

PROGRAMMING PARAMETERS (VFD CONNECTS TO 1/4 HP HCV MOTOR):

1. SET P101 (MOTOR NAMEPLATE VOLTS) TO 230V.
2. SET P102 (MOTOR NAMEPLATE HERTZ) TO 60Hz (@ 230VAC).
3. SET P103 (MOTOR OVERLOAD CURRENT) TO 0.36A (FLA X 150% @ 230VAC).
4. SET P104 (MINIMUM OUTPUT FREQUENCY) TO 0Hz (@ 230VAC).
5. SET P105 (MAXIMUM OUTPUT FREQUENCY) TO 60Hz (@ 230VAC).
6. SET P106 (START SOURCE) TO 5 FOR COMM PORT MODE.
7. SET P108 (SPEED REFRENCE) TO 5 FOR COMM PORT MODE.
8. SET P109 (ACCELERATION TIME 1) TO 3 FOR DRIVE ACCEL TIME OF 3 SECONDS.
9. SET P110 (DECELERATION TIME 1) TO 3 FOR DRIVE DECEL TIME OF 3 SECONDS.
10. SET T201 (INPUT TERMINAL 5) TO 5 FOR VFD LOCAL MODE.
11. SET T221 (RELAY OUTPUT, R1-R3) TO 3 FOR REVERSE MODE.
12. SET C302 (RS485 COMM DATA RATE) TO 4 FOR 19,200 BAUD RATE.
13. SET C303 (RS485 COMM NODE ADDRESS) TO 1 FOR MODBUS NODE ADDRESS 1.
14. SET A457 (MAXIMUM OUTPUT VOLTAGE) TO 230V.
15. SET A461 (MOTOR NAMEPLATE FLA) TO 0.24A (@ 230VAC).
16. SET THE SINK/SOURCE DIP SWITCH TO SINK.

NOTE: ALL PARAMETERS & SETTINGS STATED ABOVE HAVE BEEN MRI TESTED.

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)	DRAWN BY: LGERBER	REV 1:	HCV MOTOR CONTROL DIAGRAM
PROJECT NUMBER: MRI-1502	SCALE: N/A	REV 2:	(1/20 HP SLUDGE COLLECTOR MOTOR)
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:	CUSTOMER NUMBER N/A — DRAWING NUMBER 1502B15

WIRING/TERMINATION SCHEMATIC KEY	
◇ 00	= TERMINAL IN FLOCCULATOR MOTOR
☐ 00	= TERMINAL BLOCK IN LOCAL CONTROL PANEL
———	= INTERNAL PANEL WIRING (DONE BY MRI)
— — —	= EXTERNAL FILED WIRING (DONE BY MRI)

ABBREVIATIONS & NOTES:

1. MTB = MOTOR TERMINAL BLOCK
2. CTB = CONTROL TERMINAL BLOCK
3. VFD = VARIABLE FREQUENCY DRIVE
4. FLOCC = FLOCCULATOR
5. ES = E-STOP
6. N.O. = NORMALLY OPEN
7. N.C. = NORMALLY CLOSED
8. FLOCC CORRESPONDS TO THE HORIZONTAL 1 HP FLOCCULATOR MOTOR. IT IS POWERED BY A 1 HP VFD INSIDE THE LCP.
9. THE FLOCCULATOR E-STOP J-BOX DOES NOT HAVE TERMINAL BLOCKS. WIRES ARE TERMINATED DIRECTLY TO THE E-STOP BUTTON'S CONTACT BLOCK. (DONE BY MRI)

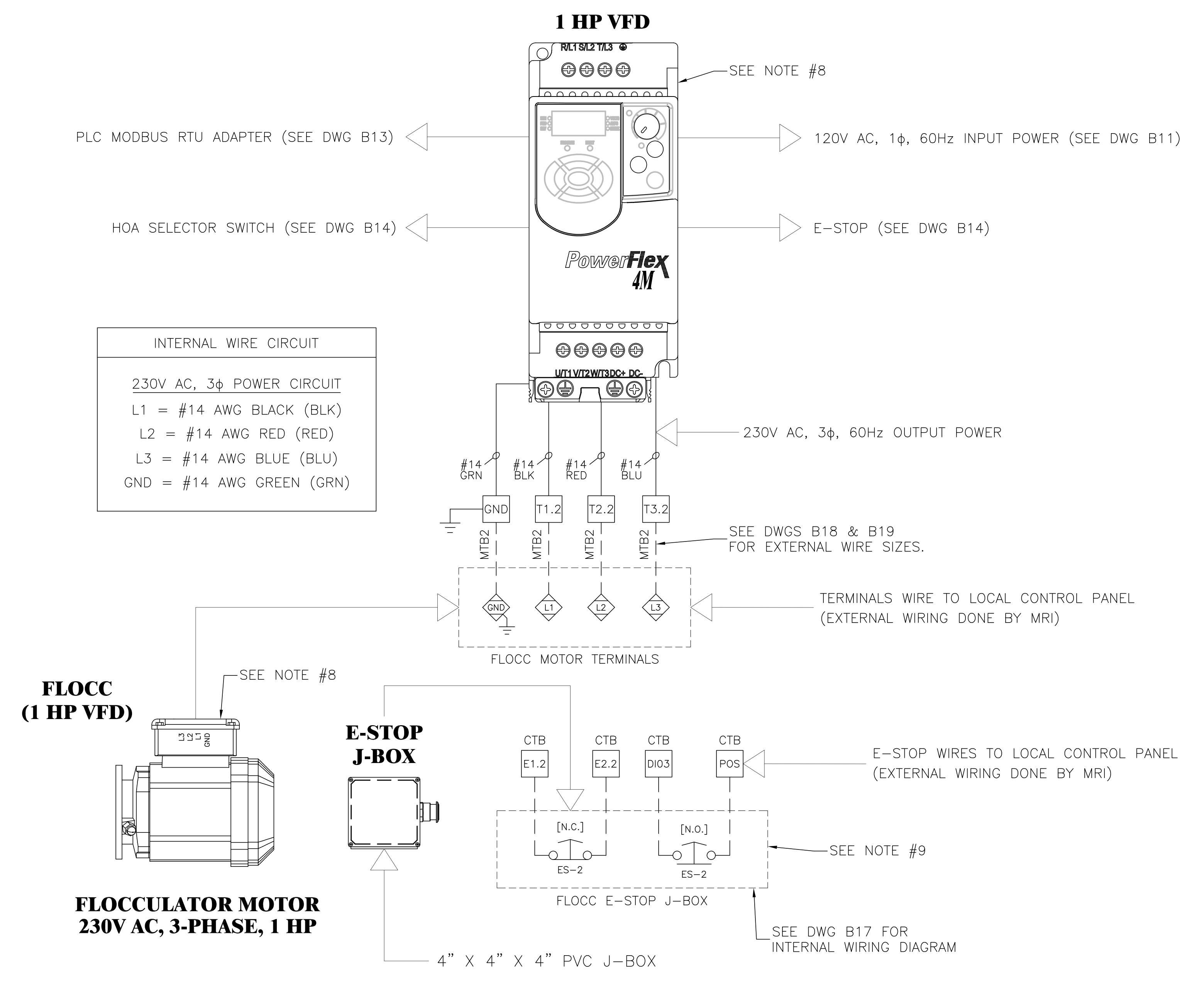
4M VFD PROGRAMMING PARAMETERS:

PROGRAMMING PARAMETERS (VFD CONNECTS TO 1 HP FLOCC MOTOR):

1. SET P101 (MOTOR NAMEPLATE VOLTS) TO 230V.
2. SET P102 (MOTOR NAMEPLATE HERTZ) TO 60Hz (@ 230VAC).
3. SET P103 (MOTOR OVERLOAD CURRENT) TO 5.7A (FLA X 150% @ 230VAC).
4. SET P104 (MINIMUM OUTPUT FREQUENCY) TO 0Hz (@ 230VAC).
5. SET P105 (MAXIMUM OUTPUT FREQUENCY) TO 60Hz (@ 230VAC).
6. SET P106 (START SOURCE) TO 5 FOR COMM PORT MODE.
7. SET P108 (SPEED REFRENCE) TO 5 FOR COMM PORT MODE.
8. SET P109 (ACCELERATION TIME 1) TO 3 FOR DRIVE ACCEL TIME OF 3 SECONDS.
9. SET P110 (DECELERATION TIME 1) TO 3 FOR DRIVE DECEL TIME OF 3 SECONDS.
10. SET T201 (INPUT TERMINAL 5) TO 5 FOR VFD LOCAL MODE.
11. SET C302 (RS485 COMM DATA RATE) TO 4 FOR 19,200 BAUD RATE.
12. SET C303 (RS485 COMM NODE ADDRESS) TO 2 FOR MODBUS NODE ADDRESS 2.
13. SET A457 (MAXIMUM OUTPUT VOLTAGE) TO 230V.
14. SET A461 (MOTOR NAMEPLATE FLA) TO 3.8A (@ 230VAC).
15. SET THE SINK/SOURCE DIP SWITCH TO SINK.

NOTE: ALL PARAMETERS & SETTINGS STATED ABOVE HAVE BEEN MRI TESTED.

FLOCCULATOR VFD/MOTOR CONTROL DIAGRAM

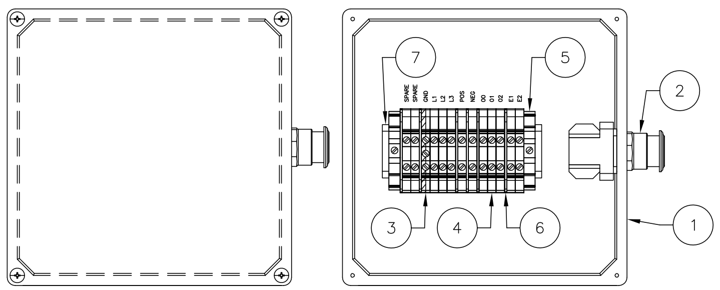


MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP) PROJECT NUMBER: MRI-1502 PROJECT LOCATION: N/A	DRAWN BY: LGERBER SCALE: N/A DATE: 3/28/16	REV 1: REV 2: REV 3:	FLOCC MOTOR CONTROL DIAGRAM (1 HP FLOCCULATOR MOTOR)	CUSTOMER NUMBER N/A DRAWING NUMBER 1502B16

HCV DRIVE J-BOX

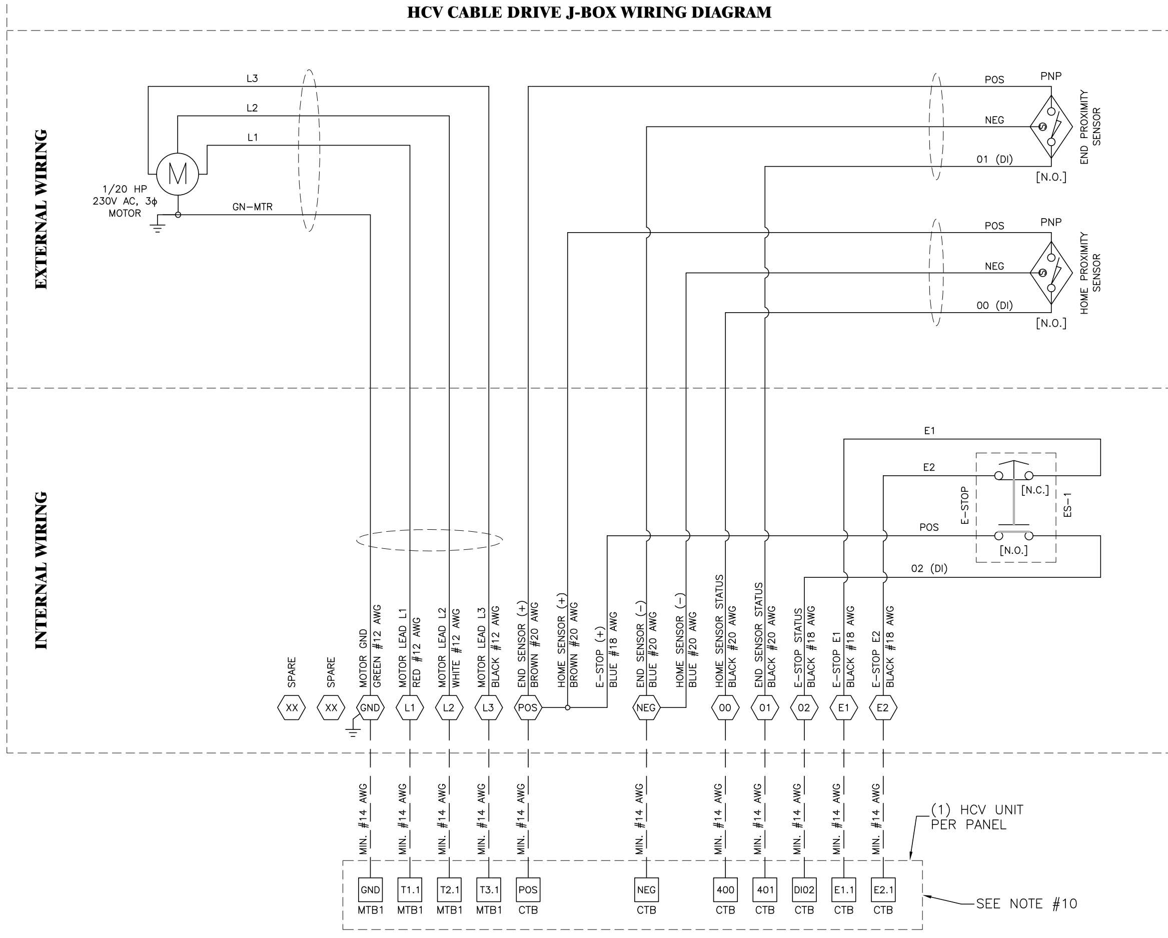
EXTERIOR VIEW | INTERIOR VIEW



TOTAL QTY. (1)

BILL OF MATERIALS				
ITEM NO.	QUANTITY	DESCRIPTION	MANUFACTURER	MODEL NO.
1	1	8" X 8" X 4" NEMA 4X PVC JUNCTION BOX	CANTEX	5133712
2	1	EMERGENCY STOP PUSH-PULL/TWIST BUTTON RED	ALLEN BRADLEY	800H-FRXT6A1
3	1	6mm GROUND TERMINAL BLOCK	ALLEN BRADLEY	1492-JG4
4	12	5mm CONTROL TERMINAL BLOCK	ALLEN BRADLEY	1492-J3
5	2	TERMINAL END STOP ANCHOR	ALLEN BRADLEY	1492-EAJ35
6	6	TERMINAL END PARTITION COVER	ALLEN BRADLEY	1492-EBJ3
7	1	ALUMINUM DIN RAIL (5")	IDEC	BNDN1000

HCV CABLE DRIVE J-BOX WIRING DIAGRAM



SYMBOL LEGEND

- = CABLE
- = CABLE DRIVE MOTOR
- = PROXIMITY SENSOR SWITCH
- = EMERGENCY STOP BUTTON

ABBREVIATIONS & NOTES:

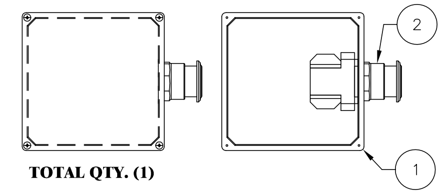
1. PNP = POSITIVE-NEGATIVE-POSITIVE (WIRING)
2. POS = POSITIVE
3. NEG = NEGATIVE
4. MTB = MOTOR TERMINAL BLOCK
5. CTB = CONTROL TERMINAL BLOCK
6. ES = EMERGENCY STOP (E-STOP)
7. N.O. = NORMALLY OPEN
8. N.C. = NORMALLY CLOSED
9. DI = DISCRETE INPUT (DIGITAL)
10. SEE DRAWINGS B11-B12 AND B14 FOR TERMINAL BLOCK DESIGNATIONS.
11. SEE DRAWING B10 FOR WIRE COLOR KEY.

WIRING/TERMINATION SCHEMATIC KEY

- 00 = TERMINAL BLOCK IN LOCAL CONTROL PANEL
- ⬡00 = TERMINAL BLOCK IN HCV CABLE DRIVE J-BOX
- —— = INTERNAL J-BOX WIRING (DONE BY MRI)
- — — = EXTERNAL FIELD WIRING (DONE BY MRI)

FLOCC DRIVE E-STOP J-BOX

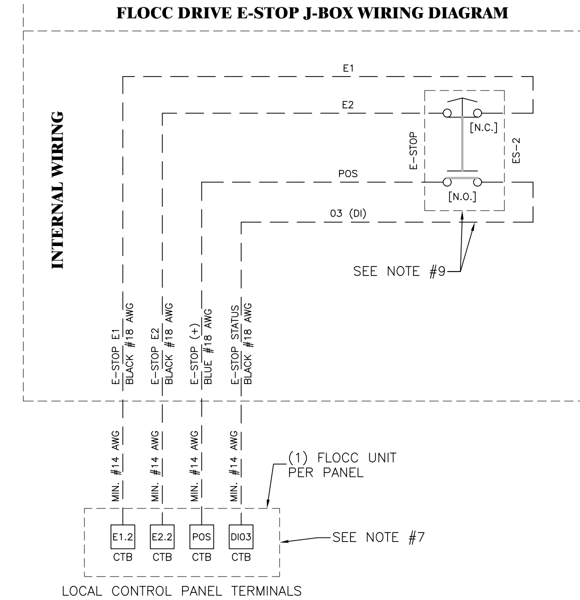
EXTERIOR VIEW | INTERIOR VIEW



TOTAL QTY. (1)

BILL OF MATERIALS				
ITEM NO.	QUANTITY	DESCRIPTION	MANUFACTURER	MODEL NO.
1	1	4" X 4" X 4" NEMA 4X PVC JUNCTION BOX	CANTEX	5133709
2	1	EMERGENCY STOP PUSH-PULL/TWIST BUTTON RED	ALLEN BRADLEY	800H-FRXT6A1

FLOCC DRIVE E-STOP J-BOX WIRING DIAGRAM



SYMBOL LEGEND

- = EMERGENCY STOP BUTTON

ABBREVIATIONS & NOTES:

1. POS = POSITIVE
2. CTB = CONTROL TERMINAL BLOCK
3. ES = EMERGENCY STOP (E-STOP)
4. N.O. = NORMALLY OPEN
5. N.C. = NORMALLY CLOSED
6. DI = DISCRETE INPUT (DIGITAL)
7. SEE DRAWINGS B11-B12, B14, AND B17 FOR TERMINAL BLOCK DESIGNATIONS.
8. SEE DRAWING B10 FOR WIRE COLOR KEY.
9. THE FLOCCULATOR E-STOP J-BOX DOES NOT HAVE TERMINAL BLOCKS. WIRES ARE TERMINATED DIRECTLY TO THE E-STOP BUTTON'S CONTACT BLOCK. (DONE BY MRI)

WIRING/TERMINATION SCHEMATIC KEY

- 00 = TERMINAL BLOCK IN LOCAL CONTROL PANEL
- — — = EXTERNAL FILED WIRING (DONE BY MRI)

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP) PROJECT NUMBER: MRI-1502 PROJECT LOCATION: N/A	DRAWN BY: LGERBER SCALE: N/A DATE: 3/28/16	REV 1: REV 2: REV 3:	HCV & FLOCC DRIVE JUNCTION BOX GENERAL ARRANGEMENT, BOM, & WIRING DIAGRAMS

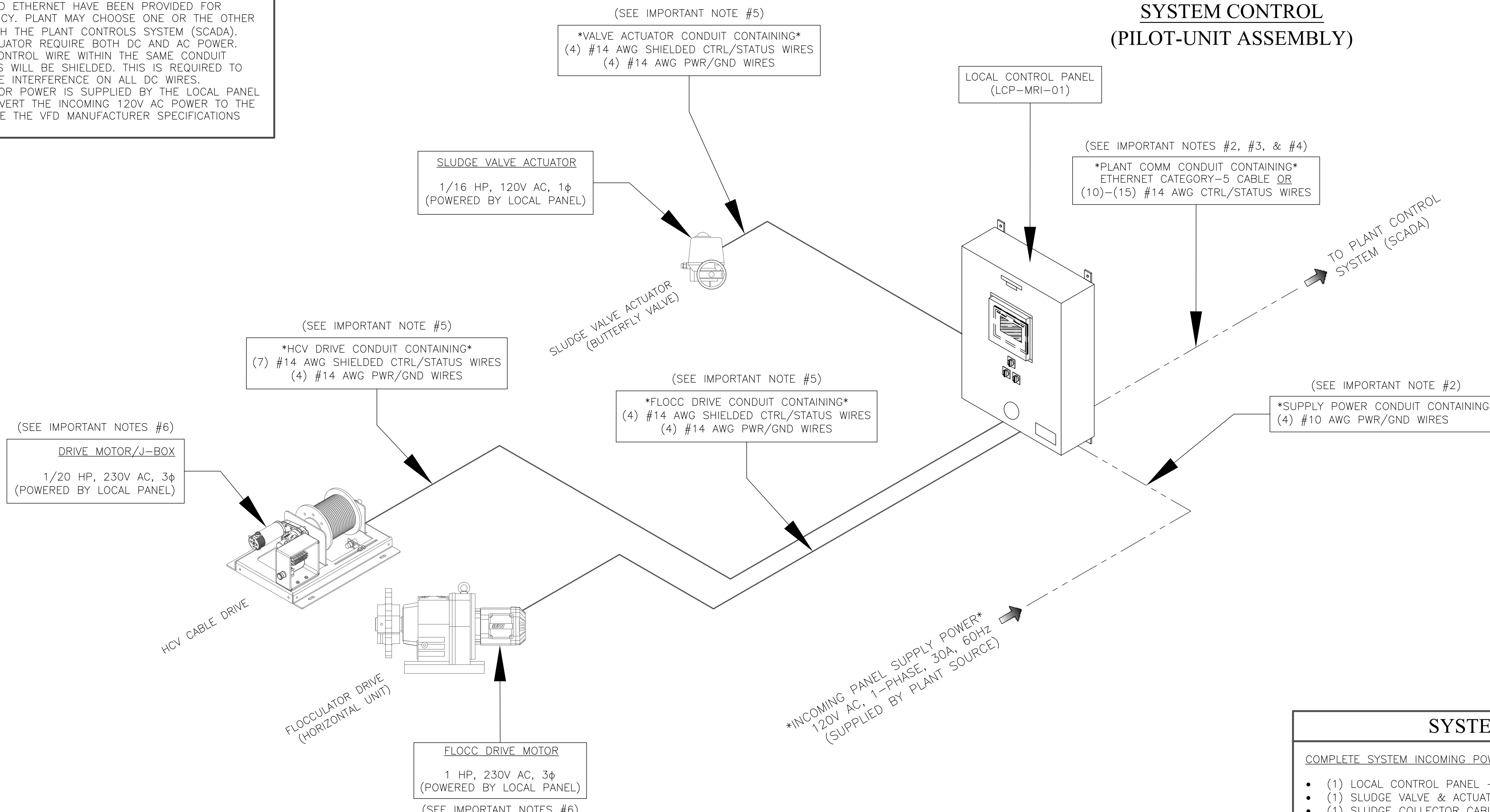
CUSTOMER NUMBER N/A

DRAWING NUMBER 1502B17

IMPORTANT NOTES:

1. THE ALLEN BRADLEY HMI TOUCH SCREEN WILL DISPLAY ALL ALARMS, CONDITIONS, AND POSITIONS REQUIRED FOR THIS SYSTEM. IT WILL ALSO PROVIDE FULL CONTROL OF EACH UNIT.
2. FIELD CONDUIT ROUTING IS SYMBOLIC. SITE INSTALLATION WILL DICTATE ACTUAL ROUTING AND SIZES OF CONDUIT INSTALLED BY OTHERS. ALL OTHER CONDUIT INSTALLED BY MRI SHALL BE AS SHOWN ON DRAWINGS.
3. THE PLANT (SCADA) CONDUIT INDICATES (10)–(15) #14 AWG WIRES BECAUSE DEPENDING ON SITE WIRING METHODS, SOME WIRES/BLOCKS MAY BE JUMPERED TOGETHER TO REDUCE THE AMOUNT OF WIRE RUNS TO THE PLANT CONTROL SYSTEM. SEE DRAWING B13.
4. BOTH DRY CONTACTS AND ETHERNET HAVE BEEN PROVIDED FOR FLEXIBILITY & REDUNDANCY. PLANT MAY CHOOSE ONE OR THE OTHER FOR COMMUNICATION WITH THE PLANT CONTROLS SYSTEM (SCADA).
5. EACH DRIVE UNIT & ACTUATOR REQUIRE BOTH DC AND AC POWER. THEREFORE, EACH DC CONTROL WIRE WITHIN THE SAME CONDUIT CONTAINING AC VOLTAGES WILL BE SHIELDED. THIS IS REQUIRED TO REDUCE POTENTIAL NOISE INTERFERENCE ON ALL DC WIRES.
6. 230V AC, 3–PHASE MOTOR POWER IS SUPPLIED BY THE LOCAL PANEL VFD DRIVES, WHICH CONVERT THE INCOMING 120V AC POWER TO THE NECESSARY VOLTAGE. SEE THE VFD MANUFACTURER SPECIFICATIONS FOR MORE INFORMATION.

SYSTEM CONTROL
(PILOT-UNIT ASSEMBLY)



SYSTEM CONTROL

COMPLETE SYSTEM INCOMING POWER REQUIREMENTS:

- (1) LOCAL CONTROL PANEL – 120V AC, 1ϕ, 30A, 60Hz
- (1) SLUDGE VALVE & ACTUATOR – 120V AC, 1ϕ, 1/16 HP, 60Hz
- (1) SLUDGE COLLECTOR CABLE DRIVE – 230V AC, 3ϕ, 1/20 HP, 60Hz
- (1) HORIZONTAL FLOCCULATOR DRIVE – 230V AC, 3ϕ, 1 HP, 60Hz

NOTES:

ALL PANEL MOUNTING, WIRE, COM CABLE, & CONDUIT WORK PROVIDED BY MRI & OTHERS. ALL WIRE GAUGES SHOWN ARE MINIMUM SIZES. CONTRACTOR MAY USE LARGER ALTERNATIVES BUT NOT SMALLER.

ENCLOSURE SIZE:

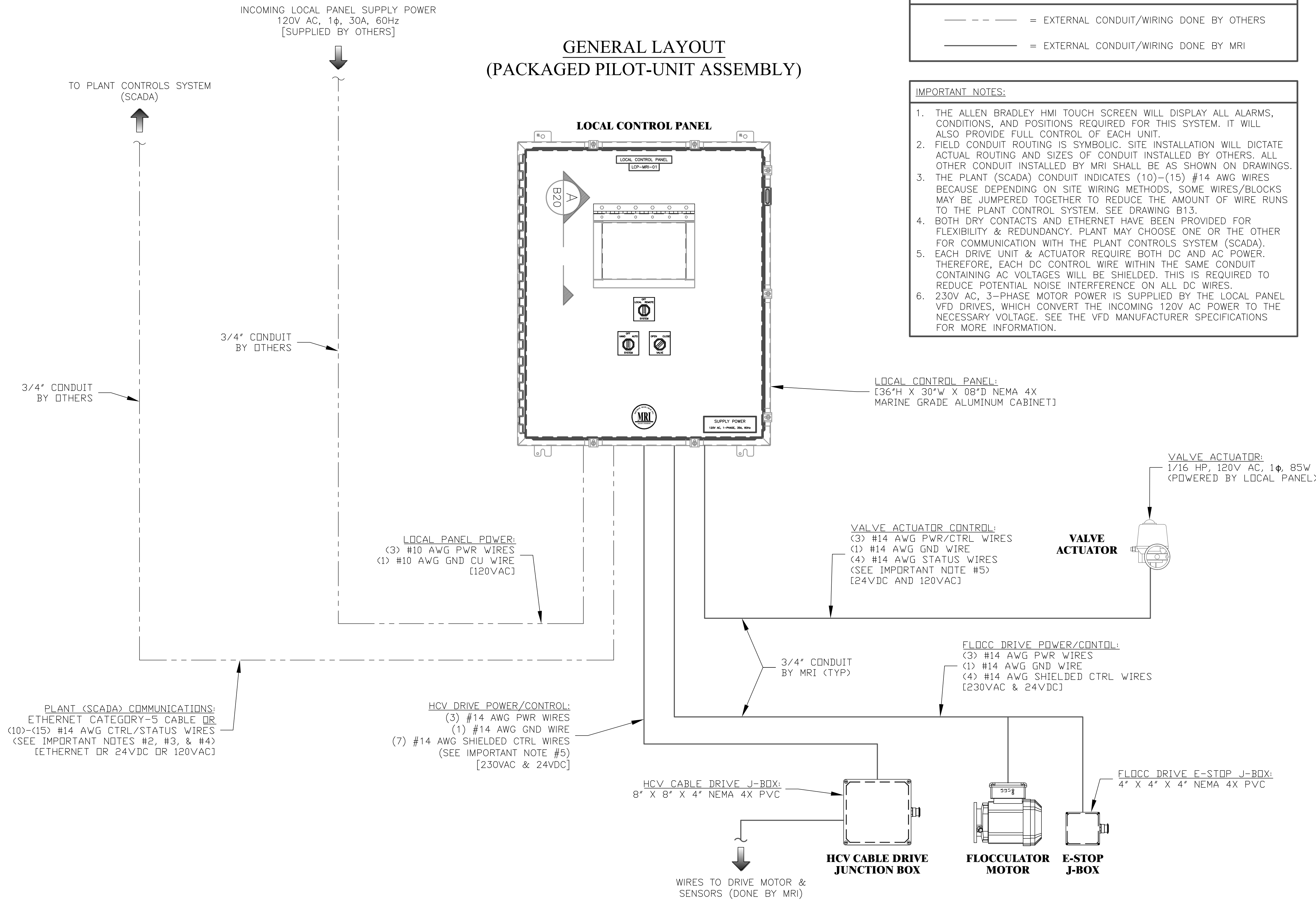
- (1) LOCAL CONTROL PANEL – 36" X 30" X 08" (NEMA 4X ALUMINUM)

CONDUIT/WIRE KEY	
— — — (dashed)	= EXTERNAL CONDUIT/WIRING DONE BY OTHERS
——— (solid)	= EXTERNAL CONDUIT/WIRING DONE BY MRI

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT–UNIT LCP)	DRAWN BY: LGERBER	REV 1:	SYSTEM CONTROL
PROJECT NUMBER: MRI–1502	SCALE: N/A	REV 2:	CONDUIT ARRANGEMENTS
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:	CUSTOMER NUMBER N/A — DRAWING NUMBER 1502B18

GENERAL LAYOUT
(PACKAGED PILOT-UNIT ASSEMBLY)



CONDUIT/WIRE KEY
— — — — = EXTERNAL CONDUIT/WIRING DONE BY OTHERS
———— = EXTERNAL CONDUIT/WIRING DONE BY MRI

IMPORTANT NOTES:

1. THE ALLEN BRADLEY HMI TOUCH SCREEN WILL DISPLAY ALL ALARMS, CONDITIONS, AND POSITIONS REQUIRED FOR THIS SYSTEM. IT WILL ALSO PROVIDE FULL CONTROL OF EACH UNIT.
2. FIELD CONDUIT ROUTING IS SYMBOLIC. SITE INSTALLATION WILL DICTATE ACTUAL ROUTING AND SIZES OF CONDUIT INSTALLED BY OTHERS. ALL OTHER CONDUIT INSTALLED BY MRI SHALL BE AS SHOWN ON DRAWINGS.
3. THE PLANT (SCADA) CONDUIT INDICATES (10)-(15) #14 AWG WIRES BECAUSE DEPENDING ON SITE WIRING METHODS, SOME WIRES/BLOCKS MAY BE JUMPERED TOGETHER TO REDUCE THE AMOUNT OF WIRE RUNS TO THE PLANT CONTROL SYSTEM. SEE DRAWING B13.
4. BOTH DRY CONTACTS AND ETHERNET HAVE BEEN PROVIDED FOR FLEXIBILITY & REDUNDANCY. PLANT MAY CHOOSE ONE OR THE OTHER FOR COMMUNICATION WITH THE PLANT CONTROLS SYSTEM (SCADA).
5. EACH DRIVE UNIT & ACTUATOR REQUIRE BOTH DC AND AC POWER. THEREFORE, EACH DC CONTROL WIRE WITHIN THE SAME CONDUIT CONTAINING AC VOLTAGES WILL BE SHIELDED. THIS IS REQUIRED TO REDUCE POTENTIAL NOISE INTERFERENCE ON ALL DC WIRES.
6. 230V AC, 3-PHASE MOTOR POWER IS SUPPLIED BY THE LOCAL PANEL VFD DRIVES, WHICH CONVERT THE INCOMING 120V AC POWER TO THE NECESSARY VOLTAGE. SEE THE VFD MANUFACTURER SPECIFICATIONS FOR MORE INFORMATION.

MEURER RESEARCH, INC.

PROJECT NAME: MRI STANDARD (PILOT-UNIT LCP)	DRAWN BY: LGERBER	REV 1:	GENERAL LAYOUT
PROJECT NUMBER: MRI-1502	SCALE: N/A	REV 2:	(MIN. EXTERNAL FIELD WIRE SIZES)
PROJECT LOCATION: N/A	DATE: 3/28/16	REV 3:	CUSTOMER NUMBER N/A — DRAWING NUMBER 1502B19

9.0 Operation of the Plate Pilot Unit

The Plate Pilot Unit is designed to operate at 110 gpm. Running the pilot at a higher rate may result in higher turbidities in the effluent (refer to table 9.3). At flows <110 gpm the pilot should produce <1 ntu effluent. Higher flow rates result in higher loading rates across the projected area of the plate settlers which may result in >1 ntu in the effluent.

9.1 Chemical Feed

Chemicals can be mixed in the 35 gallon tanks (optional). The feed pumps will inject the chemicals ahead of the rapid mix. There are three tubing sizes available for the chemical feed pumps. To determine the tubing needed per the feed rate, use the following chart:

	L/S 16 tubing	L/S 25 tubing	L/S 18 tubing
Tubing ID	3.1 mm	4.8 mm	7.9 mm
Feed rate	0.8 to 80 mL/min	1.7 to 170 mL/min	3.8 to 380 mL/min

Once the proper tubing is selected, the feed rate can be adjusted by the speed control on the chemical feed pump.

The plant personnel should be consulted as to the chemicals and dosages that have worked the best in their experience.

The Chemical feed pumps are independent of the control panel. Therefore they are not flow paced for inlet turbidity fluctuation. This needs to be done manually. The pumps however, have the ability to be flow paced if an analog output is provided. See the pump manual for details.

9.2 Flocculator Adjustments

The speed of the flocculator can be adjusted by the control knob located inside the control panel which is mounted on the side of the Plate Settler Pilot Unit. The “G” values for the different speed settings are:

@ 60°F

Setting on control	RPM’s	1st Stage G (sec-1)	2nd Stage G (sec-1)	3rd Stage G (sec^{-1})
1	3	10.2	6.1	3.2
2	4	15.7	9.4	4.9
3	5	21.9	13.2	6.9
4	6.5	32.5	19.5	10.2
5	7.5	40.3	24.2	12.7
6	9	53.0	31.8	16.6
7	10.5	66.7	40.0	21.0
8	12	81.5	49.0	25.6
9	13.5	97.3	58.3	30.6

@ 45°F

Setting on control	RPM	1st Stage G (sec-1)	2nd Stage G (sec-1)	3rd Stage G (sec^{-1})
1	**3**	9.2	5.5	2.9
2	**4**	14.1	8.5	4.4
3	**5**	19.8	11.9	6.2
4	**6.5**	29.3	17.6	9.2
5	**7.5**	36.3	21.8	11.4
6	**9**	47.7	28.6	15.0
7	**10.5**	60.1	36.0	18.9
8	**12**	73.4	44.0	23.1
9	**13.5**	87.6	52.5	27.5

@ 34°F

Setting on control	**RPM**	**1st Stage G (sec-1)**	**2nd Stage G (sec-1)**	**3rd Stage G (sec^{-1})**
1	**3**	8.3	5.0	2.6
2	**4**	12.8	7.7	4.0
3	**5**	17.9	10.7	5.6
4	**6.5**	26.5	15.9	8.3
5	**7.5**	32.8	19.7	10.3
6	**9**	43.1	29.5	13.5
7	**10.5**	54.3	32.6	17.1
8	**12**	66.4	39.8	20.9
9	**13.5**	79.2	47.5	24.9

The detention time of the flocculator is determined by the flow rate through the Plate Settler Pilot Unit. Detention times for the flocculator are:

Flow rate (gpm)	**Detention time** (3 mechanical, 1 hydraulic) *[3 mechanical only]*
60	31 min *[28 min]*
70	27 min *[24 min]*
80	23.5 min *[21 min]*
90	21 min *[18.7 min]*
100	19 min *[16.8 min]*
110	17 min *[15.3 min]*
120	15.7 min *[14 min]*
130	14.5 min *[13 min]*
140	13.5 min *[12 min]*
150	12.5 min *[11.2 min]*

9.3 Plate Settlers

Operating the plate settlers at different flow rates will change the loading rate across the projected area. The table below shows the loading rates at various flow rates and the expected effluent turbidities.

Flow rate (gpm)	Loading Rate (gpm/ft^2)	Expected Effluent (NTU)
60	.16	.2-.5
70	.19	.2-.5
80	.22	.3-.6
90	.24	.4-.7
110	.29	.5 -.8
120	.32	1-1.5
130	.35	1.5-2
140	.37	1.5-2
150	.4	2+

NOTE: The Expected Effluent (NTU) is estimated. This may vary due to actual conditions.

9.4 Hoseless Sludge Collector

The Hoseless Sludge Collector travels across the bottom of the settling area and removes the settled solids.

The speed pre-set by the MRI Service Technician at time of start up should not be adjusted.

The frequency of operation is set by the real time clock located inside the control panel. To set the desired start times simply push the black tabs located around the perimeter of the clock, toward the center of the clock. Each tab on the clock represents 15 minutes and there must be a tab “out” after each tab that is pushed “in” so the input can reset.

It is recommended that the Hoseless Sludge Collector make a cycle 2 times per hour to start with and should never go more than two hours without running. The sludge must be removed or it will carry over into the plate settlers.

The flow rate is controlled by the sludge valve and will be set by the MRI Service Technician at time of start up. Under normal operation, the Hoseless Sludge collector will remove .5% to 1% solids concentration.

10.0 Maintenance

Once per day:

1. Observe the operation of the flocculator for proper speed and smoothness of operation.
2. Observe the operation of the Hoseless Sludge Collector for proper frequency, smoothness and underflow.
3. Observe control panel for alarms.

Once per week:

Check the oil levels in the flocculator gearbox.

11.0 Procedure for after-test shipping

Instructions to shut down for pilot unit:

1. Drain tank
   Remove all (5) sludge drain ports

2. Hose out any remaining sludge in each section

3. Remove handrail, access ladder, flocculator drive cover, sludge collector drive cover and any exterior plastic piping. **Do not** remove decking or the drives themselves.

4. Securely cover flocculator drive, sludge collector drive, sludge valve, and control panel with heavy-duty plastic.

5. If the tank will be setting for over three days, cover the entire tank with plastic or plywood.

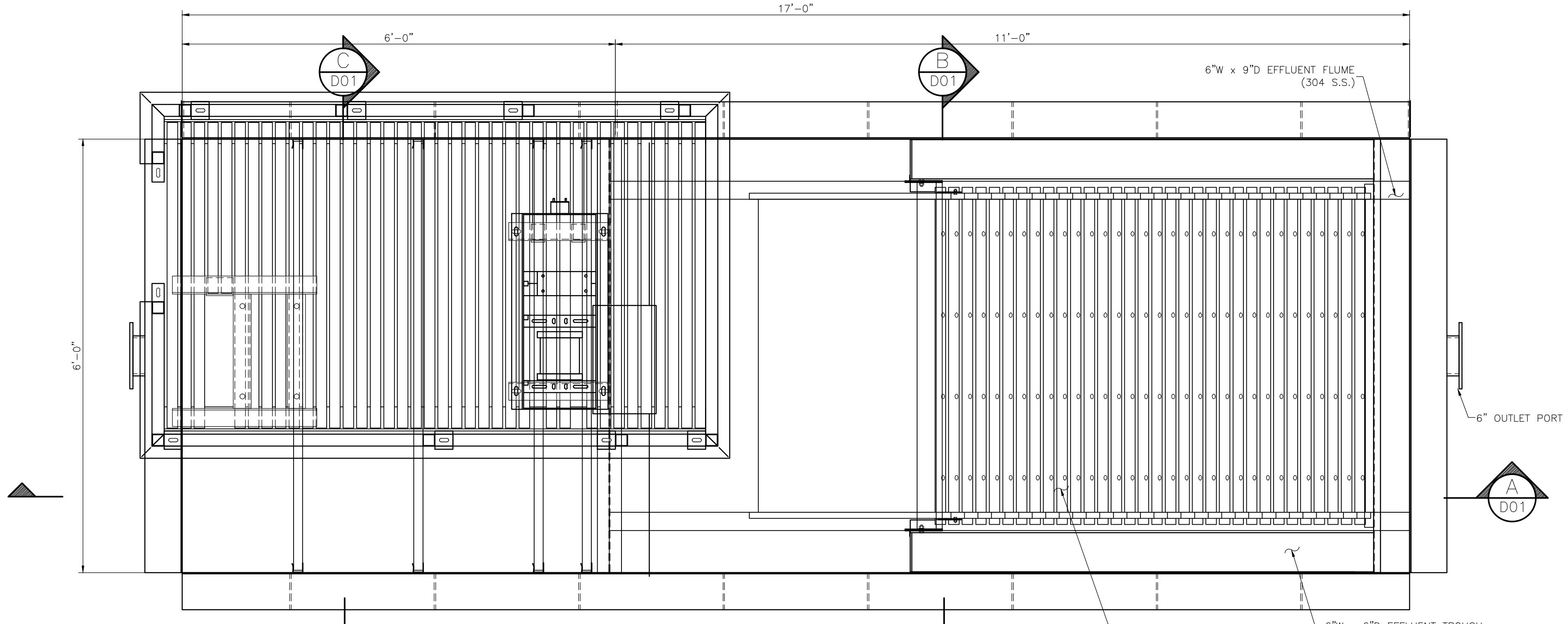
6. Secure tank and all loose items to deck of truck Reuse the crate that the loose items arrived in if possible. Use the job specific P&ID as a check list to make sure all equipment is packed up and ready to return.

7. Hose out and clean individual piping items before returning.

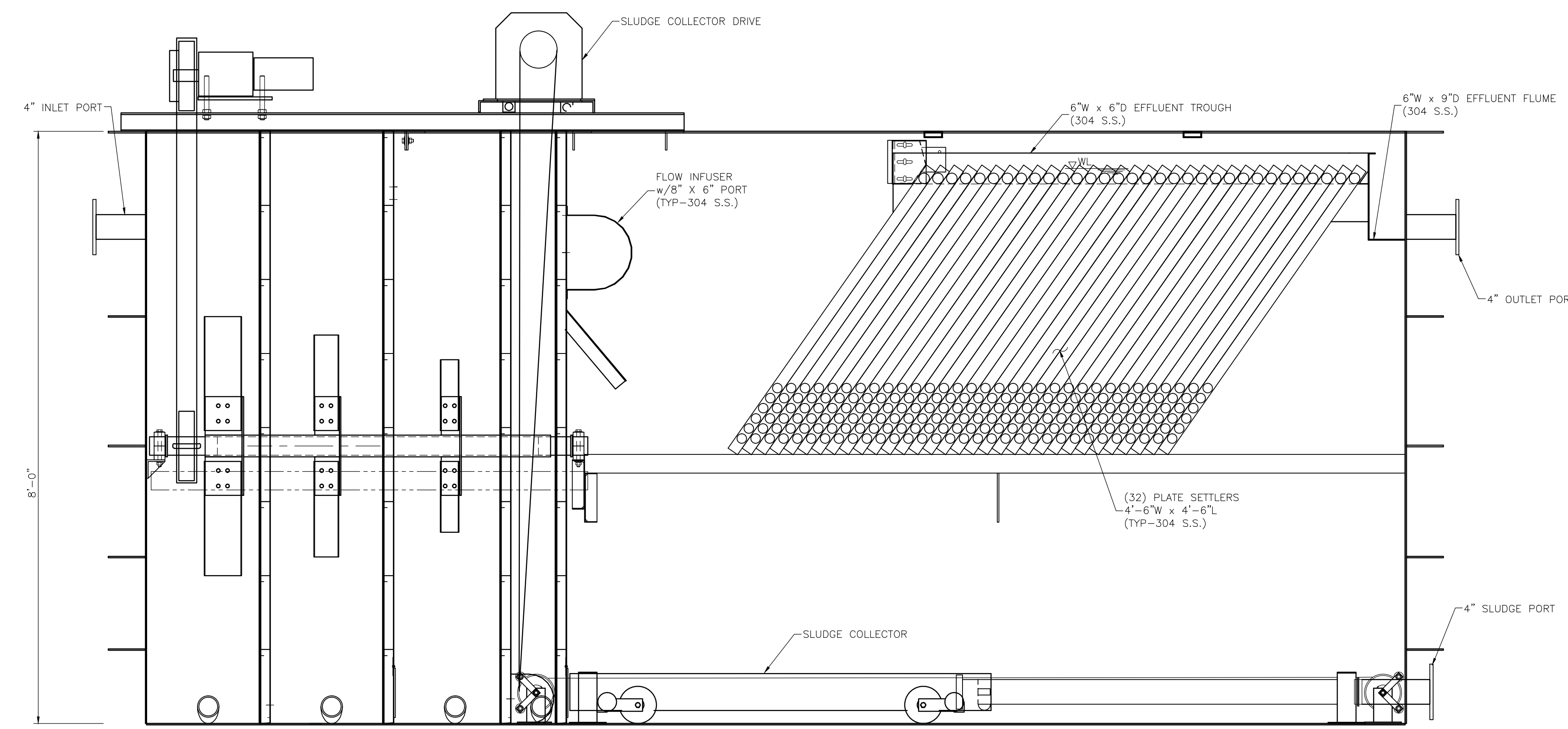
8. Check outside of tank for any loose items.

9. This is a rental unit. Please consider the next person who will use the unit.

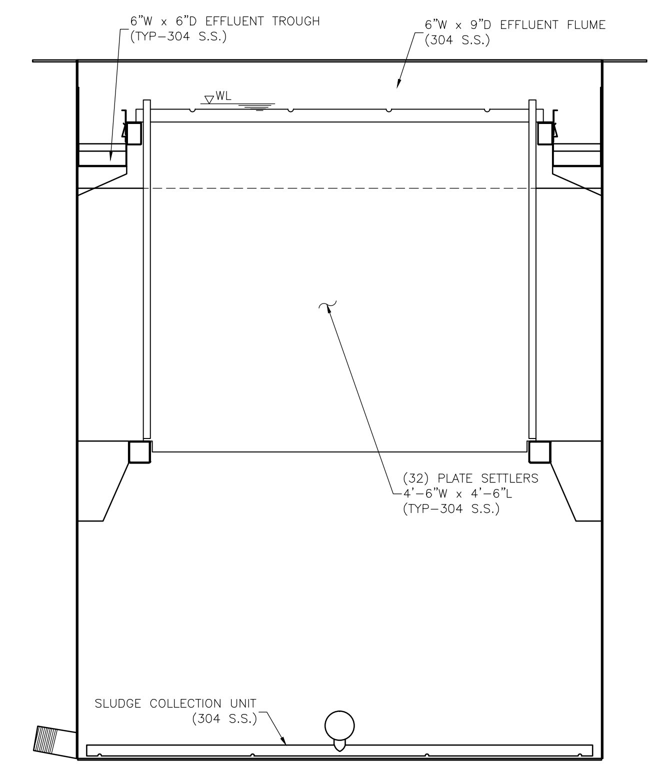
The client will be charged for any items missing upon the units return.



PLAN VIEW

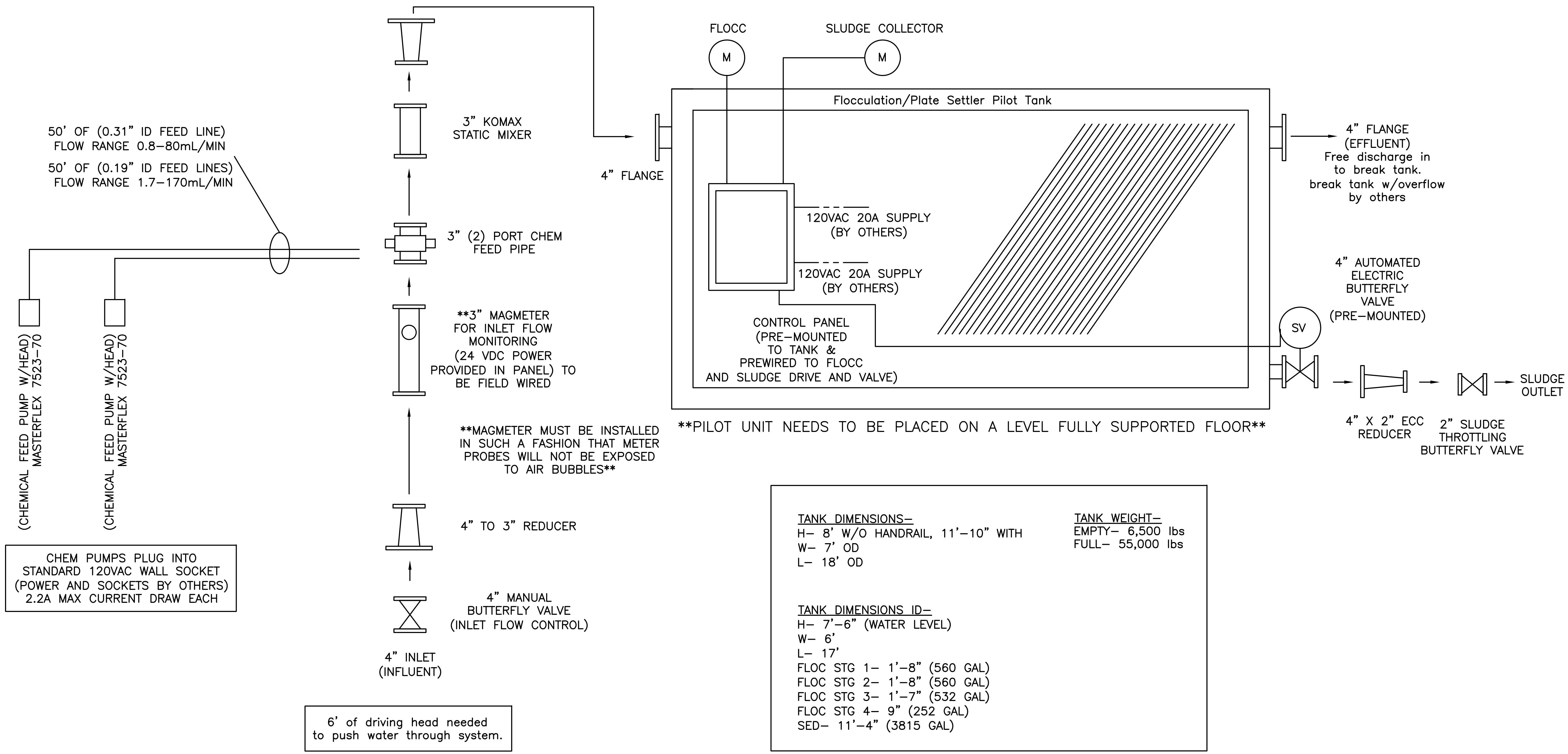


ILLUSTRATIVE SECTION A D01



ILLUSTRATIVE SECTION B D01

MEURER RESEARCH, INC. 15611 W. 6th Ave., Golden, CO 80401	PROJECT NAME: PROJECT LOCATION:	DRAWN BY: JMM DATE:	General Assembly 110 GPM (max.) Plate Settler Pilot Unit		DRAWING NUMBER D01



THESE ITEMS TO BE PIPED IN AT DESIRED LOCATION

MEURER RESEARCH, INC.

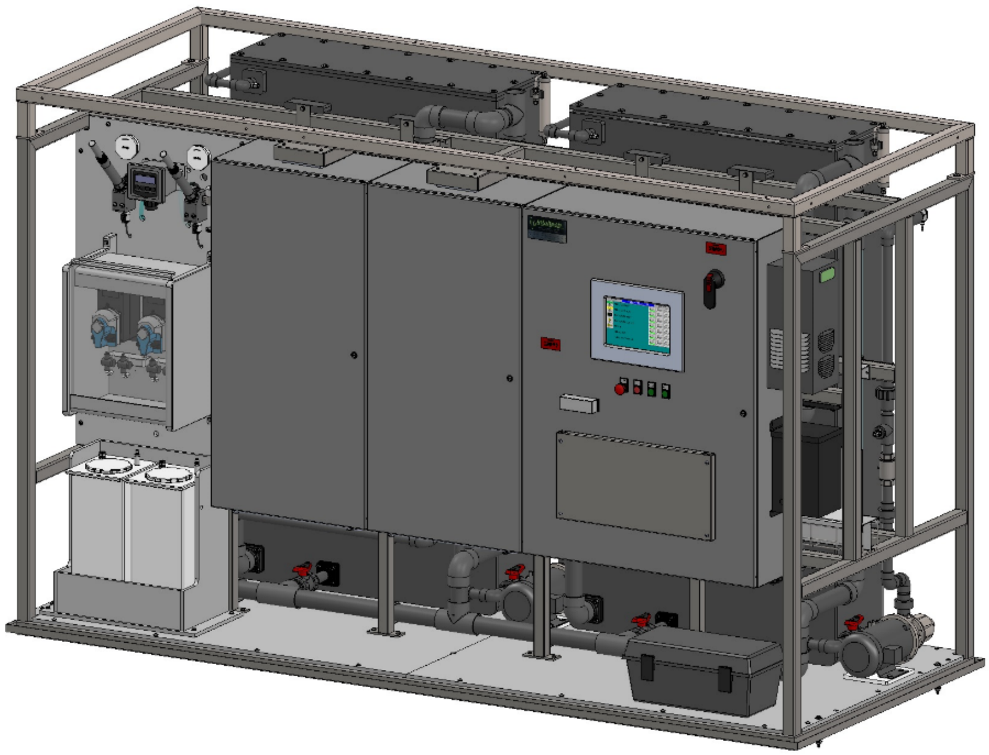
PROJECT NAME: PROJECT NUMBER: PROJECT LOCATION:	DRAWN BY: DFB SCALE: NTS DATE: 08/20/08	REV 1: REV 2: REV 3:	PLATE SETTLER PILOT UNIT P&ID	CUSTOMER NUMBER DRAWING NUMBER MRIPID01

Operations and Maintenance Manual

For

Carollo Engineers

Ozone Module



Release #1

Prepared By:

Intuitech®
"Intuitive Technology"
Process Equipment Manufacturing
Monitoring & Control Systems Integration

Project # 1602

March 21, 2018

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Appendix A- Drawings

EQUIPMENT SPECIFICATIONS

1. **Ozone Module**

   A. **Specifications**

      (1) General

Flow Rate (per contactor):	2.0…9.0 gpm (7.6...34.1 L/min)
Contactors:	2 @ 133 gal (503 L)
Ozone Delivery:	0.1...6.5 g/h
Chemical Feed Pumps:	3 @ 0.01...21.7 gpd (0.03…57 mL/min)
Chemical Feed Tanks:	3 @ 4 gal (15.1 L)
Max Feed Temperature:	100° F

(2) Instrumentation

Feed flow (per contactor) *
Feed gas (O_2) dew point temperature*
Feed gas (O_2) oxygen concentration*
Diffuser (O_3) flow (per contactor) *
Diffuser pressure (per contactor) *
Feed Gas concentration*
Off Gas concentration*
Dissolved ozone concentration 1*
Dissolved ozone concentration 2*
Ambient ozone concentration*
Chemical tank level*

*Data logged

(3) Physical

Short Assembled Dimensions:	122"L X 50"W X 75.5"H
Dry Weight:	Approx. 2,500 lbs.
Wet Weight:	Approx. 4,700 lbs.
Volume Between Sample Valves:	4.5 gal

(4) Electrical (120V or 240V configurable) Factory Measured

Phase:	1	1
Frequency:	60 Hz	60 Hz
Voltage:	120 VAC	240 VAC
Current:	16.8 A Max	8.4 A Max

INSTALLATION

1. Ozone Module

2. Un-packaging

The Ozone Module was designed using an integrated shipping crate design. Simply remove the bolts along the top edge of the "crate". As the bolts along the top of each plywood sheet are removed, that sheet can be lifted out of the retention rail along the bottom of the skid and removed. The plywood sheets mounted to the top of the skid are removed in a similar manner. Retain all plywood sheeting and hardware for return shipping. A forklift will be required to lift the crate off of the shipping truck and for final positioning of the pilot module. Ensure that the forklift is rated to safely carry the weight of the equipment (approx. 2500 lbs.).

3. Mechanical Inspection

A. Initial Visual Inspection

Carefully inspect the skid for mechanical damage to the frame, filter vessels, piping, motors, and instruments that may have occurred during the shipping or positioning of the equipment.

B. Leveling

Verify that the equipment is level. Once in position, shim the skids as necessary until the system is level. Each end of the pilot should be level to within ¼ inch of each other. It is important that the module is level to ensure proper operation, since improper leveling can cause the ozone off gas destruct units to flood, rendering them inoperable.

C. Component Mounting

Verify that all components and instruments are secure. These include pipe straps and instrument mounts.

D. Piping Connections

Verify that all PVC piping connections are secure. These include pipe straps, threaded unions, check valves, process valves, and sample valves. Confirm that the process piping connections are installed and tightened. Further confirm that the connections are in accurate alignment and free from any undue stress imposed by connecting piping.

> **WARNING:** Stress imposed by improperly aligned field piping may damage equipment. Ensure all connecting piping is free of undue stress.

> **WARNING:** The 2 inch waste line exiting the pilot module must be piped directly to a floor drain. Do not install any device on this line which could potentially restrict the flow (i.e. valves).

Never cap the weir at the top of the waste overflow piping. This weir must be left open to atmosphere at all times.

4. Electrical Inspection

A. Initial Visual Inspection

Carefully inspect for mechanical damage to the control panels that may have occurred during shipping or installation of the equipment. Excessive vibration from shipping can cause electrical components within the control enclosures to snap off of the din rail and cause damage to other components.

B. Electrical Connections

(1) Control Panel Wiring

Verify that all wires within the control panel are terminated. Vibration from shipping can cause conductors to come loose. Un-terminated wires can short to other components, conductors, or the enclosure wall and cause damage.

(2) Customer Feeder Circuit Breaker

Identify the location of the customer feeder circuit breaker so it can be easily identified and locked-out when servicing of the pilot electrical system.

5. Environmental Protection

A. Solar / UV Protection

Due to the adverse effects of UV light on PVC, it is recommended that equipment operated outdoors is protected from direct sunlight. A full tent (or similar structure) is preferred to provide protection from direct rain and sunlight, as well as blowing dirt and debris.

OPERATION

1. Operation Theory

Module consists of two feed pumps, two contactors, the oxygen concentration enclosure, ozone generation enclosure, and the system control panel enclosure. The feed flow is controlled automatically using PID tuning. The contact chambers have 19 volumetrically-spaced ports for sampling dissolved ozone. The ozone generator is air-cooled with an integral oxygen concentrator for creating ozone from ambient air and shuts down automatically if a leak is detected. Gas analyzer zero calibration can be performed either automatically (based on runtime) or manually. (Ozone delivery to the contactors is not interrupted during a zero calibration.) Ozone gas delivery can be accomplished through in-line eductors or porous ceramic diffusers in the contactors. Other features include a Bluetooth capable HMI, automatic data logging of key parameters and remote monitoring and control using a standard web browser (if web-enabled).

With the exception of the manually actuated valves, the equipment is monitored and controlled by an HMI (Human Machine Interface). The HMI communicates with the PLC (Programmable Logic Controller) in the control panel that monitors and controls various instruments and components. In other words, the operator monitors the equipment through the HMI, which interacts with the PLC, which activates the various equipment components.

2. Operation Sequence

The equipment follows a sequence of operation as summarized in the Sequence Matrix. The sequence matrix depicts the portion of the control logic that energizes pumps, valves, and other components required for each step of the operation. The PLC advances from step to step based on either an elapsed time or a specific event. A thorough understanding of the sequence matrix is essential to properly understand the equipment's operation.

Each step in the operation sequence has a number and description. The "field devices" section of the table shows which equipment components are activated in any given step. The "condition" column defines the events or time requirements for advancing from step to step. The "go to step" column indicates which step the equipment will be advancing to after the conditions or time requirements have been met in the given step. Finally, the legend defines the terminology used in the matrix.

The equipment is always in one of five stages of the operation sequence: offline, warm-up, service, zeroing or shutdown. The offline and service steps correlate to steps "0" and "7" respectively, while the warm-up sequence encompasses steps 1 – 3 and zeroing contains steps 4 - 6. The shutdown purge is step 8. An identical sequence is used to control the system while operating on an external oxygen supply (steps 9 through 16).

The equipment follows the "step advance" criterion, for example, the first step in the operation sequence is "0". Step "0" is described as OFFLINE. The "field devices" section of the matrix indicates that during the OFFLINE step, none of the equipment's components are activated (all valves are closed, all pumps are off), but the feed pump is still enabled. Therefore, the feed pump can still be operated in the auto mode even though the ozone system is offline. The "step advance" column informs that the equipment will stay in step "0" until the conditions of EVENT 1 are met. The legend defines EVENT 1 as "operator depresses the online button". When the equipment is switched to "online", the conditions of EVENT 1 are met and the "step advance" criteria states that the equipment will advance to step "1". Step "1" is described as WARM UP – PRESSURE CHECK. The "field devices" section defines which components are activated during the step. The equipment will continue in step "1" until EVENT 2 occurs (indicating the feed gas pressure has reached an allowable start-up limit). Once EVENT 2 occurs the "go to step" column states that the equipment will advance to step "2". Step "2" is another event driven step. This time the programming is checking for a minimum allowable flow rate before progressing onto step "3". Step "3" is a time-based step designed to allow the ozone generator reactor to purge any moisture. Once the allotted time has elapsed, the system progresses to step "4" and enters a zeroing cycle to zero the feed and off gas ozone analyzers.

The zeroing sequence consists of three time-based steps allowing the analyzers to purge with ozone free gas for several minutes before initializing the zero calibration. Once the zeroing process is complete, the ozone system will enter into service.

3. Sequence Matrix

STEP NUMBER	STEP DESCRIPTION	STEP ADVANCE		FIELD DEVICES																					
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		CONDITION	GO TO STEP	OZONE FEED PUMP X100	OZONE FEED PUMP X200	CHEMICAL FEED PUMP X710	CHEMICAL FEED PUMP X720	CHEMICAL FEED PUMP X730		COMPRESSOR X800			X100 FEED GAS FLOW CONTROLLER FIC-X910	X200 FEED GAS FLOW CONTROLLER FIC-X920		OZONE GENERATOR X900 REACTOR	OFF GAS SAMPLE PUMP X920	FEED GAS ZEROING VALVE DV-X903	FEED GAS SAMPLE VALVE DV-X913	X100 DIFFUSER ISOLATION VALVE DV-X931	X200 DIFFUSER ISOLATION VALVE DV-X941	X100 OFF GAS SAMPLE VALVE DV-X951	X200 OFF GAS SAMPLE VALVE DV-X952	OFF GAS ZEROING VALVE DV-X953	OZONE TRANSMITTER ZERO COMMAND
0	OFFLINE	EVENT 1	1																						
1	WARM UP - PRESSURE CHECK	EVENT 2	2	E	E					X														X	
2	WARM UP - FLOW CHECK	EVENT 3	3	E	E					X			E	E			X			E	E			X	
3	WARM UP - GENERATOR PURGE	TIME 1	4	E	E					X			E	E			X			E	E			X	
4	ZERO - PURGING	TIME 2	5	E	E	E	E	E		X			E	E		X	X	X		E	E			X	
5	ZERO - INITIATE	TIME 3	6	E	E	E	E	E		X			E	E		X	X	X		E	E			X	X
6	ZEROING	TIME 4	7	E	E	E	E	E		X			E	E		X	X	X		E	E			X	
7	SERVICE	EVENT 4	0,4,8	E	E	E	E	E		X			E	E		X	X		X	E	E	E	E		
8	SHUTDOWN - PURGING	TIME	0	E	E					X			E	E			X	X		E	E			X	
9	WARM UP - PRESSURE CHECK W/EXT 02	EVENT 2	10	E	E																			X	
10	WARM UP - FLOW CHECK W/EXT 02	EVENT 3	11	E	E								E	E			X			E	E			X	
11	WARM UP - GENERATOR PURGE W/EXT 02	TIME 5	12	E	E								E	E			X			E	E			X	
12	ZERO - PURGING W/EXT 02	TIME 6	13	E	E	E	E	E					E	E		X	X	X		E	E			X	
13	ZERO - INITIATE W/EXT 02	TIME 7	14	E	E	E	E	E					E	E		X	X	X		E	E			X	X
14	ZEROING W/EXT 02	TIME 8	15	E	E	E	E	E					E	E		X	X	X		E	E			X	
15	SERVICE W/EXT 02	EVENT 4	0,11,16	E	E	E	E	E					E	E		X	X		X	E	E	E	E		
16	SHUTDOWN - PURGING W/EXT O2	TIME	0	E	E								E	E			X	X		E	E			X	
17	SERVICE - PUMP ONLY	EVENT 4	0	E	E	E	E	E																	

LEGEND

X	OPEN OR RUNNING
E	ENABLED
TIME	TIME SETPOINT
FLOW	FLOW SETPOINT
EVENT 1	OPERATOR DEPRESSES THE "ONLINE" BUTTON
EVENT 2	FEED GAS PRESSURE EXCEEDS MINIMUM START-UP THRESHOLD
EVENT 3	FEED GAS FLOW RATE EXCEEDS MINIMUM START-UP THRESHOLD
EVENT 4	OPERATOR DEPRESSES THE "OFFLINE" OR "ZERO" BUTTON OR THE ENTERED RE-ZERO INTERVAL HAS ELAPSED.

4. Operation Interface

A. General

The system is operated from the front of the control panel. The operating controls consist of:

- HMI
- Three indicator lights
- Emergency stop button
- Main disconnect switch

B. Manual Control Panel Operators

(1) Indicator Lights

- **ON** (Green) - indicates that the equipment is operating.
- **ALARM** (Red) - indicates that an alarm is present.
- **POWER ON** (White) – indicates power is present inside the control panel.

(2) Push Button

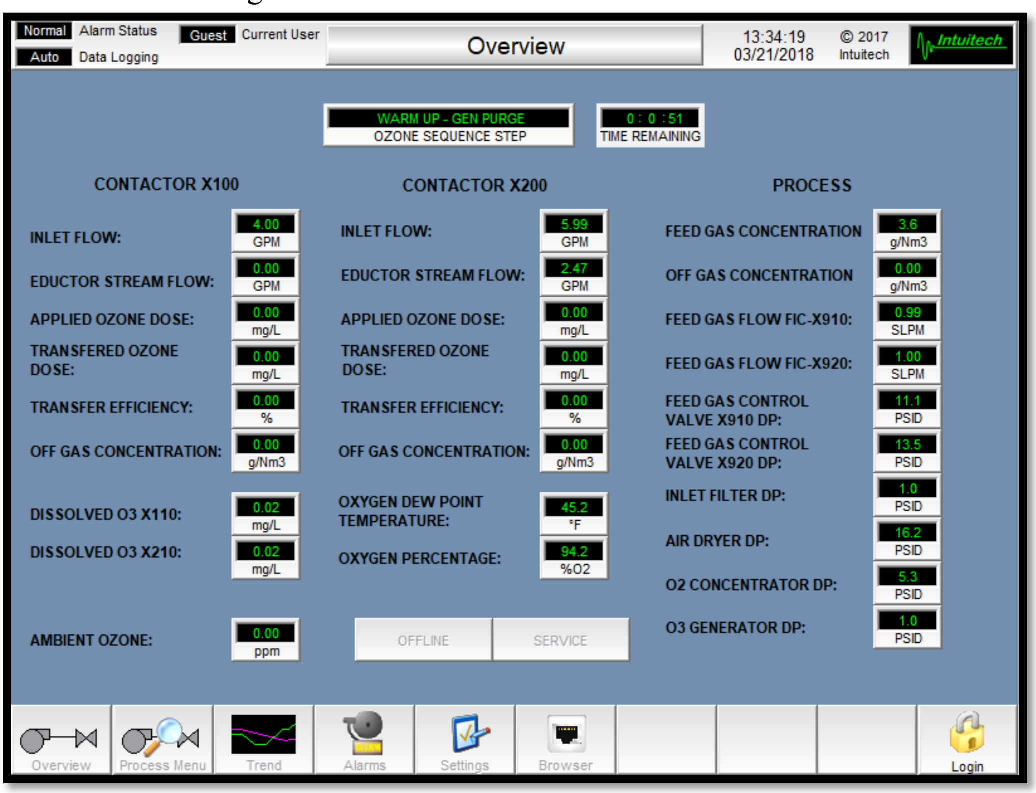
- **EMERGENCY STOP**- will stop all equipment operations.
  NOTE: Rotate clockwise to disengage or reset.

(3) Main Disconnect

Will disconnect main power to equipment.

C. Human Machine Interface (HMI)

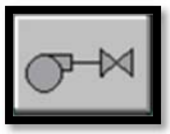
When the equipment is powered up the initial HMI screen that appears will be similar to the following screen.



D. HMI Navigation Icons

The following navigation icon buttons displayed along the bottom of the screen throughout the HMI application provide the following functions:

(1) Overview Button

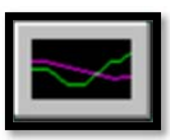


The overview screen displays a summary of data from the process screens.

(2) Process Menu Button

The monitoring and control of all automated system components is accessed through the process menu. Some of the process screens are monitoring only, some are control only, and some are for both monitoring and control of system components. For operational ease, the display of some instrument values may appear redundantly on two or more screens.

(3) Trend Menu Button



The trend menu allows the operator access to trending screens to analyze and view in a graphical format, the data coming from the system instruments.

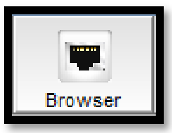
(4) Alarms Button

The alarm button is used to view the currently active alarms (Alarm Summary). The historical alarms screen (Alarm History) can be accessed from within the alarm summary.

(5) Settings Menu Button

The system menu includes buttons to access data logging, e-mail alarms, and the miscellaneous screen. The miscellaneous screen is for setting and configuring various operational features.

(6) Web Browser Button



The web browser button provides access to a built in web browser embedded into some instruments. Calibration and configuration can be performed through these screens.

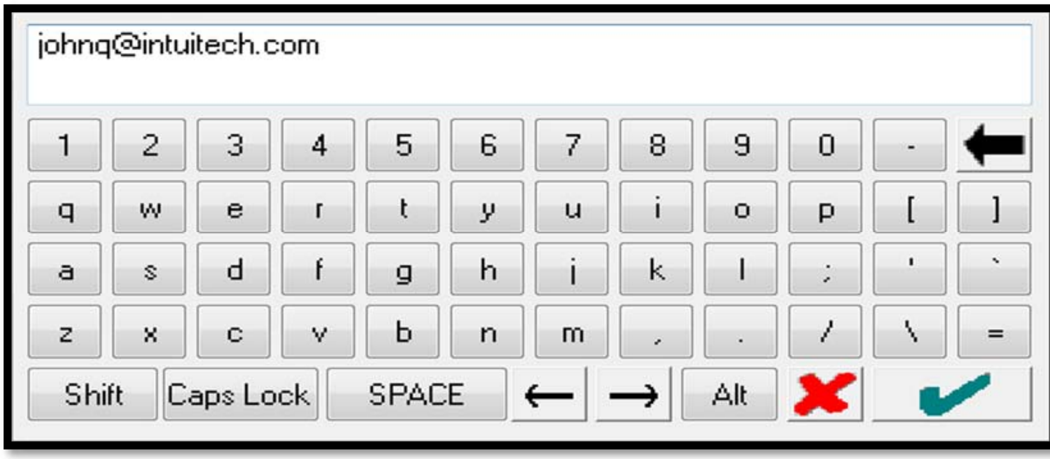
(7) Log In Button

This icon displays a screen that allows the user to log in and out of different user levels. A password is required. Operators are required to log in with a username and password before system operation is possible.

(8) Keypads

There are two different keypads which can be selected by an operator. The simple keypad allows the operator to enter in numerical control values and other information.

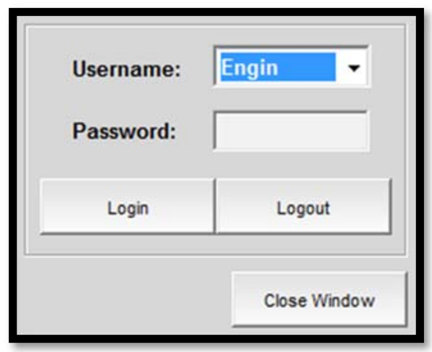
NOTE: If the component has an operating range, it will be displayed at the bottom of the keypad - any value entered must fall within that range.



The full keypad is displayed anytime alpha-numeric characters are required. Each keypad is displayed when required.

E. HMI Operation

(1) Log In/Out Screen

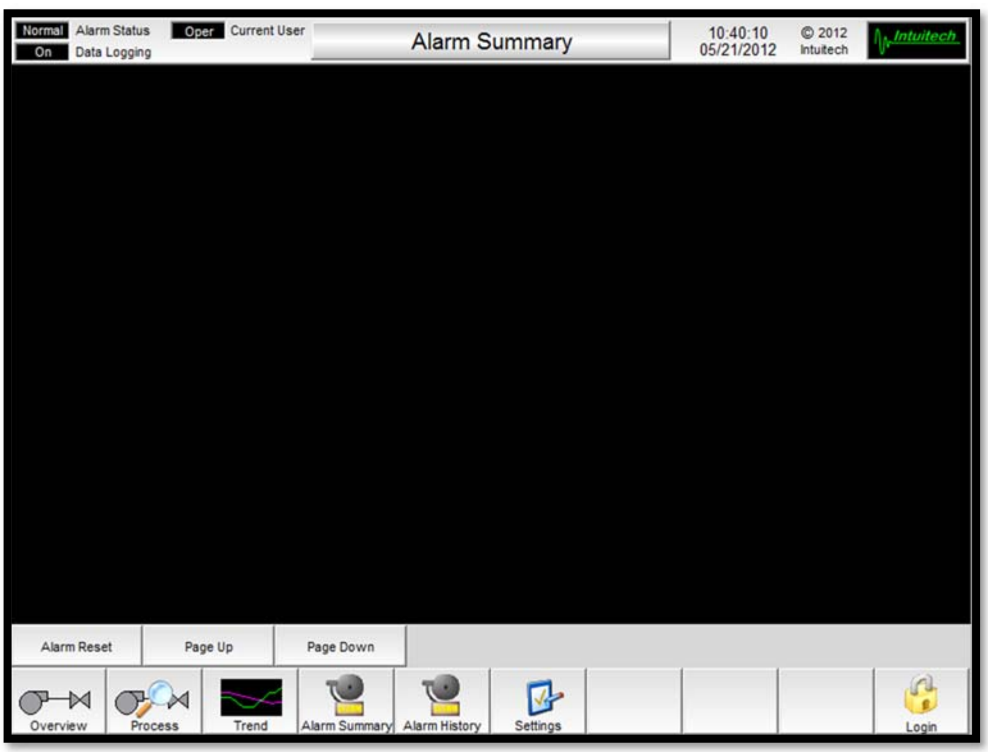


By selecting the Login icon, the login screen is displayed.

Select the desired level of access (Administrator, Engineer, Operator, Guest, or View) from the drop-down box. Then, select the PASSWORD box and type the appropriate password. Select LOGIN when done. If your login is successful, the new login level will be displayed in the upper left corner of the screen. For security purposes, the passwords for each user level will not be printed in this manual. (Password information will be sent with the manual in a sealed envelope.) Select the LOGOUT button to return to the Guest level of access. Below are the five user levels and what functions each user has access to. Some activities may not be relevant for all HMI applications.

HMI Security Level Access Permissions	Guest	View	Operator	Engineer	Administrator
View Login Screen	X	X	X	X	X
View Process Screens	X	X	X	X	X
View Trends		X	X	X	X
View Alarms		X	X	X	X
Reset Alarms			X	X	X
Control Pumps, Valves, Blowers, etc.			X	X	X
Modify Email Alarms Email Settings					X
Disable/Enable Email Alarms				X	X
Change Auto and Manual Setpoints			X	X	X
Initiate Sequencer Steps			X	X	X
Change Sequencer Step Times			X	X	X
Change PID Setpoints				X	X
Change PID Running Parameters				X	X
Change Alarm Limit Setpoints				X	X
Change Data Logging				X	X
Set Date and Time				X	X
Close Program					X

(2) Alarm Screens
The date, time, and description of alarms will be displayed on the alarm screens. Once the conditions that triggered the alarm have been corrected, select the ALARM RESET button to acknowledge and reset all current alarms. Scroll through the alarms by selecting the PAGE UP and PAGE DOWN buttons on either of the alarm screens.



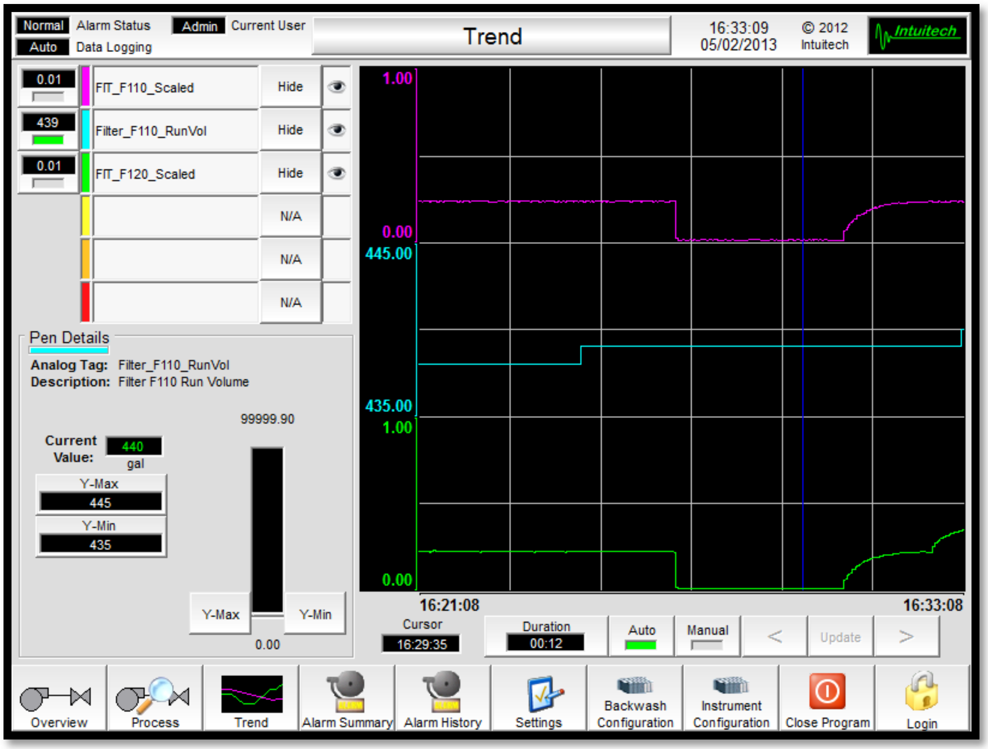
(3) Instrument Displays

Each analog instrument has its own display screen. Access this screen by selecting the display button. Once selected, a similar screen will appear.

This screen will allow the user to set any high or low alarm limits associated with the instrument, as well as view a "quick-trend" of its recent activity. To add this analog signal to the main trending screen, simply press "Load" on one of the open Trend Pens.

(4) Trending Screen and Pen Selection

The trend menu allows the operator access to the trending screens to analyze and view, in graphical/numerical format, the data coming from the system's instruments. When selected, a similar screen will be displayed



The time period displayed on the trending screen can be adjusted by selecting the desired time in hours and minutes on one of the TREND DURATION icons.

The AUTO selection allows users to view real time trends, while the MANUAL selection is for historical trends. An automatically updated trending screen will continually update itself. The manual update trending screens display a static "snap-shot" of information and will not automatically update.

If an analog signal is already selected, it will be displayed and can be manipulated from the upper-left corner of the trend screen. Each pen can either be viewed, or hidden using the VIEW/HIDE buttons. Once a pen is selected, the size of the Y-axis can be adjusted in the "Pen Details" section.

NOTE: In order to add a new analog signal to the trending screen, it must be activated from within its own display screen (as previously described).

Tap the screen at any point within the trend graph to move the vertical cursor (or select the < or > buttons to enact small moves). The color of the parameter at the top left of the screen corresponds with the color of the trend lines within the trending screen. The parameter value shown in the "Current Value" window, corresponds to the value on the graph at the position of the cursor.

(5) Settings Menu Screens

The settings menu includes buttons to access data logging, e-mail alarms, and the date and time set screen.

(6) Data Logging Screen

If the DATA LOGGING button is selected the following screen is displayed.

To operate data logging in automatic mode, select the AUTO button. To set the interval at which the process parameters are recorded, activate the keypad by pressing the interval button and enter the desired interval (in seconds).

When in the automatic mode, the data-logging feature is only active when the system is active (i.e. data are only logged for equipment in operation).

To operate data logging in manual mode, select the ON button. In manual mode data are collected whether the system is running or not.

Selecting the OFF button will disable all data logging.

Data is stored on a removable USB flash drive located on the front of the control panel door plugged into the programming port. It is NOT necessary to open the control enclosure to access this drive. It is recommended that the HMI is shut down to remove the USB data drive. The data files can then be copied or moved from the USB flash drive to another computer for viewing. Data files are stored on the USB drive as .csv (comma separated variable) files, which can be opened with and saved as Microsoft® Excel™ (.xlsx) files. The .csv files contain data columns with integrated column headers. The first column in the .csv files correlates to the date and time the data were collected.

A second USB drive, located on the back of the HMI is used as a backup to the primary USB drive. This drive automatically logs data every five minutes. To gain access to this drive, the enclosure door will have to be opened. Disconnect power before opening the enclosure door to avoid potential electrical shock. There are two USB “drives” plugged into the HMI. The silver “Intuitech” USB drive is the backup drive. The USB drive that is BLACK is the hard key for the software license. DO NOT REMOVE THE BLACK USB DRIVE as this will invalidate the software license.

ATTENTION: HOW MUCH DATA ARE YOU WILLING TO LOSE? Data should be retrieved and backed up on a separate computer regularly. How often this is performed should be based upon the amount of data loss you are willing to accept.

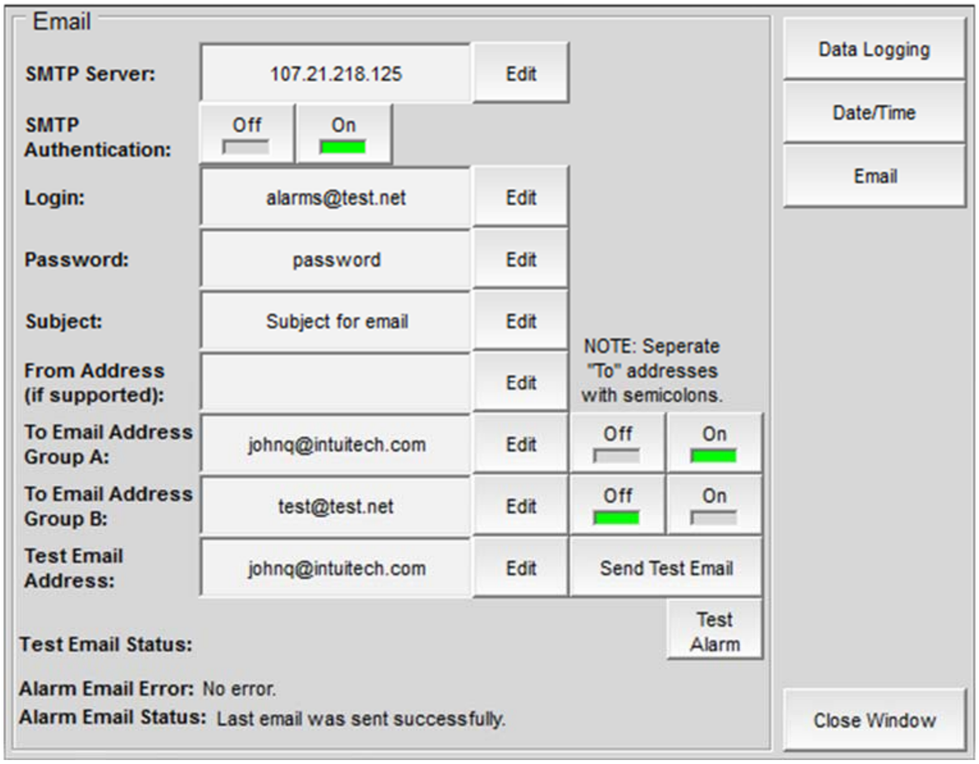
DANGER: Disconnect power to control panel before servicing to eliminate electrical shock and arc flash hazards. The white “Power On” light on the front of the control panel indicates power is present in the panel.

Once the USB flash drive is reconnected to the HMI, the data files will continue to append to the previously existing data (if files were copied to the computer in the previous step) or new files will be created (if the files were removed in the previous step).

When the size of the file exceeds the entered “High Alarm Limit” (in Mb), an alarm will be annunciated (indicating “Total Data File Size High”). Since large text files can become virtually unmanageable, it is recommended that the operator clears or moves the saved data in the data-logging file before they become larger than 30 Mb. If the file size becomes greater than the “Shutdown Limit”, an alarm will be activated indicating “Data Logging Stopped”. At this point the data logging feature will shut down.

(7) Email Alarms Screen

ATTENTION: Due to the complex nature of email security, corporate firewalls and variable service providers, email alarm indications may not be reliable. Intuitech makes no claim as to the functionality or reliability of email alarm notifications.



The HMI has the ability to send all alarm notifications to specified email addresses. The email notifications include the time and date of the alarm as well as the message generated by the alarm.

Administrator login is required to view or modify the SMTP Server IP, SMTP Authentication, Username, Password, Mail from Address, and Mail to Address 1. Without administrator login, these fields will be displayed as asterisks and cannot be accessed.

MAIL TO ADDRESS GROUP B

This field is identical to “Mail to Address Group A” except the administrator level of login is not required to modify the field. Specify any valid email address or multiple addresses separated by a semicolon (;). This can include cell phone email address (e.g. 8015551212@domain.com). Any alarms that occurred prior to email address changes (i.e. in the queue) will be sent using the old data. Messages are sent from the queue at 1-minute intervals.

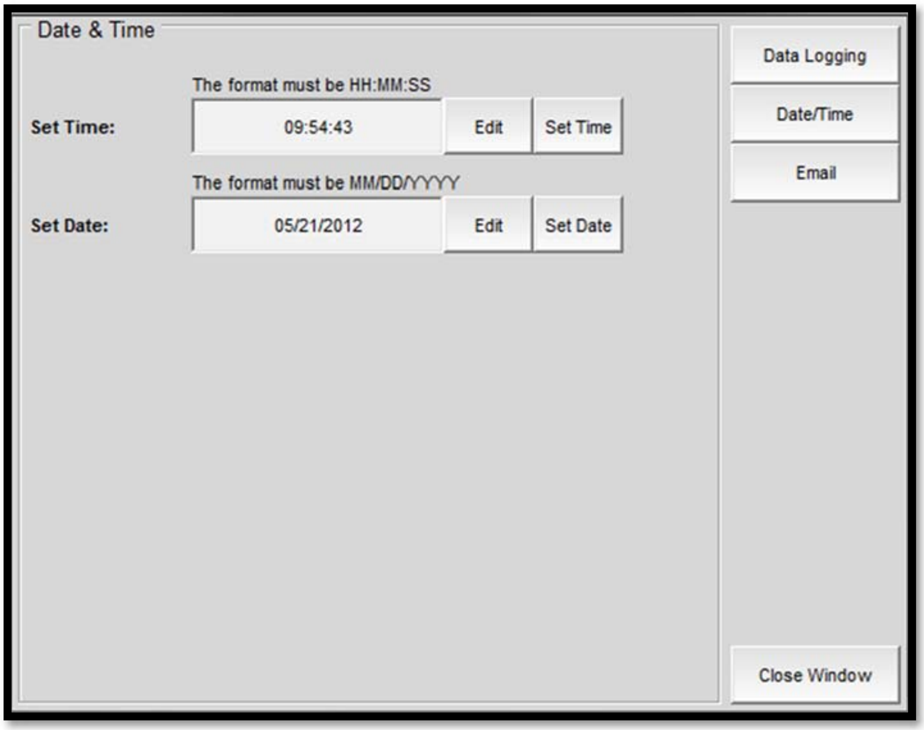
TEST EMAIL

This field is provided to easily test the function of the email screen. Pressing the “Send Test Email” button will send a test email to the email address configured to its right. Pressing the “Test Alarm” button will generate a test alarm and send the email to everyone in Group A and Group B (as long as the group control is set to ON).

MAIL ERROR STATUS

This indicates the status of the last email attempt. If it reads "No error." then the last email was sent successfully. If other errors appear they will be similar to those most mail clients report when there is a failure. Please consult your network administrator if additional assistance is required.

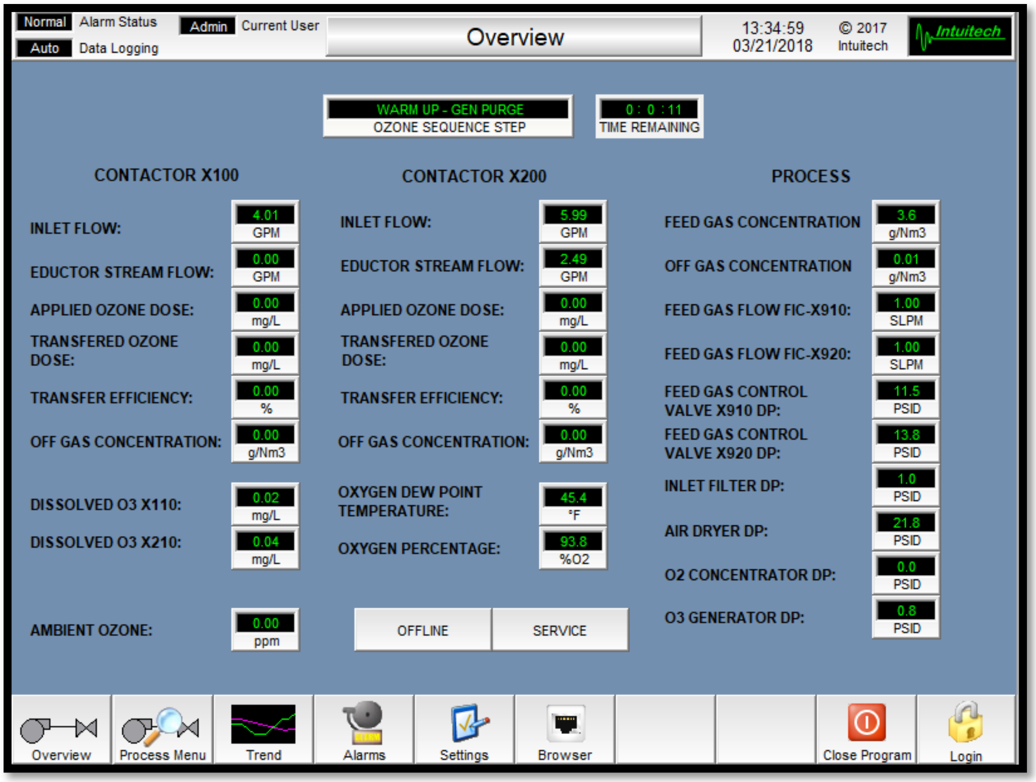
(8) Date/Time Screen
If the Date/Time button is selected the following screen is displayed.



The SET TIME and SET DATE buttons are used to set the current time and date. Use "Edit" to enable the keypad and enter the proper time or date. Once the correct time has been entered, press "Set Time" to move that time into the HMI memory.

NOTE: Ensure that the time and date are entered in the exact format as displayed. Include the necessary symbols (i.e. colon and slash marks) when entering in the time and date or the entry will be rejected.

(9) Overview Screen
When the OVERVIEW button is selected, a similar screen is displayed.

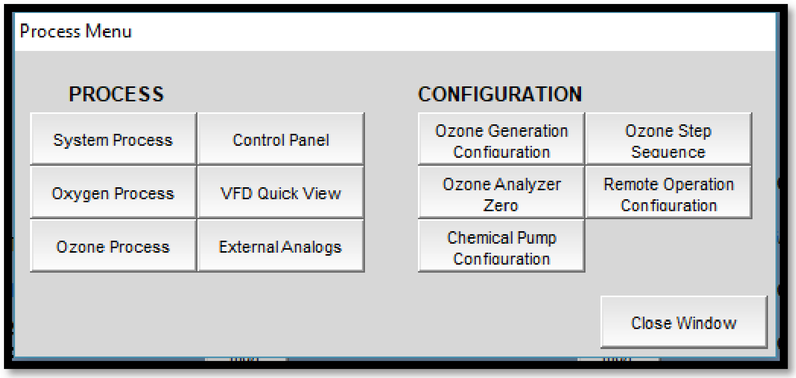


The screen displays a summary of data from all the process screens for the equipment. The system control buttons are used for energizing or de-energizing the equipment. Pressing the SERVICE button will initiate the warm-up sequence, zero the ozone gas analyzers and put the generator into service (as described in the sequence matrix). Pressing the OFFLINE button will start the purge step and shut the equipment down.

NOTE: See the Ozone Calculations and Control section below for information on how the ozone dosage and transfer efficiency is calculated.

(10) Process Menu

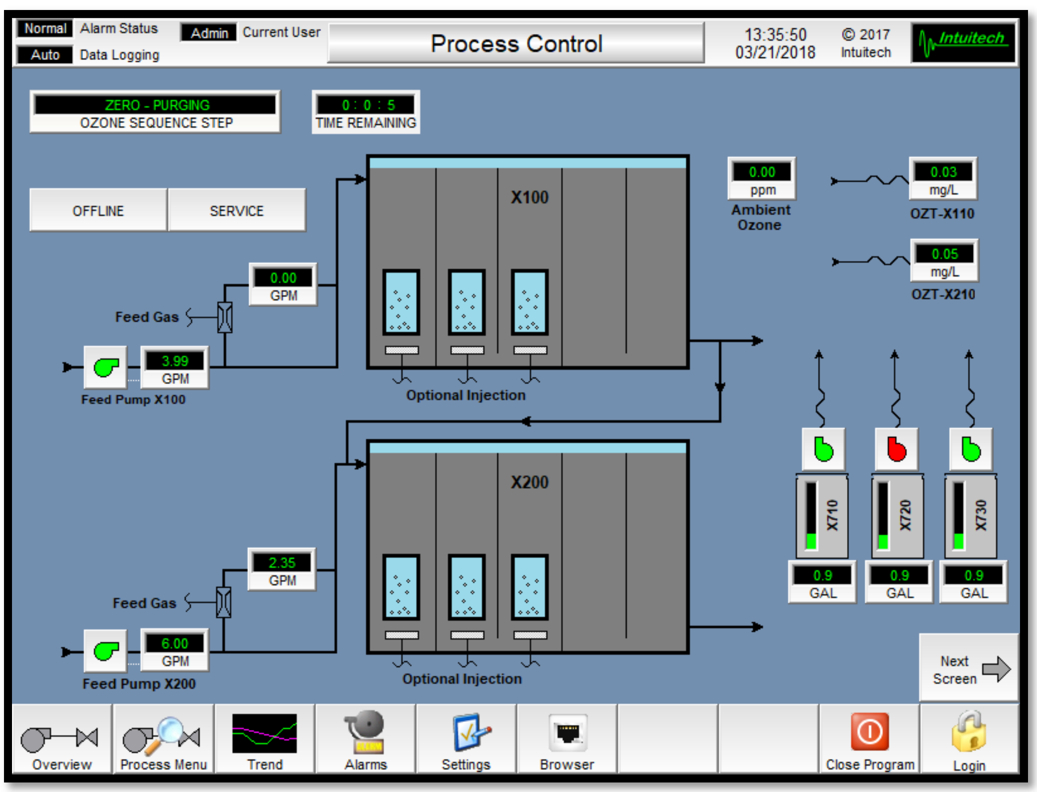
When the process menu button is selected a process menu screen similar to the one below is displayed.



The process menu allows access to screens used for monitoring/controlling different processes and components of the equipment.

(11) System Process Control Screen

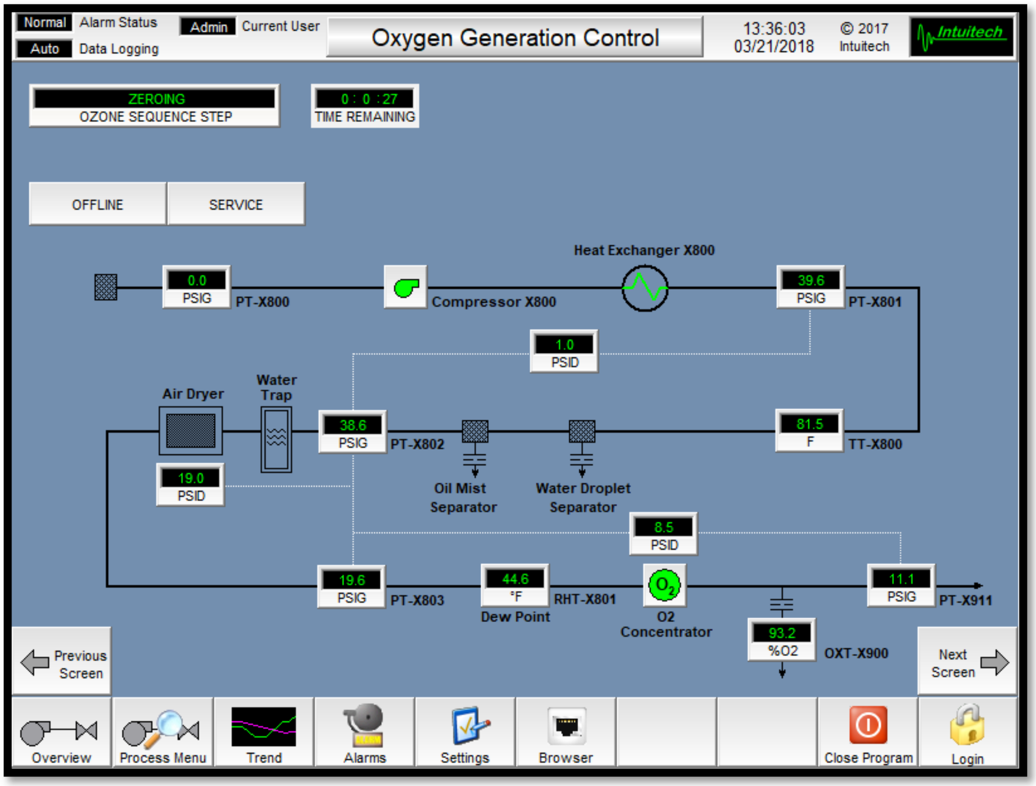
When the SYSTEM PROCESS control button is selected a process screen similar to the one below is displayed.



The system process control screen allows access to screens used for the monitoring and controlling of the feed pumps and chemical pumps on the ozone module. Feed pump flow rates and chemical dosages are set within their respective pump controls.

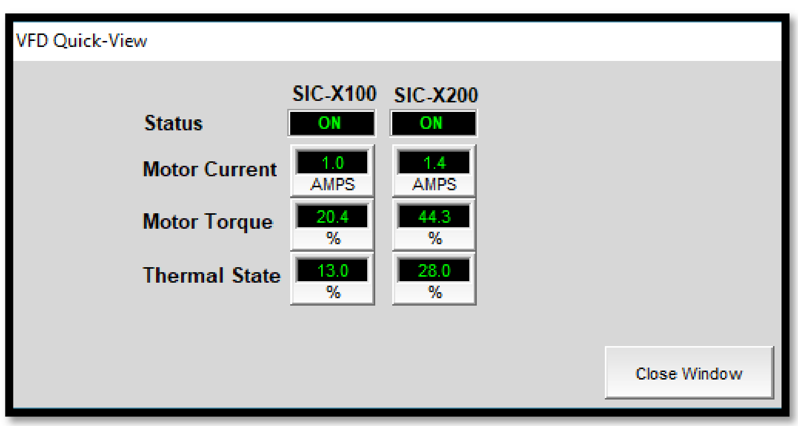
(12) Oxygen Generation Control Screen

When the OXYGEN PROCESS control button is selected a process screen similar to the one below is displayed.



The Oxygen process screen provides access to all of the components used to generate and monitor oxygen production. Differential pressures are displayed for all components and filters to provide warning in case of potential problems. Feed gas dew point temperature and oxygen concentration are also monitored and displayed here.

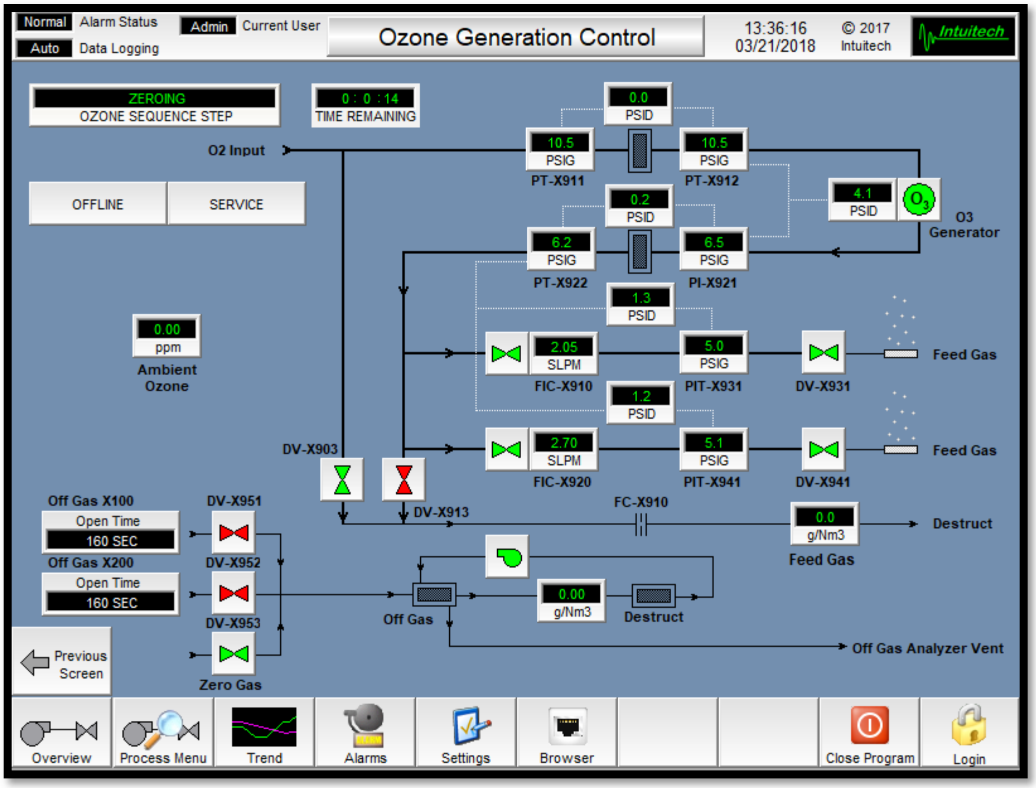
(13) VFD Quick View Screen



The VFD quick view screen displays an overview of the feed pump VFD condition. Motor voltage, current, torque and accumulated thermal state are displayed and recorded to historical trending. For more detailed information about the VFD, consult the Browser screen.

(14) Ozone Generation Control Screen

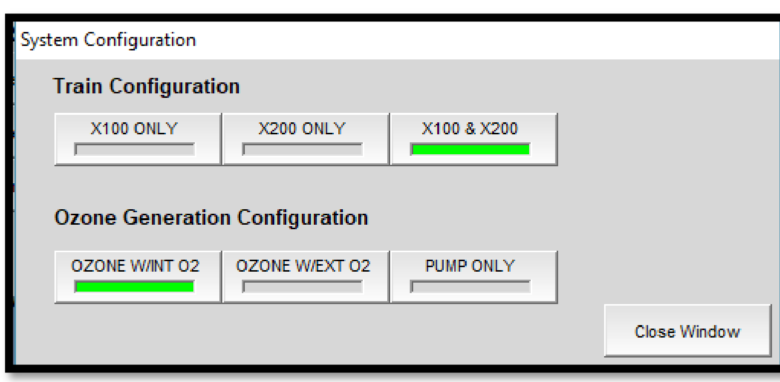
When the OZONE PROCESS control button is selected a process screen similar to the one below is displayed.



The Ozone process screen provides access to all of the components used to generate, control and monitor ozone production. Inlet, outlet and differential pressures are displayed for all components. Ozone dose is adjusted using the flow control valves FIC-X910 and FIC-X920, while the feed gas concentration is set in the ozone generator.

(15) Ozone Generation Configuration Screen

If the OZONE GENERATION CONFIGURATION button is selected, a similar screen will be displayed.

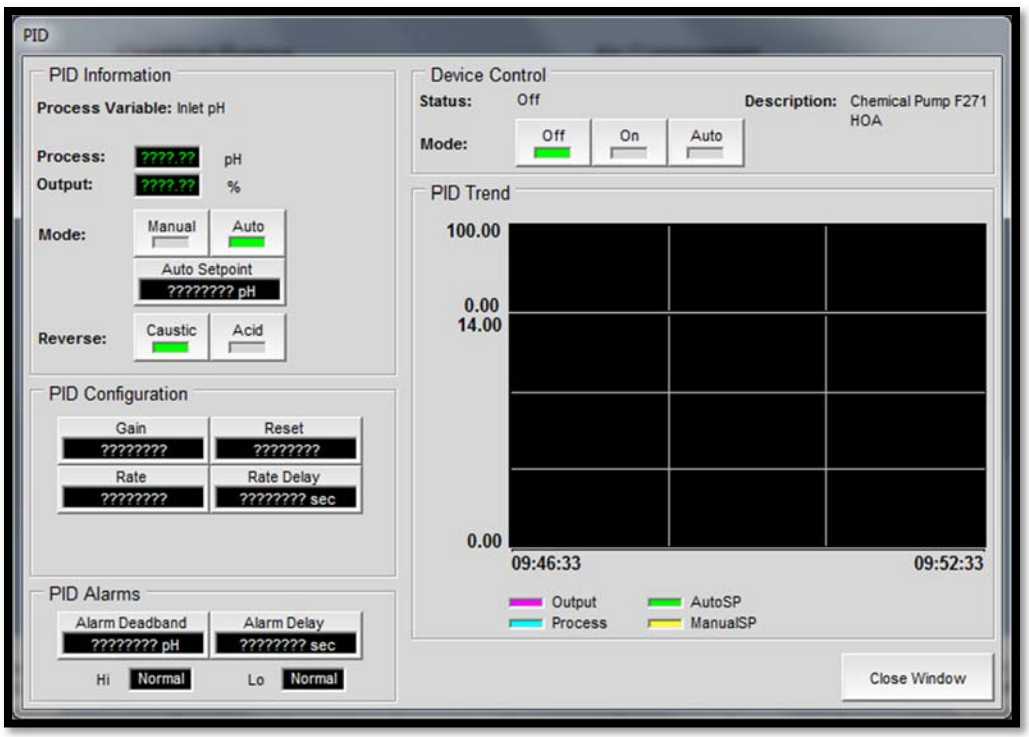


This screen is used to select which of the two trains will be put into operation, and whether the oxygen and ozone generation systems will be used during operation. When set to "Ozone

W/ Internal O2", the on-board oxygen generation system will be used to generate ozone and will shut down if there is a failure in the oxygen generation system or the ozone generation system. When set to "Ozone W/ External O_2", ozone will be generated using an external oxygen source (such as an oxygen bottle), and the system will not shut down if there is a failure in the oxygen generation system. In "Pump Only" mode, only the feed pump turns on during service and the system will not shut down if a component in the oxygen or ozone generation panels fails.

(16) PID Loop Control Screens

If any component (i.e. pump) using a PID control is selected, a similar screen is displayed.



NOTE: All module components which operate using PID control (listed below) will be controlled by a screen very similar to this one.

This screen displays important monitoring parameters, buttons for selecting control options, buttons for selecting auto or manual mode operation, and value input buttons for entering the auto and manual set-points.

The DEVICE CONTROL buttons (in the upper right corner) designate what conditions cause the pump to energize. Pressing the AUTO control button will allow the pump to be controlled automatically by the sequencer. Pressing the OFF or ON control buttons will energize or de-energize the pump manually, independent of the sequencer.

The MODE buttons (auto or manual) designate which setpoint the pump will maintain. When the mode is set to AUTO, the pump will seek the auto setpoint (using the PID control loop). When set to MANUAL, the pump will simply maintain the manual setpoint (a percentage of the pumps maximum flow, with no flow control).

The PID Configuration section contains the tuning parameters for the pump control. The gain, reset, and rate values function as the tuning parameters for the PID control loop. The Proportional–Integral–Derivative (PID) controller is a generic control loop feedback mechanism used to control equipment and maintain a setpoint. The PID controller attempts to correct for the discrepancy between a measured process variable and a desired setpoint by calculating and outputting a corrective action in order to adjust the process accordingly.

The PID controller calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values (i.e. gain, reset, and rate, respectively). The Proportional value determines the reaction to the current error, the Integral determines the reaction based on the sum of recent errors and the Derivative determines the reaction based on the rate at which the error has been changing. A weighted sum of these three actions is used to adjust the process via a control element (such as the position of a control valve).

NOTE: The PID gain, reset, rate, and rate delay values for the feed pump and backwash pump are pre-tuned by the manufacturer and should not require further adjusting. Only qualified personnel should adjust values if it becomes necessary. Before adjusting, record the current values to use as a reference.

The PID ALARMS section contains the alarm deadband and alarm delay values, which define the conditions for the High and Low alarms. The alarm deadband delineates how much the process variable may vary before an alarm occurs. The alarm delay defines the time limit (in seconds) for how long that variable can remain out of range before an alarm occurs.

For example: Using a flow rate of 1.25 gpm, an alarm deadband value of 0.5 gpm and an alarm delay value of 60 seconds; if the flow rate fluctuates above 1.75 gpm or below 0.75 gpm for longer than 60 seconds, an alarm will occur.

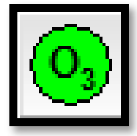
NOTE: Chemical pumps have the ability for PID control to maintain dissolved ozone, or Pace control to maintain a set chemical dose.

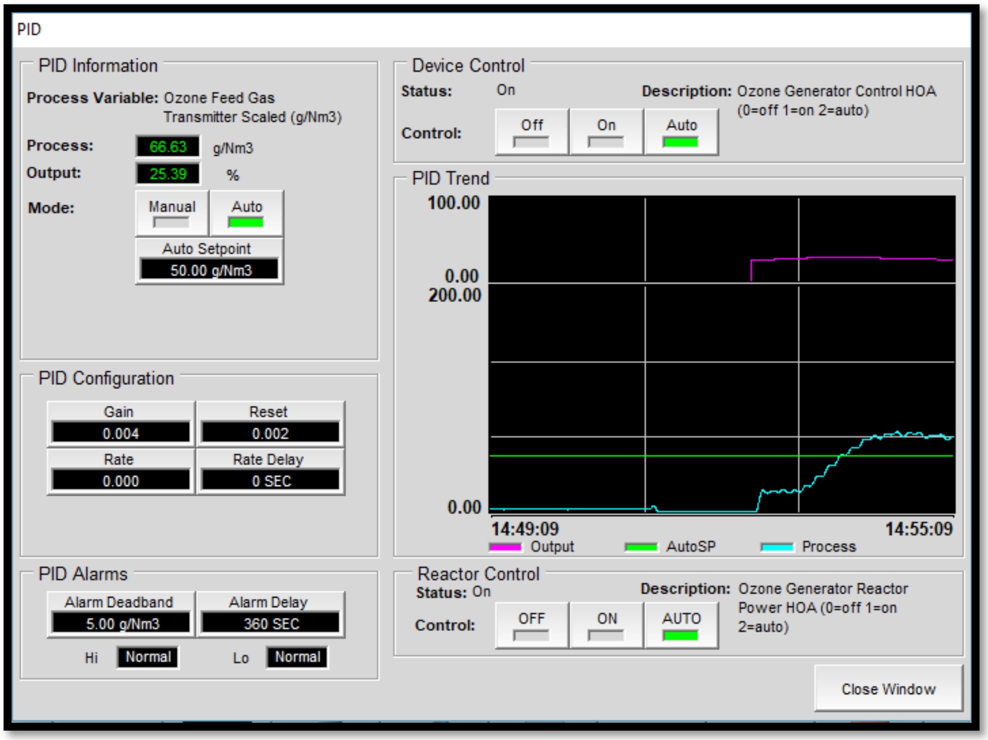
Similar screens exist for the following PID controlled components on the pilot:

- Feed Pump X100
- Feed Pump X200
- Chemical Pump X710
- Chemical Pump X720
- Chemical Pump X730

(17) Ozone Generator Screen

If the GENERATOR X900 button is selected the following screen is displayed.





The screen displays important monitoring parameters, buttons for selecting control options, and an input button for entering generator setpoints.

The Control buttons designate what conditions cause the generator control loop to energize, while the Reactor Control buttons actually provide power to the generator reactor. The default setting for this feature is AUTO. This will allow the generator to be controlled automatically by the sequencer from the Overview Screen. Pressing the OFF or ON control buttons will energize or de-energize the generator manually (independent of the Overview Screen system control buttons).

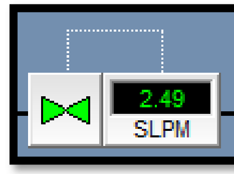
The Mode buttons dictate which setpoint the generator will maintain when energized. When set to MAN, the pump will seek the MANUAL SETPOINT (only displayed when Manual is selected). When set to AUTO, the generator will maintain the AUTO SETPOINT.

The manual setpoint designates the percentage of the generator's maximum output (%), which the generator will maintain when energized under manual Mode.

The auto setpoint designates the ozone concentration (in g/Nm3) the generator will maintain when energized under auto control.

NOTE: To disable ozone generation completely, set the MANUAL SETPOINT to zero (0%).

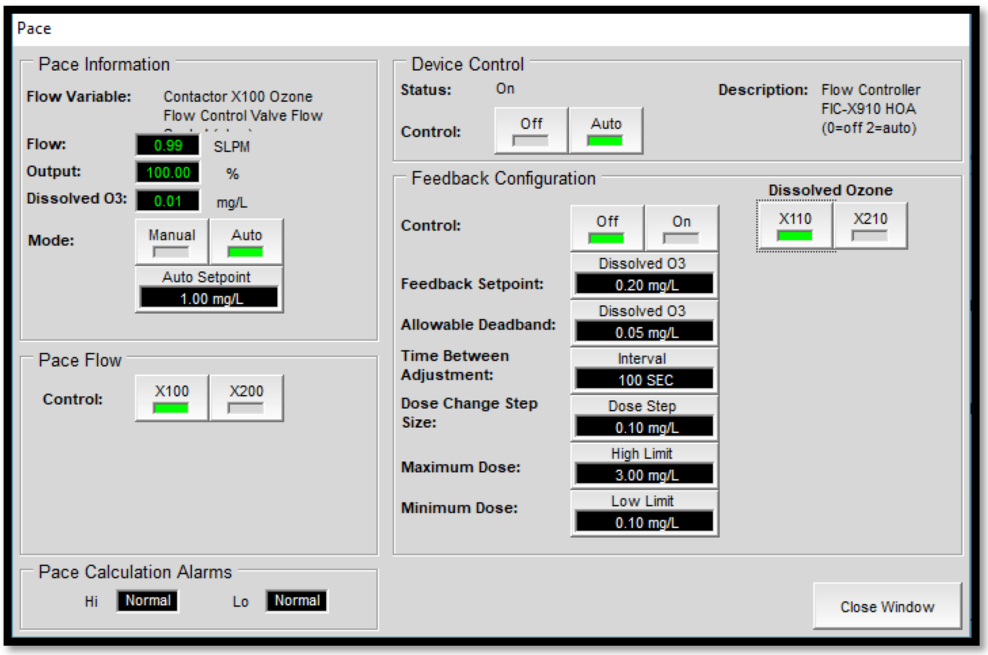
(18) Diffuser Flow Screen



If the DIFFUSER FLOW button is selected (right) the following screen is displayed.

The diffuser flow screen displays the current diffuser flow rate and the input buttons for controlling the ozone gas flow rate.

The gas flow rate is displayed in SLPM (standard liters per minute), indicating that the flow rate has already been normalized to the gas temperature and pressure.

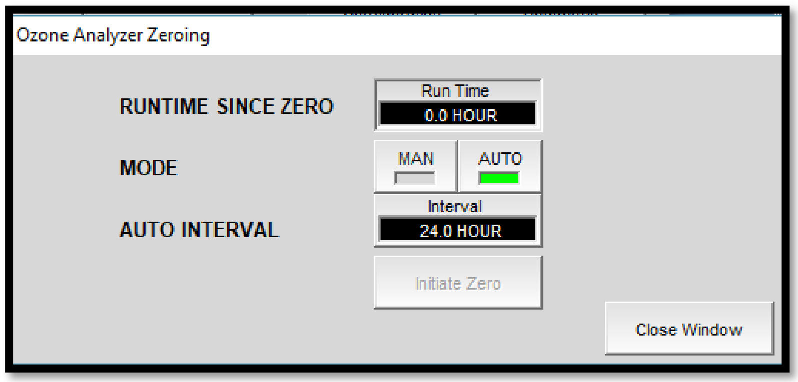


Similar to the PID control screens, the flow control valves have both a MANUAL SETPOINT (in SLPM) and an AUTO SETPOINT in ozone dose (mg/L). See the calculation section below for information on how dose is calculated.

NOTE: During the ozone analyzer zero sequence, the feed gas flow rate will be held constant to ensure the zeroing process does not interrupt ozone delivery to the contactor. **The feed gas flow control will remain constant both during, and for 30 seconds after an analyzer zero.**

In addition to the PID control, the feed flow controllers have the ability to “trim” to a dissolved ozone concentration. This Feedback Configuration can be enabled or disabled using the control buttons in the Feedback Configuration section. In simple terms, the trim function will look at a dissolved ozone SETPOINT and determine if the actual dissolved ozone is within an ALLOWABLE DEADBAND of that setpoint. If it is not, then the function will increase or decrease the dose (AUTO SETPOINT) by a defined STEP SIZE and then wait for a set amount of TIME before re-evaluating whether the dissolved ozone is now within the allowed DEADBAND of the setpoint. This will continue until the dissolved ozone concentration falls within specification. A MINIMUM and MAXIMUM DOSE range is included to ensure the dosage stays within acceptable limits.

(19) Analyzer Zero Screen
If the ANALYZER ZERO button is selected the following screen is displayed.

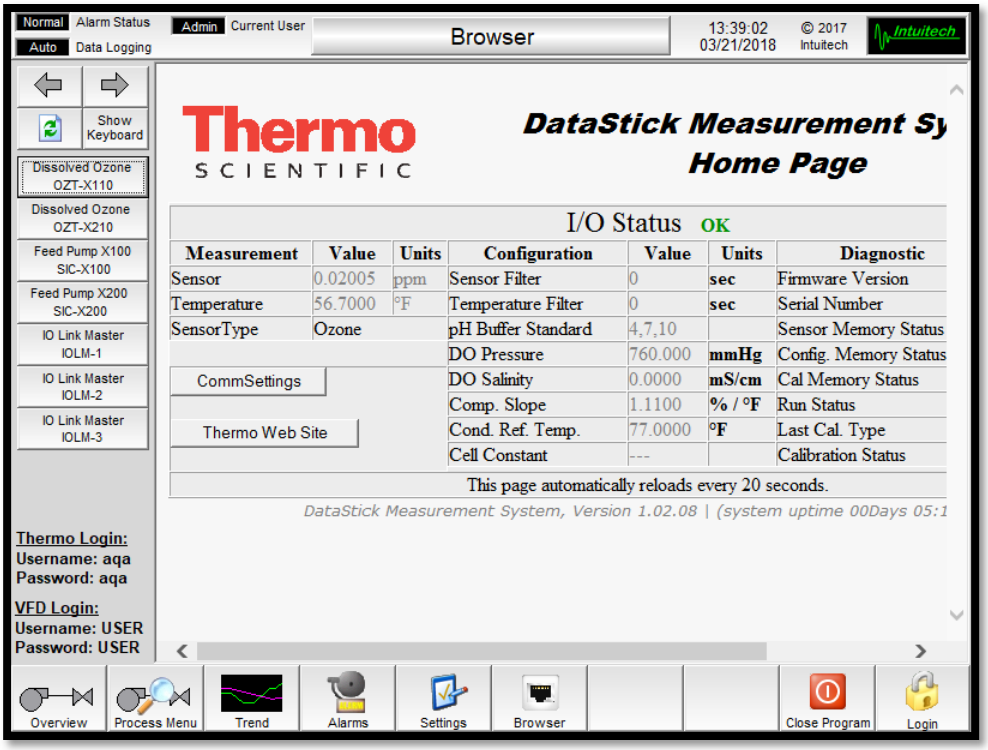


The analyzer zero screen displays the buttons for controlling how and when the feed gas and off gas ozone analyzers will perform a zero calibration.

If the zeroing MODE is set to AUTO, then the INITIATE ZERO button is disabled and the analyzers will zero based on the AUTO INTERVAL and the RUNTIME SINCE ZERO will display an increasing runtime. When this runtime timer is equal to the AUTO INTERVAL, then the feed and off gas ozone analyzers will perform an automatic re-zero sequence (and the runtime counter will reset).

If the zeroing MODE is set to SEMI, then the INITIATE ZERO button is enabled and the operator can perform a re-zero anytime the system is in service, by pressing the ZERO button. In SEMI MODE the analyzers will ONLY re-zero when the ZERO button is pressed.

(20) Browser
If the BROWSER button is selected, a screen similar to the following is displayed.

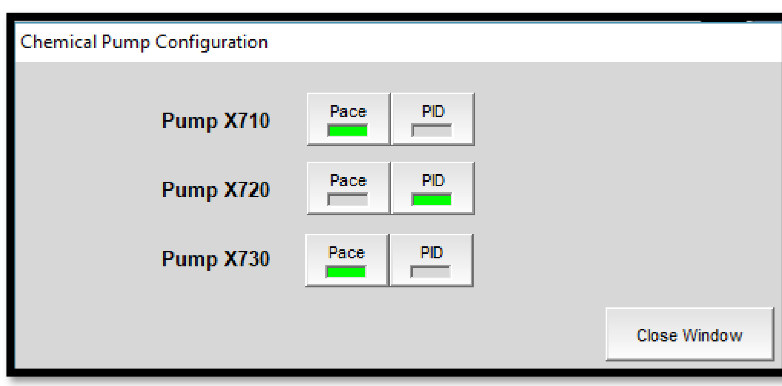


The dissolved ozone sensors, the feed pump VFDs and the IO Link Masters are equipped with internal web browser pages. To access them, press one of the sensor buttons along the top edge of the screen. Most browser pages are designed to display diagnostic information. However, instrument calibration for the dissolved ozone sensors will be accomplished through these screens. See Maintenance Section for more detailed information about calibration.

(21) Chemical Pump Configuration Screen

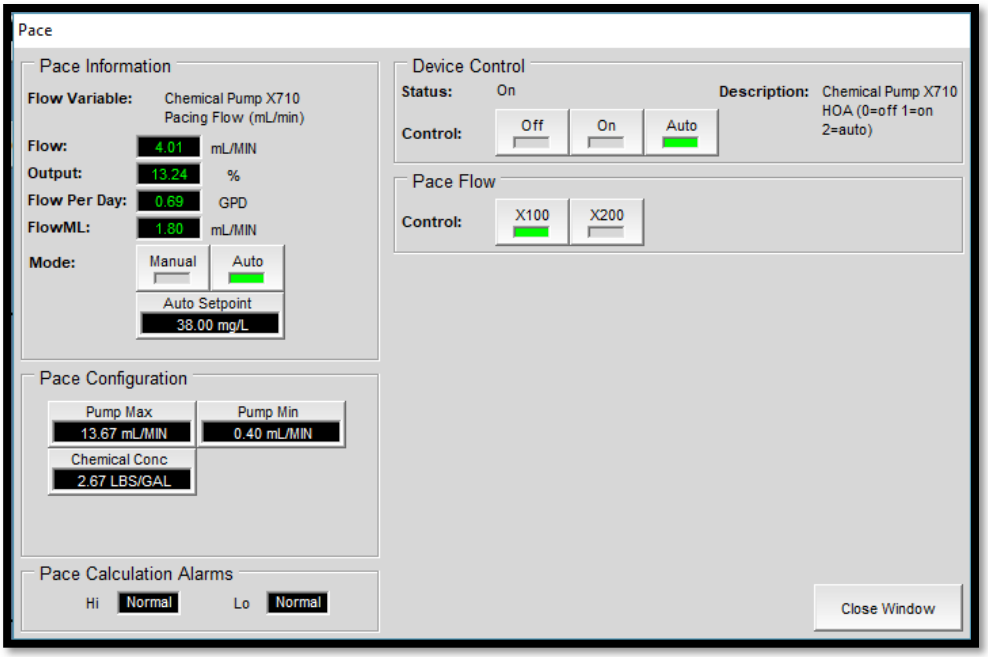
If the CHEMICAL PUMP CONFIGURATION SCREEN is selected, a similar screen is displayed.

This screen contains the configuration buttons for the chemical pumps. In PID mode the pump will maintain an ozone residual. In pace mode it will maintain a defined chemical dose.



(22) Pace Loop Control Screen

If any component (i.e. chemical pump) using a Pace control is selected, a similar screen is displayed.



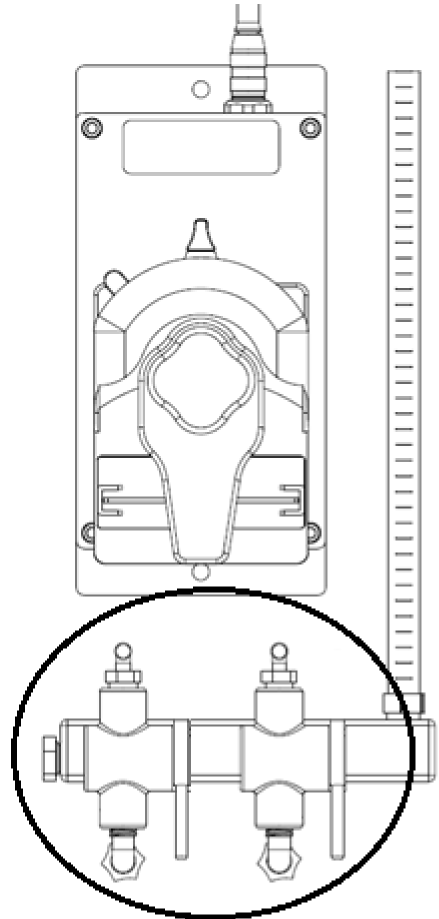
NOTE: All module components which operate using Pace control (listed below) will be controlled by a screen very similar to this one.
The screen displays monitoring parameters, control buttons, buttons for selecting auto or manual mode, auto and manual setpoint values, buttons for selecting which flow the pump will pace from (if applicable), along with; the solution concentration setpoint, and pump min/max set-points.

The Device Control buttons designate which conditions will cause the pump to energize. The Mode buttons designate which setpoint the pump will maintain.

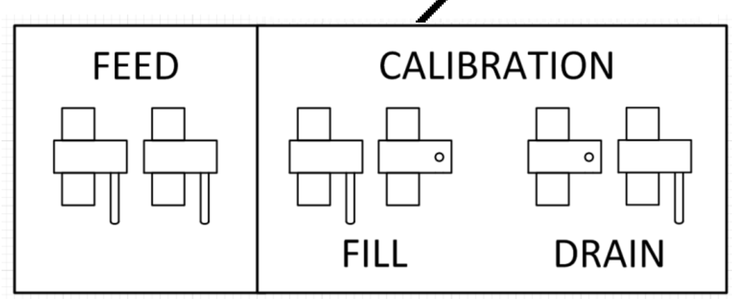
NOTE: The auto setpoint is entered in units of milligrams of chemical, per liter of water (feed flow through the module).

Pump Calibration:

To calibrate the pump for operation in auto mode, the flow capacity of the pump must be measured and entered. First, set the valve positions to FILL. Next, switch the pump mode to manual by selecting the MAN button. To determine the pump's maximum flow, access the manual setpoint keypad and enter 100%. Press the ON control button and operate the pump until the graduated cylinder is full of the chemical to be dispensed (make a note of the current chemical level). Next, set the valve positions to DRAIN and energize the pump for at 100% for 1 minute. After 1 minute of pumping, de-energize the pump and measure (in milliliters) the amount of chemical pumped from the graduated cylinder- enter this amount as the Pump Max setpoint. To determine the pump's minimum flow, repeat the process by operating the pump at the minimum manual setpoint percentage of 3% for one minute and measuring the chemical pumped. Enter this amount as the Pump Min setpoint. Repeat the process for each pump used.



Enter the solution concentration of the chemical being pumped (units are in pounds of chemical per gallon of solution). Once calibration is complete, set the valve positions back to FEED.



Concentration Example:

A utility uses 40% $FeCl_3$ with a "neat" or "product" density of 11.7 lbs/gal.

If they express their dose as active $FeCl_3$:
$FeCl_3$ active portion in product = 40%
Chemical Conc = 40% * 11.7 lbs/gal
Chemical Conc = 4.68 lbs/gal

If they express their dose as Fe^{+3}:
Fe^{+3} active portion in product = 13.7%
Chemical Conc = 13.7% * 11.7 lbs/gal
Chemical Conc = 1.60 lbs/gal

The "neat" or "product" consumption is calculated and expressed in both gallons per day and in mL/min on the HMI.

NOTE: If an auto dosing setpoint is selected which the equipment is not able to achieve, a "calculation high" or "calculation low" indication will appear.

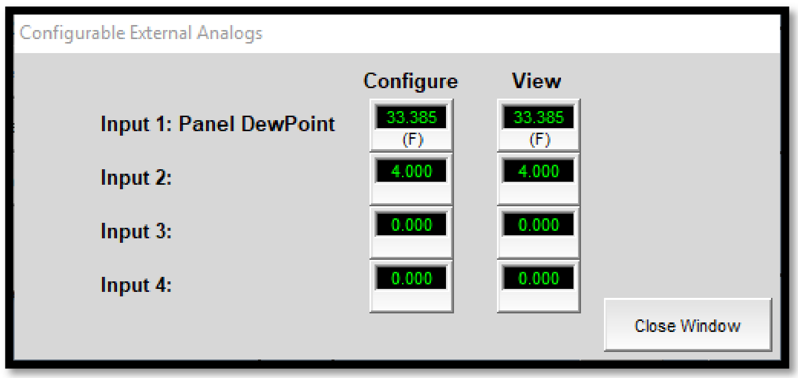
ATTENTION: If the chemical pump experiences a fault, the Pump Fault Alarm will be annunciated. **In addition to pressing the Alarm Reset button, it is necessary to cycle power to the pump in order to clear the alarm.** This can be accomplished by simply removing the wiring connector at the top of the pump, then reconnecting it.

Similar screens exist for the following Pace controlled components on the pilot:

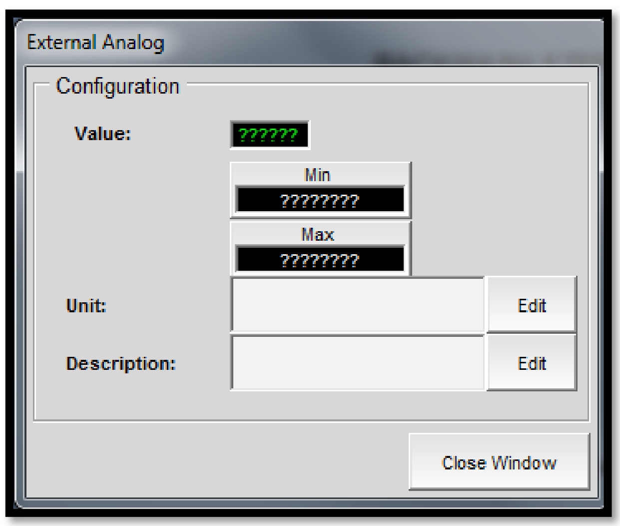
- Chemical Pump X710
- Chemical Pump X720
- Chemical Pump X730

(23) External Analog Input Screen

This equipment has the ability to display, scale, and log data from up to four additional (customer installed) analog instruments.



The External Analog Input Configuration buttons allow the operator to configure the HMI to read data from 4-20 mA signals generated from customer supplied (or "external") analog instruments. Pressing each button will allow the operator to enter the required information.



For each external instrument used, the operator may provide a description and units of measurement, but MUST provide the minimum/maximum measurement set-points.

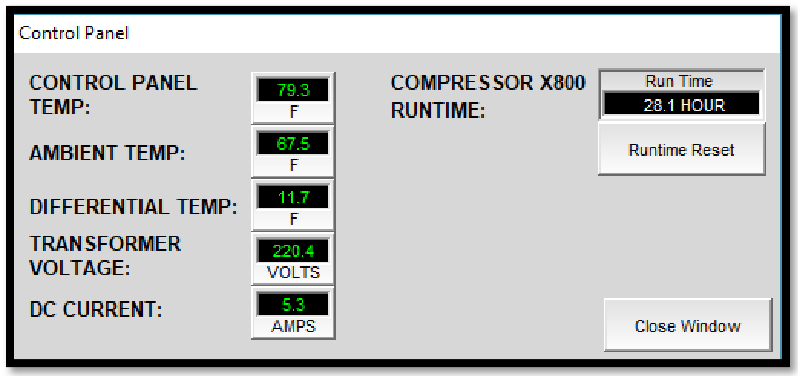
The Description line describes the instrument; the Unit line describes the engineering units the instrument is measuring in;

and the MIN/MAX entries define the range of measurement (scaling).

NOTE: The .csv file designated for the external analog instruments will be present on the removable flash drive even if no instruments are being utilized.

(24) Control Panel Screen

If the CONTROL PANEL condition button is selected, the following screen is displayed.



This screen displays important diagnostic information about the environmental condition (temperature inside and outside of the control panel) and the electrical health of the pilot module.

(25) HMI Alarms and Conditions

The alarms generated by the equipment are summarized in the Alarm List. The "Message" column indicates the alarm text shown at the bottom of each HMI screen and on the ALARM SUMMARY and ALARM HISTORY screens. The "Condition" column describes the logic that generates the alarm. The "Shutdown" column identifies if the alarm will cause the equipment to shut down.

ALARM LIST

ALARM MESSAGE	CONDITION	SHUTDOWN
Test Email Alarm	Test email generated	
Data Log File Length Shutdown Alarm	Data log file length greater than shutdown limit	
Data Log File Length High Alarm	Data log file length greater than high limit	
Data Log Interval Not Defined	Data log interval less than 1 second or greater than 65535 seconds	
Data Logging Not Enabled	Data logging set to off	
Air Dryer Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X*
Chemical Pump X710 Fault Alarm	Motor fault detected NOTE: Disconnect power wiring to pump before resetting alarm	
Chemical Pump X710 Dissolved Ozone High Alarm	Process value is greater than ALARM DEADBAND for entered ALARM	

	DELAY time	
Chemical Pump X710 Dissolved Ozone Low Alarm	Process value is less than ALARM DEADBAND for entered ALARM DELAY time	
Chemical Pump X720 Fault Alarm	Motor fault detected NOTE: Disconnect power wiring to pump before resetting alarm	
Chemical Pump X720 Dissolved Ozone High Alarm	Process value is greater than ALARM DEADBAND for entered ALARM DELAY time	
Chemical Pump X720 Dissolved Ozone Low Alarm	Process value is less than ALARM DEADBAND for entered ALARM DELAY time	
Chemical Pump X730 Fault Alarm	Motor fault detected NOTE: Disconnect power wiring to pump before resetting alarm	
Chemical Pump X730 Dissolved Ozone High Alarm	Process value is greater than ALARM DEADBAND for entered ALARM DELAY time	
Chemical Pump X730 Dissolved Ozone Low Alarm	Process value is less than ALARM DEADBAND for entered ALARM DELAY time	
Compressor X800 Not in Auto Alarm	Component control not set to AUTO	
Compressor X800 Fail Alarm	Component commanded to run but not running after 30 seconds	X*
Feed Gas Transmitter Zeroing Valve Not in Auto Alarm	Component control not set to AUTO	
Feed Gas Transmitter Sample Valve Not in Auto Alarm	Component control not set to AUTO	
Contactor X100 Ozone Diffuser Isolation Valve Not in Auto Alarm	Component control not set to AUTO	
Contactor X200 Ozone Diffuser Isolation Valve Not in Auto Alarm	Component control not set to AUTO	
Contactor X100 Off Gas Sample Valve Not in Auto Alarm	Component control not set to AUTO	
Contactor X200 Off Gas Sample Valve Not in Auto Alarm	Component control not set to AUTO	
Off Gas Concentration Zeroing Valve Not in Auto Alarm	Component control not set to AUTO	
Emergency Stop Alarm	Emergency stop button depressed NOTE: Rotate E-Stop button before resetting alarm	X
Contactor X100 Ozone Flow Control Valve Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X**

Contactor X100 Ozone Flow Control Valve Failed Alarm	No Transmitter signal for 30 seconds	X**
Contactor X100 Ozone Flow Control Valve Low Alarm	Process value less than entered limit for 30 seconds	X**
Contactor X200 Ozone Flow Control Valve Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X**
Contactor X200 Ozone Flow Control Valve Failed Alarm	No Transmitter signal for 30 seconds	X**
Contactor X200 Ozone Flow Control Valve Low Alarm	Process value less than entered limit for 30 seconds	X**
Particulate Filter X910 Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X**
Particulate Filter X920 Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X**
Contactor X100 Flow Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X
Contactor X100 Flow Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	X
Contactor X100 Flow Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	X
Contactor X100 Injector Flow Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Contactor X100 Injector Flow Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Contactor X100 Injector Flow High Alarm	Process value greater than entered limit for 30 seconds	
Contactor X100 Injector Flow Low Alarm	Process value less than entered limit for 30 seconds	
Contactor X100 Injector Flow Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	
Contactor X200 Flow Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X
Contactor X200 Flow Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Contactor X200 Flow Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	
X200 Injector Flow Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
X200 Injector Flow Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	

Contactor X200 Injector Flow High Alarm	Process value greater than entered limit for 30 seconds	
Contactor X200 Injector Flow Low Alarm	Process value less than entered limit for 30 seconds	
Contactor X200 Injector Flow Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	
Inlet Filter Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X*
Contactor X100 Liquid Gas Separator Leak Detector I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Contactor X100 Liquid Gas Separator Leak DetectorI/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Contactor X100 Liquid Gas Separator Leak Alarm	Leak detected for 30 second	
Contactor X200 Liquid Gas Separator Leak Detector I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Contactor X200 Liquid Gas Separator Leak Detector I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Contactor X200 Liquid Gas Separator Leak Alarm	Leak detected for 30 second	
Chemical Cabinet Leak Detector I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Chemical Cabinet Leak Detector I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Chemical Cabinet Leak Alarm	Leak detected for 30 second	X
O2 Panel Liquid Gas Separator Leak Detector I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
O2 Panel Liquid Gas Separator Leak Detector I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
O2 Panel Liquid Gas Separator Leak Alarm	Leak detected for 30 second	
Chemical Tank X710 Level Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Chemical Tank X710 Level Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Chemical Tank X710 Level High Alarm	Process value greater than entered limit for 30 seconds	

Chemical Tank X710 Level Low Alarm	Process value less than entered limit for 30 seconds	
Chemical Tank X710 Level Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	
Chemical Tank X720 Level Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Chemical Tank X720 Level Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Chemical Tank X720 Level High Alarm	Process value greater than entered limit for 30 seconds	
Chemical Tank X720 Level Low Alarm	Process value less than entered limit for 30 seconds	
Chemical Tank X720 Level Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	
Chemical Tank X730 Level Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Chemical Tank X730 Level Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Chemical Tank X730 Level High Alarm	Process value greater than entered limit for 30 seconds	
Chemical Tank X730 Level Low Alarm	Process value less than entered limit for 30 seconds	
Chemical Tank X730 Level Transmitter Sensor Fault Alarm	Transmitter fault detected. See IO Link for information	
Oxygen Concentrator Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X*
Oxygen Concentrator Not in Auto Alarm	Component control not set to AUTO	
Ozone Generator Differential Pressure High Alarm	Process value greater than entered limit for 30 seconds	X**
Concentrated Oxygen Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X*
Concentrated Oxygen Low Alarm	Process value less than entered limit for 30 seconds	X*
Ozone Generator Not in Auto Alarm	Component control not set to AUTO	
Ozone Generator Failed Alarm	No Transmitter signal for 30 seconds	X**
Ozone Generator Fault Alarm	Generator fault detected	X**
Ozone Generator Flooded Cell Alarm	Generator flooded cell detected	X**
Ozone Generator Concentration High Alarm	Process value greater than entered limit for 30 seconds	
Ozone Generator Concentration Low Alarm	Process value less than entered limit for 30 seconds	

Ozone Generator Reactor Not in Auto Alarm	Component control not set to AUTO	
Ambient Ozone Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X**
Ambient Ozone Permissible Exposure Limit Alarm	Ambient ozone PEL limit exceeded	X**
Ambient Ozone Short Term Exposure Limit Alarm	Ambient ozone STEL limit exceeded	X**
Ozone Feed Gas Transmitter Error Alarm	Transmitter fault detected. NOTE: Zero analyzer before resetting alarm	
Ozone Feed Gas Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X**
Ozone Off Gas Transmitter Error Alarm	Transmitter fault detected. NOTE: Zero analyzer before resetting alarm	
Ozone Off Gas Transmitter Failed Alarm	No Transmitter signal for 30 seconds	
Ozone Off Gas High Alarm	Process value greater than entered limit for 30 seconds	
Ozone Off Gas Low Alarm	Process value less than entered limit for 30 seconds	
Ozone System Sequencer Step Time Too Long Alarm	Sequencer step longer than entered limit	
Dissolved Ozone Transmitter X110 Failed Alarm	No Transmitter signal for 30 seconds	
Dissolved Ozone X110 High Alarm	Process value greater than entered limit for 30 seconds	
Dissolved Ozone X110 Low Alarm	Process value less than entered limit for 30 seconds	
Dissolved Ozone Transmitter X210 Failed Alarm	No Transmitter signal for 30 seconds	
Dissolved Ozone X210 High Alarm	Process value greater than entered limit for 30 seconds	
Dissolved Ozone X210 Low Alarm	Process value less than entered limit for 30 seconds	
X100 Feed Gas Outlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X**
X100 Feed Gas Outlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	X**
Contactor X100 Feed Gas Outlet Pressure Low Alarm	Process value less than entered limit for 30 seconds	X**
X200 Feed Gas Outlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X**
X200 Feed Gas Outlet Pressure Transmitter I/O Link	Transmitter fault detected. See IO Link for information	X**

Communications Fault Alarm		
Contactor X200 Feed Gas Outlet Pressure Low Alarm	Process value less than entered limit for 30 seconds	X**
PLC Program Downloaded Alarm	New PLC program downloaded	X
PLC Power Failed Alarm	Main PLC power failed	X
DC Power Supply Failed Alarm	No Transmitter signal for 30 seconds	
Power Supply Current High Alarm	Process value greater than entered limit for 30 seconds	
Compressor Inlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X*
Compressor Inlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Compressor Inlet Pressure Low Alarm	Process value less than entered limit for 30 seconds	X*
Compressor Outlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X*
Compressor Outlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Compressor Outlet Pressure High Alarm	Process value greater than entered limit for 30 seconds	
Compressor Outlet Pressure Low Alarm	Process value less than entered limit for 30 seconds	X*
Air Dryer Inlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X*
Air Dryer Inlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Air Dryer Outlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X*
Air Dryer Outlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Air Dryer Outlet Pressure High Alarm	Process value greater than entered limit for 30 seconds	
Oxygen Concentrator Outlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X*
Oxygen Concentrator Outlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	

Oxygen Concentrator Outlet Pressure High Alarm	Process value greater than entered limit for 30 seconds	X*
Oxygen Concentrator Outlet Pressure Low Alarm	Process value less than entered limit for 30 seconds	X*
Ozone Generator Inlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X**
Ozone Generator Inlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Ozone Generator Outlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X**
Ozone Generator Outlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Ozone Flow Controller Inlet Pressure Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	X**
Ozone Flow Controller Inlet Pressure Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Contactor X100 Feed Pump Motor Current High Alarm	Process value greater than entered limit for 30 seconds	
Contactor X100 Feed Pump Failed Alarm	Component commanded to run but not running after 30 seconds	X
Contactor X100 Feed Pump Flow High Alarm	Process value is greater than ALARM DEADBAND for entered ALARM DELAY time	
Contactor X100 Feed Pump Flow Low Alarm	Process value is less than ALARM DEADBAND for entered ALARM DELAY time	X
Contactor X200 Feed Pump Motor Current High Alarm	Process value greater than entered limit for 30 seconds	
Contactor X200 Feed Pump Failed Alarm	Component commanded to run but not running after 30 seconds	X
Contactor X200 Feed Pump Flow High Alarm	Process value is greater than ALARM DEADBAND for entered ALARM DELAY time	
Contactor X200 Feed Pump Flow Low Alarm	Process value is less than ALARM DEADBAND for entered ALARM DELAY time	X
Contactor X200 Feed Pump VFD Fault	Controller fault detected. See VFD for information	
Air Dryer Dew Point Temperature Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X*
Air Dryer Dew Point Temperature	Process value greater than entered	X*

High Alarm	limit for 30 seconds	
Off Gas Sample Pump Not in Auto Alarm	Component control not set to AUTO	
Control Panel Differential Temperature High Alarm	Process value greater than entered limit for 30 seconds	
Control Panel Interior Temperature Transmitter Failed Alarm	No Transmitter signal for 30 seconds	
Control Panel Internal Temperature High Alarm	Process value greater than entered limit for 30 seconds	
Ambient Temperature Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Ambient Temperature Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	
Ambient Temperature Transmitter High Alarm	Process value greater than entered limit for 30 seconds	
Compressor Outlet Temperature Transmitter I/O Link Communications Failed Alarm	No Transmitter signal for 30 seconds	
Compressor Outlet Temperature Transmitter I/O Link Communications Fault Alarm	Transmitter fault detected. See IO Link for information	

NOTE: Not in Auto Alarm: This alarm does not indicate an operational failure. It is simply an indicator to remind the operator that the given process is under manual control.

WARNING: Equipment protection is enabled only when control is in AUTO. Operator is responsible to protect equipment from damage when control is not in AUTO. Equipment not operating in auto is displayed on the alarm summary screen.

DANGER: High ambient ozone shutdown is only enabled when generator control is in auto. Operator is responsible for monitoring ambient ozone levels when control is in manual.

STARTUP

1. Pre-Startup Procedures

A. Pump Inspection

Qualified personnel should confirm that the feed pump energizes and rotates in the correct direction.

Verify that the pump is aligned correctly and that the shaft rotates without binding.

> **WARNING:** <u>Do not</u> run the pumps dry. Do not deadhead pump for more than 30 seconds.

B. Open Process Connections

Open all process valves required for supply to the equipment. These are not the valves on the equipment but field valves that may need to be opened to supply water to the equipment.

C. Fill Contactors

Set the feed pump to manual control (ON) and fill the contactor tanks. Check for leaks. Make sure that all drain valves are closed, so the feed water is able to flow from contactor to contactor (this step may also be performed during start-up).

D. Feed Gas and Off Gas Transmitters Warm-Up

The two ozone gas analyzers (located inside the control panel) require a minimum of 30 minutes to warm up. Therefore, every time the main power is turned on, the equipment must be allowed to sit for a minimum of 30 minutes before pressing the ONLINE button and initiating the start-up sequence.

> **ATTENTION:** Upon initial power-up, the feed gas and off gas analyzers will display instrument error alarms until the start-up sequence is completed.

E. Injecting Ozone using the Eductors

Injecting ozone through an eductor is very different from using the standard ceramic diffuser stones. The eductors used for this project (Mazzei Model 586) provide maximum suction with an injector inlet pressure around 20…25 psig, corresponding to a motive flow of approx. 4.5 gpm. Changing the water flow rate through the educator will change the suction pressure on the gas line (i.e. too much water flow accompanied by too little gas flow can cause vacuum pressures that will result in a system shutdown).

<u>Refer to the Mazzei data sheet included on the accompanying USB drive for more information about this eductor.</u>

2. Startup Procedures

A. Turn main disconnect handle to ON.
B. Log into the HMI using appropriate login level.
C. Verify the alarm limits and data log settings are correct.
D. Open or close appropriate hand-actuated valves.

E. Connect the off gas sample line to the top of the contactor.
F. Confirm that setpoints on the feed pump screen are at desired values.
G. Set Feed Pump X100 (or X200) CONTROL to ON and begin filling contactors with water. Wait until the contactor is full of water before proceeding, then set Feed Pump CONTROL to AUTO.
H. Remove caps from the dissolved ozone sensors and lock the transmitters onto their flow-through cells. Open isolation valves DV-X110 and DV-X210 on the flow-through cells.
I. If desired, set the ozone generator MANUAL SETPOINT to 0%, which will deactivate ozone production during start-up.
J. Set the diffuser flow to the desired setpoint (either in SLPM or ozone dose on the screen.
K. **NOTE:** Allow a minimum of thirty (30) minutes between applying power to the system and pressing the ONLINE button.
L. Initiate the start-up sequence by pressing the ONLINE button on the Overview screen. (The system will run through a series of pressure and flow verifications, followed by an instrument zeroing. When complete, the system will register as being in SERVICE.)
M. From the HMI, configure the ozone generator MODE to the desired operation and begin producing ozone.
N. **NOTE:** During a gas analyzer zero calibration, the ozone gas flow from the generator is held constant. Thirty seconds after the end of a zero calibration, active control of the ozone flow will resume.

CALCULATIONS

1. Ozone Calculations

Several values displayed on the HMI are calculated using the measured values from various instruments. The formulas used to calculate these values are listed below.

NOTE: These calculated values are intended to provide a quick reference based on the current operating conditions and instrument values. **Operators are strongly advised to personally verify all data and calculations. Intuitech is not responsible for incorrect data if independent verification and regular a regular calibration schedule is not enforced.**

A. Transfer Efficiency

The displayed transfer efficiency is a ratio calculated from the amount of ozone gas entering the contactor and the amount of ozone gas venting off the top of the contactor. The following equation is used:

$$TE = \frac{C_F - C_O}{C_F}(100)$$

T_E = Transfer Efficiency (%)
C_F= Feed Gas Concentration (g/Nm³)
C_O = Off Gas Concentration (g/Nm³)

B. Theoretical Ozone Dosage

The displayed theoretical ozone dosage has units of mg/l (or milligrams of ozone per liter of water). The following equation is used (the last three terms are conversion factors):

$$D_T = \frac{\dot{Q}_G}{\dot{Q}_W}(C_F)\left(\frac{1gal}{3.785l}\right)\left(\frac{1000mg}{1g}\right)\left(\frac{1m^3}{1000l}\right)$$

D_T = Theoretical Ozone Dosage (mg/l)
Q_G = Gas (Diffuser) Flow Rate (slpm)
Q_W = Feed Water Flow Rate (gpm)

C. Actual Ozone Dosage

The displayed actual ozone dosage also has units of mg/l, and is the theoretical ozone dosage multiplied by the transfer efficiency. i.e.:

$$D_A = \frac{\dot{Q}_G}{\dot{Q}_W}(C_F - C_O)\left(\frac{1gal}{3.785l}\right)\left(\frac{1000mg}{1g}\right)\left(\frac{1m^3}{1000l}\right)$$

D_A = Actual Ozone Dosage (mg/l)

SHUTDOWN

1. Shutdown Procedures

A. Disconnect Electrical power

All electrical connections are to be isolated and disconnected by qualified personnel.

B. Disconnect Process connections

All process connections (water, chemical, etc.) should be isolated and disconnected by qualified personnel.

C. Replace Cap on Dissolved Ozone Sensors.

The sensor tips on the dissolved ozone transmitters must be kept wet. If the sensor face is allowed to dry out, it will be destroyed.

WARNING: Do not allow the dissolved ozone sensors tips to dry out. Sensor caps must be saved and reinstalled when not in service and prior to storage. User is liable for all damage if caps are not installed.

D. Draining Equipment

Drain all equipment before storage or shipping to prevent freeze-damage. This includes draining all instruments, piping, contactors, and pump housings.

F. Secure Loose Parts

All loose parts are to be properly secured and stored with equipment. Place hardware in a plastic bag and store in the toolbox.

MAINTENANCE

1. General

All maintainable equipment is listed along with suggested maintenance procedures and replacement parts. Replacement parts can be purchased through Intuitech, Inc. A minimum maintenance schedule is provided for components that can be maintained on a timetable. However, maintenance intervals for all components are determined by such factors as the environment, runtime, and water quality. Operational experience is the most important factor when determining a maintenance schedule.

2. Maintainable Equipment

A. Feed Pump Assemblies (X100, X200)

Pump head - Mfr: Moyno, PN: 34450
Stator - Mfr: Moyno, PN: 340-3504-120
Maintenance information:

(1) Pump head maintenance

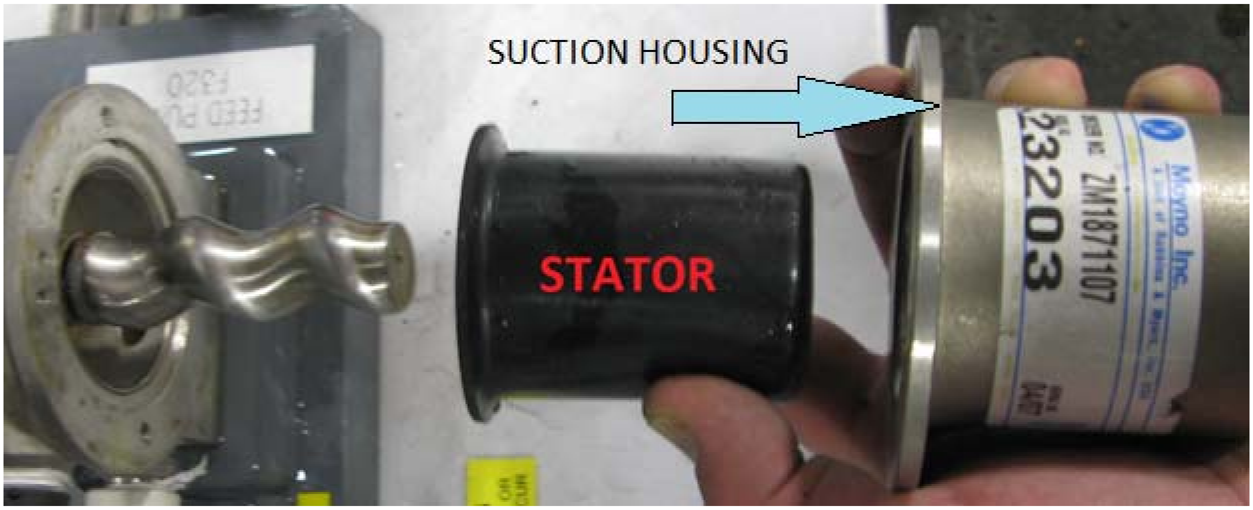
The filter feed pumps require a minimum amount of maintenance. Maintenance includes routine cleaning with regular stator and coupling inspection.

(2) Coupling maintenance

The rubber spider coupling connecting the two ends of the coupling assembly (between the pump head and motor) should be periodically checked for wear. Replacement is necessary if excessive slop or noise is observed between the pump and motor couplings, or if the spider coupling appears cracked or broken.

(3) Stator maintenance

The progressive cavity pump stator may need to be replaced if the pump performance decreases. Several factors can affect stator life, including runtime, pump speed, water quality, etc. Over time the pump speed will increase to maintain the same flow rate. This is a sign the stator is wearing. If the pump cannot maintain the desired flow rate at a speed of 100%, then the stator should be replaced. Replace the stator by first removing the four screws holding the suction housing to the pump body (red arrows). Set suction housing aside. Slide old stator off the rotor and replace with new stator. Do not "unscrew" the old stator, or "screw" the new stator into place. Simply push or pull the stator straight on-to or off-of the rotor. (Rotating the spiral pump shaft may cause it to loosen and become detached.) When installing the new stator make sure the edges of the stator seal up within the groove in the pump body. Replace screws.



B. Feed Gas Transmitter, Off Gas Transmitter (X910, X920)

Mfr: IN-USA, PN: Mini-HiCon

Maintenance information:

(1) Zeroing

The feed and off gas ozone analyzers will require periodic zero calibrations to maintain accuracy. Leaving the analyzers powered (24-7) will minimize the amount of zero drift, but it is recommended the transmitters be zeroed at least once a week to ensure accurate readings. To begin a zeroing sequence, follow the zeroing instructions listed under the HMI operation section of this manual. The units will be automatically purged with ozone free gas for several minutes before being zeroed.

C. Dissolved Ozone Sensor

Mfr: Thermo Scientific,
Sensor Tip PN: OZ31B
Data Stick PN: DS21
Ethernet Adapter PN: CA27 R2A
Maintenance information:

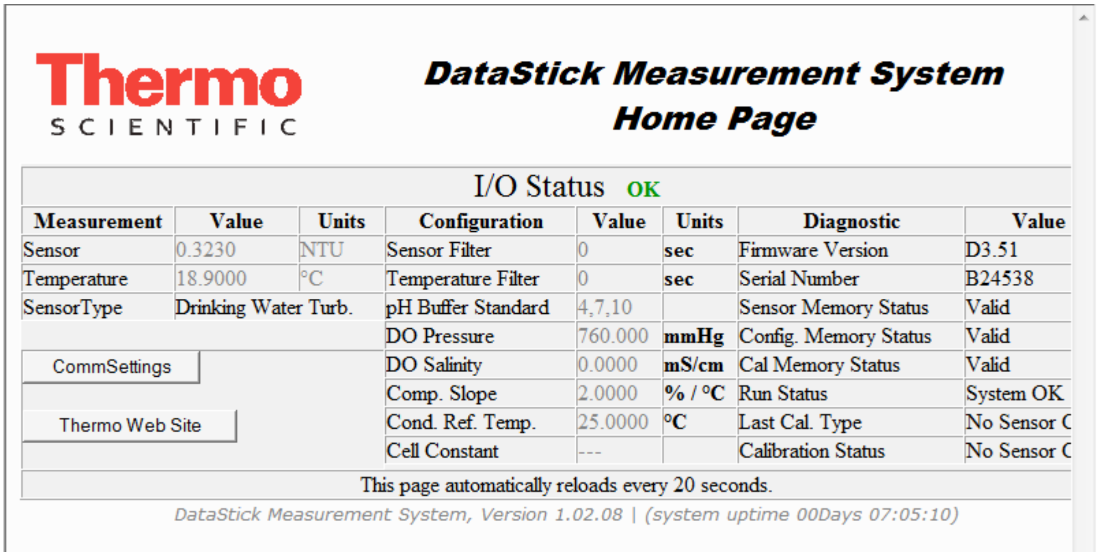
(1) Sensor Tip

The dissolved ozone sensor on the pilot is equipped with a removable sensor tip. This tip is designed to be replaced when the sensor reaches its end-of-life. To replace tip, simply unscrew retaining ring and remove old tip. Reassemble in reverse.

WARNING: When handling the assembled sensor, do not set the sensor on its tip or damage to the membrane will result. Severe impacts on the tip of the sensor from dropping or other misuse may cause permanent damage to the sensor.

(2) Calibration

Intuitech Inc. recommends the Thermo Scientific dissolved ozone transmitters be calibrated <u>on-site</u> prior to equipment operation and at regular intervals during operation. Refer to the Thermo Scientific user manual on the accompanying USB Drive for additional calibration information.



Thermo SCIENTIFIC

DataStick Measurement System Home Page

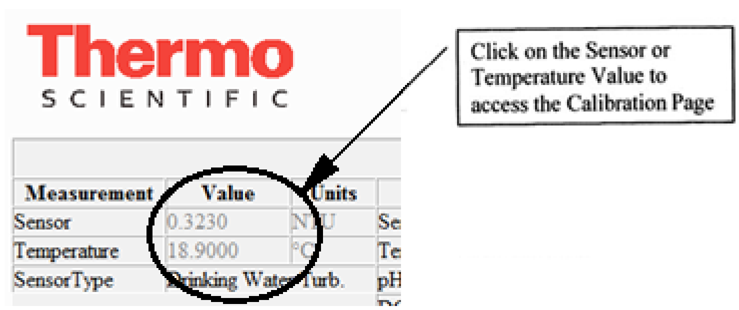
I/O Status OK

Measurement	Value	Units	Configuration	Value	Units	Diagnostic	Value
Sensor	0.3230	NTU	Sensor Filter	0	sec	Firmware Version	D3.51
Temperature	18.9000	°C	Temperature Filter	0	sec	Serial Number	B24538
SensorType	Drinking Water Turb.		pH Buffer Standard	4,7,10		Sensor Memory Status	Valid
			DO Pressure	760.000	mmHg	Config. Memory Status	Valid
CommSettings			DO Salinity	0.0000	mS/cm	Cal Memory Status	Valid
			Comp. Slope	2.0000	% / °C	Run Status	System OK
Thermo Web Site			Cond. Ref. Temp.	25.0000	°C	Last Cal. Type	No Sensor C
			Cell Constant	---		Calibration Status	No Sensor C

This page automatically reloads every 20 seconds.

DataStick Measurement System, Version 1.02.08 | (system uptime 00Days 07:05:10)

To access the calibration screen, press the instrument configuration button. Once connected, the above screen will appear. To begin a calibration, simply click on the sensor value displayed, this will open



the calibration screen. Then enter the value of the calibration standard and press "Set".

NOTE: The user name is "aqa". The password is "aqa".

If additional assistance is required, contact Intuitech technical support.

D. Ozone Destruct (X100, X200, X910, X920)

Mfr: Intuitech Inc.

Maintenance information:

(1) Drain Valve

Due to the fact that moisture can collect in the bottom of the main destruct units, bleed valves have been installed (DV-X109, X209). Visually inspect the clear piping above the valve for signs of moisture buildup and drain accordingly. Some ozone gas may escape while the drain valve is open.

(2) Destruct

The ozone destruct system is based on a catalyst. There is no chemical reaction, so the destruct won't be exhausted, or "used up". However, the catalyst can be poisoned by foreign contaminants (the most common being water or water vapor). If the ozone destruct unit quits working and ozone is escaping through the vent at the top of the unit, contact Intuitech immediately for a replacement.

E. Minimum Maintenance Schedule

Maintenance Schedule

Component	Daily	Monthly	Quarterly	Yearly
Feed Pump Stator			X	
Feed Pump Coupling				X
Ozone Destruct Drain Valves	X			
Zero Feed Gas and Off Gas Transmitters		X		

SAFETY

1. Safety Information

WARNING: INHALATION HAZARD –

Inhalation of ozone gas has been known to cause extreme irritation to the upper and lower respiratory tract. High exposure may cause pulmonary edema. OSHA Permissible Exposure Limit (PEL) to ozone is 0.1 ppm for a period of 8 hours. The Short Term Exposure Limit (STEL) is defined as 0.3 ppm for 30 seconds.
(Ref. OSHA Air Contaminants Standard, 29 CF R 1910.1000)
(EU Directives – 96/62/EC, 96/72/EC, 99/30/EC)

WARNING: FIRE HAZARD –

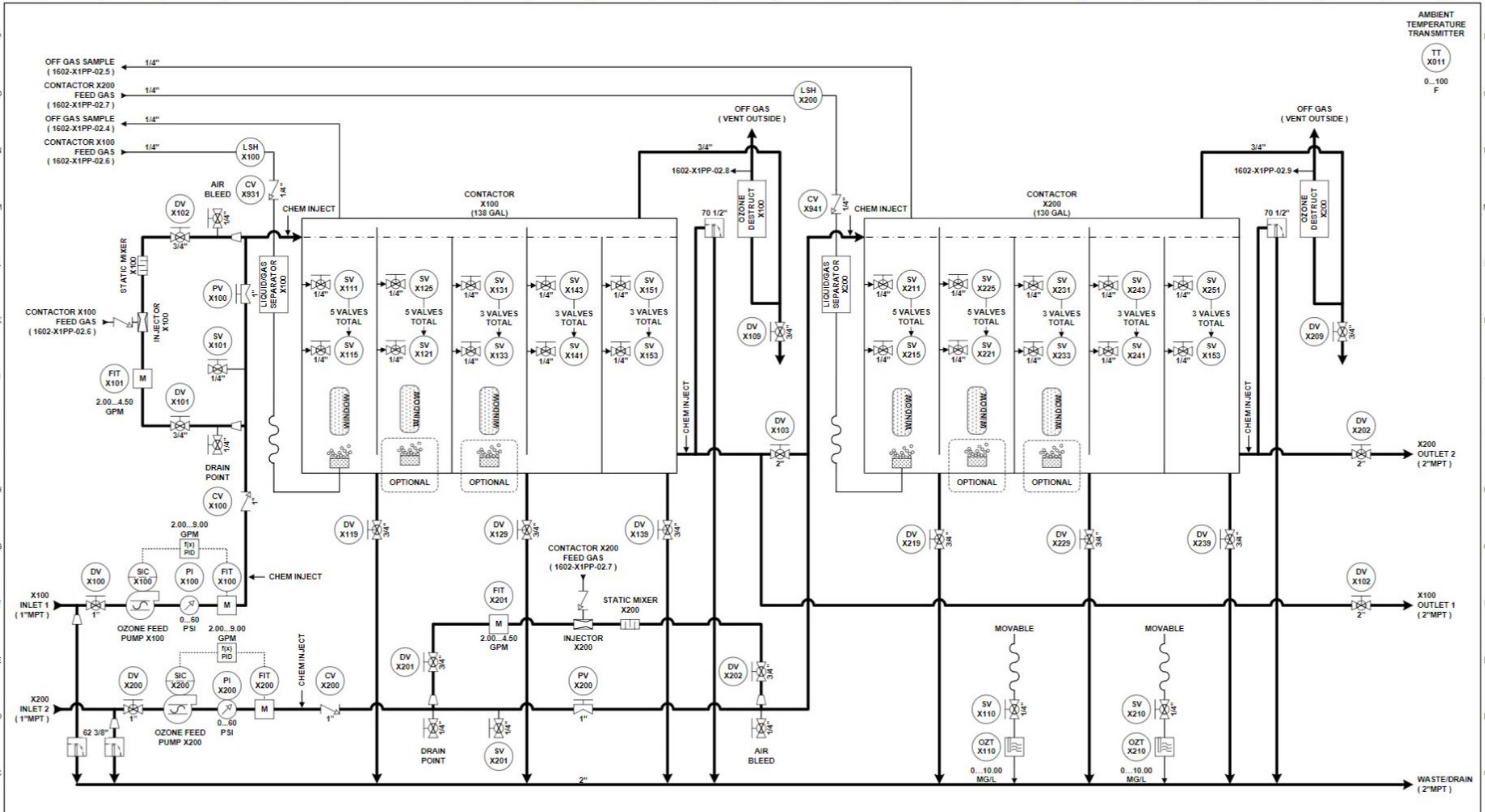
Oxygen is a fire hazard. It is very flammable and vigorously accelerates the burning of combustible materials. To avoid fire and/or explosion, never use oil, grease or any other combustible materials on or near the ozone or oxygen equipment. Smoking, heat and open flame should be kept at a distance of no less than 25 feet from any part of the system. It is recommended that only individuals experienced in the safe handling of oxygen be allowed to operate this equipment.

WARNING: OXIDATION HAZARD –

Ozone is a highly toxic oxidizer known to accelerate the decomposition of rubber and react with non-saturated organic compounds. Avoid contact with all reducing materials, organic or inorganic. The health hazards associated with ozone are due to its oxidizing potential.

OZONE HAZARDS –
Ozone has a distinctive odor, which is easily recognized at very low concentrations (0.01 – 0.05 ppm). In the event of accidental release, evacuate the danger area. Open windows and doors and allow area to ventilate. Personnel exposed to high levels of ozone should be removed to fresh air; if breathing is difficult a trained person can administer oxygen. Get medical attention.

APPENDIX- A



REV	DATE	BY	DESCRIPTION
1	06-21-18	CLR	ADD INJECTOR TAG NAMES
2			
3			
4			

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DIMENSIONAL TOLERANCES ARE AS FOLLOWS, UNLESS OTHERWISE SPECIFIED

FRAC: ± 1/16 0.XX: ± 0.01
ANGLES: ± 1° 0.XXX: ± 0.005

TITLE: OZONE MODULE PROCESS & INSTRUMENTATION DIAGRAM – PROCESS

CLIENT: CAROLLO ENGINEERS	PROJECT: 1602
DRAWN BY: AJB	DRAWN DATE: 12-18-17
DRAWING NAME: 1602-X1PP-03.VSD	P.O.:
SCALE: NONE	REVISION: 1

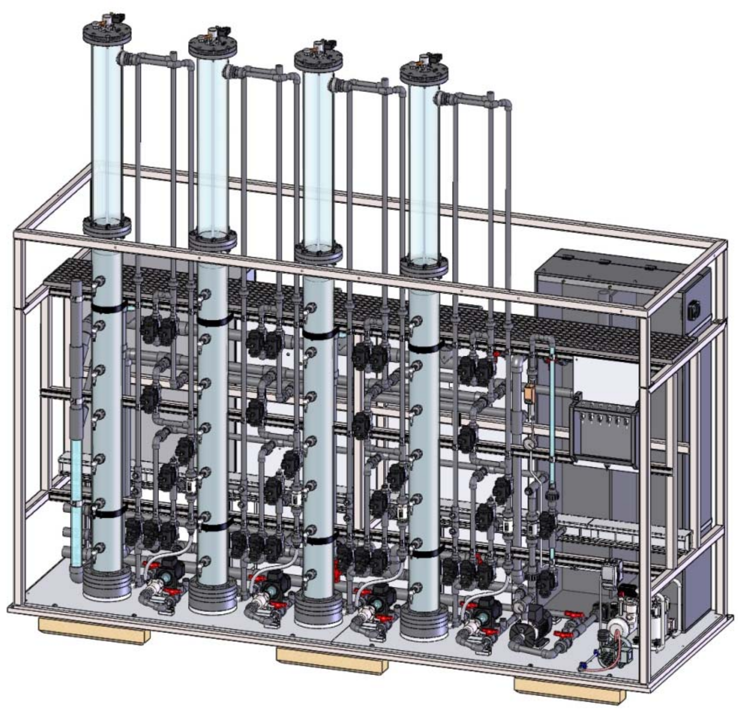
FILTERS - INTUITECH

Operations and Maintenance Manual

For

Carollo Engineers

Filtration Module



Release #1

Prepared By:

Intuitech®
"Intuitive Technology"
Process Equipment Manufacturing
Monitoring & Control Systems Integration

Project # 1554

August 12, 2016

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APPENDIX- A

1. O&M Drawing Release

SPECIFICATIONS

1. Filtration Module

A. Specifications

1. General

Maximum Total Flow Rate:	12.0 gpm (45.4 L/min)
Filters:	4 @ 6 inch diameter (150 mm) x 117 inch height (3.0 m)
Maximum Media Depth:	72 inch (1.83 m)
Filtration Rate:	2.55…15.3 gpm/ft² (6.23…37.4 m/h)
Backwash Rate:	5.1…30.6 gpm/ ft² (12.4...74.8 m/h)
Backwash Tank Capacity:	150 gal (568 L)
Air Scour Rate:	2.55…10.2 scfm/ft² (46.6…186.7 m/h)
Chemical Feed Pumps:	5 @ 0.01 21.7 gpd (0.03…57 mL/min)
Chemical Feed Tanks:	5 @ 4 gal (15.1 L)

2. Instrumentation

Flow rate*
Headloss (each filter)*
Effluent turbidity (each filter)*
Air scour flow*
Backwash flow*
Backwash tank level

*Data logged

3. Physical

Assembled Dimensions:	136"H X 146"W X 50"D
Dry Weight:	Approx. 2600 lbs.
Wet Weight:	Approx. 5000 lbs.

4. Electrical

Phase:	1
Frequency:	60 Hz
Voltage:	120 VAC
Current:	20 A Max

INSTALLATION

1. Un-packaging

The Filter Module upper vessel sections were removed for shipping. A forklift will be required to lift the crate off of the shipping truck and for final positioning of the pilot module. Ensure that the forklift is rated to safely carry the weight of the equipment (approx. 2700 lbs).

2. Mechanical Inspection

A. Initial Visual Inspection

Carefully inspect the skid for mechanical damage to the frame, filter vessels, piping, motors, and instruments that may have occurred during the shipping or positioning of the equipment.

B. Leveling

Verify that the equipment is level. The module is equipped with six adjustable leveling feet. Ensure the leveling feet are extended sufficiently to lift the module off of the castors. Each foot should be level to within ¼ inch of each other.

C. Component Mounting

Verify that all components and instruments are secure. These include pipe straps and instrument mounts.

D. Piping Connections

Verify that all PVC piping connections are secure. These include pipe straps, threaded unions, check valves, process valves, and sample valves. Confirm that the process piping connections are installed and tightened. Further confirm that the connections are in accurate alignment and free from any undue stress imposed by connecting piping.

> **WARNING:** Stress imposed by improperly aligned field piping may damage equipment. Ensure all connecting piping is free of undue stress.

ATTENTION: When installing, take care that <u>all</u> o-rings are installed with their corresponding connections or the assembly will leak. O-rings within PVC unions are frequently missed.

3. Electrical Inspection

A. Initial Visual Inspection

Carefully inspect for mechanical damage to the control panels that may have occurred during shipping or installation of the equipment. Excessive vibration from shipping can cause electrical components within the control enclosures to snap off of the din rail and cause damage to other components.

B. **Electrical Connections**

1. **Control Panel Wiring**
   Verify that all wires within the control panel are terminated. Vibration from shipping can cause conductors to come loose. Un-terminated wires can short to other components, conductors, or the enclosure wall and cause damage.
2. **Customer Feeder Circuit Breaker**
   Identify the location of the customer feeder circuit breaker so it can be easily identified and locked-out when servicing of the pilot electrical system.

OPERATIONAL OVERVIEW

1. Equipment Information

Module consists of four constant rate filters with individual feed pumps, and five chemical pumps. Each filter operates using automatic PID flow control. The module can be operated as four independent filters, or two sets of two filters in series (vessel 1 feeds vessel 2 and vessel 3 feeds vessel 4). The air scour and backwash systems are shared by all filters, and also utilize automatic PID flow control. Chemical feed pumps are flow paced with direct entry of chemical dosage. Each chemical pump can be selectively paced to any of the filter feed flows, the combined filter feed flow, or the backwash flow. An improved backwash process is included, providing superior performance when operating biological filtration processes. Backwashing is initiated manually by an operator in the manual mode, or on runtime, run volume, headloss, or effluent turbidity in the automatic mode. Only one filter may be backwashed at a time. Other features include automatic data logging of key parameters, remote monitoring and control using a standard web browser, and email alarm notification.

With the exception of the manually actuated valves, the equipment is monitored and controlled by an HMI (Human Machine Interface). The HMI communicates with the on-board PLC (Programmable Logic Controller) which monitors and controls various instruments and components. In short, the operator monitors the equipment through the HMI, which interacts with the PLC, which in turn activates the various equipment components.

2. Operation Sequence

The equipment follows a sequence of operation as summarized in the Sequence Matrix. The sequence matrix depicts the portion of the control logic that energizes pumps, valves, and other components required for each step of the operation. The PLC advances from step to step based on either an elapsed time or a specific event. A thorough understanding of the sequence matrix is essential to properly understand the equipment’s operation.

The sequence matrix defines step advance criteria for manual, semi-automatic and automatic modes of operation. Each step in the operation sequence has a number and description. The “field devices” section of the table shows which equipment components are activated in any given step. The “condition” columns define the events or time requirements for advancing from step to step. The “go to step” columns indicate which step the equipment will be advancing to after the conditions or time requirements have been met in the given step. The “flow” columns define which flow setpoint the system will attempt to maintain as it applies to each step. Finally, the legend defines terminology used in the matrix.

While running, the equipment is always in one of three stages of the operation sequence: offline, service, or backwash. Prior to entering service, each filter will progress through a filter to waste step. Filter to waste will continue until the entered time limit has elapsed or the effluent turbidity drops below a user-defined limit. Offline correlates to step “0”, filter to waste and service are steps “1” and “2” (respectively), while the complete backwash sequence encompasses the remaining steps.

For example, when the equipment is running in “auto” mode it follows the “auto step advance”. The first step in the operation sequence is “0”. Step “0” is described as OFFLINE. The “field devices” section of the matrix indicates that during the OFFLINE step none of the equipment’s components are activated (all valves are closed, all pumps are off). The “auto step advance” column informs that the equipment will stay in step “0” until the conditions of EVENT 1 are met. The legend defines EVENT 1 as “system mode is in “auto” or in other words the equipment is switched to “auto” mode. When the equipment is switched to “auto” mode the conditions of EVENT 1 are met, the “auto step advance” criteria states that the equipment will advance to step “1”. Step “1” is described as FILTER TO WASTE (i.e. filtering water with the effluent going to drain, instead of the backwash tank). The “field devices” section defines which components are activated during the step. The equipment will continue in step “1” until EVENT 3 occurs (indicating the step time has elapsed or the effluent turbidity has dropped below the defined limit). Once EVENT 3 occurs the “go to step” column states that the equipment will advance to step “2”. Step “2” is described as “SERVICE”. This is normal filtration.

During the backwash sequence the equipment will advance from step to step based on the elapsing of time limits as well as events. Once a backwash sequence is started the equipment will continue through the entire sequence. **In Semi-Auto mode an operator can start, stop or interrupt the filter sequence in any step. Be aware that interrupting a backwash sequence may foul the backwash tank or otherwise allow debris to bypass the filter. The operator is responsible for all equipment operation when not in Auto mode.** Once the backwash sequence is complete the sequence of operations will start over.

Note: Each column is an independent filter with its own sequencer.

3. Sequence Matrix

STEP NUMBER	STEP DESCRIPTION	AUTO STEP ADVANCE		SEMI STEP ADVANCE		FLOW			FIELD DEVICES														
									1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		CONDITION	GO TO STEP	CONDITION	GO TO STEP	FEED	BACKWASH	AIR	FEED PUMP X*00	BACKWASH PUMP X800	AIR SCOUR BLOWER X600		FILTER INFLUENT VALVE DV-X*01	FILTER EFFLUENT VALVE DV-X*02	BACKWASH INLET VALVE DV-X*03	BACKWASH OUTLET VALVE DV-0X*04	FILTER TO WASTE VALVE X*05	AIR SCOUR INLET VALVE X*06	AIR DRAIN VALVE X*07	FILTER TO TANK VALVE X*08			
0	OFFLINE	EVENT 1	1	EVENT 2	1,4																		
1	FILTER TO WASTE 1	TIME 1	2	TIME 1	2	FLOW 1			X				X	X			X						
2	FILTER TO WASTE 2	EVENT 3	3	EVENT 3	3	FLOW 1			X				X	X			X						
3	SERVICE	EVENT 4	4	EVENT 2	0,1,4	FLOW 1			X				X	X						X			
4	BACKWASH REQUIRED	EVENT 5	5	EVENT 5	5																		
5	AIR DRAIN	EVENT 6	6	EVENT 6	6			FLOW 1			X			X			X		X				
6	AIR SCOUR	TIME 2	7	TIME 2	7			FLOW 2			X					X		X					
7	AIR SCOUR / BACKWASH	EVENT 7	8	EVENT 7	8		FLOW 1	FLOW 3		X	X				X	X		X					
8	BACKWASH 1	TIME 3	9	TIME 3	9		FLOW 2			X					X	X							
9	BACKWASH 2	TIME 4	10	TIME 4	10		FLOW 3			X					X	X							
10	BACKWASH 3	TIME 5	11	TIME 5	11		FLOW 4			X					X	X							
11	SETTLE	TIME 6	0	TIME 6	0											X							

LEGEND

X	OPEN OR RUNNING
TIME	TIME SETPOINT
FLOW	FLOW SETPOINT
EVENT 1	SYSTEM MODE IS "AUTO".
EVENT 2	SYSTEM MODE IS "SEMI" AND OPERATOR DEPRESSES "OFFLINE", "SERVICE", OR "BACKWASH" BUTTON.
EVENT 3	FILTER EFFLUENT TURBIDITY IS LESS THAN LIMIT.
EVENT 4	SYSTEM MODE IS "AUTO" AND RUNTIME, RUN VOLUME, HEADLOSS OR TURBIDITY IS GREATER THAN LIMIT.
EVENT 5	BACKWASH TANK LEVEL IS GREATER THAN LIMIT AND NO OTHER FILTER IS BACKWASHING.
EVENT 6	FILTER VESSEL WATER LEVEL IS LESS THAN LIMIT.
EVENT 7	FILTER VESSEL WATER LEVEL IS GREATER THAN LIMIT.

4. Operation Interface

With the exception of the manually actuated valves, the equipment is operated from the touch-screen HMI located on the front of the main control panel. The HMI monitors and controls the process by communicating with a PLC that in turn monitors and controls the automated components of the equipment. The HMI gathers data, annunciates alarms, displays historical and real-time trends and can be used to enter set points and adjust alarm limits.

A. General

The system is operated from the front of the control panel. The operating controls consist of:

- HMI
- Two indicator lights
- Emergency stop button
- Main disconnect switch

B. Manual Control Panel Operators

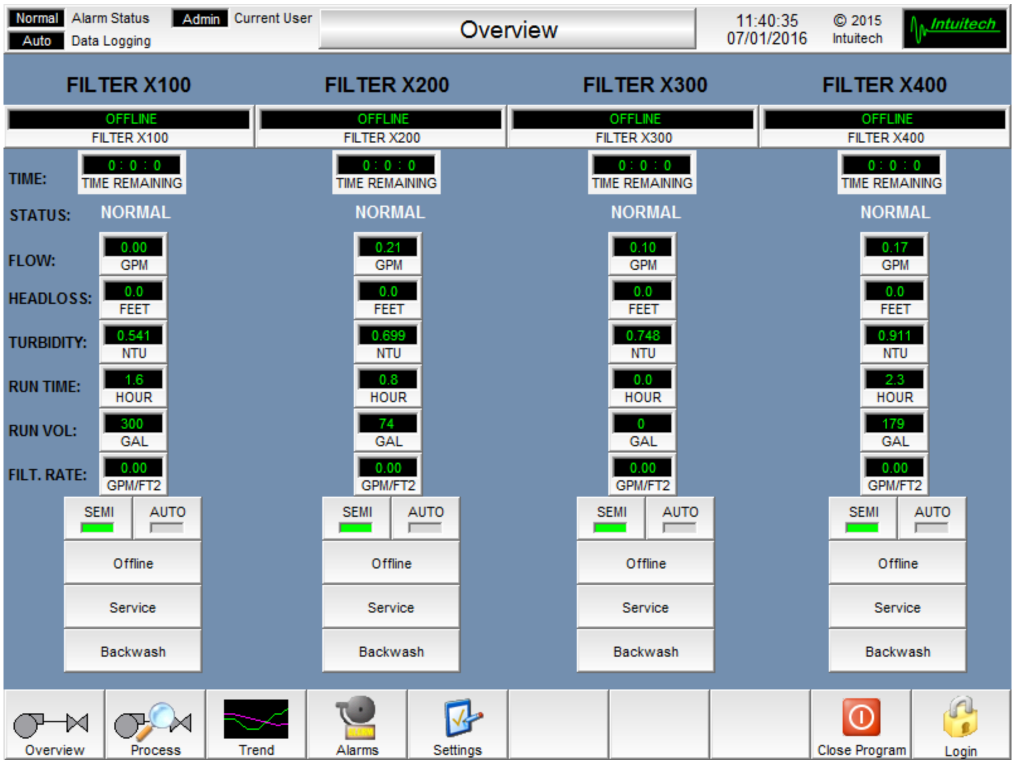
1. **Indicator Lights**
   - **RUNNING (Green) -** indicates that the equipment is operating.
   - **ALARM (Red) -** indicates that an alarm is present.
2. **Push Buttons**
   - **EMERGENCY STOP-** will stop all equipment operations.

> **ATTENTION:** To clear an emergency stop alarm, the pushbutton must be turned 1/8th turn clockwise before pressing the alarm reset button.

3. **Main Disconnect**
   - **DISCONNECT SWITCH -** will disconnect main power to equipment.

C. Human Machine Interface (HMI)

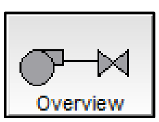
When the equipment is powered up, the HMI will display the following screen. It is necessary to log in with a username and password before system operation is possible.



D. HMI Navigation Icons

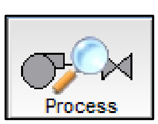
The following navigation icon buttons displayed along the bottom of the screen throughout the HMI application provide the following functions:

1. Overview Button



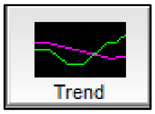
The overview screen displays the entire pilot process.

2. Process Menu Button



The monitoring and control of all automated system components is accessed through the process menu. Some of the process screens are monitoring only, some are control only, and some are for both monitoring and control of system components. For operational ease, the display of some instrument values may appear redundantly on two or more screens.

3. Trend Menu Button

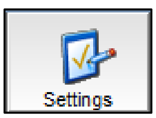


The trend menu allows the operator access to trending screens to analyze and view in a graphical format, the data coming from the system instruments.

4. Alarms Button

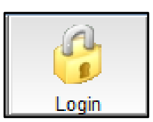
The alarm button is used to view the currently active alarms (Alarm Summary). The historical alarms screen (Alarm History) can be accessed from within the alarm summary.

5. Settings Menu Button



The system menu includes buttons to access data logging, e-mail alarms, and the miscellaneous screen. The miscellaneous screen is for setting and configuring various operational features.

6. Log In Button



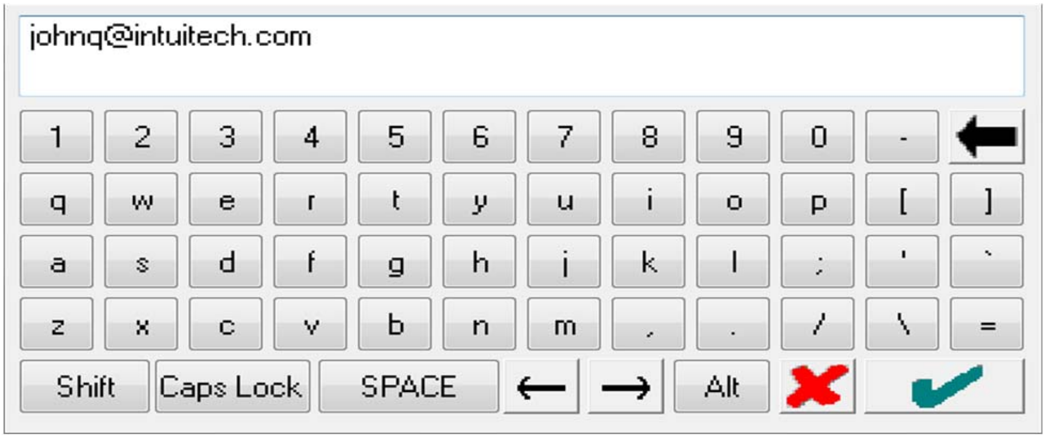
This icon displays a screen that allows the user to log in and out of different user levels. A password is required. Operators are required to log in with a username and password before system operation is possible.

This icon displays a screen that allows the user to log in and out of different user levels. A password is required. Operators are required to log in with a username and password before system operation is possible.

7. Keypads

There are two different keypads which can be selected by an operator. The simple keypad allows the operator to enter in numerical control values and other information.

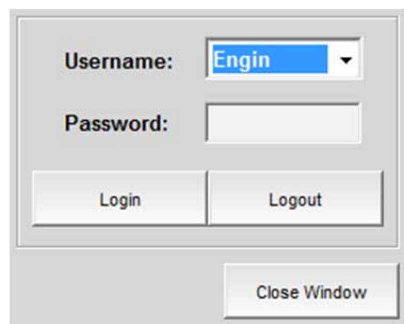
NOTE: If the component has an operating range, it will be displayed at the bottom of the keypad - any value entered must fall within that range.



The full keypad is displayed anytime alpha-numeric characters are required. Each keypad is displayed when required.

E. HMI Operation

1. Log In/Out Screen



By selecting the Login icon, the login screen is displayed.

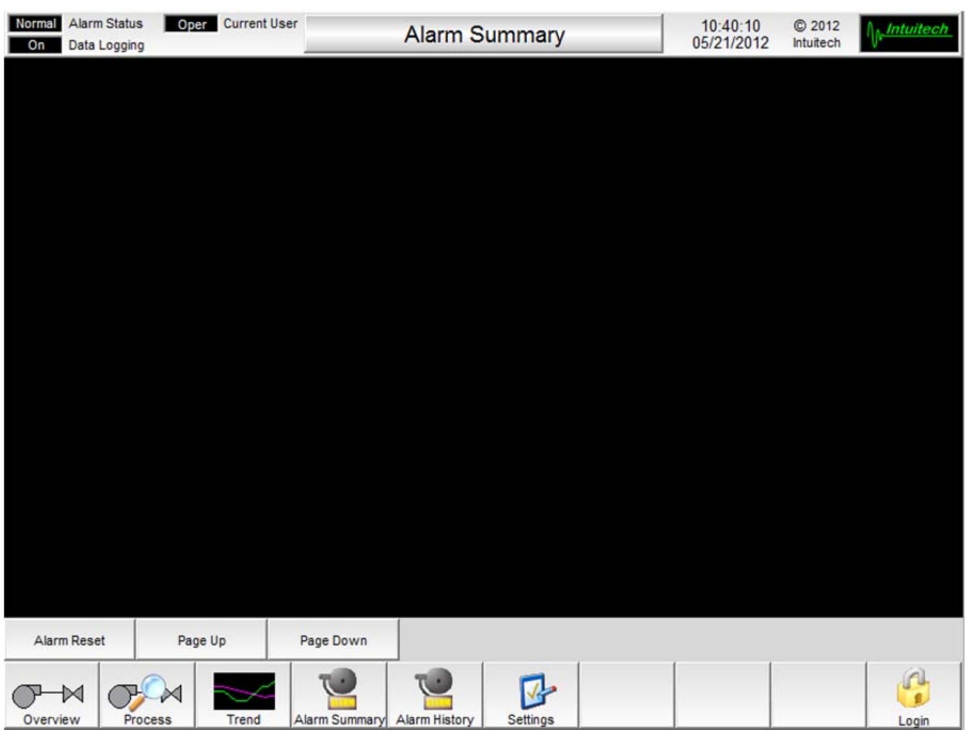
Select the desired level of access (Administrator, Engineer, Operator, Guest, or View) from the drop-down box. Then, select the PASSWORD box and type the appropriate password. Select LOGIN when done. If your login is successful, the new login level will be displayed in the upper left corner of the screen. For security purposes, the passwords for each user level will not be printed in this manual. (Password information will be sent with the manual in a sealed envelope.) Select the LOGOUT button to return to the Guest level of access. Below are the five user levels and what functions each user has access to. Some activities may not be relevant for all HMI applications.

HMI Security Level Access Permissions

	Guest	View	Operator	Engineer	Administrator
View Login Screen	X	X	X	X	X
View Process Screens	X	X	X	X	X
View Trends		X	X	X	X
View Alarms		X	X	X	X
Reset Alarms			X	X	X
Control Pumps, Valves, Blowers, etc.			X	X	X
Modify Email Alarms Email Settings					X
Disable/Enable Email Alarms				X	X
Change Auto and Manual Setpoints			X	X	X
Initiate Sequencer Steps			X	X	X
Change Sequencer Step Times			X	X	X
Change PID Setpoints				X	X
Change PID Running Parameters				X	X
Change Alarm Limit Setpoints				X	X
Change Data Logging				X	X
Set Date and Time				X	X
Close Program					X

2. Alarm Screens

The date, time, and description of alarms will be displayed on the alarm screens. Once the conditions that triggered the alarm have been corrected, select the ALARM RESET button to acknowledge and reset all current alarms. Scroll through the alarms by selecting the PAGE UP and PAGE DOWN buttons on either of the alarm screens.



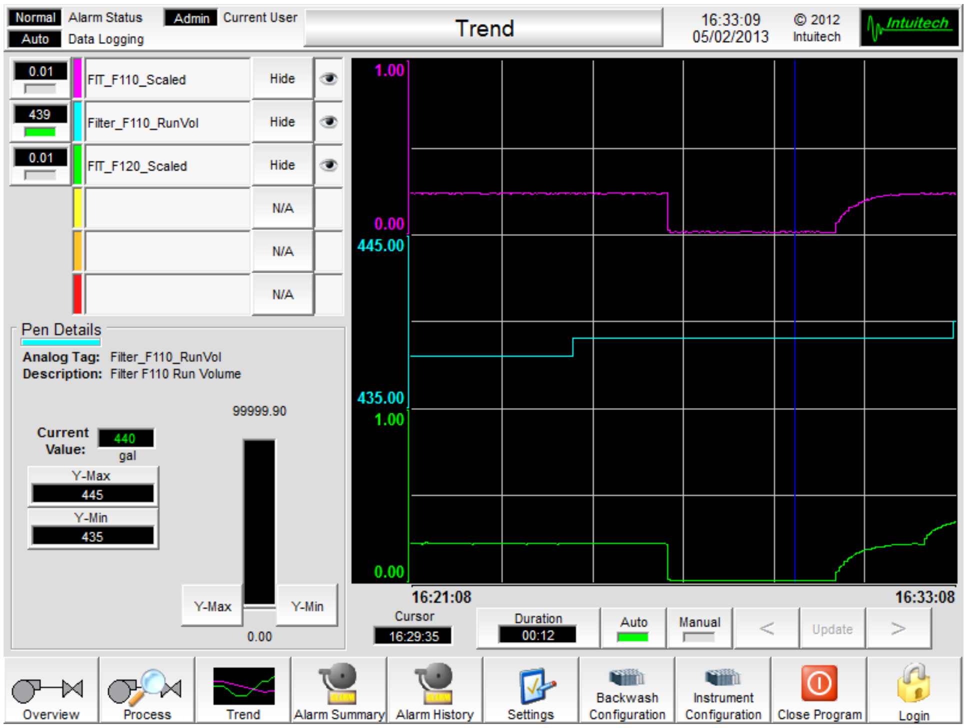
3. Instrument Displays

Each analog instrument has its own display screen. Access this screen by selecting the display button. Once selected, a similar screen will appear.

This screen will allow the user to set any high or low alarm limits associated with the instrument, as well as view a "quick-trend" of its recent activity. To add this analog signal to the main trending screen, simply press "Load" on one of the open Trend Pens.

4. Trending Screen and Pen Selection

The trend menu allows the operator access to the trending screens to analyze and view, in graphical/numerical format, the data coming from the system's instruments. When selected, a similar screen will be displayed



The time period displayed on the trending screen can be adjusted by selecting the desired time in hours and minutes on one of the TREND DURATION icons.

The AUTO selection allows users to view real time trends, while the MANUAL selection is for historical trends. An automatically updated trending screen will continually update itself. The manual update trending screens display a static “snap-shot” of information and will not automatically update.

If an analog signal is already selected, it will be displayed and can be manipulated from the upper-left corner of the trend screen. Each pen can either be viewed, or hidden using the VIEW/HIDE buttons. Once a pen is selected, the size of the Y-axis can be adjusted in the “Pen Details” section.

NOTE: In order to add a new analog signal to the trending screen, it must be activated from within its own display screen (as previously described).

Tap the screen at any point within the trend graph to move the vertical cursor (or select the < or > buttons to enact small moves). The color of the parameter at the top left of the screen corresponds with the color of the trend lines within the trending screen. The parameter value shown in the “Current Value” window, corresponds to the value on the graph at the position of the cursor.

5. Settings Menu Screens

The settings menu includes buttons to access data logging, e-mail alarms, and the date and time set screen.

6. Data Logging Screen

If the DATA LOGGING button is selected the following screen is displayed.

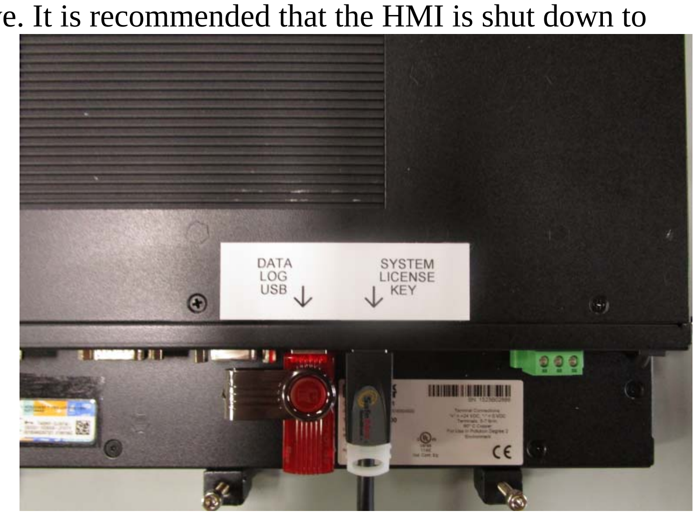
To operate data logging in automatic mode select the AUTO button. To set the interval at which the process parameters are recorded, activate the keypad by pressing the interval button and enter the desired interval (in seconds).

When in the automatic mode, the data-logging feature is only active when the system is active (i.e. data are only logged for equipment in operation).

To operate data logging in manual mode select the ON button. In manual mode data are collected whether the system is running or not.

Selecting the OFF button will disable all data logging.

Data are stored on a removable USB flash drive located on the front of the control panel door underneath the enclosure shelf. It is NOT necessary to open the control enclosure to access this drive. It is recommended that the HMI is shut down to remove the USB data drive. The data files can then be copied or moved from the USB flash drive to another computer for viewing. Data files are stored on the USB drive as .csv (comma separated variable) files, which can be opened with and saved as Microsoft® Excel™ (.xlsx) files. The .csv files contain data columns with integrated column headers. The first column in the .csv files correlates to the date and time the data were collected.



A second USB drive, located on the back of the HMI is used as a backup to the primary USB drive. This drive automatically logs data every five minutes. To gain access to this drive, the enclosure door will have to be opened. Disconnect power before opening the enclosure door to avoid potential electrical shock. There are two USB “drives” plugged into the HMI. The red USB drive is the backup drive. The USB drive that is BLACK is the hard key for the software license. DO NOT REMOVE THE BLACK USB DRIVE as this will invalidate the software license.

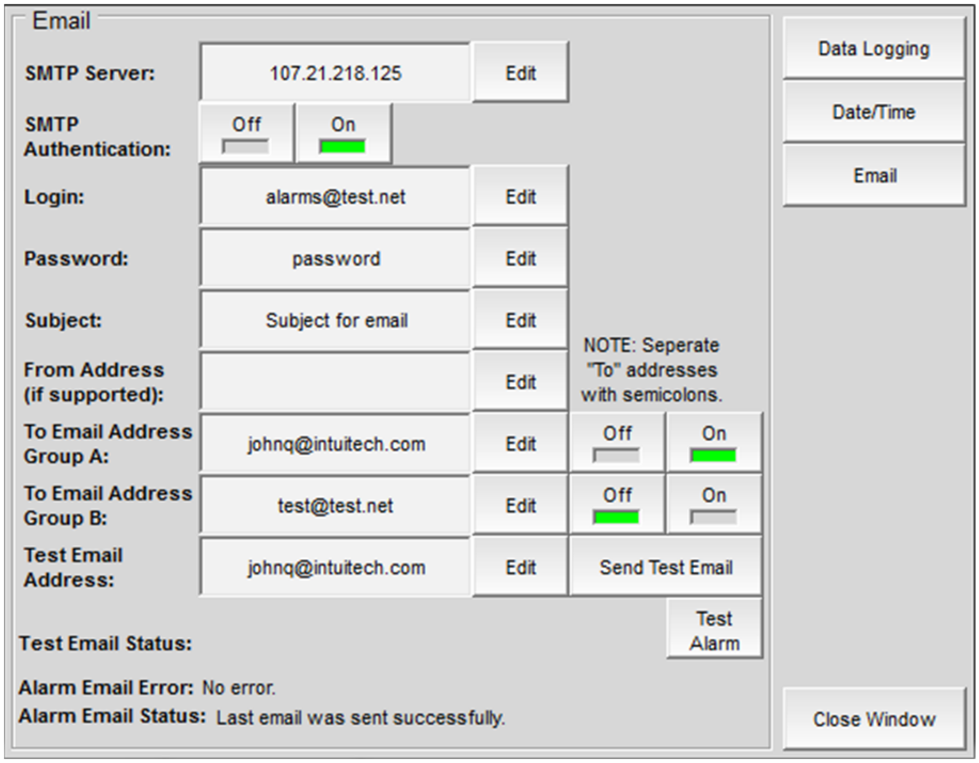
ATTENTION: HOW MUCH DATA ARE YOU WILLING TO LOSE? Data should be retrieved and backed up on a separate computer regularly. How often this is performed should be based upon the amount of data loss you are willing to accept.

DANGER: Disconnect power to control panel before servicing to eliminate electrical shock and arc flash hazards.

Once the USB flash drive is reconnected to the HMI, the data files will continue to append to the previously existing data (if files were copied to the computer in the previous step) or new files will be created (if the files were removed in the previous step).

When the size of the file exceeds the entered “High Alarm Limit” (in Mb), an alarm will be annunciated (indicating “Total Data File Size High”). Since large text files can become virtually unmanageable, it is recommended that the operator clears or moves the saved data in the data-logging file before they become larger than 30 Mb. If the file size becomes greater than the “Shutdown Limit”, an alarm will be activated indicating “Data Logging Stopped”. At this point the data logging feature will shut down.

7. Email Alarms Screen



When web enabled, the HMI has the ability to send all alarm notifications to specified email addresses. The email notifications include the time and date of the alarm as well as the message generated by the alarm.

Administrator login is required to view or modify the SMTP Server IP, SMTP Authentication, Username, Password, Mail from Address, and Mail to Address 1. Without administrator login, these fields will be displayed as asterisks and cannot be accessed.

MAIL TO ADDRESS GROUP B

This field is identical to "Mail to Address Group A" except the administrator level of login is not required to modify the field. Specify any valid email address or multiple addresses separated by a semicolon (;). This can include cell phone email address (e.g. 8015551212@domain.com). Any alarms that occurred prior to email address changes (i.e. in the queue) will be sent using the old data. Messages are sent from the queue at 1-minute intervals.

TEST EMAIL

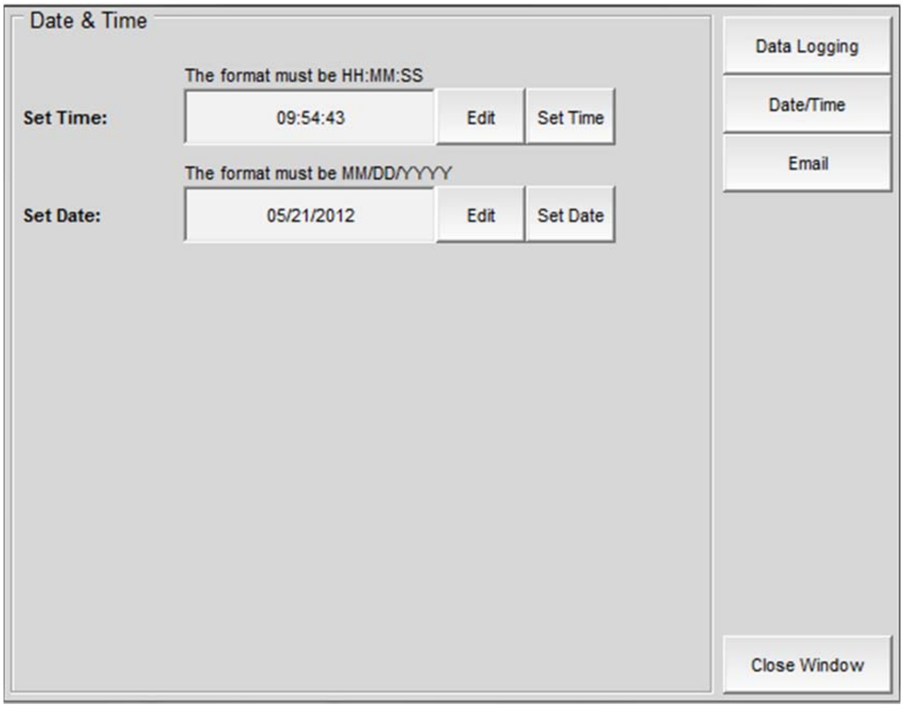
This field is provided to easily test the function of the email screen. Pressing the "Send Test Email" button will send a test email to the email address configured to its right. Pressing the "Test Alarm" button will generate a test alarm and send the email to everyone in Group A and Group B (as long as the group control is set to ON).

MAIL ERROR STATUS

This indicates the status of the last email attempt. If it reads “No error.” then the last email was sent successfully. If other errors appear they will be similar to those most mail clients report when there is a failure. Please consult your network administrator if additional assistance is required.

8. Date/Time Screen

If the Date/Time button is selected the following screen is displayed.

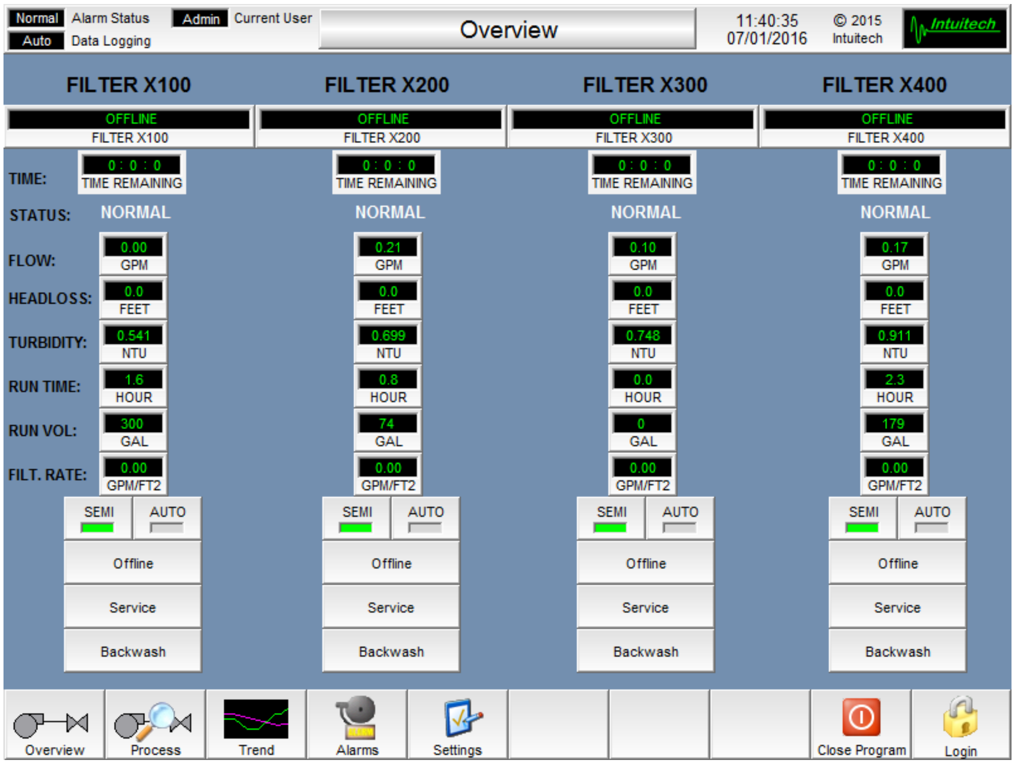


The SET TIME and SET DATE buttons are used to set the current time and date. Use “Edit” to enable the keypad and enter the proper time or date. Once the correct time has been entered, press “Set Time” to move that time into the HMI memory.

NOTE: Ensure that the time and date are entered in the exact format as displayed. Include the necessary symbols (i.e. colon and slash marks) when entering in the time and date or the entry will be rejected.

9. Overview Screen

When the OVERVIEW button is selected, a similar screen is displayed.



The screen displays an overview of data from all the equipment process screens, along with control buttons for activating the sequencer. All instruments can be accessed from this screen.

Selecting the SEMI buttons will enable the OFFLINE, SERVICE, and BACKWASH control buttons.

In manual (SEMI) mode, following the manual step advance, if the SERVICE button is pressed the filter will begin servicing water, pressing the BACKWASH button will initiate a backwash cycle for the filter, and pressing the OFFLINE button will shut the filter components down. Backwashing will not be initiated automatically, and the filter will not re-enter service after a backwash.

Pressing the auto button (AUTO) will allow for fully automatic operation of the filter (in accordance with the sequence matrix). When operating in auto mode backwashing is initiated based on the high runtime, run volume, headloss or turbidity and the filter will automatically re-enter service after backwashing.

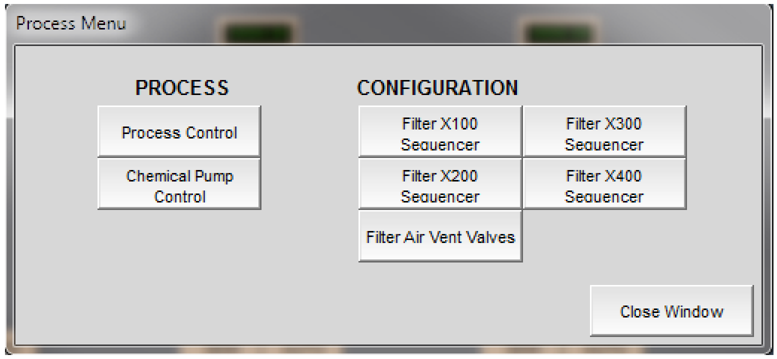
Refer to the sequence matrix for details of the sequencer operation.

ATTENTION: In manual or semi-auto mode, an operator can start, stop or interrupt the filter sequence in any step. Be aware that interrupting a backwash sequence may foul the backwash tank or otherwise allow debris to bypass the filter. The operator is responsible for all equipment operation when not operating in Auto mode.

NOTE: The alarm limits used to initiate backwash are found within the display buttons for each filter's headloss, runtime, run volume or turbidity.

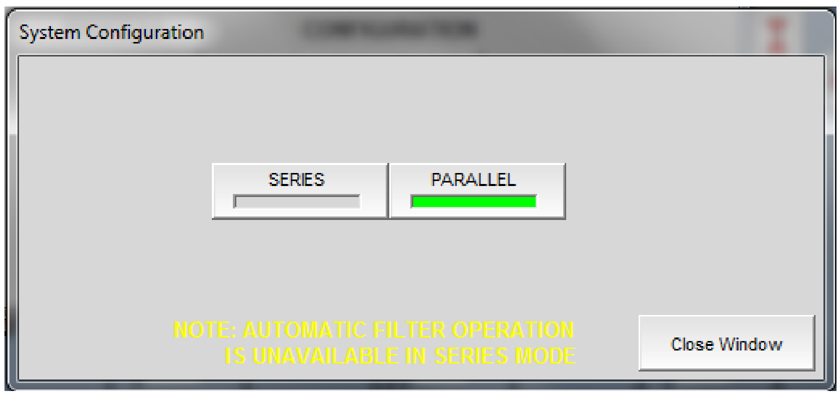
10. Process Menu

If the PROCESS button is selected, it will bring up the process menu, similar to the screen displayed. This screen provides access to all of the process control and configuration screens.



11. Series / Parallel Configuration

If the SERIES / PARALLEL button is selected, it will bring up the following screen. This screen provides acess to the system configuration.



In parallel configuration, each filter vessel acts as a completely independent system. In series configuration the first two filter vessels feed into the second two filters. This provides the ability to "double filter" the raw water.

During series operation, the downstream filters rely on upstream filters for feed water. Therefore, anytime a filter enters backwash, the remaining filters will wait in the offline step. Because of this limitation, **<u>AUTO mode is unavailable when operating in series configuration.</u>**

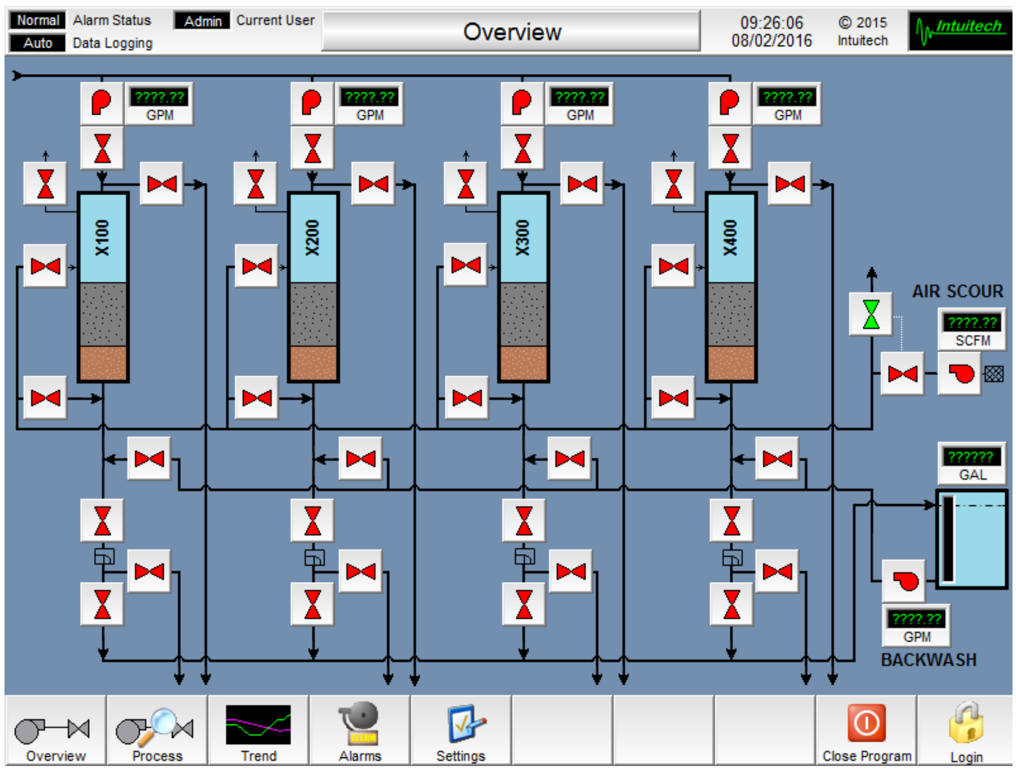
NOTE: When operating in series configuration, valves DV-X002, DV-X003, and DV-X005 should be closed and valve DV-X004 should be open.

During series operation, the downstream filters rely on upstream filters for feed water. Therefore, anytime an upstream filter (1 or 3) enters backwash, the corresponding downstream filter (2 or 4) will wait in the offline step.

WARNING: When operating in series configuration, it is necessary to run the upstream filters at a slightly higher flow rate than the downstream filters. In this way, a small amout of water is constantly overflowing into the backwash tank, which provides constant flooded suction to the downstream feed pumps. A section of clear piping was incorporated so flooded suction to the pumps can be visually confirmed.

12. Process Control Screen

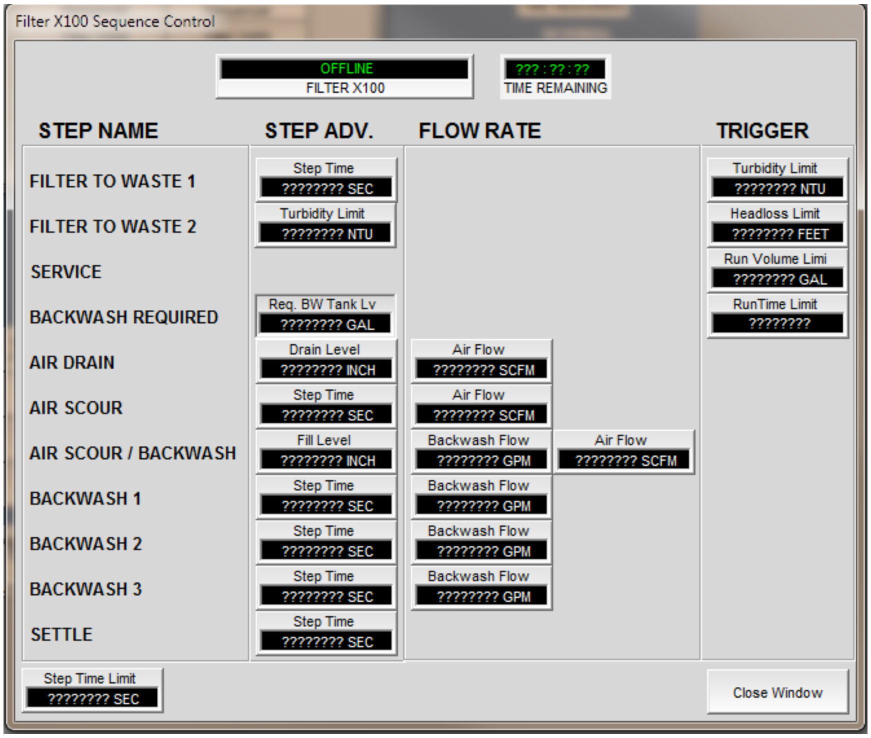
When the process control button is selected a process overview screen similar to the one below is displayed.



This process control screen allows access to all of the valves, feed pumps, backwash pump and air scour blower. Except for the chemical pump controls, all equipment on the module can be controlled through this screen.

13. Sequencing Controls

The sequencing controls used for backwashing can be accessed by pressing one of the Filter Sequencer buttons from the process menu . Similar buttons exist for each filter. When pressed, a screen similar to the one below is displayed.



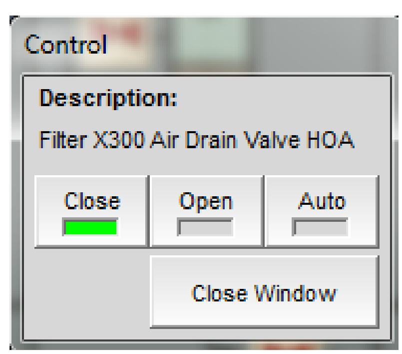
Similar to the sequence matrix, this screen displays each of the steps included in the backwash sequence, listed in order, from the top-down. The step times, drain and fill levels, and flow rates used throughout the backwash sequence can be viewed and modified by pressing any of the EVENT buttons. Similar screens exist for each filter.

NOTE: The Required Backwash Tank Level (Req. BW Tank Lvl) is calculated from the backwash flow rates and times entered on this screen. If there is insufficient water in the backwash tank to perform a backwash, this value will be displayed in red. If this tank level is still low when a backwash attempts to initiate, a Backwash Tank Level Low alarm will be annunciated and the backwash will not begin until the tank level increases or the backwash configuration is modified.

14. Valve Controls

If any valve control button is selected a similar screen is displayed.

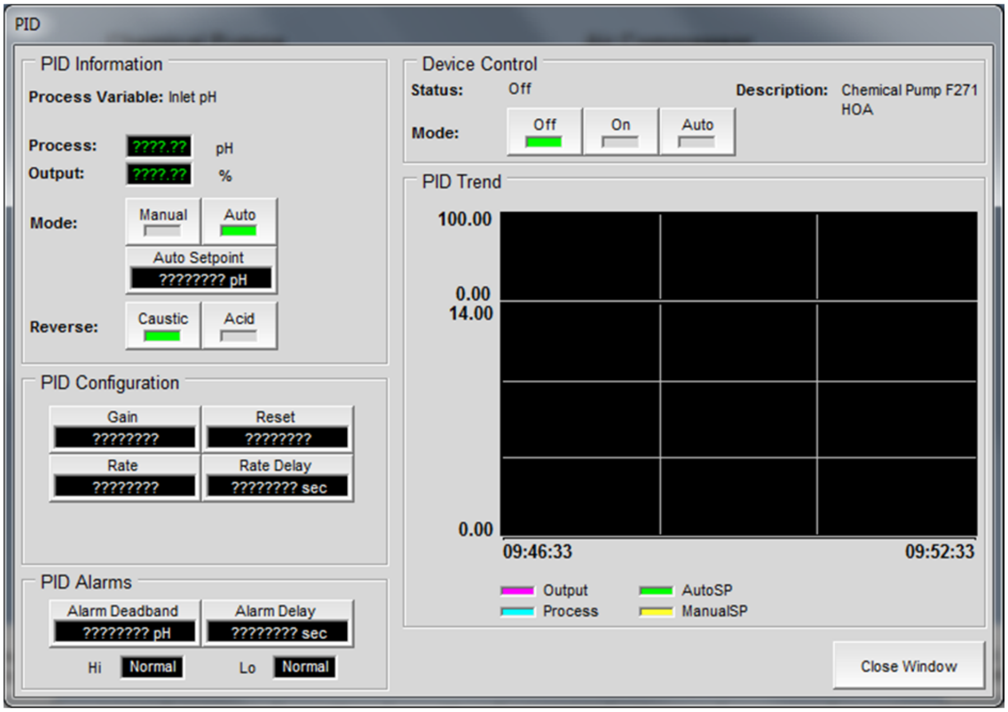
These control buttons designate what conditions open or close the valves. Pressing the AUTO control button will allow the valve to be controlled by the sequencer (activated from the Overview Screen). Pressing the CLOSE or OPEN



control buttons will actuate the valve independent of the sequencer.

15. PID Loop Control Screens

If any component (i.e. pump) using a PID control is selected, a similar screen is displayed.



NOTE: All module components which operate using PID control (listed below) will be controlled by a screen very similar to this one.

This screen displays important monitoring parameters, buttons for selecting control options, buttons for selecting auto or manual mode operation, and input buttons for entering the auto and manual set-points.

The DEVICE CONTROL buttons (in the upper right corner) designate what conditions cause the pump to energize. Pressing the AUTO control button will allow the pump to be controlled automatically by the sequencer. Pressing the OFF or ON control buttons will energize or de-energize the pump manually, independent of the sequencer.

The MODE buttons (auto or manual) designate which setpoint the pump will maintain. When the mode is set to AUTO, the pump will seek the auto setpoint (using the PID control loop). When set to MANUAL, the pump will simply maintain the manual setpoint (a percentage of the pumps maximum flow, with no flow control).

The PID Configuration section contains the tuning parameters for the pump control. The gain, reset, and rate values function as the tuning parameters for the

PID control loop. The Proportional–Integral–Derivative (PID) controller is a generic control loop feedback mechanism used to control equipment and maintain a setpoint. The PID controller attempts to correct for the discrepancy between a measured process variable and a desired setpoint by calculating and outputting a corrective action in order to adjust the process accordingly.

The PID controller calculation (algorithm) involves three separate parameters; the Proportional, the Integral and Derivative values (i.e. gain, reset, and rate, respectively). The Proportional value determines the reaction to the current error, the Integral determines the reaction based on the sum of recent errors and the Derivative determines the reaction based on the rate at which the error has been changing. A weighted sum of these three actions is used to adjust the process via a control element (such as the position of a control valve).

NOTE: The PID gain, reset, rate, and rate delay values for the feed pump and backwash pump are pre-tuned by the manufacturer and should not require further adjusting. Only qualified personnel should adjust values if it becomes necessary. Before adjusting, record the current values to use as a reference.

The PID ALARMS section contains the alarm deadband and alarm delay values, which define the conditions for the High and Low alarms. The alarm deadband delineates how much the process variable may vary before an alarm occurs. The alarm delay defines the time limit (in seconds) for how long that variable can remain out of range before an alarm occurs.

For example: Using a flow rate of 1.25 gpm, an alarm deadband value of 0.5 gpm and an alarm delay value of 60 seconds; if the flow rate fluctuates above 1.75 gpm or below 0.75 gpm for longer than 60 seconds, an alarm will occur.

NOTE: The pH adjustment pump screens also include buttons for selecting whether acid or caustic is being pumped to maintain pH. These buttons are not available on the standard chemical pump screens.

Similar screens exist for the following PID controlled components on the pilot:

- Feed Pump X100
- Feed Pump X200
- Feed Pump X300
- Feed Pump X400
- Backwash Pump X800
- Air Scour Blower X600

16. Pace Loop Control Screens

If any component (i.e. chemical pump) using a Pace control is selected, a similar screen is displayed.

NOTE: All module components which operate using Pace control (listed below) will be controlled by a screen very similar to this one.

The screen displays monitoring parameters, control buttons, buttons for selecting auto or manual mode, auto and manual setpoint values, buttons for selecting which flow the pump will pace from (if applicable), along with; the solution concentration setpoint and pump min/max set-points.

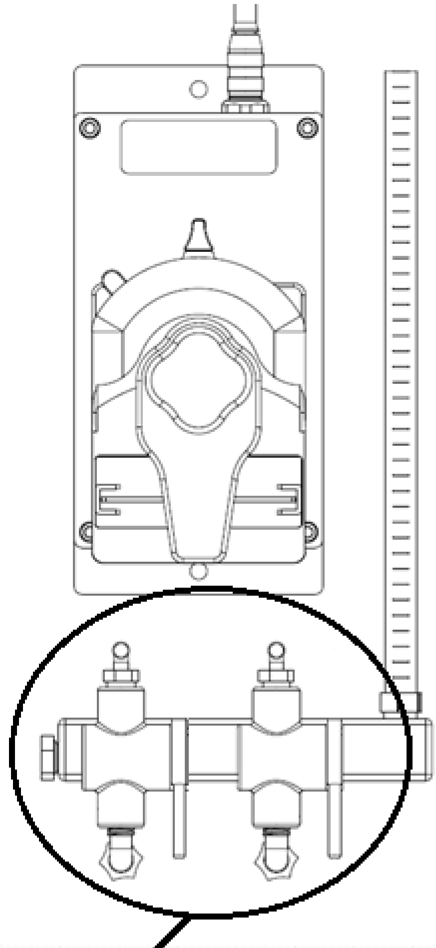
The Device Control buttons designate which conditions will cause the pump to energize. The Mode buttons designate which setpoint the pump will maintain.

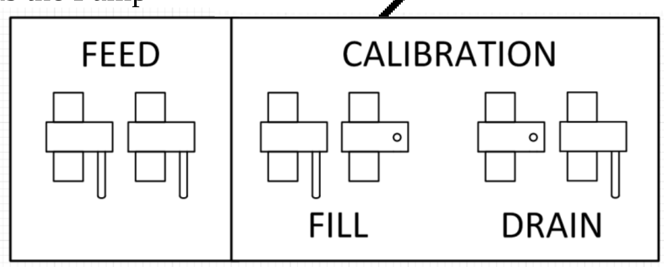
NOTE: The auto setpoint is entered in units of milligrams of chemical, per liter of water (feed flow through the module).

NOTE: Each chemical will display a PACE FROM option. Selecting SUM will cause the chemical pump to dose based on the sum of the feed flows from all filters currently in service. Selecting any of the filter numbers, will pace to the feed flow through that filter, and selecting BW will cause the chemical pump to dose based on the backwash flow rate.

Pump Calibration:
Each chemical pump needs to be calibrated to existing conditions before operating in auto mode.

To calibrate the pump for operation in auto mode, the flow capacity of the pump must be measured and entered. First, set the valve positions to FILL. Next, switch the pump mode to manual by selecting the MAN button. To determine the pump's maximum flow, access the manual setpoint keypad and enter 100%. Press the ON control button and operate the pump until the graduated cylinder is full of the chemical to be dispensed (make a note of the current chemical level). Next, set the valve positions to DRAIN and energize the pump for at 100% for 1 minute. After 1 minute of pumping, de-energize the pump and measure (in milliliters) the amount of chemical pumped from the graduated cylinder- enter this amount as the Pump Max setpoint. To determine the pump's minimum flow, repeat the process by operating the pump at the minimum manual setpoint percentage of 3% for one minute and measuring the chemical pumped. Enter this amount as the Pump Min setpoint. Repeat the process for each pump used.





Enter the solution concentration of the chemical being pumped (units are in pounds of chemical per gallon of solution). Once calibration is complete, set the valve positions back to FEED.

NOTE: If an auto dosing setpoint is selected which the equipment is not able to achieve, a "calculation high" or "calculation low" indication will appear.

ATTENTION: If the chemical pump experiences a fault, the Pump Fault Alarm will be annunciated. **In addition to pressing the Alarm Reset button, it is necessary to cycle power to the pump in order to clear the alarm.** This can be accomplished by simply removing the wiring connector at the top of the pump, then reconnecting it.

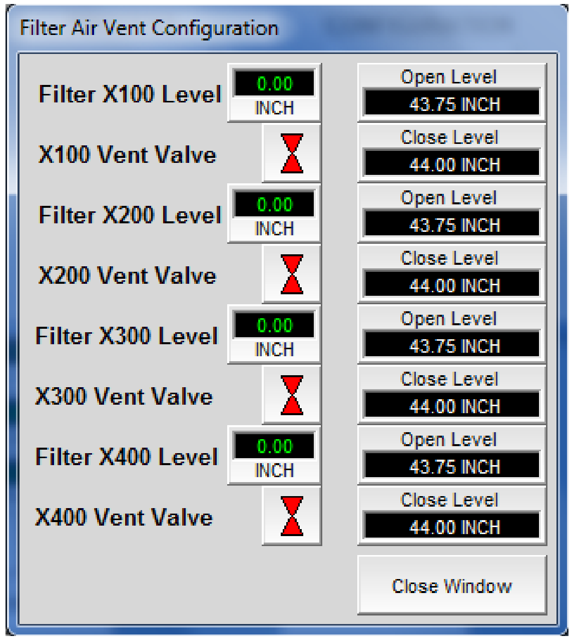
Similar screens exist for the following Pace controlled components on the pilot:

- Chemical Pump X710
- Chemical Pump X720
- Chemical Pump X730
- Chemical Pump X740

- Chemical Pump X750

17. Filter Air Vents

If the FILTER AIR VENTS button is selected, the following screen is displayed.



The filter vent valves are designed to open if air becomes trapped in the filter vessel and is unable to escape during normal filtration. In this case, the vent valve will automatically open and slowly bleed the air out of the column, until the water level returns to normal. The open and close levels on this screen have been set at the factory and should not require further adjustment. Record previous setpoint values BEFORE modifying the values.

18. HMI Alarms and Conditions

All alarms generated by the equipment are summarized in this table. The "Message" column indicates the alarm text shown on the ALARM SUMMARY and ALARM HISTORY screens. The "Condition" column describes the logic that generates the alarm. The "Shutdown" column identifies whether the alarm will cause the pilot to shutdown.

Message	Condition	Shutdown
Test Email Alarm	Test email generated to test email function	
Data Log File Length Shutdown Alarm	File length greater than defined shutdown limit	
Data Log File Length High Alarm	File length greater than defined high limit	
Data Log interval Not Defined	Entered data logging time interval is invalid	
Data Logging Not Enabled	Data logging set to OFF	
PLC Power Failed Alarm	Main power failed	
Compressor Air Pressure Low Alarm	Air compressor pressure less than 50 psig for 2 seconds	X
PLC Program Downloaded Alarm	New PLC program downloaded	X
Emergency Stop Alarm	Emergency stop button depressed **NOTE:** Rotate button clockwise to release before resetting alarm.	X
Chemical Pump X720 Fault Alarm	Chemical pump motor has experienced a fault **NOTE:** Cycle power to the chemical pump (by disconnection wiring) to allow alarm reset.	
Blower X600 Not in Auto Alarm	Control not in auto mode	

Blower X600 Failed Alarm	Device commanded to run but not running after 30 seconds	X
Blower X600 Flow High Alarm	Value outside of defined deadband for the specified delay time	
Blower X600 Flow Low Alarm	Value outside of defined deadband for the specified delay time	X
Chemical Pump X710 Fault Alarm	Chemical pump motor has experienced a fault **NOTE:** Cycle power to the chemical pump (by disconnection wiring) to allow alarm reset.	
Chemical Pump X730 Fault Alarm	Chemical pump motor has experienced a fault **NOTE:** Cycle power to the chemical pump (by disconnection wiring) to allow alarm reset.	
Filter X100 Backwash Tank Level Too Low to Perform Backwash Alarm	Backwash tank level too low to perform currently configured backwash	
Filter X100 Headloss High Alarm	Value greater than defined limit for 30 seconds	
Filter X100 Vessel Pressure High Alarm	Value greater than 15 PSIG for 2 seconds	X
Filter X100 Runtime High Alarm	Value greater than defined limit	
Filter X100 Run Volume High Alarm	Value greater than defined limit	
Chemical Pump X740 Fault Alarm	Chemical pump motor has experienced a fault **NOTE:** Cycle power to the chemical pump (by disconnection wiring) to allow alarm reset.	
Chemical Pump X750 Fault Alarm	Chemical pump motor has experienced a fault **NOTE:** Cycle power to the chemical pump (by disconnection wiring) to allow alarm reset.	
Filter X100 Step Time Too Long Alarm	Elapsed step time greater than defined limit.	X
Filter X300 Headloss High Alarm	Value greater than defined limit for 30 seconds	
Filter X300 Vessel Pressure High Alarm	Value greater than 15 PSIG for 2 second	X
Filter X300 Runtime High Alarm	Value greater than defined limit	
Filter X300 Run Volume High Alarm	Value greater than defined limit	
Filter X300 Step Time Too Long Alarm	Elapsed step time greater than defined limit.	X
Filter X200 Backwash Tank Level Too Low to Perform Backwash Alarm	Backwash tank level too low to perform currently configured backwash	
Filter X200 Headloss High Alarm	Value greater than defined limit for 30 seconds	
Filter X200 Vessel Pressure High Alarm	Value greater than 15 PSIG for 2 seconds	X
Filter X200 Runtime High Alarm	Value greater than defined limit	
Filter X200 Run Volume High Alarm	Value greater than defined limit	
Filter X200 Step Time Too Long Alarm	Elapsed step time greater than defined limit.	X
Filter X300 Backwash Tank Level Too Low to Perform Backwash Alarm	Backwash tank level too low to perform currently configured backwash	
Filter X400 Backwash Tank Level Too Low to Perform Backwash Alarm	Backwash tank level too low to perform currently configured backwash	

Filter X400 Headloss High Alarm	Value greater than defined limit for 30 seconds	
Blower Flow Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Backwash Flow Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Filter X100 Level Transmitter Failed Alarm	No transmitter signal for 30 seconds	
Filter X200 Level Transmitter Failed Alarm	No transmitter signal for 30 seconds	
Filter X300 Level Transmitter Failed Alarm	No transmitter signal for 30 seconds	
Filter X400 Level Transmitter Failed Alarm	No transmitter signal for 30 seconds	
Filter X400 Vessel Pressure High Alarm	Value greater than 15 PSIG for 2 seconds	X
Filter X400 Runtime High Alarm	Value greater than defined limit	
Filter X400 Run Volume High Alarm	Value greater than defined limit	
Filter X400 Step Time Too Long Alarm	Elapsed step time greater than defined limit.	X
Filter X100 Feed Flow Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Filter X200 Feed Flow Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Filter X300 Feed Flow Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Filter X400 Feed Flow Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Backwash Tank Level Transmitter Failed Alarm	No transmitter signal for 30 seconds	X
Backwash Tank Level Low Alarm	Value less than 10 gal for 2 seconds	X
Filter X100 Feed Pump Flow High Alarm	Value outside of defined deadband for the specified delay time	
Filter X100 Feed Pump Flow Low Alarm	Value outside of defined deadband for the specified delay time	X
Filter X200 Feed Pump Not in Auto Alarm	Control not in auto mode	
Filter X200 Feed Pump Failed Alarm	Device commanded to run but not running after 30 seconds	X
Filter X200 Feed Pump Flow High Alarm	Value outside of defined deadband for the specified delay time	
Filter X200 Feed Pump Flow Low Alarm	Value outside of defined deadband for the specified delay time	X
Chemical Cabinet X701 Leak Alarm	Leak detected in chemical cabinet	X
Chemical Cabinet X702 Leak Alarm	Leak detected in chemical cabinet	X
Filter X100 Pressure Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X
Filter X200 Pressure Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X
Filter X300 Pressure Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X

Filter X400 Pressure Transmitter Failed Alarm	No Transmitter signal for 30 seconds	X
Filter X100 Feed Pump Not in Auto Alarm	Control not in auto mode	
Filter X100 Feed Pump Failed Alarm	Device commanded to run but not running after 30 seconds	X
Filter X300 Feed Pump Not in Auto Alarm	Control not in auto mode	
Filter X300 Feed Pump Failed Alarm	Device commanded to run but not running after 30 seconds	X
Backwash Pump Flow High Alarm	Value outside of defined deadband for the specified delay time	
Backwash Pump Flow Low Alarm	Value outside of defined deadband for the specified delay time	X
Filter X100 Turbidity Transmitter Failed Alarm	No Transmitter signal for 30 seconds	
Filter X100 Turbidity High Alarm	Value greater than defined limit for 5 minutes	
Filter X200 Turbidity Transmitter Failed Alarm	No Transmitter signal for 30 seconds	
Filter X200 Turbidity High Alarm	Value greater than defined limit for 5 minutes	
Filter X300 Feed Pump Flow High Alarm	Value outside of defined deadband for the specified delay time	
Filter X300 Feed Pump Flow Low Alarm	Value outside of defined deadband for the specified delay time	X
Filter X400 Feed Pump Not in Auto Alarm	Control not in auto mode	
Filter X400 Feed Pump Failed Alarm	Commanded to run but not running after 30 seconds	X
Filter X400 Feed Pump Flow High Alarm	Value outside of defined deadband for the specified delay time	
Filter X400 Feed Pump Flow Low Alarm	Value outside of defined deadband for the specified delay time	X
Backwash Pump Not in Auto Alarm	Control not in auto mode	
Backwash Pump Failed Alarm	Commanded to run but not running after 30 seconds	X
Filter X300 Turbidity Transmitter Failed Alarm	No Transmitter signal for 30 seconds	
Filter X300 Turbidity High Alarm	Value greater than defined limit for 5 minutes	
Filter X100 Air Drain Valve DV-X107 Not in Auto Alarm	Control not in auto mode	
Filter X100 Filter to Tank Valve DV-X108 Not in Auto Alarm	Control not in auto mode	
Filter X100 Air Vent Valve DV-X110 Not in Auto Alarm	Control not in auto mode	
Filter X200 Inlet Valve DV-X201 Not in Auto Alarm	Control not in auto mode	
Filter X200 Outlet Valve DV-X202 Not in Auto Alarm	Control not in auto mode	
Filter X200 Backwash Inlet Valve DV-X203 Not in Auto Alarm	Control not in auto mode	
Filter X400 Turbidity Transmitter Failed Alarm	No Transmitter signal for 30 seconds	
Filter X400 Turbidity High Alarm	Value greater than defined limit for 5 minutes	

Filter X100 Inlet Valve DV-X101Not in Auto Alarm	Control not in auto mode	
Filter X100 Outlet Valve DV-X102 Not in Auto Alarm	Control not in auto mode	
Filter X100 Backwash Inlet Valve DV-X103 Not in Auto Alarm	Control not in auto mode	
Filter X100 Backwash Outlet Valve DV-X104 Not in Auto Alarm	Control not in auto mode	
Filter X100 Filter to Waste Valve DV-X105 Not in Auto Alarm	Control not in auto mode	
Filter X100 Air Scour Inlet Valve DV-X106 Not in Auto Alarm	Control not in auto mode	
Filter X200 Backwash Outlet Valve DV-X203 Not in Auto Alarm	Control not in auto mode	
Filter X200 Filter to Waste Valve DV-X205 Not in Auto Alarm	Control not in auto mode	
Filter X300 Filter to Waste Valve DV-X305 Not in Auto Alarm	Control not in auto mode	
Filter X300 Air Scour Inlet Valve DV-X306 Not in Auto Alarm	Control not in auto mode	
Filter X300 Air Drain Valve DV-X307 Not in Auto Alarm	Control not in auto mode	
Filter X300 Filter to Tank Valve DV-X308 Not in Auto Alarm	Control not in auto mode	
Filter X300 Air Vent Valve DV-X310 Not in Auto Alarm	Control not in auto mode	
Filter X400 Inlet Valve DV-X401 Not in Auto Alarm	Control not in auto mode	
Filter X200 Air Scour Inlet Valve DV-X206 Not in Auto Alarm	Control not in auto mode	
Filter X200 Air Drain Valve DV-X210 Not in Auto Alarm	Control not in auto mode	
Filter X200 Filter to Tank Valve DV-X208 Not in Auto Alarm	Control not in auto mode	
Filter X200 Air Vent Valve DV-X210 Not in Auto Alarm	Control not in auto mode	
Filter X300 Inlet Valve DV-X301 Not in Auto Alarm	Control not in auto mode	
Filter X300 Outlet Valve DV-X302 Not in Auto Alarm	Control not in auto mode	
Filter X300 Backwash Inlet Valve DV-X303 Not in Auto Alarm	Control not in auto mode	
Filter X300 Backwash Outlet Valve DV-X304 Not in Auto Alarm	Control not in auto mode	
Filter X400 Outlet Valve DV-X402 Not in Auto Alarm	Control not in auto mode	
Filter X400 Backwash Inlet Valve DV-X403 Not in Auto Alarm	Control not in auto mode	
Filter X400 Backwash Outlet Valve DV-X404 Not in Auto Alarm	Control not in auto mode	

Filter X400 Filter to Waste Valve DV-X405 Not in Auto Alarm	Control not in auto mode	
Filter X400 Air Scour Inlet Valve DV-X406 Not in Auto Alarm	Control not in auto mode	
Filter X400 Air Drain Valve DV-X407 Not in Auto Alarm	Control not in auto mode	
Filter X400 Filter to Tank Valve DV-X408 Not in Auto Alarm	Control not in auto mode	
Filter X400 Air Vent Valve DV-X410 Not in Auto Alarm	Control not in auto mode	
Filter X400 Inlet Valve DV-X401 Not in Auto Alarm	Control not in auto mode	
Filter X300 Backwash Outlet Valve DV-X304 Not in Auto Alarm	Control not in auto mode	
Filter X400 Outlet Valve DV-X402 Not in Auto Alarm	Control not in auto mode	
Filter X400 Backwash Inlet Valve DV-X403 Not in Auto Alarm	Control not in auto mode	
Air Blower Block & Bleed Valves DV-X601 & DV-X602 Not in Auto Alarm	Control not in auto mode	
Chemical Cabinet 1 Leak Alarm	Chemical cabinet leak detected for 5 seconds	X
Chemical Cabinet 2 Leak Alarm	Chemical cabinet leak detected for 5 seconds	X

NOTE: Not in Auto Alarm: This alarm does not indicate an operational failure. It is simply an indicator to remind the operator that a given process is under manual control.

WARNING: Equipment protection is enabled only when control is in AUTO. Operator is responsible to protect equipment from damage when control is not in AUTO. Equipment not operating in auto is displayed on the alarm summary screen.

STARTUP

1. Pre-Startup Procedures

A. Electrical Installation

DANGER: All electrical connections shall be made by a qualified electrician.

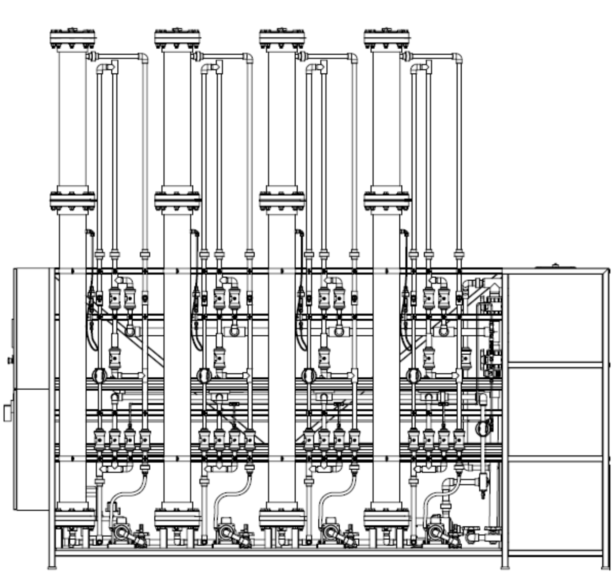
B. Media-Installation

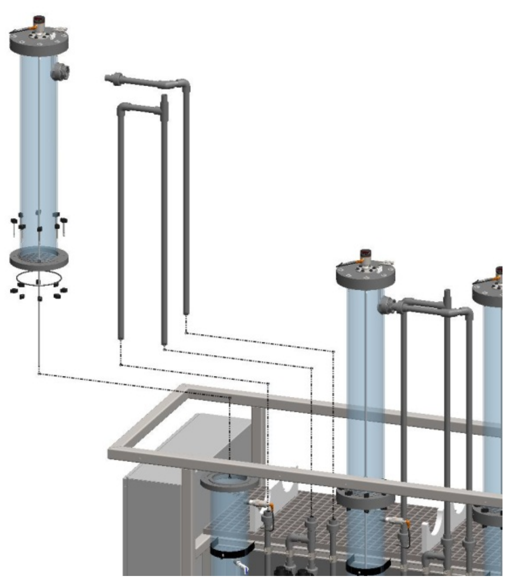
Disassemble the upper portion of the filter vessels to install media. If using a dual media filter, you may consider backwashing each media separately during the initial installation. For example, if sand and anthracite are being used, the sand would be loaded first. Once the sand is installed, a backwashing of the vessel for 15 – 30 minutes may be necessary to purge the sand of fines that can lead to premature filter clogging, or slip through the media support and contaminate the backwash tank. Once backwashing is complete and the water exiting the filter is clear, it may be necessary to manually remove the top layer of fines. Once the sand is thoroughly washed, the anthracite would be loaded and backwashed according to the same procedure. (Virgin anthracite will often require a manual removal of the top 1/4” to 1/2” of fines after the initial backwash. These fines can be distinguished from the rest of the media as a fine, dense, uniform layer on top of the anthracite.) Keep in mind, backwashing times and methods will vary by application and the above example may not apply to all situations.

ATTENTION: When installing media, ensure there is 2–3 feet of water in the bottom of the vessel before adding media. This will add a cushioning effect to the falling media and help minimize the possibility of damage to the media support plate.

C. Top Section of Vessels Installation

Equipment is shipped with the top sections of the filter vessels disassembled. Assembly of the upper vessels and piping is similar to the drawings below. Also refer to the General Arrangement drawings in Appendix-A of this manual for project-specific assembly arrangements.





NOTE: When installing, take care that all o-rings are installed with their corresponding connections or the assembly will leak. Be sure to individually clean and thoroughly blow/wipe out all grooves in connecting flanges where o-rings are installed. Failure to do this may result in leakage. Tighten flanges by hand to the point where the opposing edges come into contact with each other. Do not over tighten or damage could occur.

NOTE: Since the filter vessels are pressurized, the backwash pump (instead of a feed pump) must be used to fill each vessel with water for the first time.

D. Gravity Waste vs. Pressure Waste

The Filter Module is equipped with two different waste lines, a gravity waste and a pressurized waste. As indicated by their names, the pressurized waste may be piped into a tank (with existing back-pressure), but the gravity waste must be run directly to a floor drain (or equivalent). Do not pipe the gravity waste against more than six inches of headloss. Excessive back-pressure on this line may cause sputtering and back spray from the filter overflow weirs.

ATTENTION: Do not connect process lines to field piping smaller than the sizes listed on drawings. Doing so may cause unpredictable equipment operation, backflow and possible flooding.

E. Open Process Connections

Open all process valves required for supply to the equipment. These are not the valves on the equipment but field valves that may need to be opened to supply water to the equipment.

F. Backwash Tank

The backwash tank must be filled with clean water prior to startup.

NOTE: Never use raw water for backwash supply.

G. Pump Inspection

1. **Feed Pumps**

   Verify that each pump is aligned correctly and that the shaft rotates without binding.

2. **Backwash Pump**

   Bleed all air from the backwash pump before operating. Failure to do this will result in poor pump performance and possible damage. To bleed air from the pump, first fill the backwash tank with water then open the air bleed located above the outlet of the pump and allow any trapped air to escape.

   ATTENTION: All centrifugal pumps are prone to air binding. Bleed all air from the following pumps before operating. Failure to do this will result in poor pump performance and possible damage. To bleed air from these pumps, first allow the inlet (suction) piping to the pump to fill, then open the air bleed located above the outlet (discharge) of the pump (or loosen a union) and allow all trapped air to escape.

- Backwash pump X800

WARNING: Do not run this pump dry. Do not deadhead pump for more than 30 seconds

H. Fill Filter Vessels

While in operation the filter vessels are pressurized and must therefore be initially filled using the backwash pump (i.e. from the bottom up). This will allow excess air inside the vessels to escape. The backwash inlet and backwash outlet valves can be opened manually, then energize the backwash pump by setting it to ON.

2. Startup Procedures

A. Turn on main disconnect for Filter Module
B. Log into HMI
C. Fill the backwash tank with clean water.
D. Go to the Process Control Screen and manually open the following valves: DV-X103, DV-X104, DV-X203 DV-X204, DV-X303, DV-X304, DV-X403 and DV-X404.
E. Open the Backwash Pump control screen and set the MODE to manual. The Manual setpoint should be between 40% and 70%. Bleed all air from the pump head. Turn the Control to ON to begin filling the filter vessels with water.
F. When all four filter vessels are full, turn the backwash pump control to Auto, and set all the open valves back to Auto.
G. Set all pump control and alarm set-points are set at desired values (pump settings, alarm limits, backwash configurations, etc.)
H. Verify all required component controls to Auto (feed, chemical and backwash pumps, valves, etc.).
I. Verify that all necessary manual valves are open/closed for servicing water.
J. Verify proper hand valve positions for parallel or series operation.
K. Energize each filter from the Overview screen and begin to service water.
L. If operating in manual mode, initiate a backwash sequence once headloss, turbidity, run volume or runtime has increased to undesirable levels. When operating in auto mode, backwash will be initiated based on configured alarm limits.

3. Backwashing

As explained in the HMI Operation section earlier, backwashing is initiated either automatically (based on the alarm limits entered in the HMI) or manually (from the filter summary screen). However, if the water level in the backwash tank is less than the displayed required backwash tank level, the backwash sequence will not initiate for the filter in question. The required backwash tank level is calculated using the flow rates and step times entered by the operator in backwash configuration screen. If the required backwash tank level is displayed in red, then the water level in the backwash tank is too low to perform the currently configured backwash. Reduce backwash flow rates, step times or wait for the water level in the tank to increase to allow the backwash to initiate.

NOTE: If sputtering or back-spray is observed from the weirs during backwashing, it may be necessary to lower the air flow rate during that particular step.

EQUIPMENT OPERATION

1. Standard Operation

A. On-Board Air Supply

The Filter Module is equipped with an air compressor and a rotary air blower. The air compressor (X900) is used exclusively for actuating the process valves. The air blower (X600) is used to provide air for the “air scour” and the “air drain” steps during backwash.

NOTE: If the air compressor pressure drops below 50 psig the pneumatic valves may no longer actuate properly and the filter module will shut down. Pressure is displayed on the pressure indicator PIT-X900 inside the control panel or on the dial gauge mounted to the compressor.

B. Water Flow Meters

Each filter vessel and the backwash pump are equipped with a dedicated flow meter to measure water flow into the filter. Flow values are displayed on the flow meter display as well as the HMI (in gpm). These flowmeters have been configured at the factory and no further adjustment or configuration should be necessary.

C. Air Flow Meter

The air blower flow rate is measured using a compressed air flow transmitter. This flowmeter measures the air scour flow rates and the flow rate for the pre-air-scour “drain down” step. Flow values are displayed on the flow meter display as well as the HMI (in SCFM. This transmitter has been configured at the factory and no further adjustment or configuration should be necessary.

D. Pneumatic Valve Solenoids

All pneumatic valves on the filter module are controlled using the air solenoid manifold inside the electrical enclosure. Each valve uses compressed air to open and an internal spring to close. In addition, each valve can be manually overridden from within the electrical enclosure. To override a valve, insert a small flat-blade screwdriver into one of the blue actuator “buttons” (12 or 14) and rotate it 90° clockwise. To release, simply rotate 90° counter-clockwise.

NOTE: Intuitech recommends that valves only be operated from the VALVES screen in the HMI. This manual override should only be used if necessary. **Remember to disengage the override when finished.**

E. Air Scour Blower Protection

The piping connecting the air scour blower to the filter vessels is equipped with several redundant protection systems designed to prevent water from entering the blower unit. First, a small drain orifice is always open at the discharge of the blower to ensure any coalescing water is expelled before it can cause damage to the blower components. A check valve is installed to keep water from flowing backwards into the blower, and finally, a block-and-bleed valve system is used. The normally closed valve DV-X601 and the normally open air valve (DV-X602) are operated together. Installed at a low point in the piping, the bleed valve is always open to drain water and only closes when the air blower is in operation, creating a positive pressure and restricting any backwards flow of the water. The block valve is normally closed, blocking the path of water to the blower, only opening when the blower is running.

F. Filter Vessel Level Transmitters

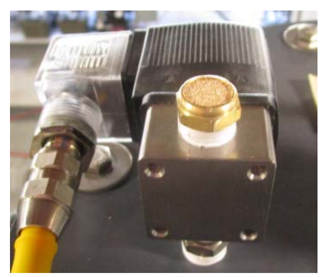
Water levels in the filter vessels are measured using the transmitters attached to the stainless steel rod located in the center of each vessel (guided wave radar type). Water levels are required to control the Air Drain-Down and Air Scour/Backwash steps (steps 5 and 7 respectively). When entering the level set-points for these steps, zero is defined as the bottom edge of the steel rod.

G. Filter Vessel Pressure Relief

As a safety measure, each filter vessel is equipped with a pressure relief valve located on top of the upper filter vessel. This valve is a mechanical device and will open at 15 psi venting excess pressure to atmosphere.

H. Filter Column Vent Valve

During normal system operation, water levels are maintained at approximately 4 to 6 inches below the top of the filter column. If the water level in the filter column drops below the operational lower limit, excess air will be evacuated from the filter column until the water level is restored. The flow rate of evacuated air is regulated using a flow restrictor to prevent rapid water-level fluctuations (and headloss fluctuations) as a result of an uncontrolled release.



SHUTDOWN

1. Shutdown Procedures

A. Disconnect Electrical Power

All electrical connections are to be isolated and disconnected by qualified personnel.

B. Disconnect Process Connections

All process connections (water, chemical, etc.) should be isolated and disconnected by qualified personnel.

C. Draining Equipment

Drain all water from equipment before storage to prevent biological growth and freeze-damage. This includes draining all filter vessels, tanks, piping, pump housings, instruments, and opening all valves. Some unions and fittings may need to be loosened to ensure complete drainage.

NOTE: Use caution when manually opening pneumatic valves. If water is allowed to enter the air scour blower X600 it will be destroyed. Allowing water to enter the blower will void all manufacturer warranties.

D. Media Removal

The equipment is not to be transported while containing media. To avoid damage, all media is to be removed from filter vessels before the equipment is transported.

For 6 inch diameter filter vessels or smaller, it is possible to tilt the vessel over and dump the media out. To accomplish this, first remove the upper section of the filter vessel. Next, remove the two black pipe-straps restraining the lower filter vessel, and disconnect all pipes and tubing attached to the filter. Take care not to damage the flange assemblies, any sample ports, or piping connections while tipping the vessel over. Two people will be required to safely tip the filter vessel. A water hose can be used to help wash media out of the vessel. During reassembly, ensure the vessel is properly aligned before reattaching the vessel pipe-straps or reconnecting any rigid piping.

A wet/dry shop vacuum is the recommended method for media removal from filter vessels greater than 6 inches in diameter, but it is generally the easiest method for all filter vessels. Remove the upper section of the filter vessel in order to vacuum out the media. Extra vacuum hose will be necessary to provide the required reach. Several rigid, straight sections of vacuum hose can be connected to access the media inside the vessel itself. Always follow safe practices, do not place the vacuum on top of the frame during this process and make sure the filter is accessed from a stable platform.

NOTE: Do not disassemble the bottom filter vessel flange assemblies at any time. It is not necessary to do so in order to remove media.

E. Filter Vessels and Weir Piping Disassembly

Disassemble top section of vessels and corresponding piping. The upper sections of filter inlet and weir piping are to be removed for storage or shipping.

F. Secure Loose Parts

Any loose parts should be properly secured and stored with equipment.

MAINTENANCE

1. General

All maintainable equipment is listed below, along with suggested maintenance procedures and replacement parts. Replacement parts can be purchased through Intuitech, Inc. A suggested maintenance schedule is provided for components that can be maintained on a timetable. However, maintenance intervals are affected by factors such as environment, runtime, and water quality. **Operational experience is the most important factor when formulating a maintenance timetable.** The maintenance timetable in this manual is provided as a recommendation only, actual maintenance schedules will vary by application.

2. Maintainable Equipment

A. Feed Pump Assemblies (X100, X200, X300, X400)

Motor - Mfr: Oriental, PN: BHI62ST-A
Coupling - Mfr: Lovejoy, PN: 685144-10406
Pump head - Mfr: Moyno, PN: 23203
Stator **-** Mfr: Moyno, PN: 330-6385-120
Maintenance information:

1. **Pump head maintenance**

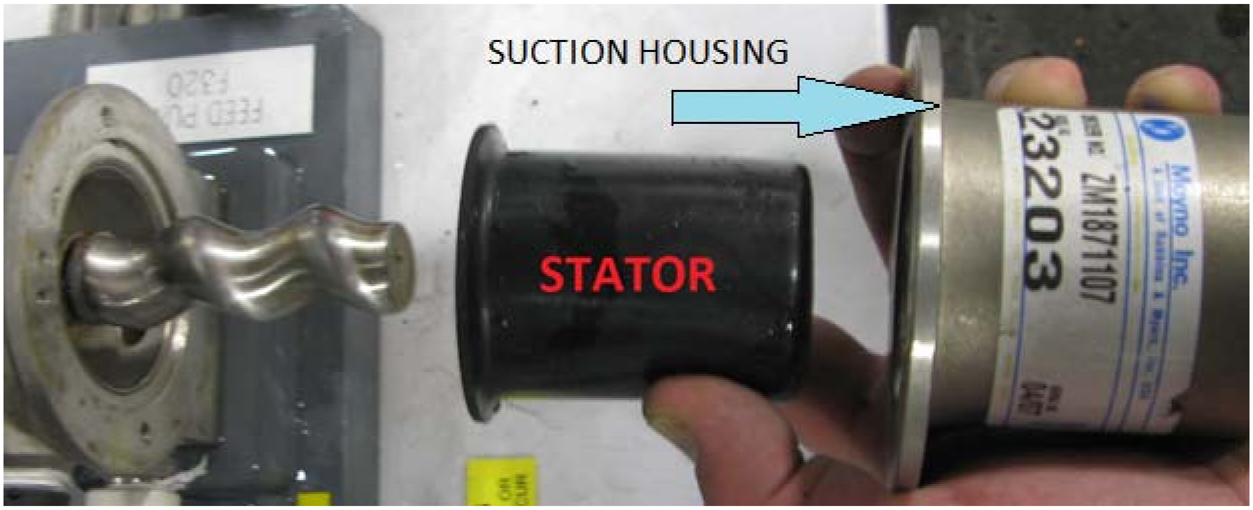
The filter feed pumps require a minimum amount of maintenance. Maintenance includes routine cleaning with regular stator and coupling inspection.

2. **Coupling maintenance**

The rubber spider coupling connecting the two ends of the coupling assembly (between the pump head and motor) should be periodically checked for wear. Replacement is necessary if excessive slop or noise is observed between the pump and motor couplings, or if the spider coupling appears cracked or broken.

3. **Stator maintenance**

The progressive cavity pump stator may need to be replaced if the pump performance decreases. Several factors can affect stator life, including runtime, pump speed, water quality, etc. Over time the pump speed will increase to maintain the same flow rate. This is a sign the stator is wearing. If the pump cannot maintain the desired flow rate at a speed of 100%, then the stator should be replaced. Replace the stator by first removing the four screws holding the suction housing to the pump body (red arrows). Set suction housing aside. Slide old stator off the rotor and replace with new stator. Do not "unscrew" the old stator, or "screw" the new stator into place. Simply push or pull the stator straight on-to or off-of the rotor. (Rotating the spiral pump shaft may cause it to loosen and become detached.) When installing the new stator make sure the edges of the stator seal up within the groove in the pump body. Replace screws.



B. Backwash Pump Assembly (X800)

Pump – Mfr: Grundfos, PN: CM1-2 A-S-G-E-AQQE-E-A-A-N
Maintenance information:

1. General

After an extended operational time or during shipping, the bolts connecting the pump body to the motor or the pump cover to the pump body may loosen. Tighten these bolts periodically. Also, if the pump has been out of use for an extended period of time, tighten all fasteners before the pump is used again.

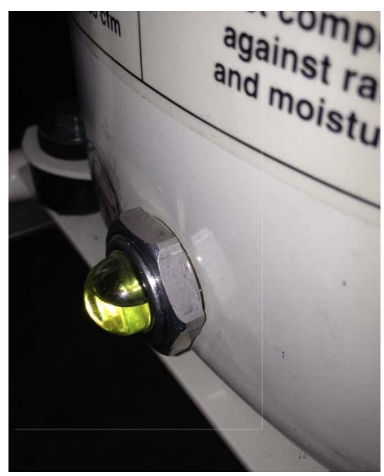
2. Troubleshooting

The backwash pump X800 is a centrifugal pump. This type of pump is very sensitive to air being trapped in the pump head. **If the pump does not create positive flow, of the flow rate is less than typical, there is likely air trapped in the pump head. Stop the pump, open a bleed valve or loosen a union on the discharge side of the pump to allow all trapped air to escape.** Once there is a steady flow of water exiting the pump, close the bleed valve (or tighten the union) and re-energize the pump. It may require several of these "bleed cycles" before all of the air is purged from the pump head.

> **ATTENTION:** Do not run the pump dry. Do not deadhead for more than 30 seconds. Failure to follow these directions will result in pump failure.

C. Air Compressor (X900)

Mfr: Werther International, PN: P 50-TC AL
Maintenance information:



1. Air Filter

Inspect air filter periodically. Clean filter with soap and water as necessary. Squeeze excess moisture from filter and allow it to dry before re-installing. If filter becomes clogged or damaged, replace it. **NEVER** clean filter with a flammable liquid or solvent. Explosive vapors can accumulate in the air tank and cause an explosion, resulting in injury or death. **DO NOT** operate air compressor without an air filter.

2. **Compressor Oil**

Inspect compressor oil level monthly. Oil level should fill half of the level sight dome. Top off as required. Entire oil volume should be replaced yearly. Manufacturer recommends draining oil by removing piston housing and dumping contents.

D. Air Preparation Assembly (X900)

Mfr: SMC, PN: CHS20-ND2-Z
AMG150C-N02BC
AM150C-N02C-T
AR20K-N02E-Z

Maintenance information:

1. **Filter Element**

The SMC air prep assembly contains a filter replacement indication. If the red indicator pops up and fills the clear window completely (red arrow) the filter element should be replaced.

E. Air Scour Blower (X600)

Mfr: Becker, PN: 163191WD

Maintenance information:

1. **Pressure Regulator**

The integral pressure regulator on the air scour blower has been tuned at the factory and does not require further adjustment. <u>If regulator requires re-setting, rotate knob clockwise “+” until regulator is fully closed and then open regulator (clockwise or “-“) ¼ - ½ turn.</u>

2. **Air Filter**

Inspect air filter periodically. Light dust and dirt can be removed by blowing the filter out with compressed air. Heavier deposits on the filter may necessitate filter replacement.

F. Universal Controller Assemblies (TUIT-X100, TUIT-X200, TUIT-X300, TUIT-X400)

Controller – Mfr: Hach, PN: sc200

Maintenance information:

1. **General**

For more detailed and step-by-step instructions for the controller assembly maintenance refer to the Hach sc200 user manual included on the CD-ROM.

2. **Controller Maintenance**

Clean: Periodically inspect enclosure exterior for cleanliness, wipe thoroughly with a damp cloth if needed.

Fuse Replacement: The instrument contains two main fuses. Repeatedly failing fuses are an indication that an equipment problem could exist. Refer to manufacturer’s manual for fuse loading.

G. Turbidimeter Analyzer (TUE-X100, TUE-X200, TUE-X300, TUE-X400)

Sensor – Mfr: Hach, PN: Ultra-Turb
Controller – Mfr: Hach, PN: sc200
Maintenance information:

1. **Sensor Maintenance**

Frequency of required maintenance will depend on the installation, sample type, and water quality. Operational experience will dictate actual maintenance schedules. Maintenance requirements of the UltraTurb include regular cleaning of the measuring chamber and periodic replacement of the wiper profiles and desiccant bags. Refer to the UltraTurb user manual for the full procedure. A suggested maintenance schedule is defined in the UltraTurb user manual (included on the CD-ROM) and listed below.

- **Wiper Replacement:**
  The rubber wiper profiles inside of the measurement chamber will require periodic replacement. The manufacturer recommends replacing the wipers after 1200 wipe cycles. Refer to the "Hach UltraTurb Plus SC Turbidity Sensor Manual" on CD ROM for replacement details.

2. **Calibration**

The Hach UltraTurb turbidimeter requires periodic calibration to ensure accurate measurements. Verification using a standard solution or a dry standard CVM was performed at Intuitech before shipping, but calibration should be performed periodically in the field. Refer to the "Hach Ultraturb Plus SC Turbidity Sensor Manual" on CD ROM for field calibration details.

H. Peristaltic Chemical Pump Assemblies (X710, X720, X730, X740, X750)

Motor Mfr: Intuitech Inc. PN:5110-200
Pump head Mfr: Masterflex, PN: OE-77800-50
Maintenance information:

1. **General**

Periodically inspect pump head for cleanliness. Use a mild detergent solution or 70% isopropyl alcohol only to clean the pump. **Do not immerse or use excess fluid.**

2. **Peristaltic tubing maintenance and troubleshooting**

The peristaltic pump tubing may need to be replaced if the pump performance decreases. Several factors including run-time, pump speed and tubing pressure will determine how long the tubing will last. **<u>If the pump cannot maintain the desired flow rate or the tubing begins to leak, then the tubing should be replaced.</u>**

Tube loading:

1. To load tubing, open pump by moving the actuator lever to the far left (counterclockwise, if pump is mounted vertically - see Figures 1 and 2).
2. Insert a loop of tubing into one open tubing retainer, then between the occlusion bed and the rollers and into the other tubing retainer (see figure 3).
3. Position the tubing so that it seats firmly against the rollers and is centered on the length of the roller.
4. While holding the tubing ends, move the actuator lever back to the far right (clockwise) position, as shown in Figure 1. The pump will

automatically grip the tubing. Approximately 5 pounds of force must be applied to the actuator lever to fully close the pump and place the lever in its locked position. A similar amount of force is required to fully open the pump.

5. Connect pump tubing to the correct chemical inlet and outlet connections.

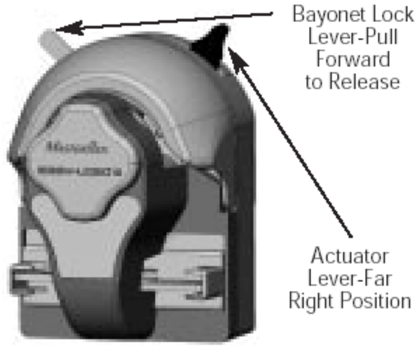


Figure 1
Fully Closed Position

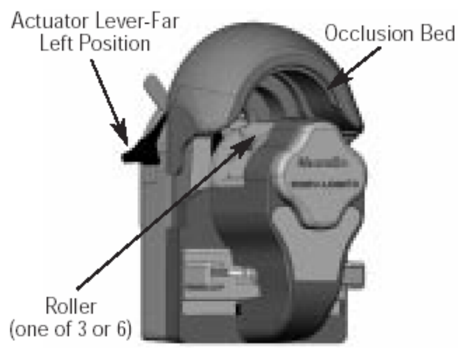


Figure 2
Fully Open Position

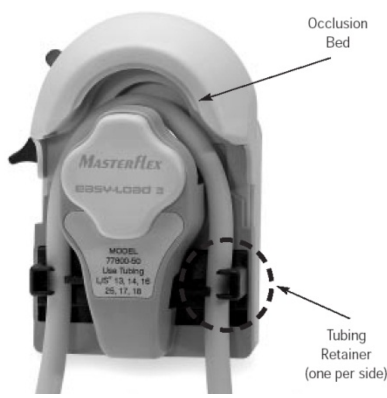


Figure 3
Tubing Path Through Pump - Loaded

NOTE: To unload tubing from the pump, turn off the drive. Then open the pump head by moving the actuator lever counterclockwise (left), as described above. The pump will open the tubing retainers and lift the tubing occlusion bed away from the tubing. Then remove the tubing from the pump.

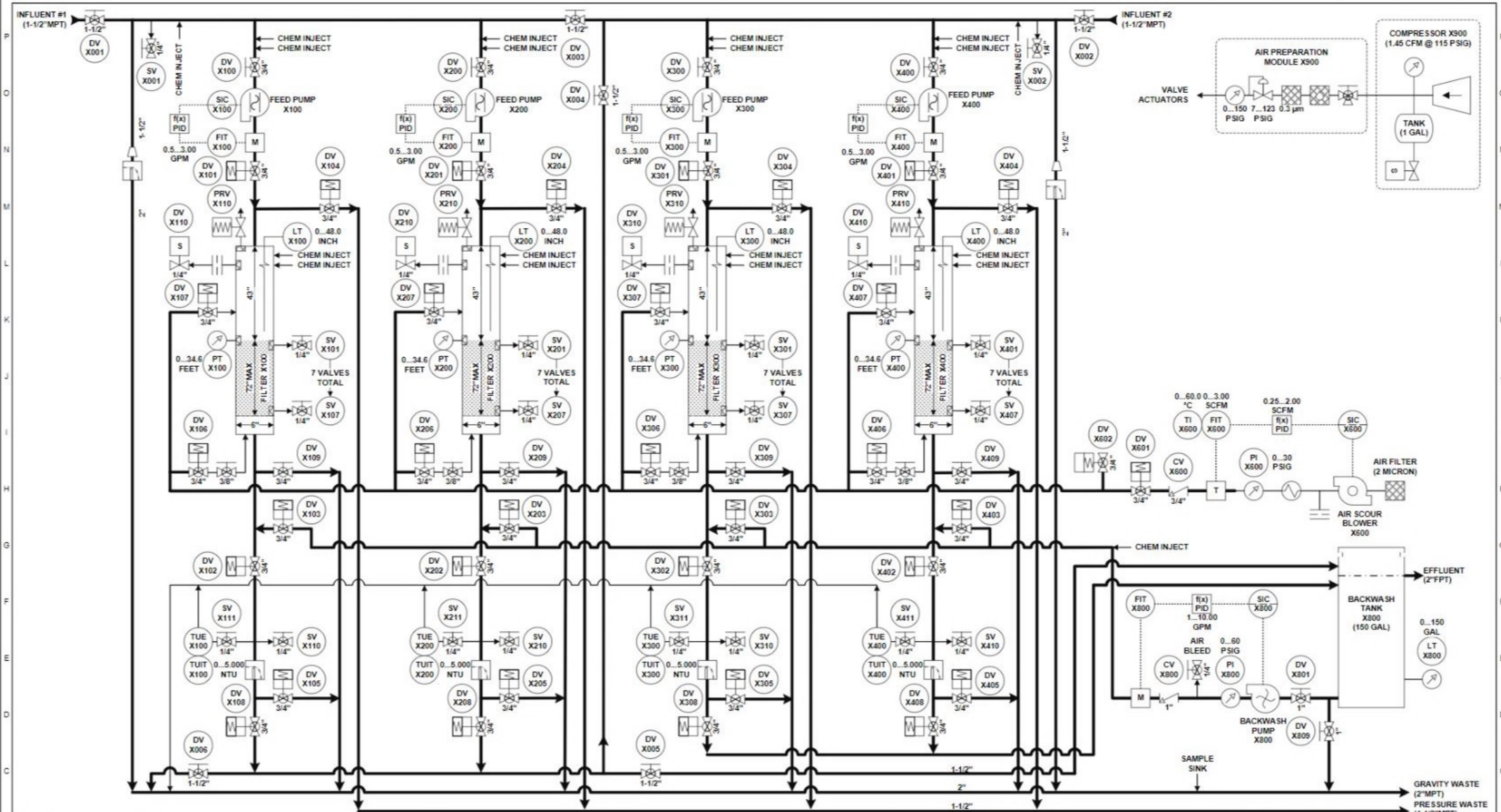
WARNING: De-energize pump before servicing or injury may occur.

3. Maintenance Schedule

Component	Weekly	Monthly	Quarterly	Yearly
Progressive Cavity Pump Stator			X*	
Progressive Cavity Pump Coupling				X*
Peristaltic Pump Head & Tubing		X*		
Air Compressor Coolant Level		X*		
Air Compressor Coolant Filter	X*			

Replace Air Compressor Coolant				X*
Air Compressor Package Pre-Filter			X*	
Air Scour Blower Filter		X*		
Turbidimeter Cleaning		X*		

*Or as necessary



REV	DATE	BY	DESCRIPTION
1	07-15-16	AJB	MINOR UPDATES FOR RECORD AS BUILTS.
2			
3			
4			

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DIMENSIONAL TOLERANCES ARE AS FOLLOWS, UNLESS OTHERWISE SPECIFIED

FRAC: ± 1/16 0.XX: ± 0.01

ANGLES: ± 1° 0.XXX: ± 0.005

TITLE: FILTRATION MODULE PROCESS & INSTRUMENTATION DIAGRAM – PROCESS	
CLIENT: CAROLLO ENGINEERS	PROJECT: 1554
DRAWN BY: AJB	DRAWN DATE: 06-14-16
DRAWING NAME: 1554-10PP-01.VSD	P.O.:
SCALE: NONE	REVISION: 1

Appendix B

SAMPLE PROCESSING AND METHODOLOGIES

Sample analysis for this pilot was performed by various test facilities. Additional bench-scale testing was relied upon to evaluate different coagulants, additional chemical dosing, potential disinfection by-product formation and determination of ozone demands.

1.1 Routine Water Quality Testing

1.1.1 COT DLTWTF Lab

Routine pilot water quality was predominantly performed by the COT Tippin Lab onsite. Samples were collected daily or weekly, depending on analyte. Test methods for these data are provided in Table B1. Daily UVT was measured at the pilot by the pilot operator.

Table B1 Sample Analytical Test Methods and Analysis Responsibility

Parameter	Grab Sample Analytical Methods	Analysis Responsibility
Turbidity	SM 2130 B	City Lab
pH	EPA 150.1	City Lab
Apparent Color	SM 2120B	City Lab
Odor (TON)	SM 2150 B	City Lab
UVT_{254}	SM 5910B	Carollo
Conductivity	SM 2510 B	City Lab
TDS (total dissolved solids)		City Lab
TOC	SM 5310 C	City Lab
Alkalinity	SM 2320B	City Lab
Hardness, Total	SM 2340C - RL is 1	City Lab
Calcium		City Lab
Magnesium	Not certified / EPA 200.8 - RL is 0.1 mg/L	City Lab
Chloride	EPA 300.0	City Lab
Sodium		City Lab
Iron		City Lab
Manganese		City Lab
Fluoride	EPA 300.0	City Lab
Bromate		City Lab
Nitrate	EPA 300.0	City Lab
Sulfate	EPA 300.0	City Lab
MIB(1)	SM 6040D	City Lab
Geosmin(1)	SM 6040D	City Lab

1.2 Water ARC®

A significant component of this dynamic piloting effort has come from bench-scale testing. Samples of the raw water, SIX effluent water, and filter effluent water were sent to the bench-scale testing facility so that chemical dosing requirements, impacts on ozone demand, and subsequent disinfection byproduct (DBP) formation and chloramines decay during the pilot may be evaluated. Subsequently, additional samples were sent to Water ARC® for testing, as needed. A summary of the test methods used for this testing is provided in Table B2.

Table B2 Water ARC® Test Methods

Parameter	Method	Range or MRL	Unit	Laboratory
Alkalinity	Hach Method 10280	2 to 200	mg/L $CaCO_3$	Water ARC®
ATP	Photomultiplier Tube (PMT)	4 x 10-12 to 1 x 10-6M ATP	tATP (pg ATP/g) or(pg ATP/mL)	Field
Conductivity	Hach Method 8160	0.01 to 200,000	µS/cm	Water ARC®
Monochloramine	Hach Method 10270	0.04-4.0	mg/L Cl_2	Water ARC®
Nitrate	Hach TNT835	0.2-13.5	mg/L NO_3-N	Water ARC®
Nitrite	Hach Method 10271			
ORP	Hach Method 10228	-2,000 to 2,000	mV	Water ARC®
Orthophosphate	Hach Method 10282	0.15-4.5	mg/L PO_4^{3-}-P	Water ARC®
pH	Hach Method 8156	2 to 14	S.U.	Water ARC®
SDS	SM5710C	Not applicable		Water ARC®
Sulfate	EPA 300.0A	0.5 (MRL)	mg/L	Contract Lab
Temperature	SM 2550B	0-50	°C	Water ARC®
TOC	EPA 415.3	0.0004-100	mg/L	Water ARC®
Free Ammonia	Hach Method 10268	0.05-1.5	mg/L NH_3-N	Water ARC®
Free Chlorine	Hach Method 10260	0.04-10	mg/L Cl_2	Water ARC®
Total Hardness	Hach Method 1284	3-100	mg/L $CaCO_3$	Water ARC®
Total Iron	EPA 200.7	0.05 (MRL)	mg/L	Contract Lab
Total Manganese	EPA 200.8	2 (MRL)	µg/L	Contract Lab

Parameter	Method	Range or MRL	Unit	Laboratory
Total Sulfide	Hach Method 8131	0.005-0.8	mg/L	Water ARC®
True Color	Hach Method 8025	3 (MRL)	PtCo	Water ARC®
Turbidity	Hach Method 10258	0-700	NTU	Water ARC®
UV254	SM5910B	0.009 (MRL)	AU	Water ARC® and Contract Lab
Zeta Potential	Electrophoretic Light Scattering	-500 - +500	mV	Water ARC®

1.3 Specialized Testing

1.3.1 LC-OCD

Organics speciation is an important component of the analysis of this pilot. LC-OCD was utilized to assess the relative organics speciation in the HR RW to understand the anticipated treatability effectiveness of the downstream processes with respect to TOC removal. Additional LC-OCD analysis was performed on pilot effluent samples and compared to that of the full-scale. This analysis was performed by the University of Boulder, XX lab. The test equipment and method is summarized below.

Analysis was conducted using an Agilent 1260 high performance liquid chromatography (HPLC) system. The system included an Agilent 1200 Series Vacuum Degasser, Agilent 1200 Series G1310A Isocratic Pump, Agilent 1260 Infinity II Vialsampler, Toyopearl HW-50S column (internal diameter (ID) 20 mm x 25 cm, 92 mL total volume), Agilent 1260 Infinity Series G1315D Diode Array Detector (DAD), and a Sievers M9 Total Organic Carbon (TOC) Analyzer. Agilent OpenLab software (Rev. C01.09) captures data directly from the absorbance detector while data from the TOC was transferred to the software using an Agilent Universal Interface Box II in voltage units, and then converted to [TOC] (ppb).

The system was operated utilizing injection volumes of 1.8 mL, a flow rate of 0.5 mL/min, and a phosphate buffer mobile phase (0.0016M Na_2HPO_4, 0.0024M NaH_2PO_4, and 0.0031M Na_2SO_4, pH 6.8, ionic strength 0.1M). Following collection, samples were passed through a 0.45 µm filter, spiked with a concentrated phosphate buffer (0.016M Na_2HPO_4, 0.024M NaH_2PO_4), and 0.025M Na_2SO_4 to match the mobile phase ionic strength, and stored in combusted amber glass bottles at (4-5 deg C) prior to analysis.

Appendix C

SUPPLEMENTARY WATER QUALITY DATA AND PLOTS

1.1 Overall Pilot

The below graphs provide supplementary data for the SIX pilot at DLTWTF.

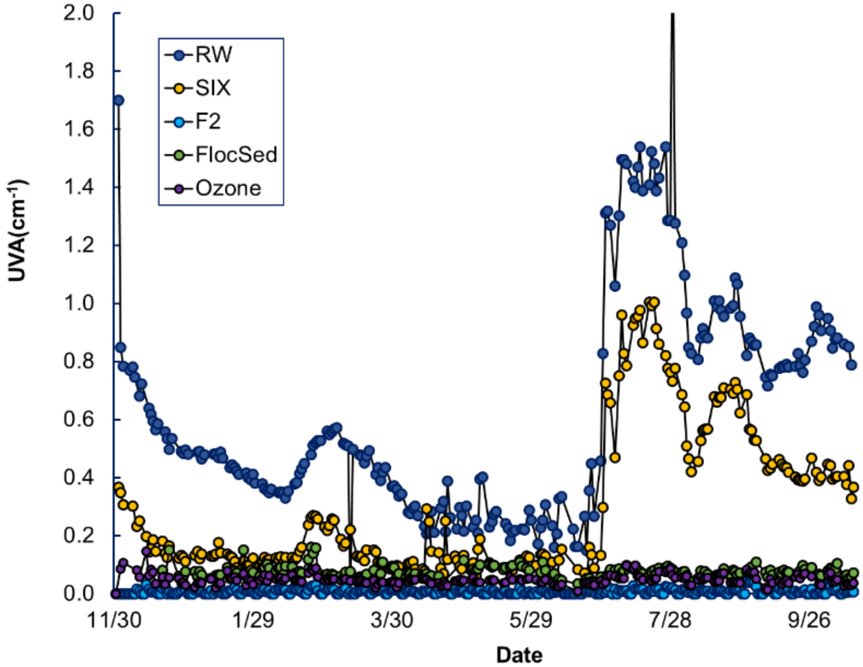


Figure 1 Pilot UVA

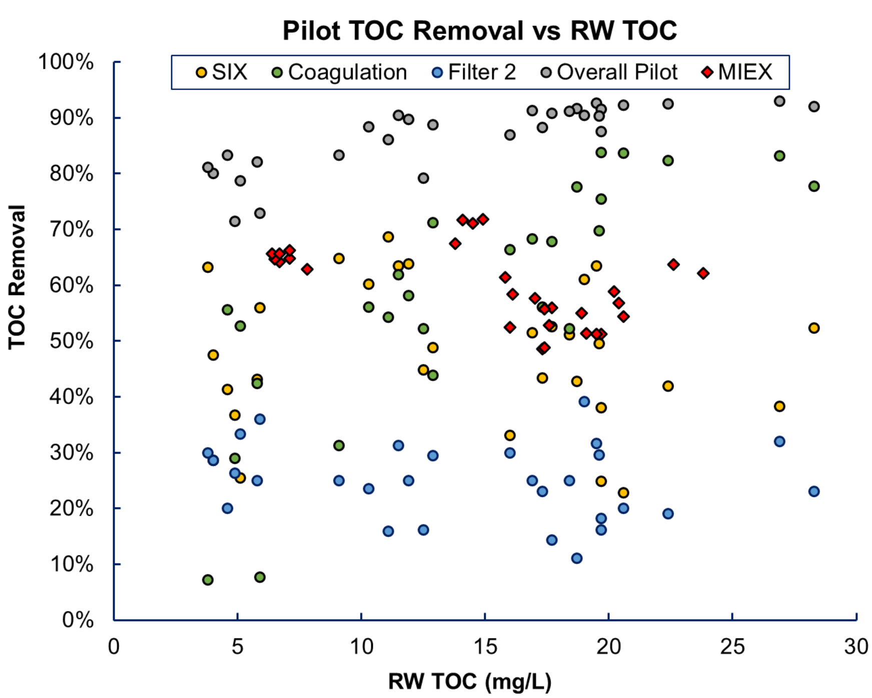


Figure 2 Pilot TOC Removal vs RW TOC

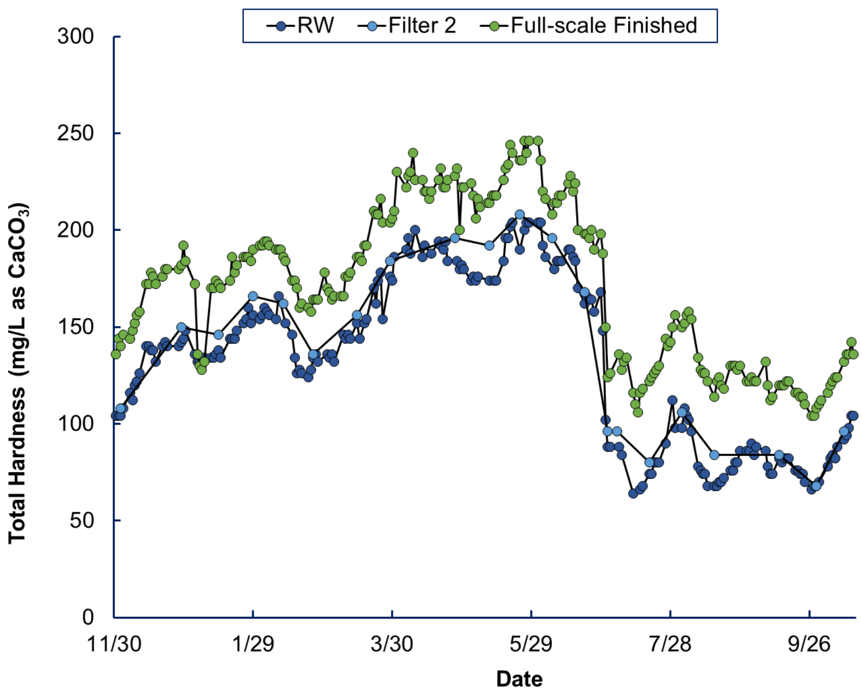


Figure 3 Pilot and Full-scale Total Hardness

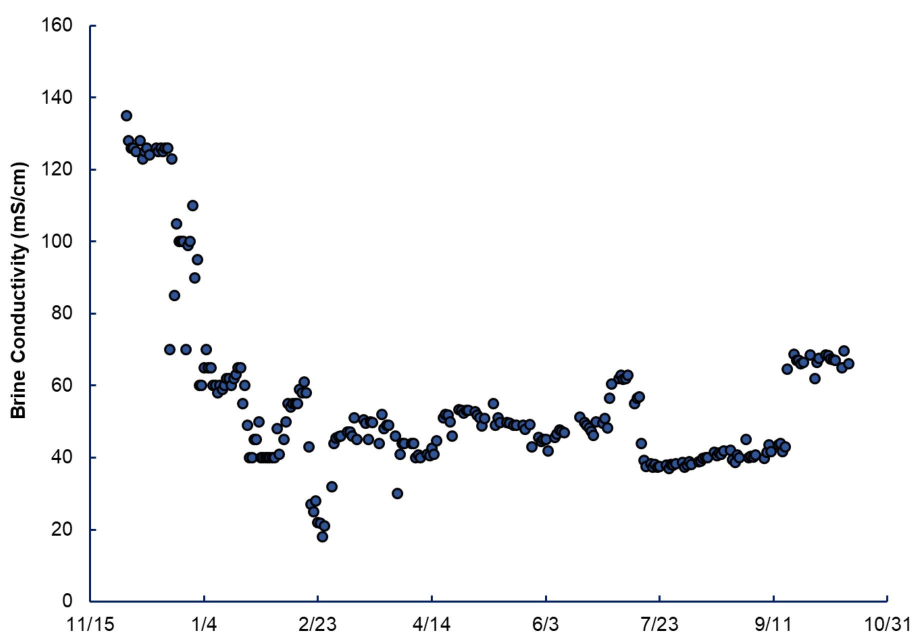


Figure 4 SIX Brine Conductivity (1x Brine Setpoint)

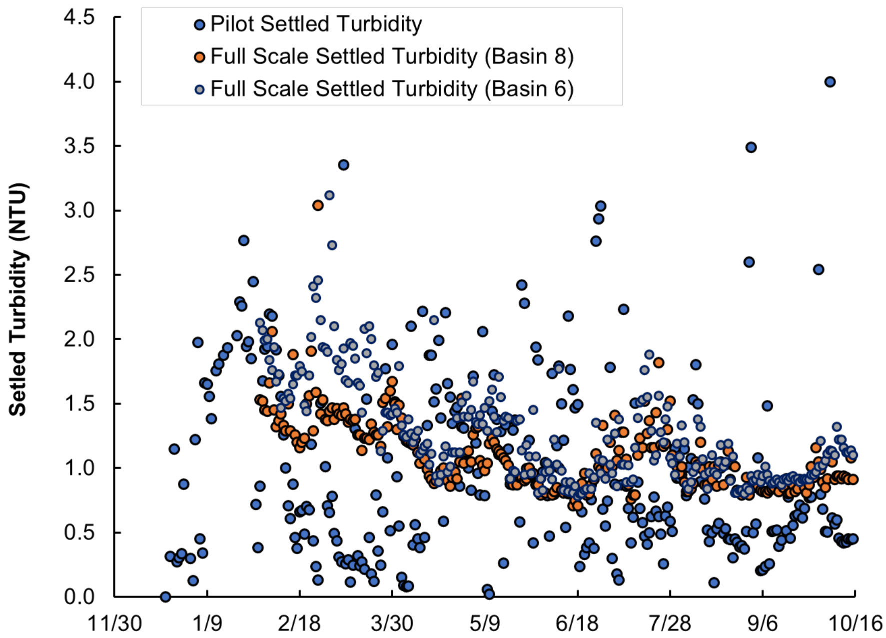


Figure 5 Full-scale and Pilot Settled Turbidity

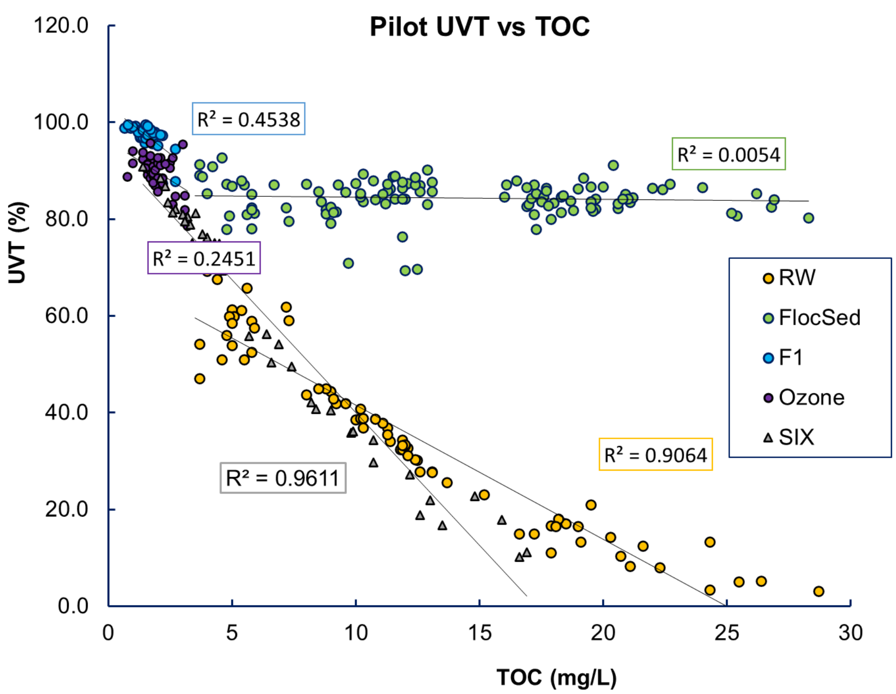


Figure 6 Pilot Effluents- UVT vs. TOC Correlation

1.2 Filters

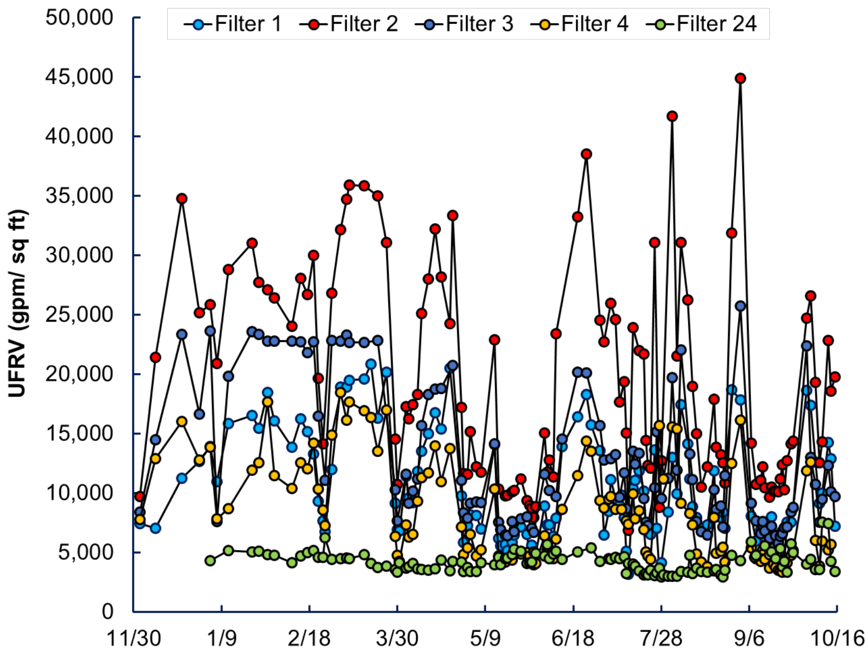


Figure 7 Pilot and Full-scale UFRVs

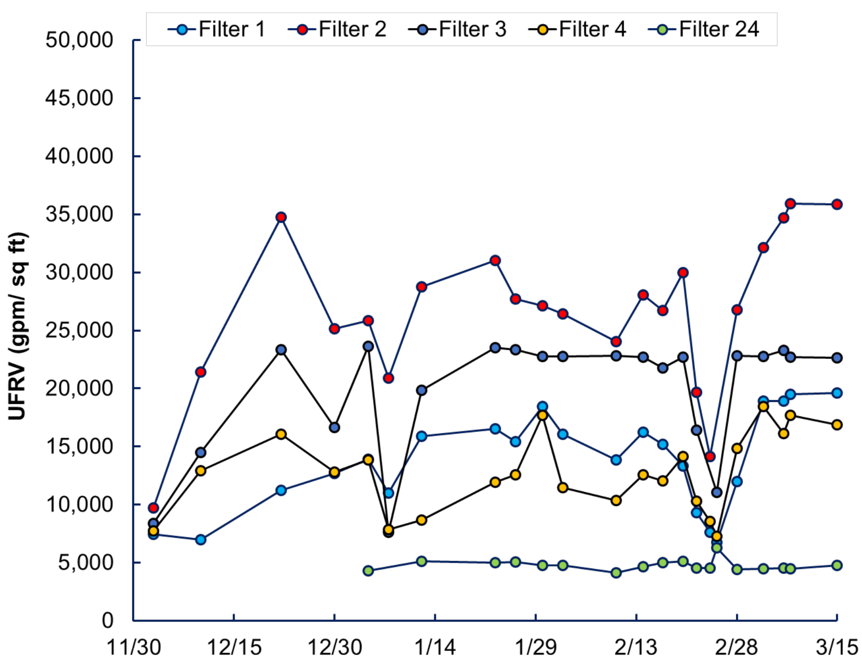


Figure 8 Pilot and Full-scale UFRVs (Phase 1)

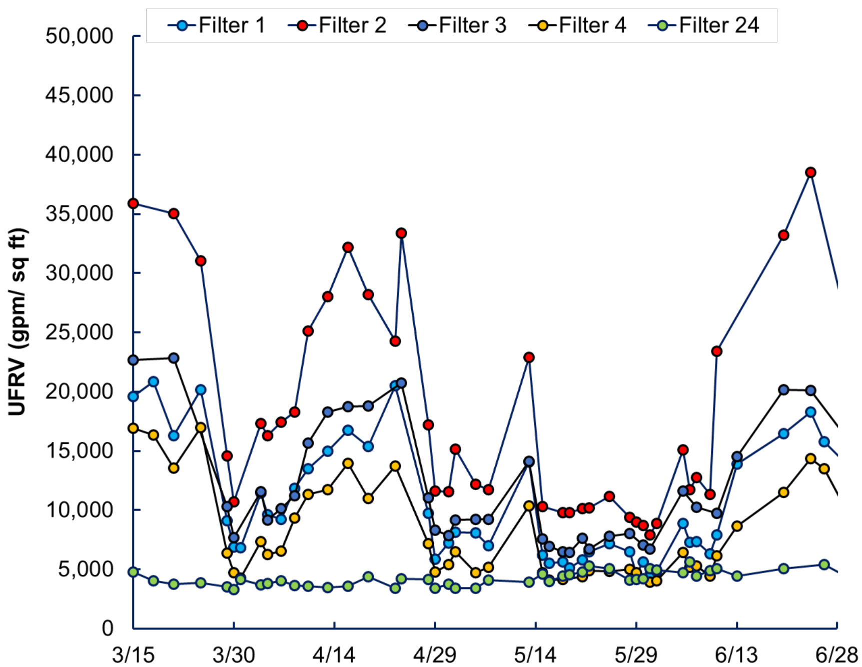


Figure 9 Pilot and Full-scale UFRVs (Phase 2)

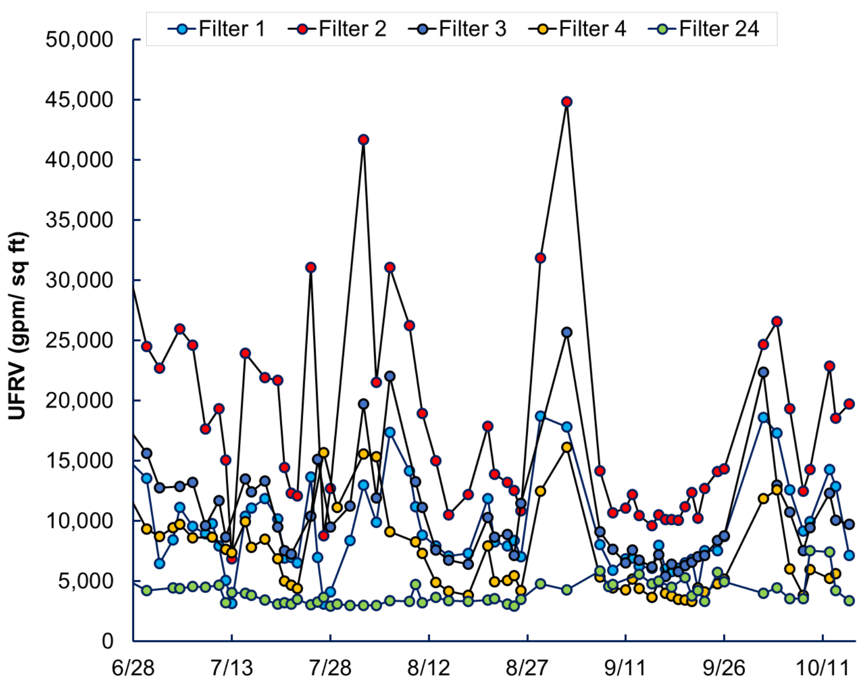


Figure 10 Pilot and Full-scale UFRVs (Phase 3)

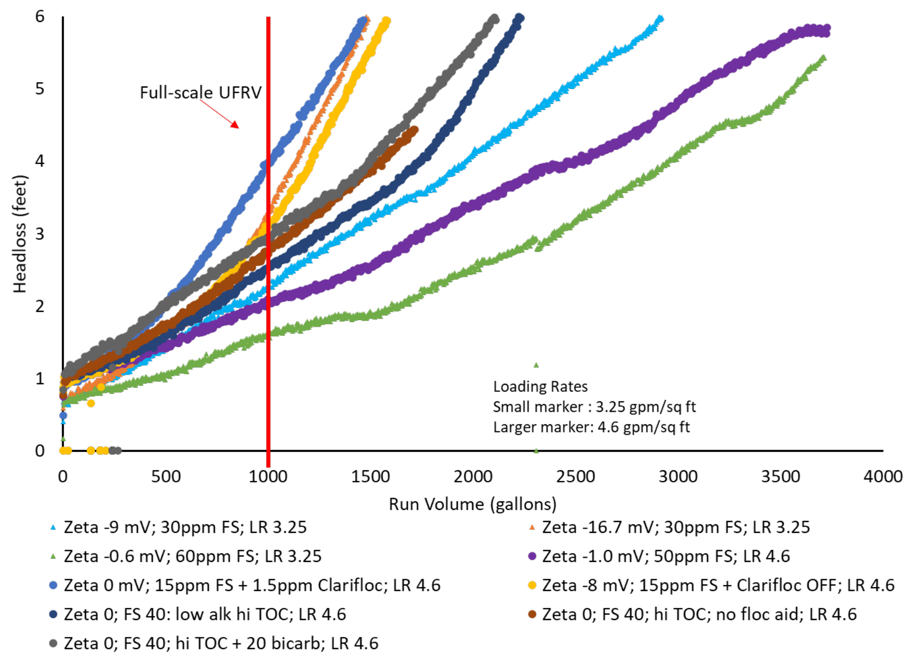


Figure 11 Filter 1 Headloss with Ferric Sulfate Coagulation

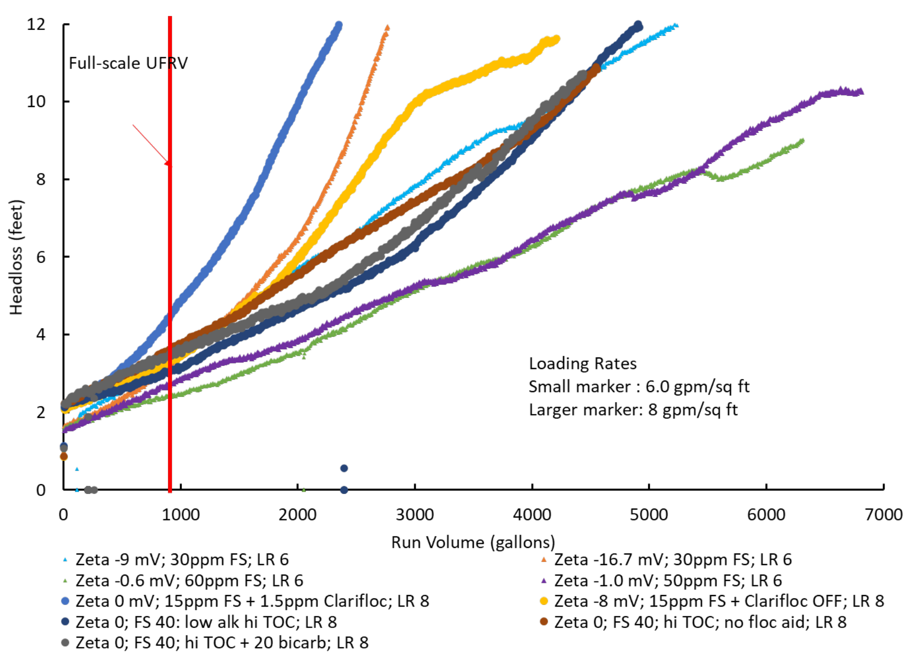


Figure 12 Filter 2 Headloss with Ferric Sulfate Coagulation

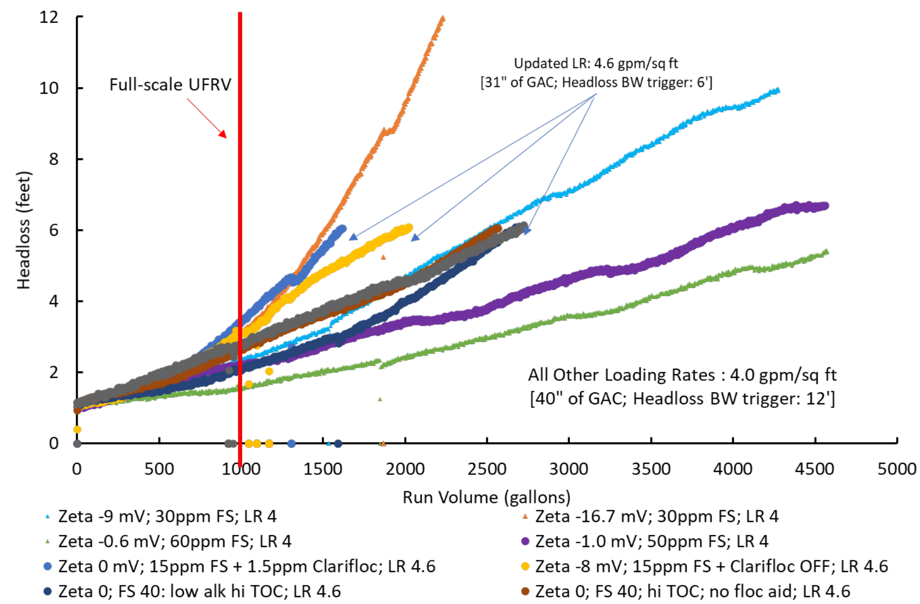


Figure 13 Filter 3 Headloss with Ferric Sulfate Coagulation

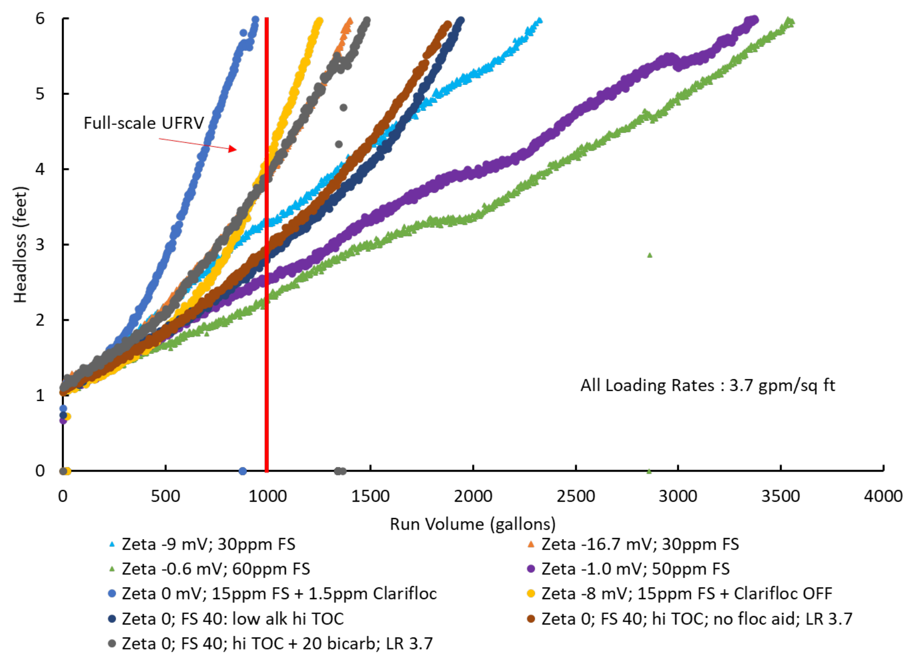


Figure 14 Filter 4 Headloss with Ferric Sulfate Coagulation

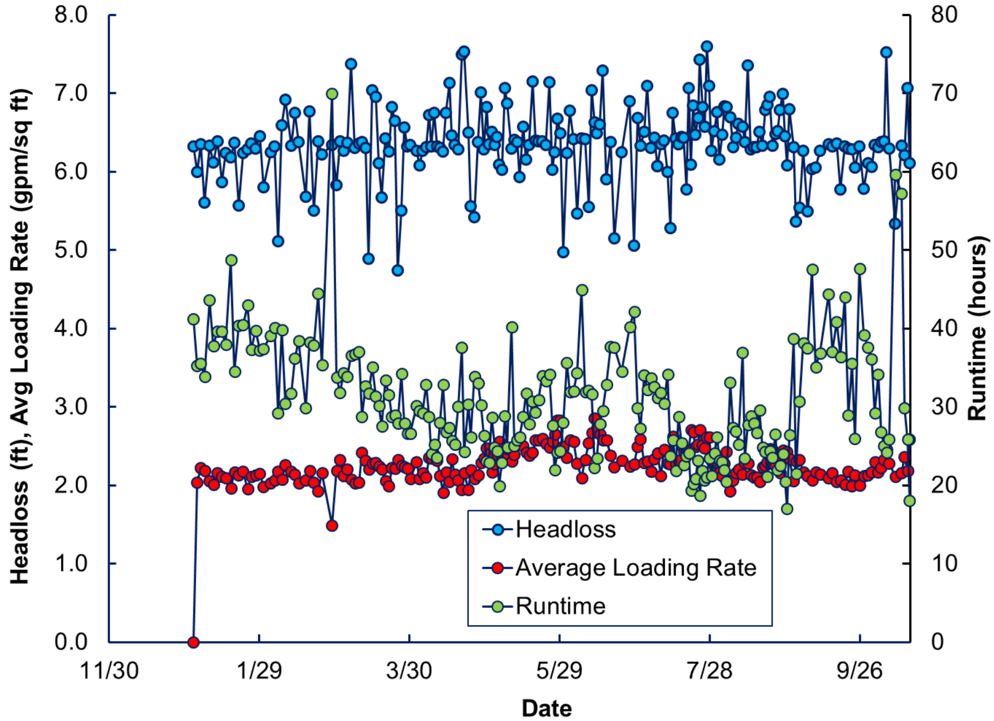


Figure 15 Full-scale Filter #24 Operations during pilot testing

1.3 Chlorine Demand/Decay, SDS, DBP

Three rounds of simulated distribution system (SDS) and DBP formation testing were performed. Tests included both free chlorine and monochloramine disinfection. The first two rounds (7/20 and 8/17) targeted 4 mg/L free chlorine at 10 min CT; the last round (10/12) targeted 2.75 mg/L free chlorine at 10 min CT, per request by COT. For both full-scale and pilot, samples did not exceed DBP MCLs with chloramination. Pilot samples disinfected with free chlorine stayed within MCLs for HAAs; however THM MCLs were exceed with free chlorine by day 3-5. Full-scale exceeded DBPs MCLs with free chlorine for each sample. Figure 16 through Figure 27 show the results of this testing.

1.3.1 Pilot Free Chlorine

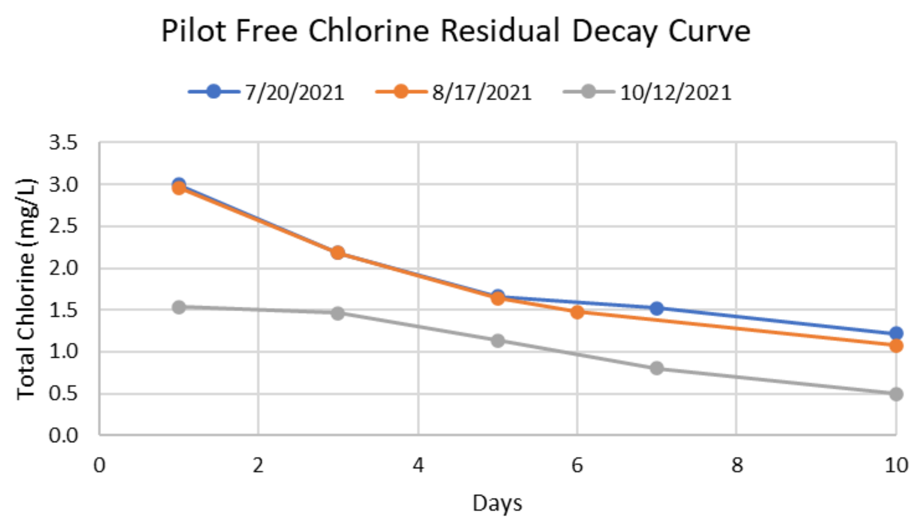


Figure 16 Pilot Free Chlorine Decay Curve

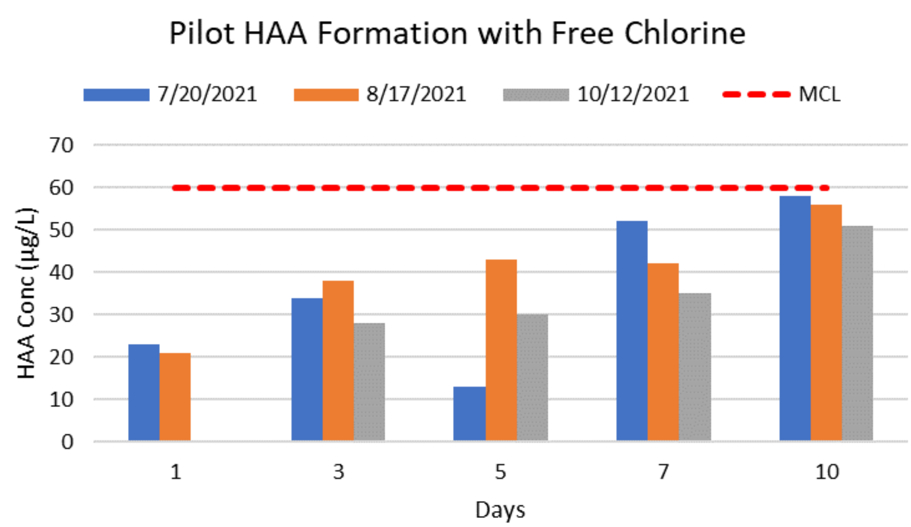


Figure 17 Pilot HAA Formation with Free Chlorine

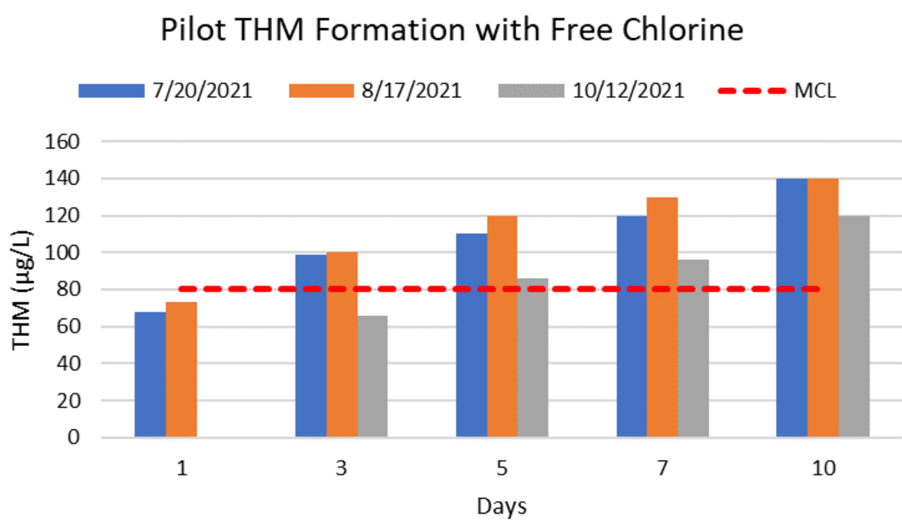


Figure 18 Pilot THM Formation with Free Chlorine

1.3.2 Pilot Chloramine

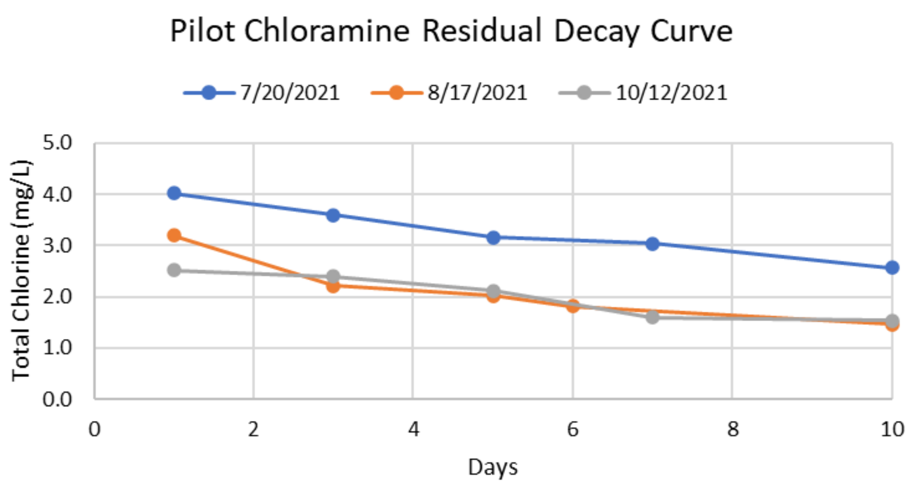


Figure 19 Pilot Monochloramine Decay Curve

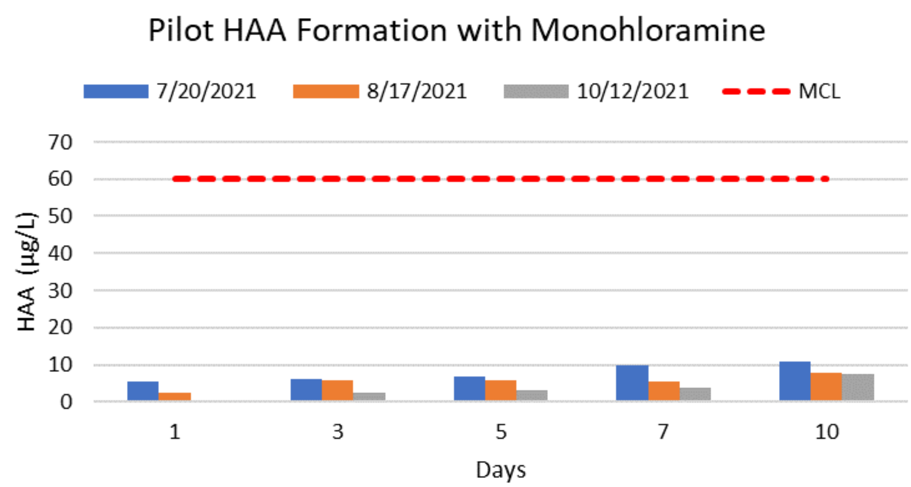


Figure 20 Pilot HAA Formation with Monochloramine

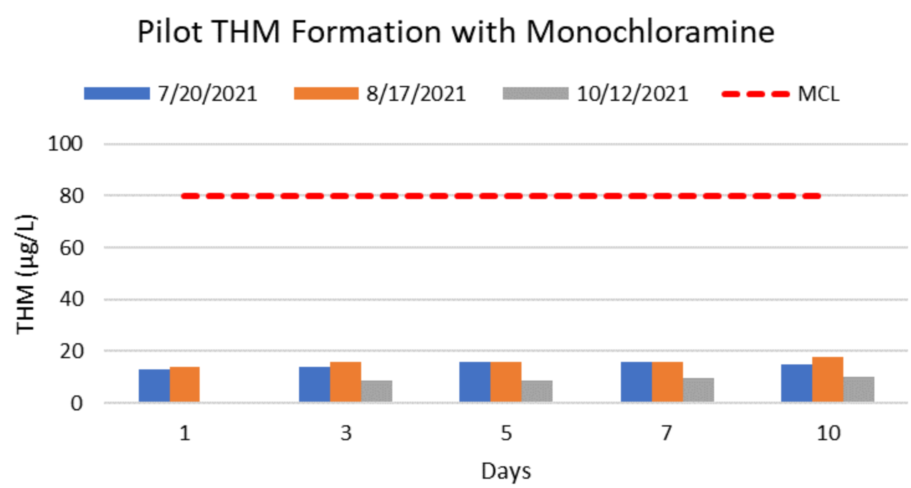


Figure 21 Pilot THM Formation with Monochloramine

1.3.3 Full-scale Free Chlorine

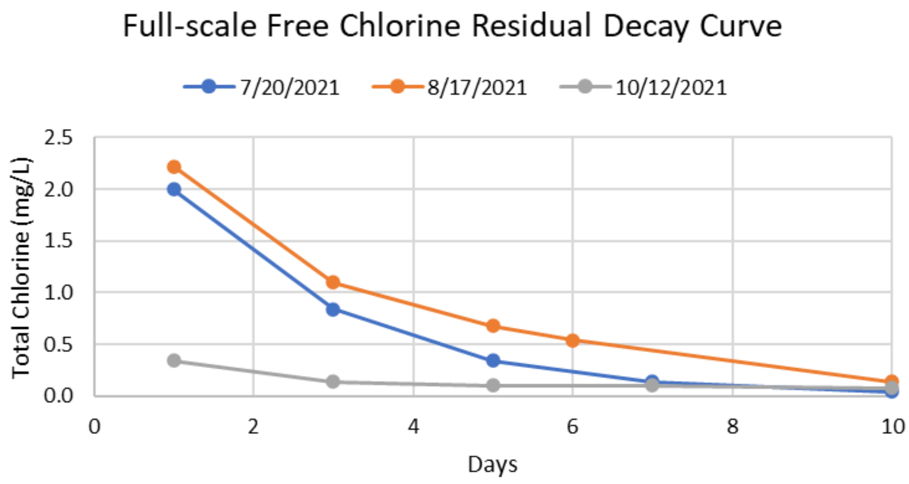


Figure 22 Full-scale Free Chlorine Decay Curve

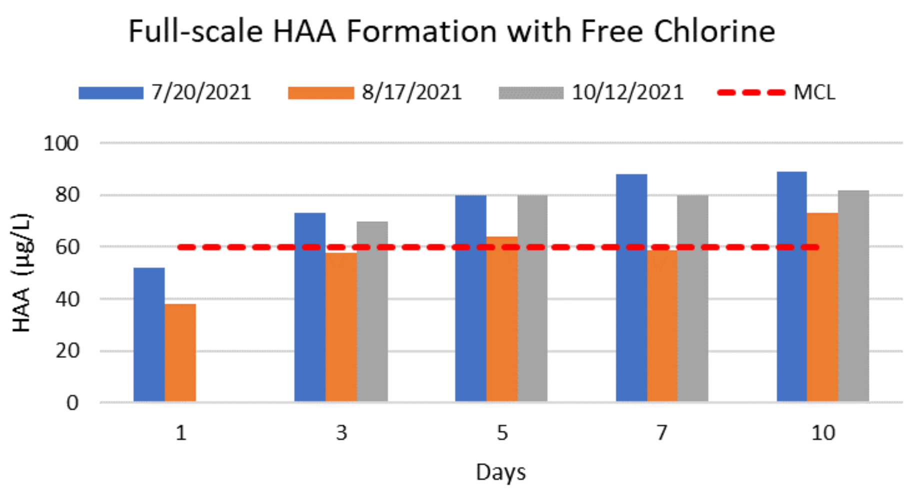
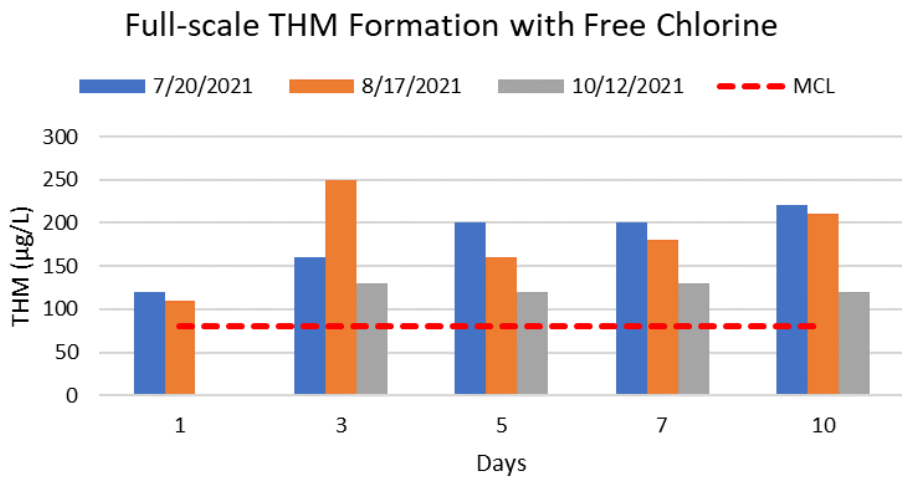


Figure 23 Full-scale HAA Formation with Free Chlorine



1.3.4 Full-scale Chloramine

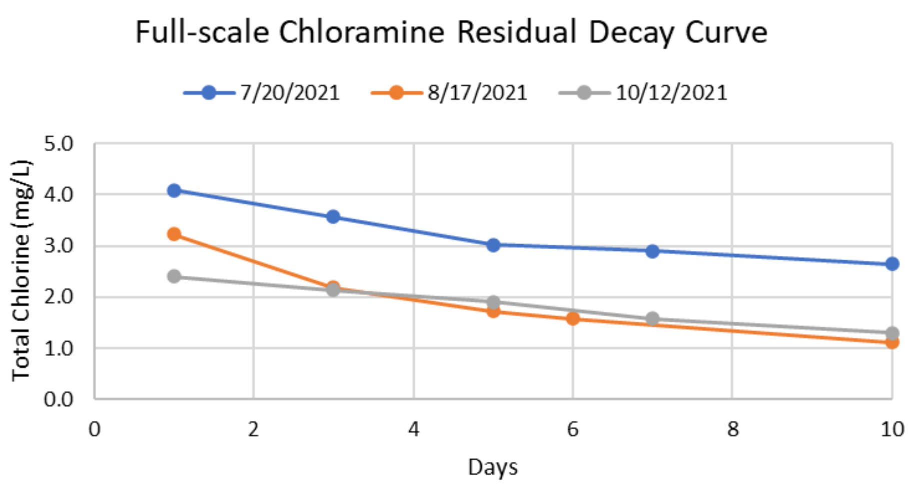


Figure 25 Full-scale Monochloramine Decay Curve

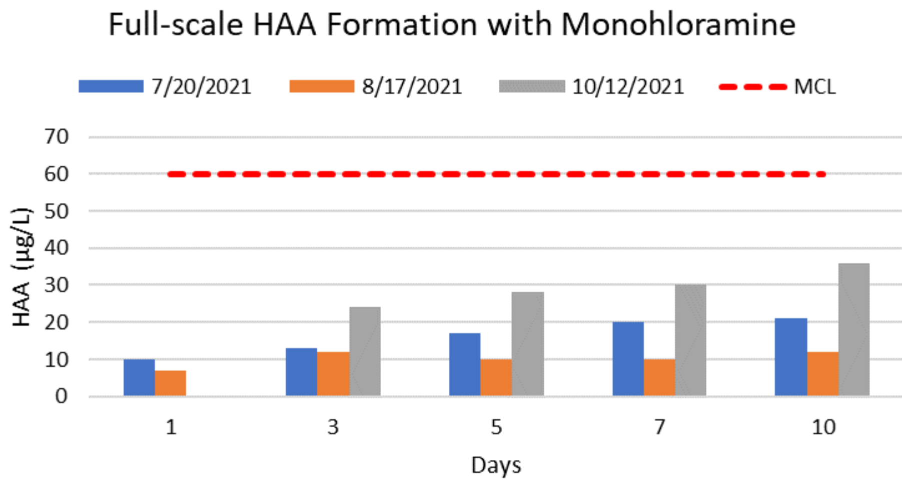
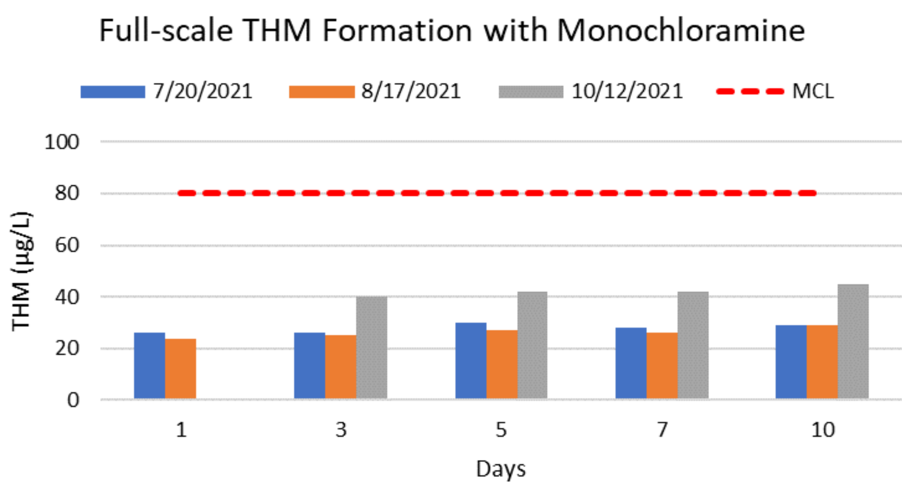


Figure 26 Full-scale HAA Formation with Free Monochloramine



1.4 Organics Speciation via LC-OCD

LC-OCD analysis was performed on 4 batches of samples from the SIX pilot. These samples were collected on December 28, 2020, April 12, July 14, and October 7, 2021. The RW TOC for these samples is summarized in Table 1. Methodology for the LC-OCD analysis is provided in Appendix B. A summary of the results of this testing can be found in Figure 28 through Figure 35.

Table 1 RW TOC from LC-OCD Sampling Events

	RW TOC (mg/L)
12/28/2020	13.1
4/12/2021	6.7
7/14/2021	27.3
10/7/2021	18.4

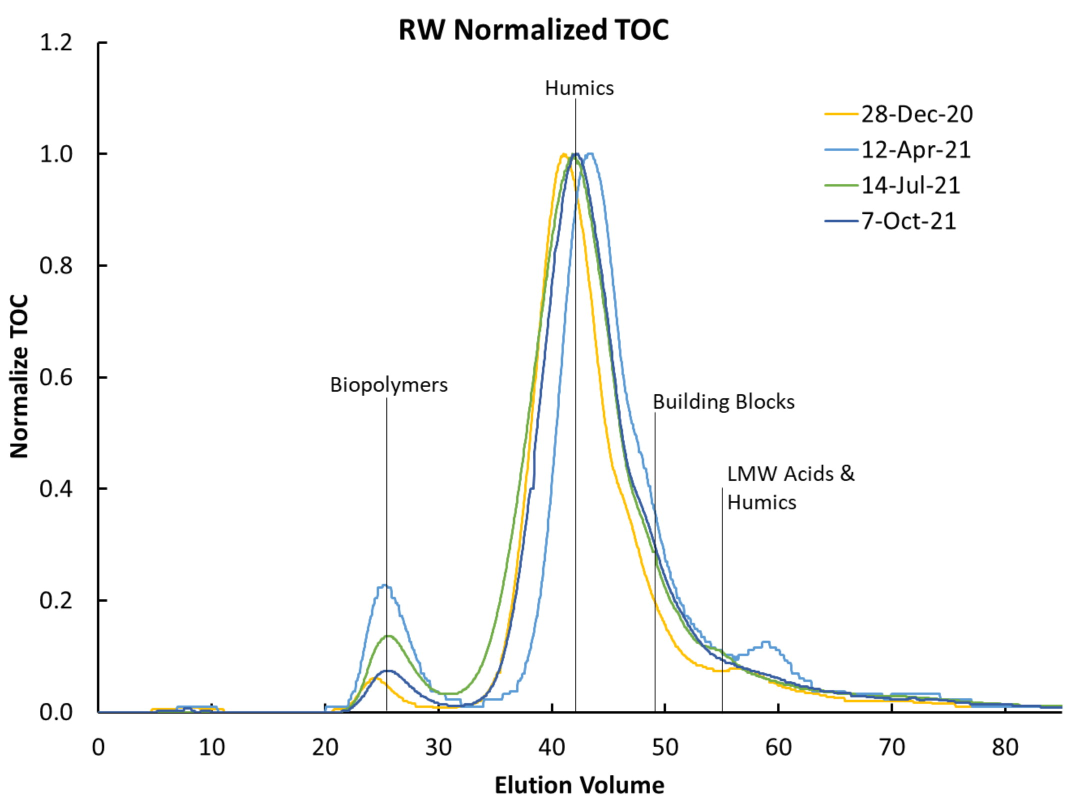


Figure 28 RW LC-OCD Results - Normalized to TOC

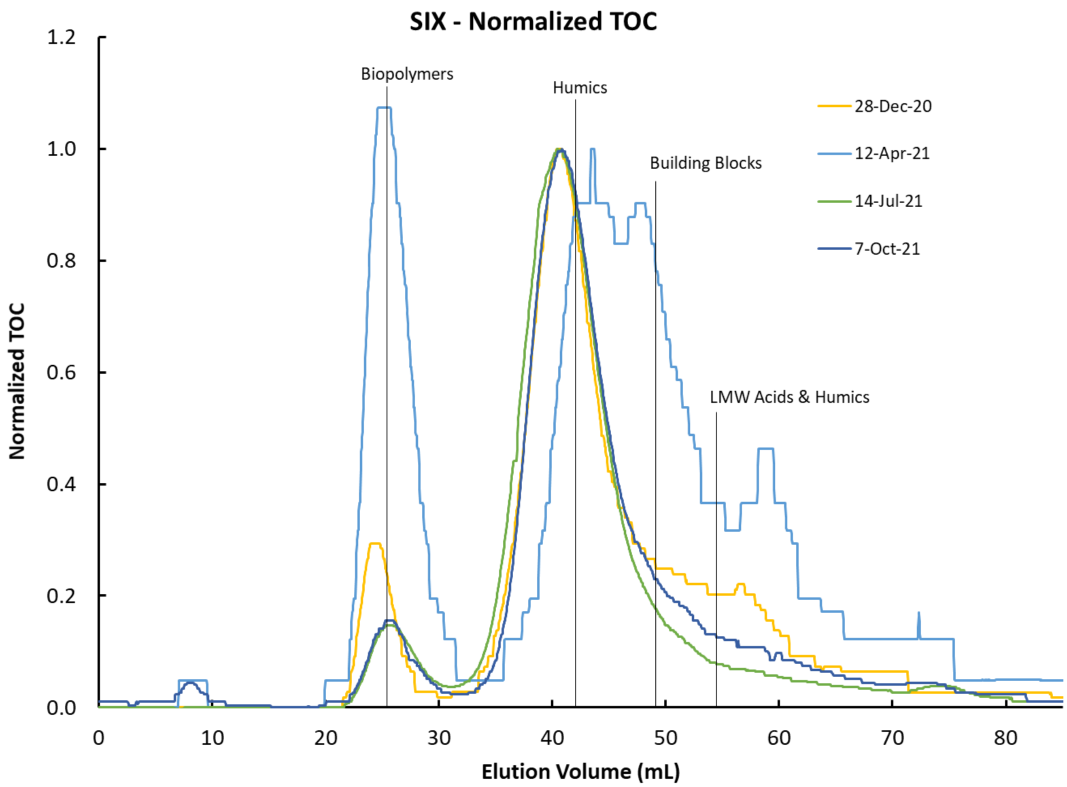


Figure 29 SIX effluent LC-OCD Results - Normalized to TOC. Note higher resolution in the April 12 sample is due to the much lower TOC during this time.

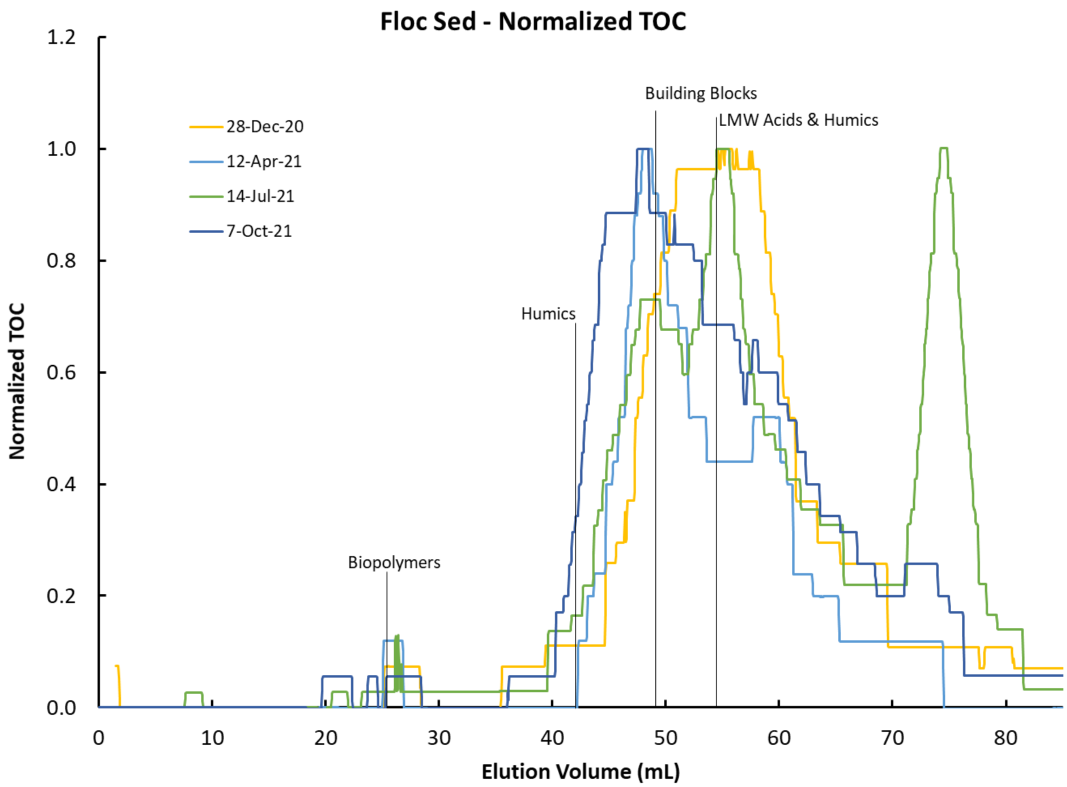


Figure 30 Pilot Floc/Sed LC-OCD Results - Normalized to TOC. Note that after IX and Coagulation, most of the humics have been removed.

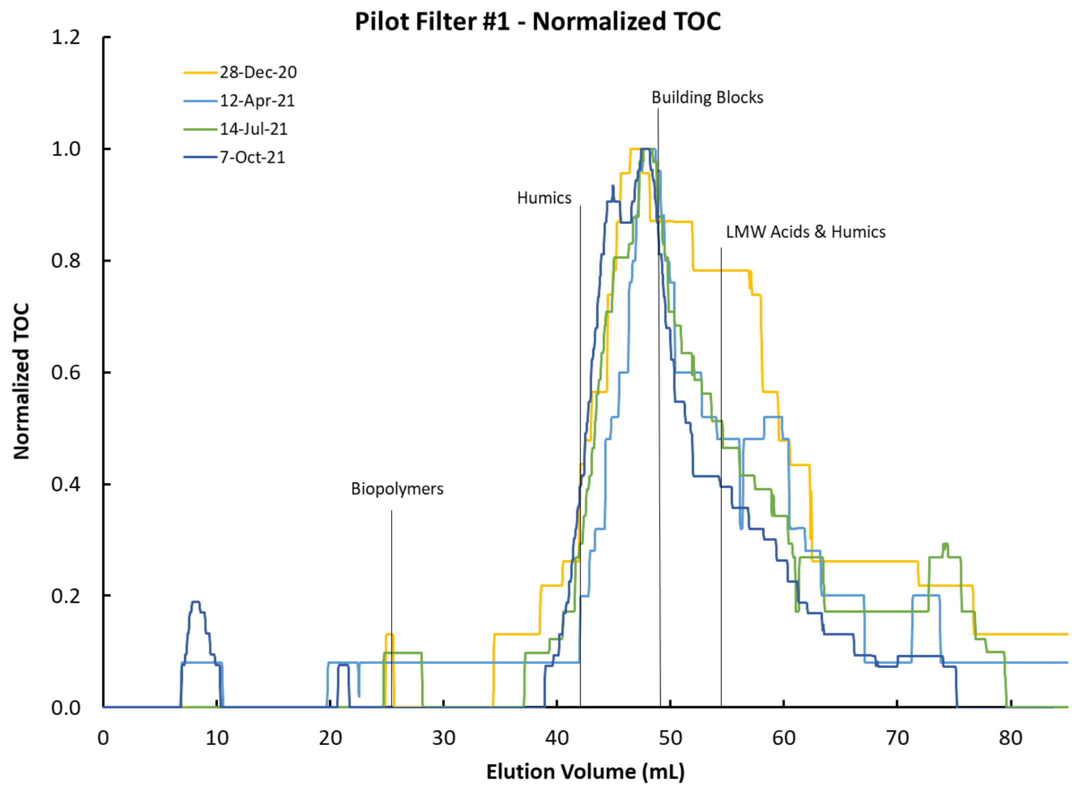


Figure 31 Pilot Filter LC-OCD Results - Normalized to TOC. Note that nearly all humics have been removed and organics remaining shift to predominantly building blocks and LMW acids.

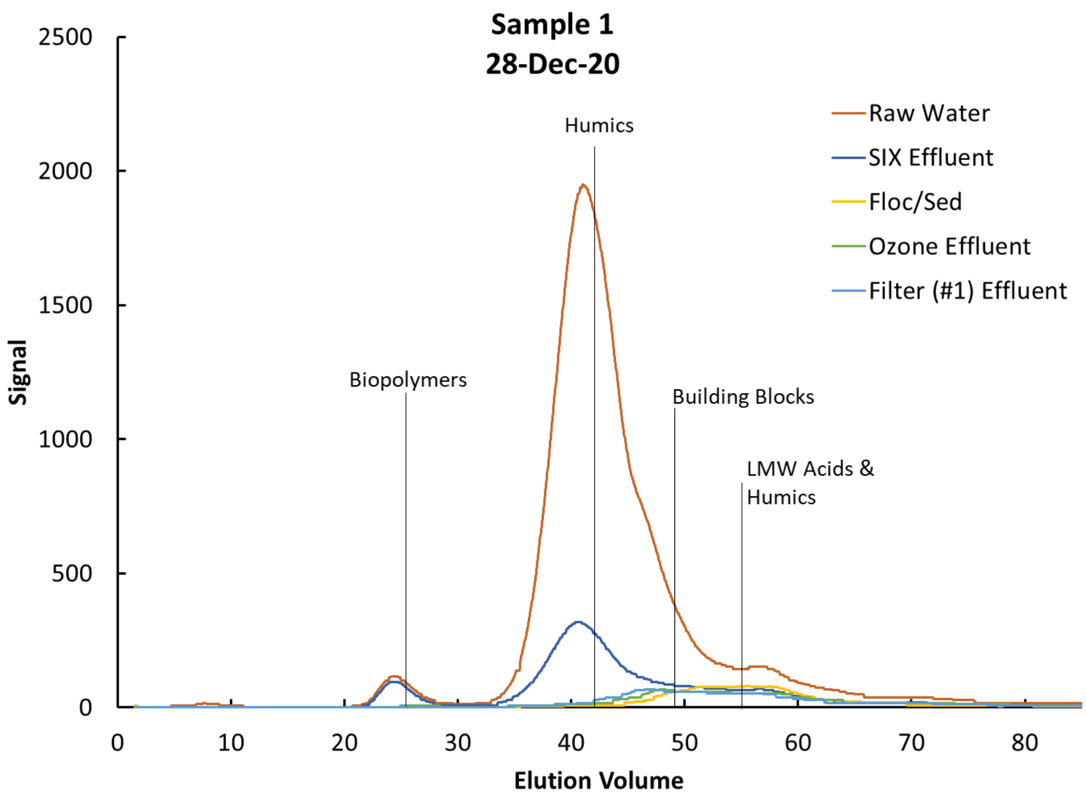


Figure 32 Sample 1 LC-OCD Results (12/28/20)

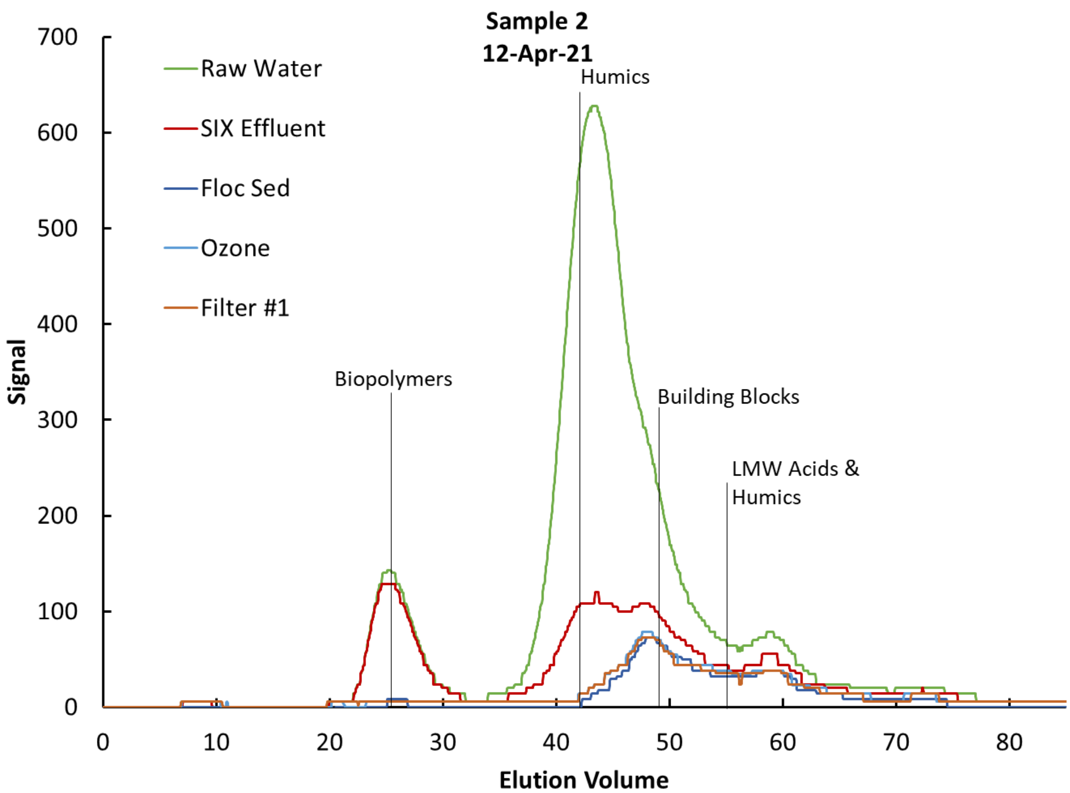


Figure 33 Sample 2 LC-OCD Results (4/12/21)

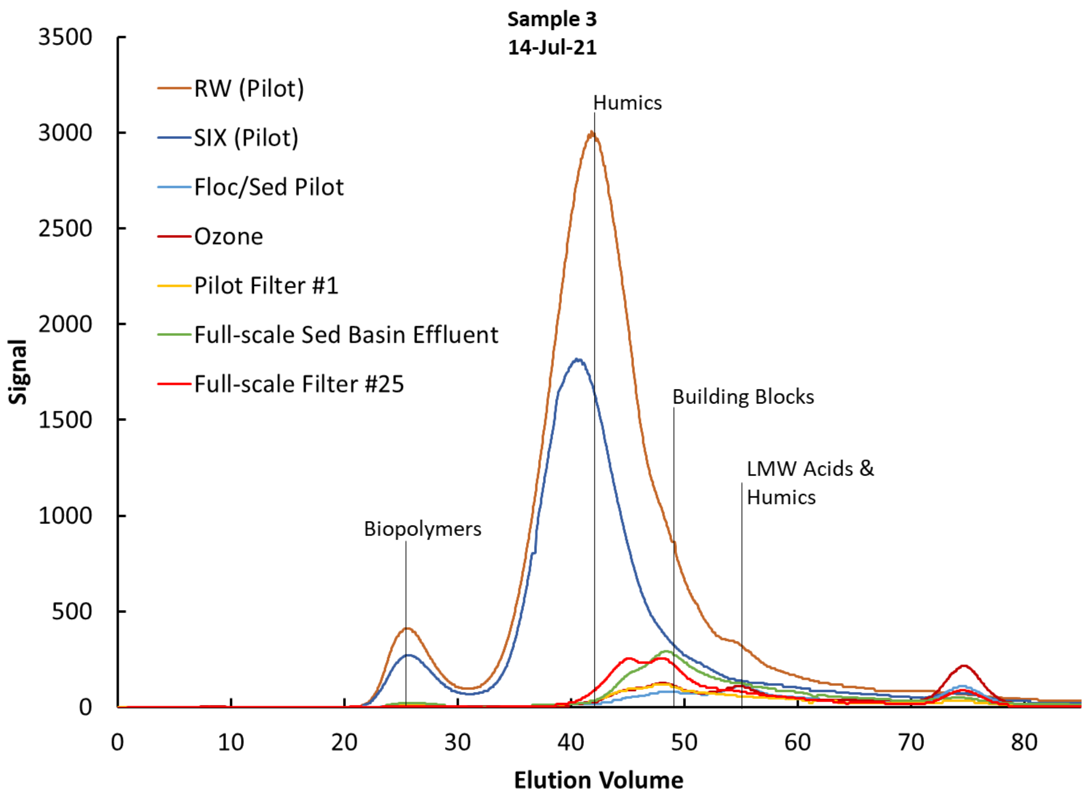


Figure 34 Sample 3 LC-OCD Results (7/14/21)

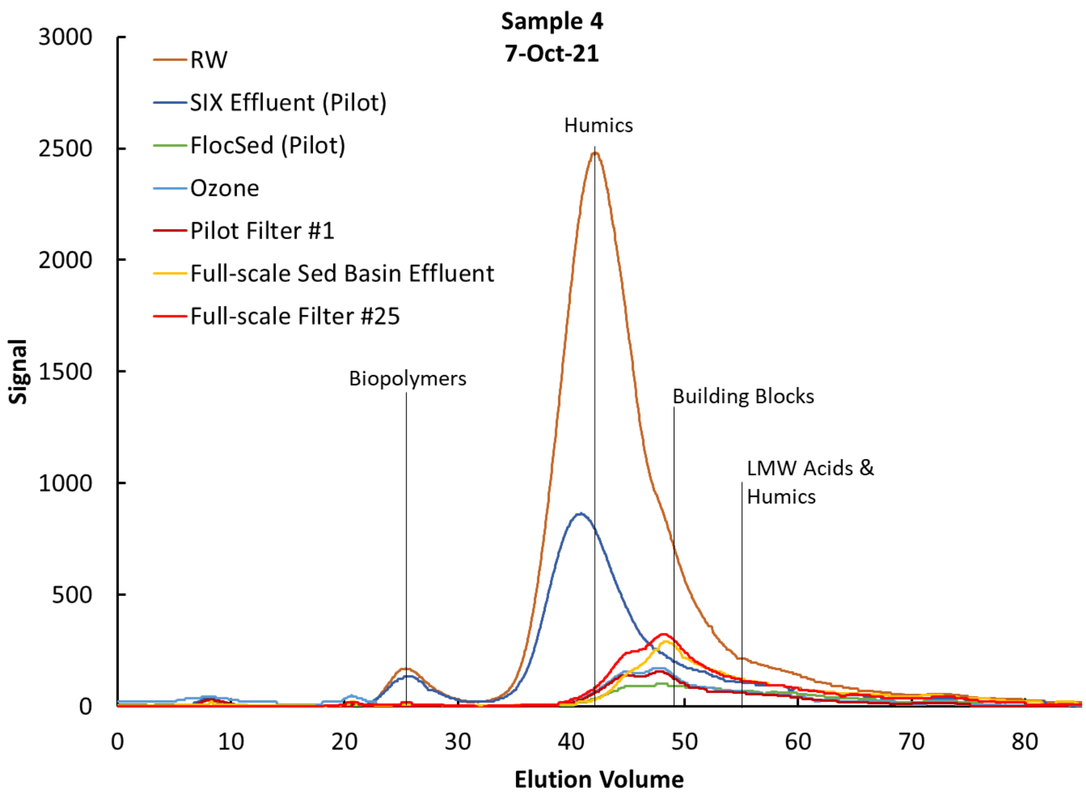


Figure 35 Sample 4 LC-OCD Results (10/7/21)

Appendix D

ALTERNATIVE RESIN TESTING

DLTWTP Upgrade

Alternative Resin Investigation Study

For Report – February, 2022

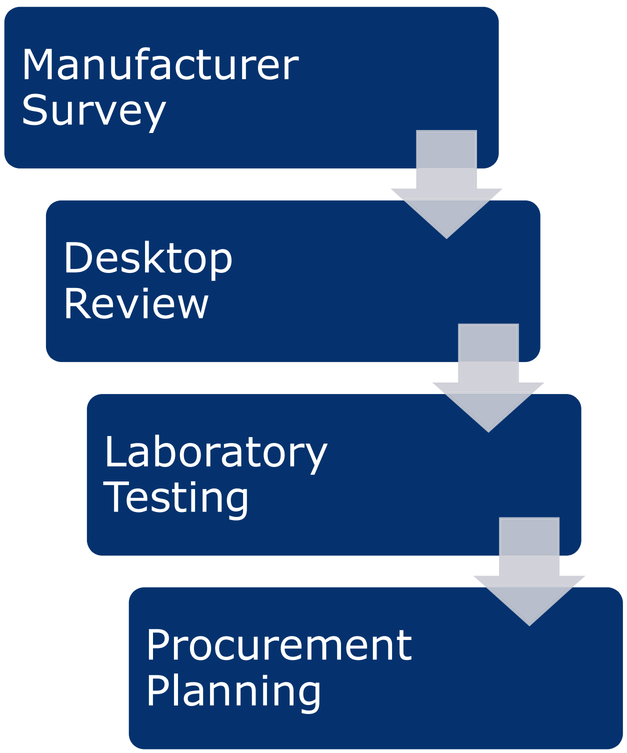
RAMBOLL

Bright ideas.
Sustainable change.

Presentation Overview

1. Investigation Scope
2. Manufacturer Survey
3. Technical Comparison
4. Supply Considerations
5. Procurement Approach

Investigation Scope



One of the key benefits of the SIX process developed by PWNT is the ability to use a wide range of ion exchange resins from different manufacturers. In the long term, this can provide the City with comfort that resin can be purchased into the future at a commercially reasonable price.

To date, the trial has used a type 1 strong base anion (SBA) resin provided by Lanxess. This resin has also been used in previous SIX projects in Europe. The resin has performed well, but there are technical and commercial reasons why the City should investigate alternative resins.

From a technical perspective, suitability of ion exchange resin can be evaluated to some extent based on a desktop review of technical specifications. However, testing is also recommended to ensure it meets the application needs. This may be a multi-step process, initially with bench testing, then followed by a pilot trial for either short duration (1 month) and/or longer period (12 months).

From a commercial perspective, the challenge is to design a procurement process that enables the City to purchase the right quantity/quality of resin at a fair price. Developing a procurement plan requires input on supplier availability, lead times, price. The initial resin order is likely to be an owner direct purchase, with estimated value of $4.5M.

Manufacturer Survey

Four resin suppliers were approached:

- Lanxess
- Du Pont
- Purolite
- Graver

The survey sought responses to a written questionnaire to be completed by suppliers, covering:

- Ability to supply a resin with same (or similar) specifications to the resin already piloted
- Recommendation for alternative resin(s) for this application
- Supply chain considerations
- Budget pricing

In addition to the written questionnaire, Ramboll conducted a short teleconference with each supplier before and after the questionnaire to enable two-way information sharing about the project.

The Piloted Resin – Lanxess S5128

Lanxess S5128 is a Type 1 strong base anion (SBA) resin.

The resin was chosen for piloting because it had been used in two previous SIX installations in Europe.

In 2021, the produce was certified against ANSI/NSF Standard 61 for use in drinking water systems.

Supplier	Lanxess
Product Name	S5128
Delivery Form	Cl-
Functional Group	Quat Ammonium Type I
Matrix	Acrylic DVB
Structure	Gel
Uniformity Coefficient	1.8
Effective Size	500-750 micron (D10)
Fines (max)	0.5% max (<315)
SG	1.09
Shipping Weight	730 g/L ± 5%
Total Capacity	>1.35 eq/L
Moisture Retention	48-55%
Stability	0-14 pH

Similar Resins – Acrylic Gel SBA

All resin suppliers were able to supply a gel-based Type I SBA resin with similar properties to the Lanxess S5128 resin.

The fundamental resin chemistry will be the same between the resins. This means that the resins should will have similar specific gravity and chemical resistance.

However some properties will vary, most importantly the cross-linking density. This will affect the total capacity and moisture retention in the resin beads. Resin particle size specification varies between manufacturers. In principle, smaller beads will have a relatively higher surface area, and so improved kinetics.

Supplier	Lanxess	Du Pont	Purolite	Graver
Product Name	S5128	PWA12	A850	GX330
Delivery Form	Cl-	Cl-	Cl-	Cl-
Functional Group	Quat Ammonium Type I	Quat Ammonium Type I	Quat Ammonium Type I	Quat Ammonium Type I
Matrix	Acrylic DVB	Acrylic DVB	Acrylic DVB	Acrylic DVB
Structure	Gel	Gel	Gel	Gel
Uniformity Coefficient	1.8	<1.9	1.7	1.6
Effective Size	500-750 micron	600-900 micron	300-1200 micron	500-750 micron
Fines (max)	0.5% (<315)	<2% (<300)	NS	0.5% (<315)
SG	1.09	NS	1.09	1.09
Shipping Weight	730 g/L ± 5%	730	680-730 g/L	730 g/L ± 5%
Total Capacity	>1.35 eq/L	≥ 1.25 eq/L	1.2 eq/L	1.2 eq/L
Moisture Retention	48-55%	57-64%	57-62%	55-65%
Stability	0-14 pH	0-14 pH	0-14 pH	0-14 pH
Certification?	ANSI/NSF61	ANSI/NSF61	ANSI/NSF61	Not yet

Alternative Resins

Resin suppliers were asked whether they could recommend an alternative resin to trial, either on the basis of improved performance and/or lower cost.

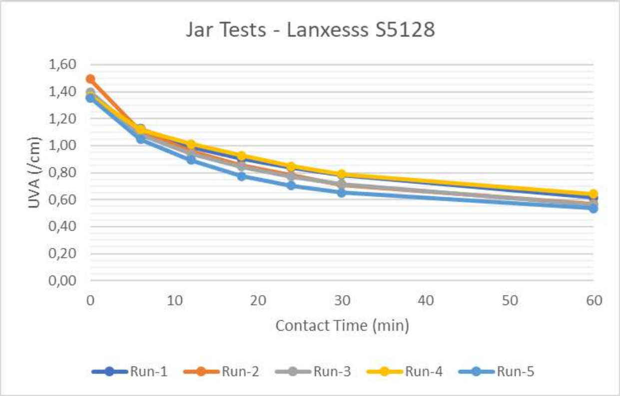
Du Pont offered a slightly larger acrylic gel resin that has been piloted successfully previously with SIX.

Macroporous resins have been widely used for organics removal applications. However macroporous resins have not been trialled long term in the SIX process and so there is some uncertainty around the long term robustness of the bead in this application.

Globally, the production of acrylic resins depends on a single supplier of acrylic monomer. Purolite proposed the use of a styrene-based resin. This would potentially reduce cost, and also improve supply chain robustness.

Product	Lanxess	Du Pont	Purolite	Purolite
Product Name	S5128	PWA12 RF	A860	A502P
Delivery Form	Cl-	Cl-	Cl-	Cl-
Functional Group	Quat Ammonium Type I	Quat Ammonium Type I	Quat Ammonium Type I	Quat Ammonium Type I
Matrix	Acrylic DVB	Acrylic DVB	Acrylic DVB	Styrene-DVB
Structure	Gel	Gel	Macroporous	Macroporous
Uniformity Coefficient	1.8	<1.8	1.7	1.7
Effective Size	500-750 micron	700-1000 micron	300-1200 micron	300-1200 micron
Fines (max)	0.5% (<315)	0.5% (<365)	NS	NS
SG	1.09	NS	1.08	1.04
Shipping Weight	730 g/L ± 5%	730	680-730 g/L	640-690 g/L
Total Capacity	>1.35 eq/L	≥ 1.25 eq/L	0.8 eq/L	0.85 eq/L
Moisture Retention	48-55%	57-64%	66-72%	66-72%
Stability	0-14 pH	0-14 pH	0-14 pH	0-14 pH
Certification?	ANSI/NSF61	Not yet	ANSI/NSF61	ANSI/NSF61

Similar Resins



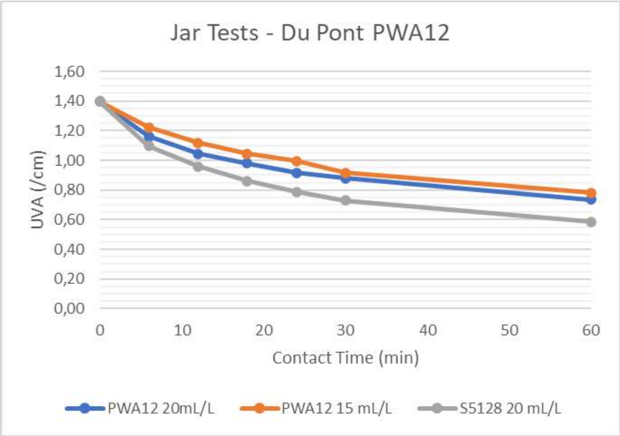
Resin samples were obtained from Du Pont and Purolite for testing.

Process performance was assessed with jar test conducted at Ramboll laboratories in Syracuse. The jar test method was validated against performance at the pilot. Process performance was compared using UV-absorbance as a surrogate for TOC, consistent with the pilot. Final pH was measured to determine if there was any difference in alkalinity removal.

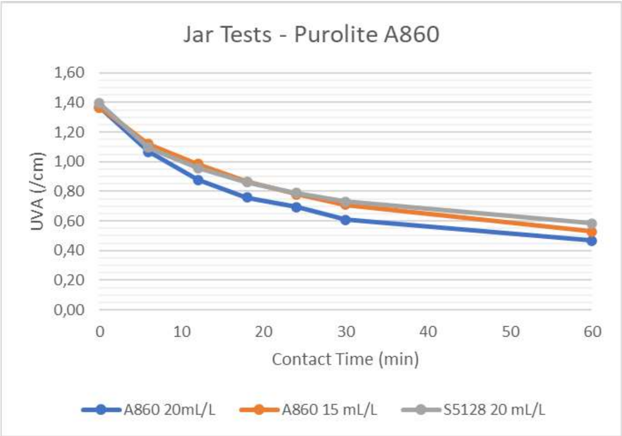
Raw water for the test was sourced from DL Tippin WTP in August 2021, during peak TOC season (TOC 28.7 mg/L). The graph on the left illustrates the results of 5 repetitions of the test at a dose rates of 20 mL/L, using S5128 resin. There is some variability between sample runs, due to issues such as subsampling and measurement variability.

Resins were also examined by microscope, and settling tests were measured and calculated.

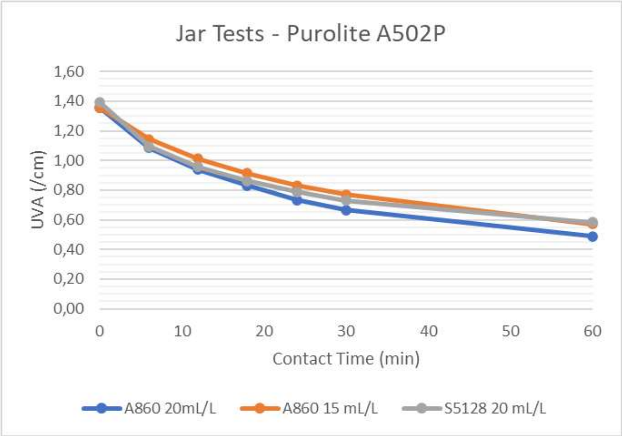
Alternative Resin Testing



- Du Pont PWA12 performed worse than the S5128 for UVA removal.
- This may be due to the larger particle size (smaller surface area)



- Purolite A860 performed better than the S5128 for UVA removal
- This may be due to the macroporous structure and/or the higher water content.



- Purolite A502P performed better than the S5128 for UVA removal, and similar to A860
- This may be due to the macroporous structure and/or the higher water content.

Resin Testing Outcomes

Product	Lanxess	Du Pont	Purolite	Purolite
Product Name	S5128	PWA12 RF	A860	A502P
Difference to S5128	N/A	Larger bead size	Macroporous	Styrenic macroporous
UVA Removal (20 mL/L, 30 min)	48%	37%	56%	51%
UVA Removal (15 mL/L, 30 min)	37%	34%	48%	43%
Final pH (20 mL/L, 30 min)	6.8	6.4	6.0	6.0
Final pH (15 mL/L, 30 min)	6.6	6.5	6.1	6.3
Mechanical	Acceptable	Acceptable	Potential higher risk of attrition	Potential higher risk of attrition

The Du Pont PWA12 RF appeared to remove fewer organics than S5128, which was surprising given that resin should be similar, although with a larger bead size.

The two macroporous resins tested showed significantly better performance. However it is uncertain whether this performance would be maintained over time, or whether there would be additional resin attrition in long term operation.

Supply Considerations

Ion exchange resin pricing is influenced by systematic and specific factors such as:

- increase in transport costs (eg current shipping price surcharges)
- changes in tariffs (eg current tariffs imposed on imports from China)
- raw material costs
- incidents at production facilities.

Being able to purchase resin from multiple suppliers can reduce exposure to the risk.

Typical lead time for an order of this quantity would be 6-12 months.

To mitigate risks of delays in production or shipping, it is recommended to place the resin order 12-18 months prior to commencement of commissioning.

Budget resin prices ranged from \$5-\$8/L delivered Tampa.

Some suppliers indicated that further volume discounts could be obtained through a competitive tender process, with firm order quantity and timeline.

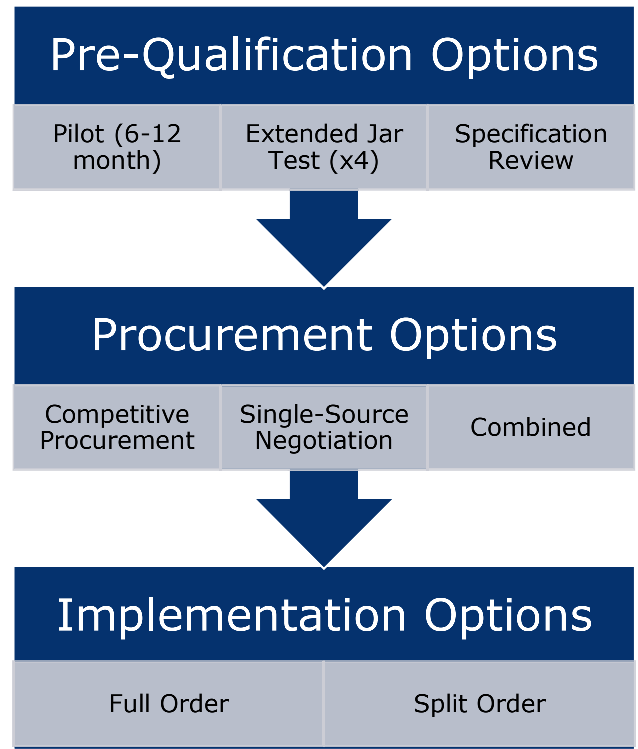
Procurement Options

The Lanxess S5128 resin performed acceptably through pilot. This resin is the lowest risk choice because of the experience in the Tippin pilot (12 months) and operating track record in other systems since 2012.

Gel SBA resins with similar particle size profiles are likely to perform adequately. It would be possible to run a competitive tender process with a specification, including tight requirements for particle size. Performance risk could be reduced further by conducting either additional jar tests at different seasons, and/or a pilot of alternative resins.

Choosing a different resin type would introduce significantly greater risks. It is not recommended to proceed with this approach without piloting for at least 6-12 months.

The SIX process is typically designed with separate trains. This enables different resins to be loaded into different trains. As an alternative to additional pre-qualification testing prior to tender, it may be prudent for the City to split the order, with 1 or more trains being filled with an alternative resin.



Report Summary

The pilot trial ran for almost 12 months using the Lanxess S5128 resin, which is a gel strong-base anion resin. This resin is the lowest risk choice because of the experience in the Tippin pilot (12 months) and operating track record in other systems since 2012.

Jar trials conducted in August 2021 demonstrated that system performance will vary depending on resin characteristics.

Gel SBA resins with similar chemistry and particle size profiles are likely to perform adequately. Performance risk could be reduced further by conducting either additional jar tests at different seasons, and/or a pilot of alternative resins. Choosing a different resin type (eg a macroporous styrenic resin) would introduce greater risks. It is not recommended to proceed with this approach without piloting for at least 6-12 months. Resin procurement strategy should be considered further during design phase.