Weston & Sampson

westonandsampson.com

5 Centennial Drive
Peabody, MA 01960 (HQ)
tel: 978.532.1900

REPORT

September 2018

CITY OF
Portsmouth
NEW HAMPSHIRE

Haven Well Pilot Testing Program

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The City of Portsmouth (City) is currently working with Weston & Sampson to design a water treatment facility to remove perfluoroalkyl substances (PFAS) from water supplied by the Harrison, Smith, and Haven Wells. To facilitate an appropriate final design, Weston & Sampson and the City have implemented a pilot study at the Haven Well, set up and operated by ECT2, to compare two different water treatment processes, Granular Activated Carbon (GAC) and ion exchange resin. The concentrations of PFAS contaminants in both raw and treated water were compared over various contact times for both filtration processes.

The primary goal for this study was to confirm the effectiveness of GAC and resin media in the removal of contaminants for the high PFAS concentrations seen in the Haven Well. This work is being performed separately from the full scale GAC demonstration study on going at the Grafton Road Facility.

Initially a 10-week pilot study, the study was extended to obtain further data on resin performance. The time extension was concurrent with a reduction in the frequency of PFAS sampling. Pilot testing demonstrated that the resin media, which uses adsorption and ion exchange to remove contaminants, was a more efficient process in comparison to the GAC which uses only adsorption. The use of resin media resulted in higher removal of contaminants within a shorter contact period. The final plant design should include the use of resin filtration as the primary means of PFAS removal, followed by GAC polishing in the event of resin breakthrough.

During the pilot study, high levels of iron were found on the tubing between the filter columns. As iron and manganese have historically been low during normal activity at the Haven Well, this recent iron buildup was likely due to corrosion of the well casing associated with inactivity of the well. Should the iron accumulation be caused by another means, or should the groundwater chemistry change due to site remediation efforts, the resin supplier is requiring 10 μm prefiltration to warranty the performance of the resins. Weston & Sampson will include 10 μm cartridge filters in the final plant design to remove this particulate material.

Each type of PFAS compound contains a unique internal chemistry; one specific example includes chain length of the carbon-fluorine backbone. Data from the pilot study showed that chain length plays a major role in contaminant removal. Long chain contaminants, those with a greater number of C-F bonds, are better candidates for adsorption as they have a larger surface area to sorb to the filtration media. It was also evident from the data that PFAS contaminants with sulfonated head groups are better candidates for ion exchange versus contaminants with carboxyl head groups.

1.0 INTRODUCTION

1.1 General

In April 2014, the United States Air Force (USAF) and its contractors conducted water quality sampling of several of the City of Portsmouth's drinking water supply wells after high levels of per- and poly-fluoroalkyl substances (PFAS) were identified in the groundwater at the former Pease Air Force Base. The Pease Tradeport Drinking Water System receives drinking water from three different wells: Harrison, Smith, and Haven. Testing results indicated that two of the PFAS, perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) were detected above EPA's provisional health advisory levels in the Haven Well. In May 2014, the City of Portsmouth (City) was notified of these results and discontinued the use of the Haven Well from service. Monitoring of the City's water supply wells and nearby groundwater has been ongoing since that time. In May 2016, the EPA established a lifetime health advisory of 70 parts per trillion (ppt) for individual or combined levels of PFOS and PFOA.

In an effort to return the Haven well to service, pilot studies have been performed on the three different wells in order to determine the most efficient water treatment process. The Haven Well pilot study was performed (October 2017 - June 2018) to compare two different water treatment processes, GAC (Granular Activated Carbon) and ion exchange resin, to test media performance on the higher PFAS concentrations seen in the Haven Well water (average Total PFAS around 3.26 μg/L). ECT2 was retained by Weston & Sampson to conduct the pilot study to obtain data for the final design. Analyses were run for 23 PFAS compounds, but only 12 were consistently present in the raw water. Compounds included PFOS, PFOA, PFNA, PFHxA, PFHpS, PFHpA, PFBS, PFBA, PFPeA, PFHxS, 6:2 FTS, and 8:2 FTS. Based on the current EPA health advisories, final concentrations of PFOS, PFOA, and combined PFOS and PFOA were focused on to confirm removal of the contaminants. This report summarizes the results of the pilot testing at the Haven Well.

1.2 Pease Water System

The Pease International Tradeport (Tradeport) is home to commercial and industrial developments with over 250 companies and is continuing to grow. The near 10,000 employees in this area create a significant daytime water demand. The Tradeport and some abutting residential areas in Newington make up the Pease Pressure Zone. Current average day demand (ADD) is approximately 0.6 MGD. The City reports that the current maximum day demand is approximately 1.2 MGD for the Pease Tradeport Water System. The 600,000-gallon Hobbs Hill tank with an overflow elevation of 230 feet is used as the controlling tank in the Pease Pressure Zone.

The City of Portsmouth's Harrison, Smith, and Haven municipal wells have historically provided drinking water to the Tradeport system. In addition, portions of Newington were connected to the Tradeport in 2014 at the Town's request to increase water pressure in their community. The Tradeport supply is supplemented through the Pease booster pumps, which are connected to the City's main pressure zone. All of these sources are piped through the Pease WTP at Grafton Road. Since the PFAS contamination of the Haven Well was discovered in May 2014, the City has been using these booster pumps to blend water in the Pease Pressure Zone, initially combining GAC filtered water from the Harrison and Smith Wells at approximately 50% of flow with water from the City's other surface and groundwater sources providing the remaining 50% of flow. When the activated carbon demonstration filters for the Harrison and Smith Wells were brought into service in September 2016, the supply parameters were set so that the two wells provide 400 gpm of flow to the system, with the remainder of the system demand provided by water pumped from the Portsmouth Water System.

1.3 Source Water Quality

Currently, water from the Harrison and Smith Wells is filtered through the demonstration GAC filters, located at the Pease WTP, which went into service September of 2016. After filtration, sodium hypochlorite (disinfection), hydrofluorosilicic acid (cavity prevention), and an ortho/polyphosphate blend (corrosion control) are added. The Harrison and Smith Wells currently supply the Pease Pressure Zone with drinking water that meets federal and state drinking water regulatory standards; the Haven Well is currently offline. Prior to the detection of PFAS in this well, the Haven Well also met all drinking water standards.

In November 2016, the Haven Well was pumped to allow for additional water chemistry sampling. The water was stored in two 20,000-gallon frac tanks and slowly discharge to the ground after being run through a temporary GAC filter. Table 1-1 summarizes the water quality for parameters of interest and concern for all three of the Tradeport Wells. Water quality testing has discovered the presence of PFAS in all three of these wells, with the Haven Well exceeding the current lifetime health advisory level set by the EPA for combined PFOS and PFOA at 0.07 ppb. The PFOS and PFOA levels in the Harrison and Smith Wells have been consistently measured at levels below the lifetime health advisory level. PFOS and PFOA results are listed in Table 1-2. Several other PFAS are also found in very low levels in all of the wells.

1.4 Scope of Services

The scope of services for this project included the following tasks:

1. Obtain the services of ECT2 to construct a pilot unit with the equipment necessary to perform testing of the Haven Well water.
2. Provide pilot start up, operational, sampling, and reporting services for a 10-week period of piloting at the Pease WTP site for treatment of the Haven Well and as detailed below. The pilot was extended after no significant PFAS breakthrough of the resin media had occurred during the initial 10-week period.

   a. Perform installation and mobilization of the pilot equipment including columns filled with filter media, pumps, flow meters, valves, miscellaneous parts and materials as required.
   b. Provide a 55-gallon drum of GAC to ensure the removal of all PFAS from the final column testing effluent.
   c. Provide initial startup and operation of the pilot plant, including calibration.
   d. Perform routine field water quality sampling for PFAS compounds.
   e. Assist in the removal of pilot plant at the completion of the study and clean the area.
3. Prepare and submit the pilot report to the City. The report shall include:
   a. A summary of all tasks completed for the pilot testing.
   b. Results of all field and laboratory tests, data and calculations.
   c. Findings, conclusions, and comparison of the performance of GAC and resin treated water.

Table 1-1 Historic Water Quality Parameters, All Wells

Constituent	Units	Harrison	Smith	Haven
Alkalinity	*mg/L*	108 (4)	130 (3)	160 (1)
Arsenic	*mg/L*	ND (2)	ND (2)	ND (1)
Calcium	*mg/L*	34 (2)	57 (2)	55 (1)
Chloride	*mg/L*	30 (2)	80 (2)	49 (1)
Conductivity	*µmhos/cm*	0.35 (27)	0.52 (27)	-
Hardness	*mg/L*	101 (2)	183 (2)	180 (1)
Iron	*mg/L*	0.05 (2)	0.08 (2)	0.1 (2)
Manganese	*mg/L*	ND (2)	ND (2)	0.3 (3)
Nitrate/Nitrite	*mg/L*	1.2 (1)	1.5 (1)	ND (1)
pH	-	7.4 (*)	7.7 (*)	7.4 (*)
Combined Radium	*pCi/L*	ND (1)	ND (1)	ND (*)
Gross Alpha	*pCi/L*	ND (1)	ND (1)	-
Radon	*pCi/L*	1043 (1)	769 (1)	1200 (1)
Uranium	*µg/L*	0.71 (1)	0.79 (1)	ND (1)
SVOC	*µg/L*	ND (2)	ND (2)	ND (1)
Sulfate	*mg/L*	17 (2)	15 (2)	15 (1)
TDS	*mg/L*	230 (2)	360 (2)	260 (1)
TOC	*mg/L*	<0.5 (5)	<0.5 (5)	<0.5 (3)
True Color	*CU*	ND (1)	ND (1)	-
Turbidity	*NTU*	ND (1)	ND (1)	ND (1)
VOC	*µg/L*	ND (2)	ND (2)	ND (1)

* - Historic Result, unknown number of samples collected
(#) - Number of samples the average is derived from

Table 1-2 – Haven Well PFOA and PFOS Concentrations

Sampling Date	Units	PFOA	PFOS
16-Apr-2014	*µg/L*	0.35	2.5
14-May-2014	*µg/L*	0.32	2.4
16-Nov-2016	*µg/L*	0.27	1.0
28-Nov-2016	*µg/L*	0.32	1.4
Pilot Average*	*µg/L*	0.24	1.3

* - Average of 14 pilot samples collection between 11/1/2017 and 6/28/2018; full results are located in Appendix B.

2.0 PILOT TESTING PROGRAM

2.1 General

This pilot study was conducted from October 2017 to June 2018. As previously noted, the primary purpose of the pilot testing was to compare the performance of two different water treatment filtration processes, Granular Activated Carbon (GAC) and ion exchange resin. By comparing the two treatment processes, Weston & Sampson could subsequently compare the raw water PFAS concentrations with concentrations after filter contact times of 2.5, 5, 7.5, and 10 minutes. Sample analysis results were graphed over time to show side by side performance of the two filter media.

The pilot test began on 10/27/2017 and terminated on 6/30/2018. Initially a 10-week pilot study, the study was extended with reduced sampling to obtain further data on resin performance. PFAS was initially sampled weekly by ECT2 staff. Sample locations included the raw Haven Well water and the 2.5, 5, 7.5, and 10-minute empty bed contact time (EBCT) for both treatment processes. A schematic of the Haven Well pilot study is shown in Figure 2-1.

Haven Well Pilot Testing Program

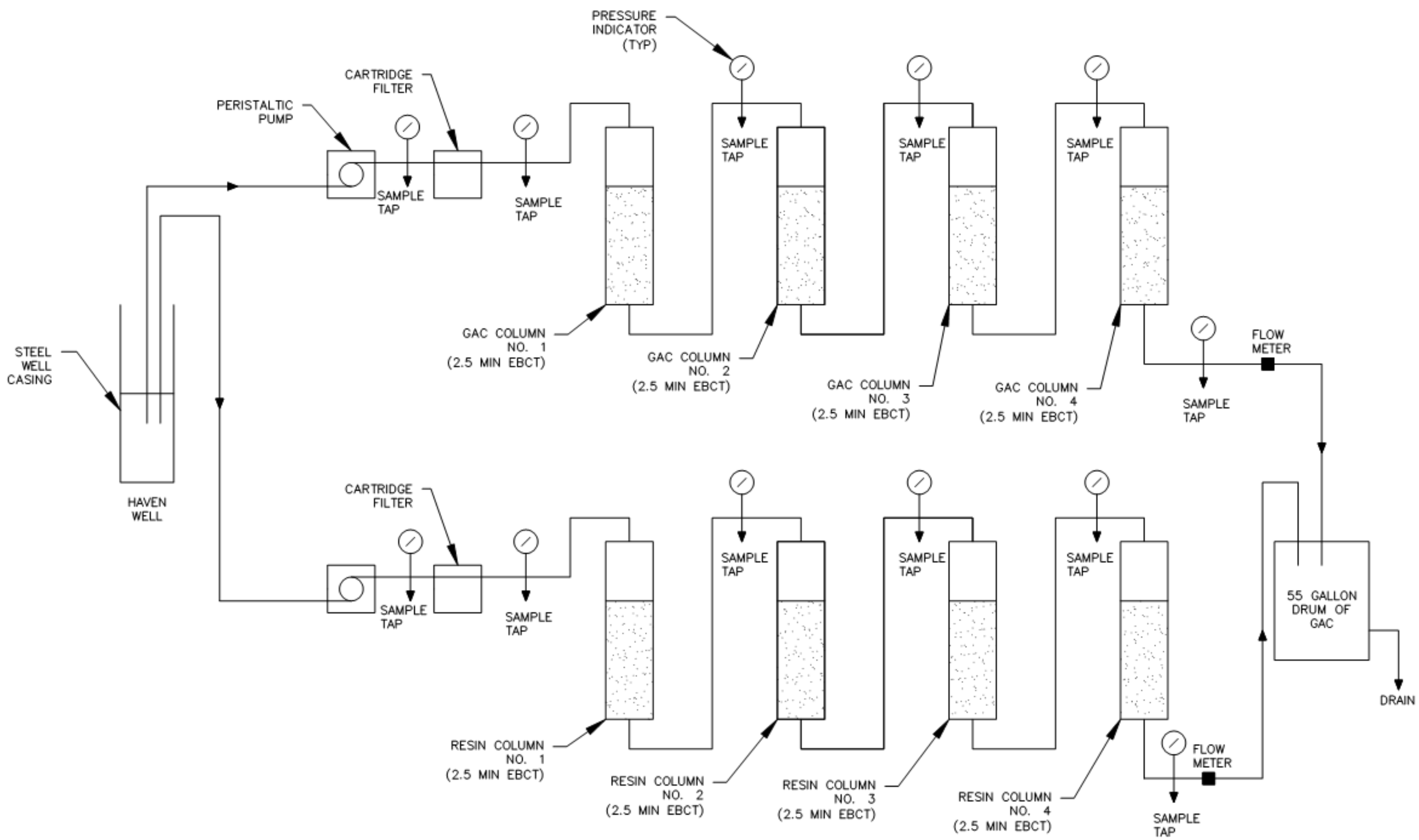


Figure 2-1: Haven Well Pilot Study Schematic as Adapted from ECT2

2.2 Pilot Description

The pilot system consisted of four GAC columns, 2 inches in diameter and 5 feet long. The four columns were connected in series and each column contained enough media for 2.5 minutes of contact time for a total of 10-minutes of contact time. Raw water from the Haven Well casing was pumped by a peristaltic pump through the columns at a rate of 1-2 gpm. Sample ports were located at the effluent of each column and were collected weekly for 10 weeks and monthly thereafter. The set-up for the resin pilot was identical to the GAC pilot. All samples were analyzed by Maxxam Analytics. Photos of the pilot system are included in Appendix A of this report.

2.3 Pilot Testing Results

The method detection limits and reporting limits for Maxxam's PFAS analysis during the Haven Well pilot study are reported in Table 2-1. Test results above the reported detection limit (RDL) are quantitatively accurate. Test results between the RDL and the method detection limit (MDL) are not quantitatively accurate, rather they are estimates of the value present. Test results below the MDL are not statistically separable from blank samples, samples without any PFAS present; these results are listed as non-detect (ND).

Table 2-1 Method Detection and Reporting Limits

PFAS Compound	Reported Detection Limit (RDL)	Method Detection Limit (MDL)
6:2 Fluorotelomer sulfonate (6:2 FTS)	0.020	0.0066
8:2 Fluorotelomer sulfonate (8:2 FTS)	0.020	0.0066
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	0.020	0.0100
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	0.020	0.0079
N-Methyl Perfluorooctane Sulfonamide (MEFOSA)	0.020	0.0130
N-Methyl Perfluorooctane Sulfonamidoethanol (MEFOSE)	0.020	0.0120
Perfluorobutanesulfonic acid (PFBS)*	0.020	0.0054
Perfluorobutanoic acid (PFBA)*	0.020	0.0055
Perfluorodecane sulfonate (PFDS)	0.020	0.0060
Perfluorodecanoic acid (PFDA)	0.020	0.0061
Perfluorododecanoic acid (PFDoA)	0.020	0.0050
Perfluoroheptane sulfonate (PFHpS)	0.020	0.0080
Perfluoroheptanoic acid (PFHpA)*	0.020	0.0074
Perfluorohexanesulfonic acid (PFHxS)	0.020	0.0056
Perfluorohexanoic acid (PFHxA)*	0.020	0.0035
Perfluorooctanoic acid (PFOA)	0.020	0.0033
Perfluorononanoic acid (PFNA)	0.020	0.0087
Perfluorooctane sulfonamide (PFOSA)	0.020	0.0034
Perfluorooctanesulfonic acid (PFOS)	0.020	0.0060
Perfluoropentanoic acid (PFPeA)*	0.020	0.0075
Perfluorotetradecanoic acid (PFTeDA)	0.020	0.0027
Perfluorotridecanoic acid (PFTrDA)	0.020	0.0038
Perfluoroundecanoic acid (PFUnA)	0.020	0.0025

*Short Chain PFAS

Observing the contaminant PFOS, it was found that a minimum contact time of 10 minutes with the GAC media is required to ensure that the PFOS is below the EPA advisory of 0.07 ppb; lesser contact times show rapid breakthrough of PFOS above 0.07 ppb (Figure 2-2). Conversely, the 2.5-minute column containing resin media showed non-detectable effluent concentrations. A similar conclusion was found for PFOA when comparing the concentration over time using GAC filtration (Figure 2-3) and resin filtration.

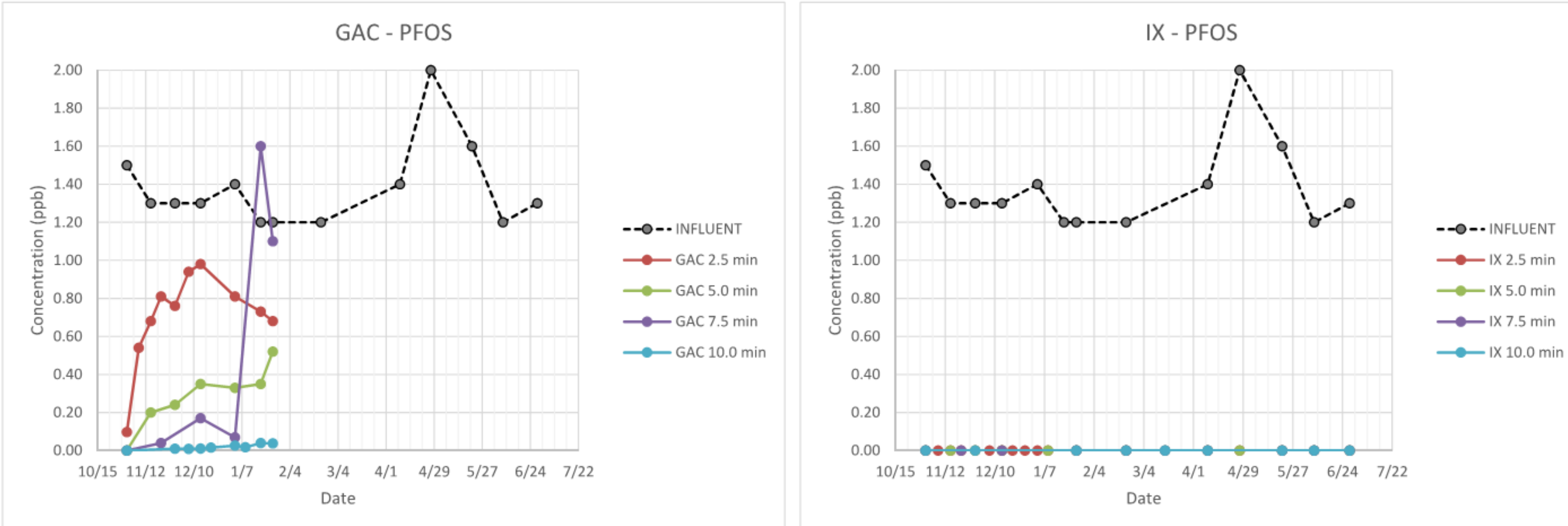


Figure 2-2: Concentration of contaminant PFOS over time using GAC in comparison to ion exchange resin

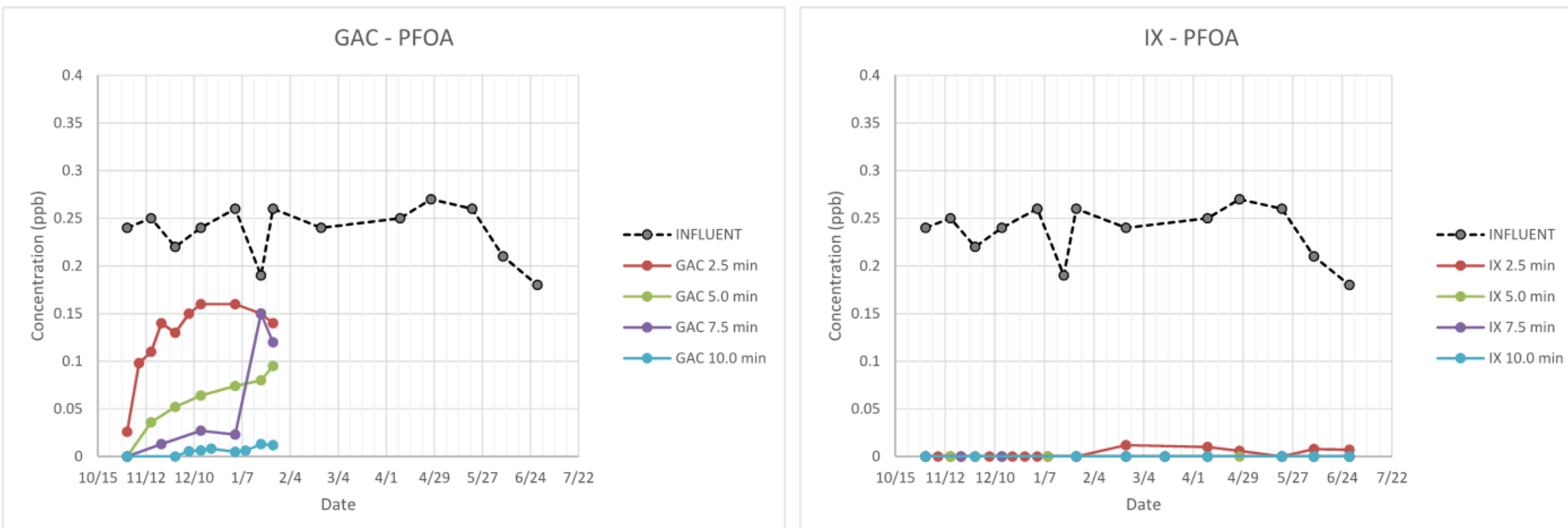


Figure 2-3: Concentration of contaminant PFOA over time using GAC in comparison to ion exchange resin

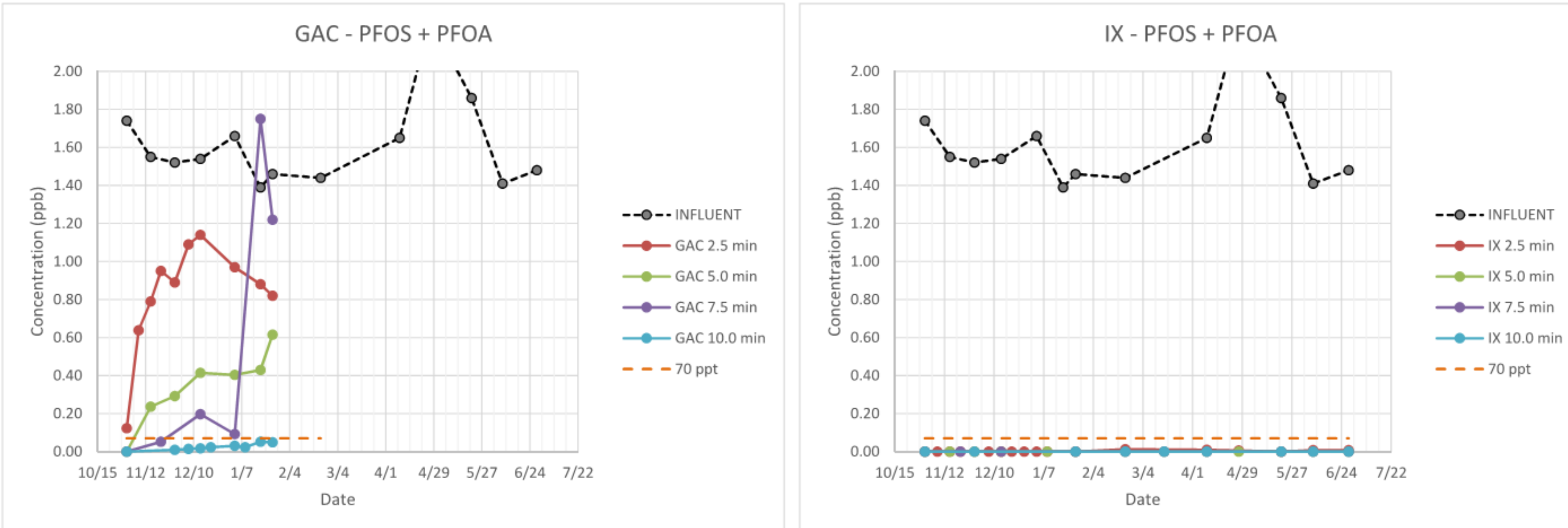


Figure 2-4: Concentration of combined contaminants PFOS+PFOA over time using GAC in comparison to ion exchange resin

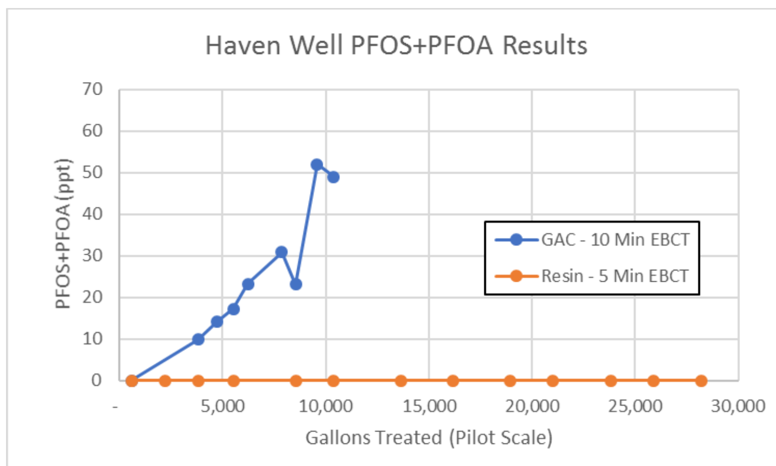
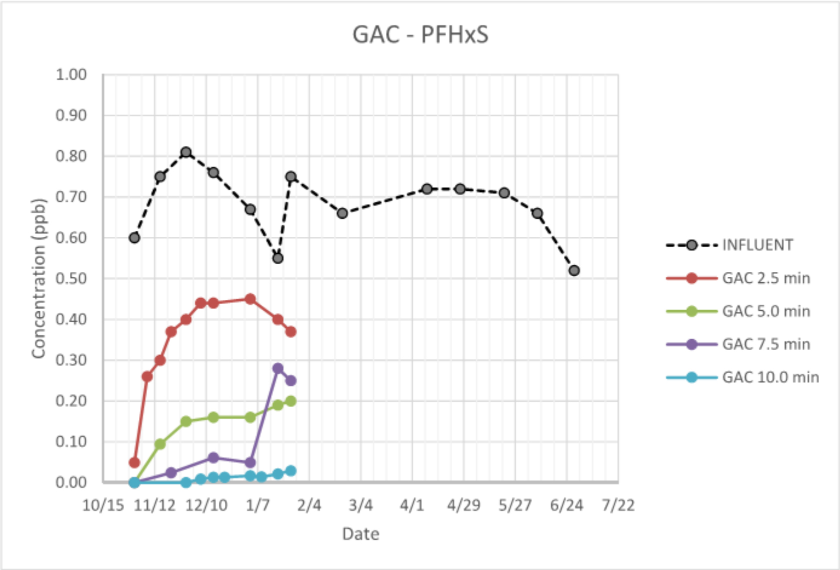


Figure 2-5: Concentration of combined contaminants PFOS+PFOA over time using GAC in comparison to ion exchange resin

This higher removal rate can be seen for the other PFAS compounds as well, including combined PFOS and PFOA (Figure 2-4). Therefore, the resin media which uses ion exchange, in addition to adsorption, to remove contaminants, is a more efficient process as it results in higher removal of contaminants within a shorter contact period.

Two PFAS data points fell outside the normally observed data trends while using the GAC filters. These points were observed at the 7.5-minute column on a sampling date between 01/03/18 and 01/09/18. These outliers were likely a result of a tube breakage that occurred in that time frame. There were no other readily available explanations for the outlying data.

Long chain PFAS removal efficiencies exceeded short chain compounds. These compounds are better candidates for adsorption likely due to their larger surface area. In the GAC columns, the short chain compound PFPeA has almost immediate breakthrough with effluent concentrations approaching that of the raw water concentration whereas PFHxS, a long chain compound, experiences a much more gradual progression of the compound through the filter media. Figure 2-5 shows this long chain vs short chain comparison.



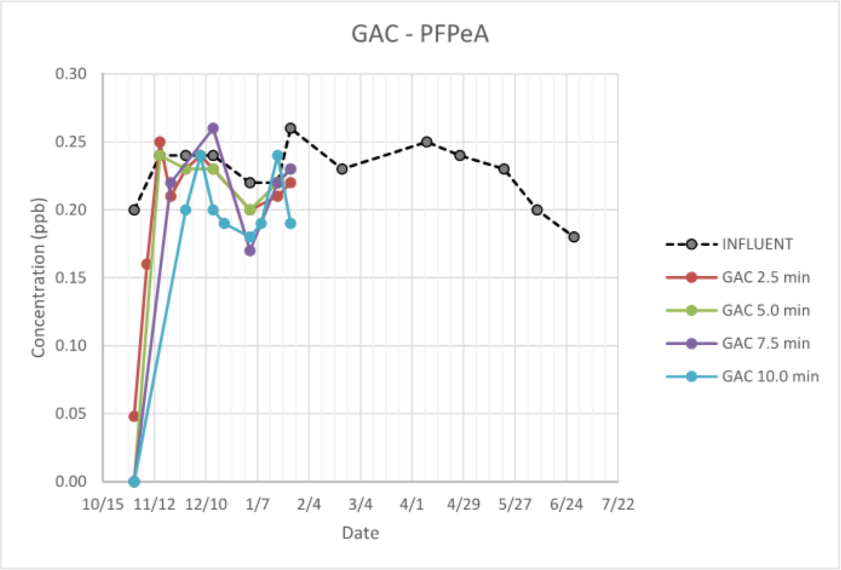


Figure 2-5: Concentration of long chain contaminant PFHxS over time using GAC in contrast to the short chain contaminant PFPeA

PFAS are comprised of a carbon-fluorine backbone and a charged “head” at the end of the backbone. Evidence from the pilot study shows the chemistry of the head group of the compound may impact the effectiveness of the ion exchange resin. PFAS compounds with sulfonated head groups are better candidates for the ion exchange process when compared to PFAS compounds with carboxyl head group. Figure 2-6 shows the comparison of ion exchange resin on two short chain compounds, one with a carboxyl head (PFBA) and one with a sulfonated head (PFBS). PFBA required a minimum EBCT of 7.5 minutes to observe ND levels after a few weeks of operation, while PFBS required just 2.5 minutes of EBCT during that same period. This trend is seen with other compounds of similar chain length but differing head groups, therefore, it was concluded that ion exchange is more effective for contaminants with sulfonated head groups.

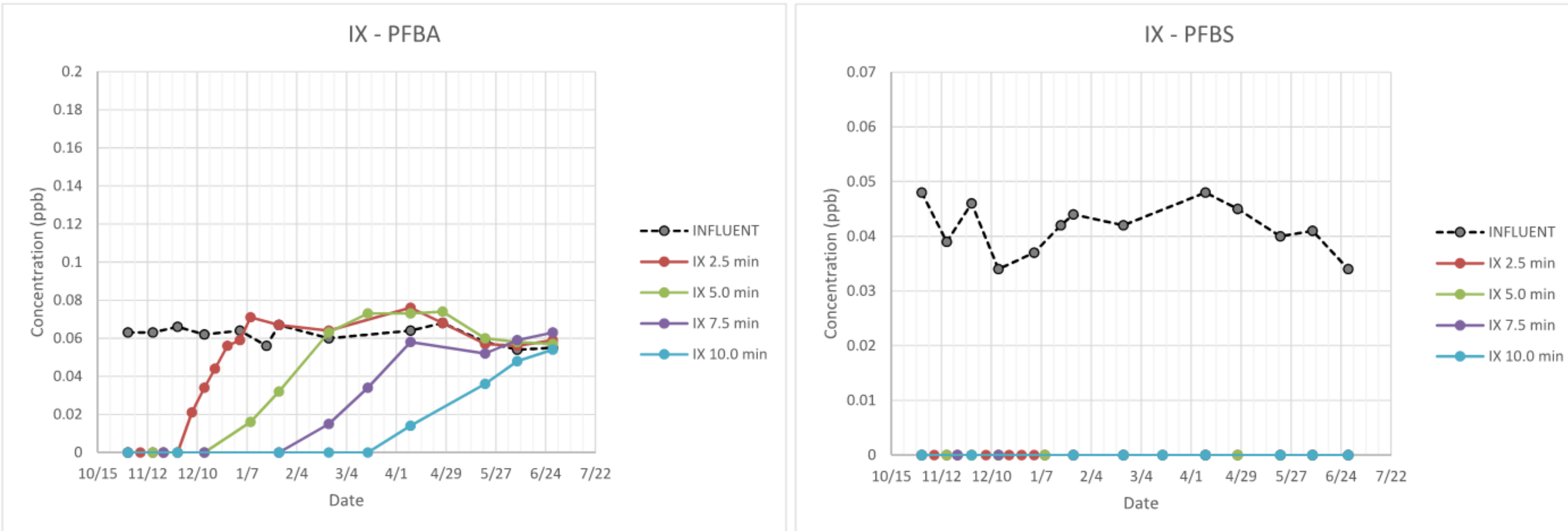


Figure 2-6: Concentration of a carboxyl head contaminant PFBA over time using ion exchange resin in comparison to the sulfonated head contaminant PFBS

During the pilot, high levels of iron were observed in the raw water. The pre-filtration cartridge required frequent replacement due to iron fouling. Iron was seen adsorbing to the insides of the plastic tubing as can be seen in the photos in Appendix A. Sample results showed raw water iron levels of 0.81 mg/L significantly higher than the 0.1 mg/L seen during the November 2016 pumping test. Because of this increase, it is believed that this iron is from rusting of the steel well casing which impacts the low flows of 1-2 gpm used in the pilot. Elevated iron levels will require pre-filtration with 10 μm cartridge filters in the final plant design to obtain the manufacturer's warranty for performance of the media.

The results of this pilot study confirmed the high effectiveness of the resin media with its dual removal mechanisms to remove the PFAS contaminants. Based on these results, resin filtration should be incorporated into the final design for the City's Grafton Road Drinking Water Treatment Plant. Raw water from the three wells will first be pumped into four 10 μm cartridge filters to remove any particulate matter that may be present. The filtered water will then be distributed across six pairs of resin filters where PFAS removal will occur. For final polishing, and to act as a back-up, the effluent from the resin filters will be distributed across three GAC filters where any remaining PFAS compounds will be adsorbed by the carbon. The filtered effluent will then be injected with sodium hypochlorite (disinfection), hydrofluorosilic acid (cavity prevention), and ortho/polyphosphate (corrosion control) before flowing to the distribution system. A recycle system is proposed to reuse backwash waste, filter to waste, and analyzer waste water. A schematic of the final design is shown below in Figure 2-7.

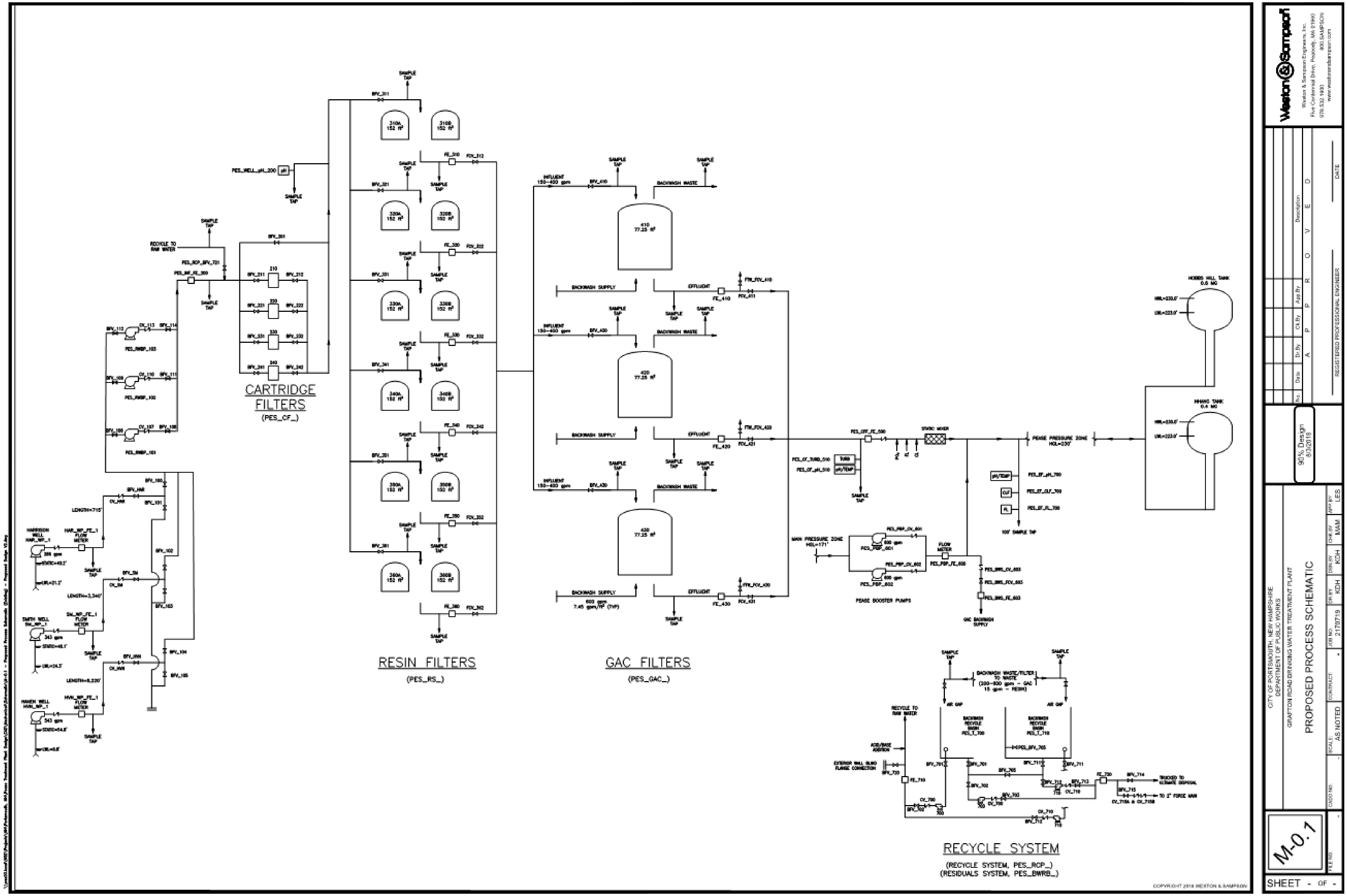


Figure 2-7: Final Proposed Process Schematic

2.4 Operational Considerations

A cost analysis was performed by Weston & Sampson in February 2018 to determine which treatment option is economically preferable. The first treatment option included using exclusively GAC to remove PFAS. The second option included using resin to pretreat the water to remove the majority of contaminants, followed by GAC treatment. The third option included using resin in series followed by GAC treatment for final polishing. It was assumed the plant would operate at the current average daily demand of 605,000 gallons/day, with 50% of the water coming from the Harrison and Smith Wells, and 50% coming from the Haven Well.

The equipment capital cost for GAC treatment alone and for resin in parallel and GAC in series, was slightly more expensive than the equipment capital cost of resin in series and GAC in parallel at a cost of $2,140,000 and $2,430,000 vs. $2,000,500. Regarding operations and maintenance costs, treatment using exclusively GAC is more expensive ($304,000/year) than treatment involving both GAC and resin ($91,300/year-$99,300/year). This large difference in O&M costs is associated with the longer projected media life the for the resin.

For this analysis, 4% interest was assumed over a 20-year period. The analysis shows that including resin in the treatment scheme is more cost effective over a 20-year period (Table 2-2).

Table 2-2 Twenty Year Present Worth Analysis
Grafton Road Drinking Water Treatment Plant

Treatment Option	Construction Cost		Operations Costs		Present Worth Cost (20 year, 4%)
	Vessels and Media	Credits*	Annual Media Cost	Increase Electrical Cost Due to Additional Headloss	
GAC Only Treatment	$2,140,000	-	$304,000	-	$6,271,000
Resin in Parallel and GAC in Series	$2,430,000	-	$91,300	$2,000	$3,698,000
Resin in Series and GAC in Parallel	$2,000,500	$(910,000)	$99,300	$8,000	$3,173,000

* Credits associated with reduction in building footprint and elimination of backwash supply and recycle tanks.

2.5 Pilot Testing Conclusions

1. The resin media, which uses ion exchange and adsorption to remove PFAS, is a more efficient treatment process than GAC, which uses only adsorption. Because of the dual removal mechanisms, higher removal of PFAS can be experienced within a shorter contact period resulting in higher flow rates and a smaller equipment footprint.
2. Resin costs have fallen significantly in the past few years resulting in a favorable cost comparison.
3. Cartridge filters have the potential to significantly increase process headloss if high levels of particulate matter are encountered. Raw water booster pumps may be required to overcome the headloss of the new filters.
4. Resin outperforms GAC for PFAS removal from Haven Well water for both long chain and short chain compounds.
5. Long chain compounds are better candidates for adsorption due to their large surface area.
6. Contaminants with sulfonated head groups are better candidates for ion exchange when compared to contaminants with carboxyl head groups.

7. Resin filters should be designed with a minimum EBCT of 5 minutes while GAC filters should be designed with a minimum EBCT of 10 minutes.

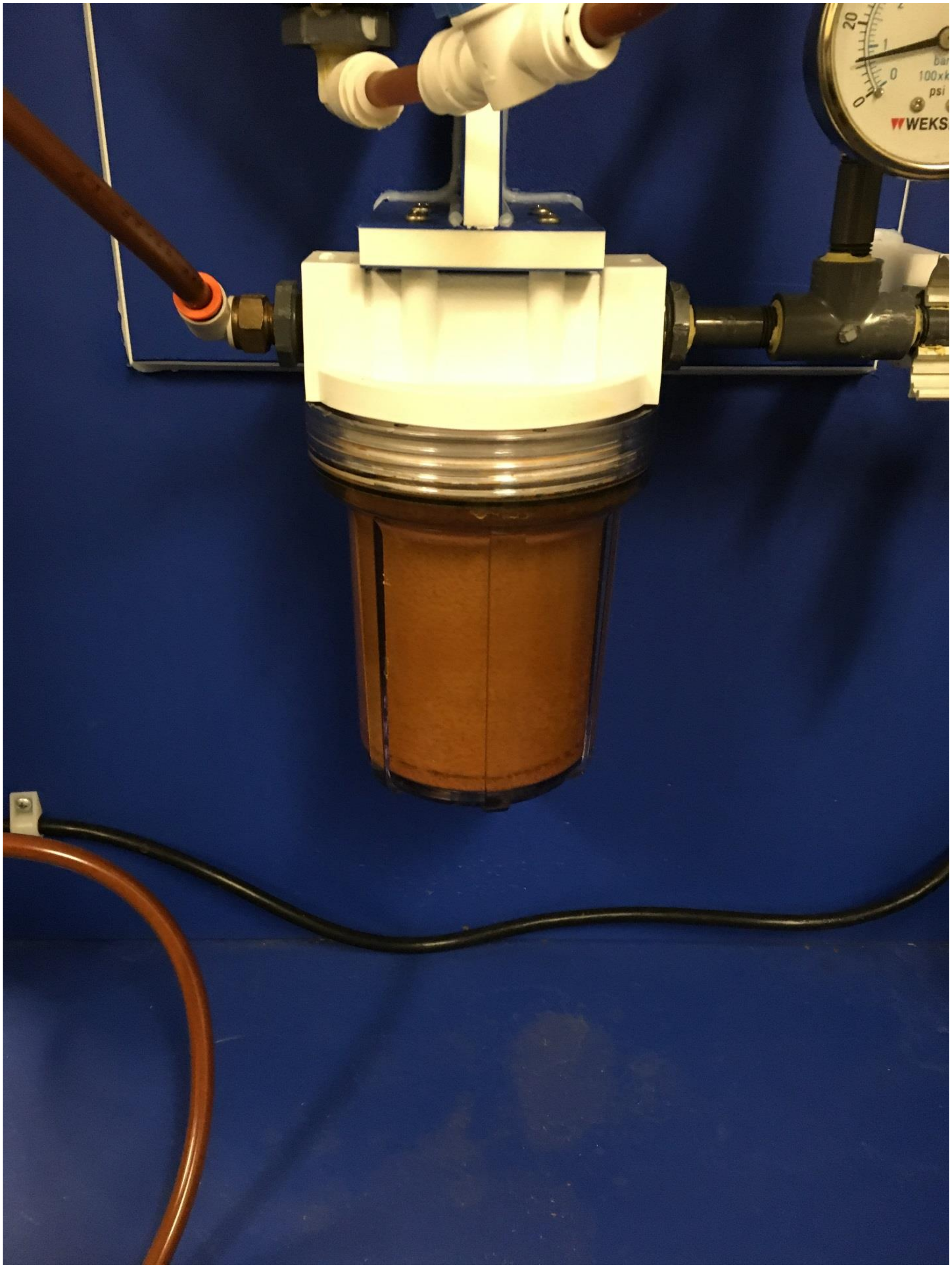
\\wse03.local\wse\projects\nh\portsmouth, nh\pease treatment plant design\haven pilot\haven well pilot report.docx

APPENDIX A

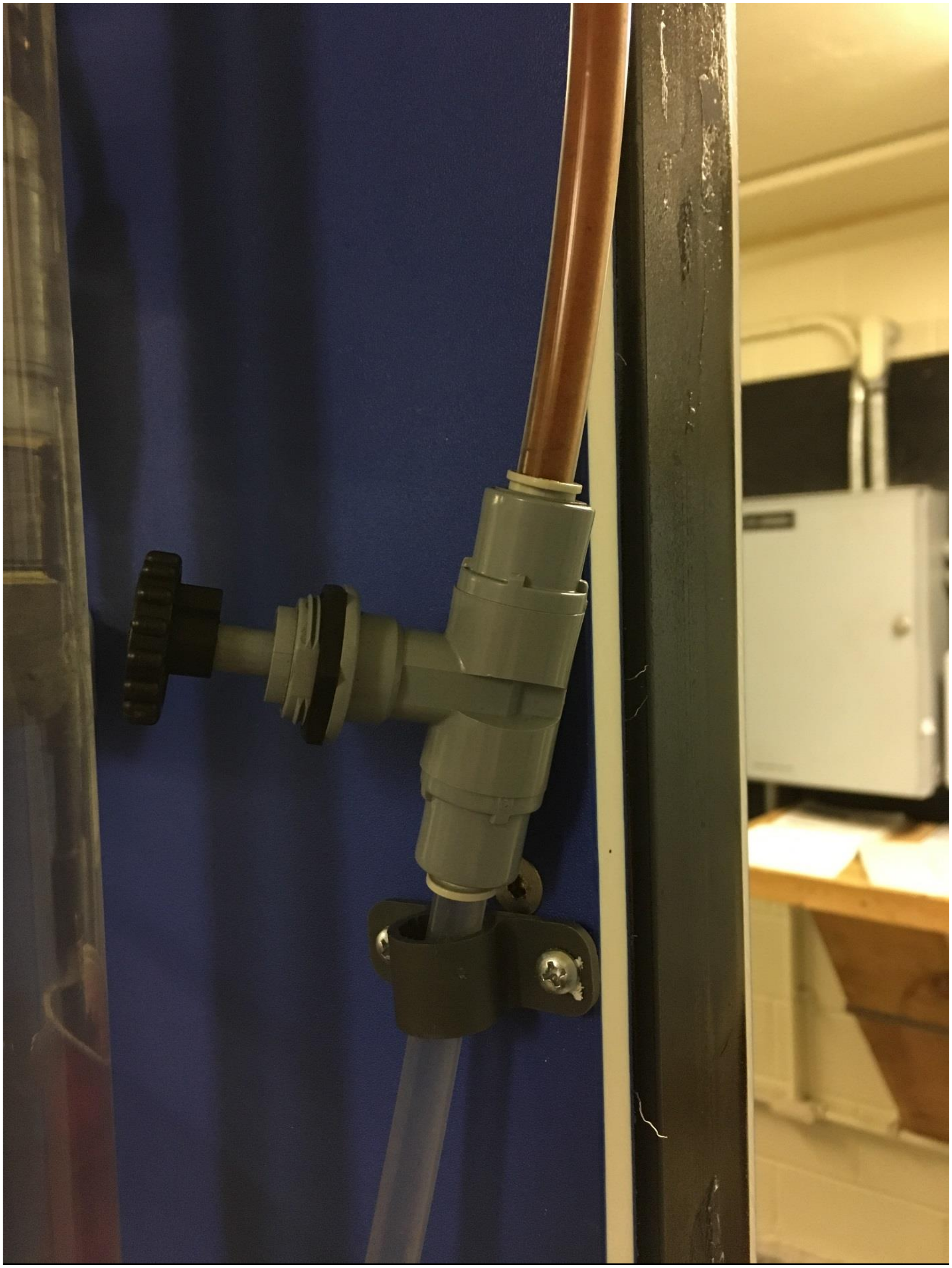
Pilot Setup Photos

Haven Well Pilot Testing Program

August 2018 – DRAFT

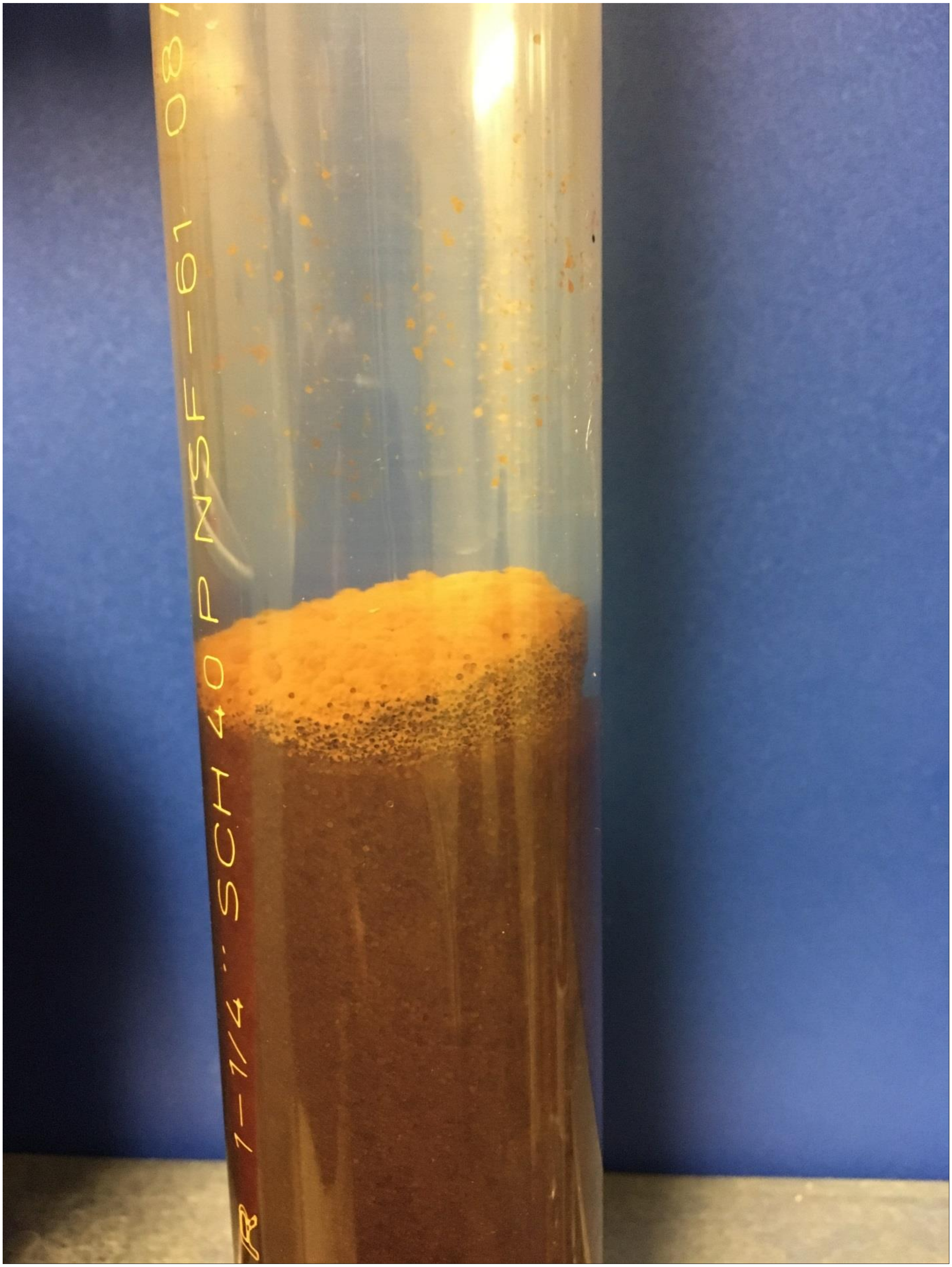

WEKS
psi
bar

August 2018 – DRAFT



August 2018 – DRAFT

August 2018 – DRAFT

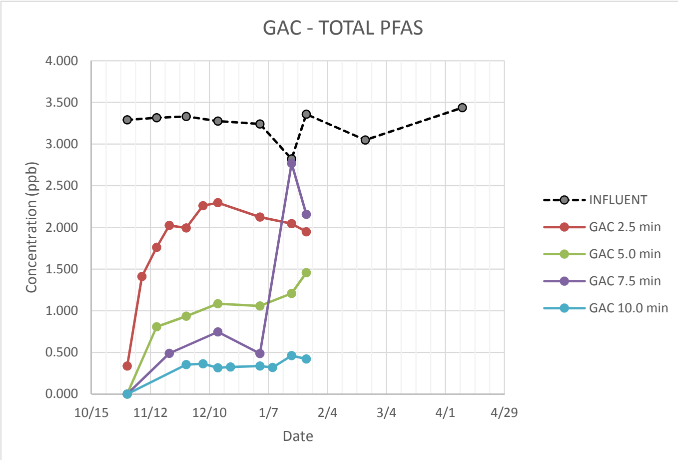


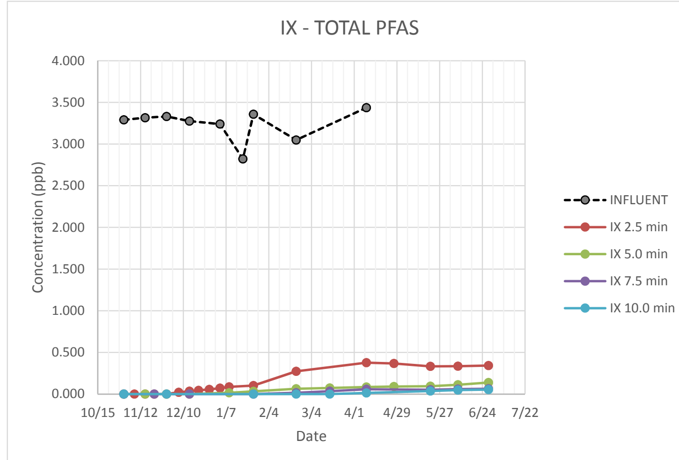
August 2018 – DRAFT

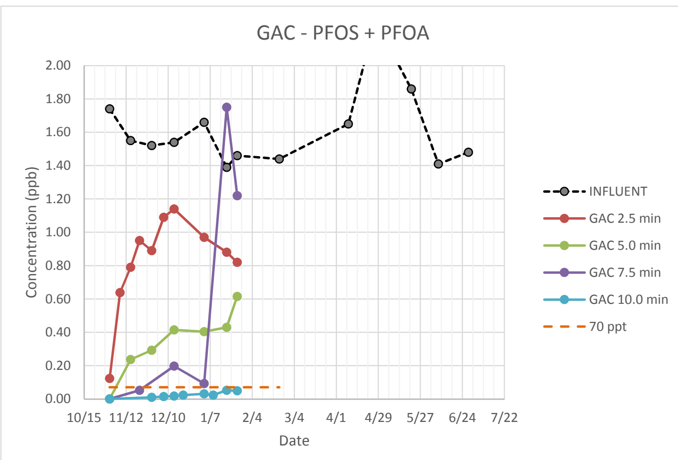
APPENDIX B

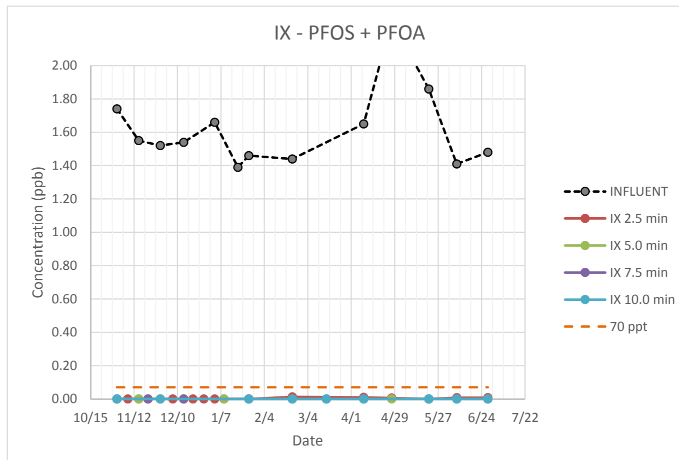
Field Operating Data

HAVEN WELL PRELIMINARY DATA - UPDATED 7/11/18

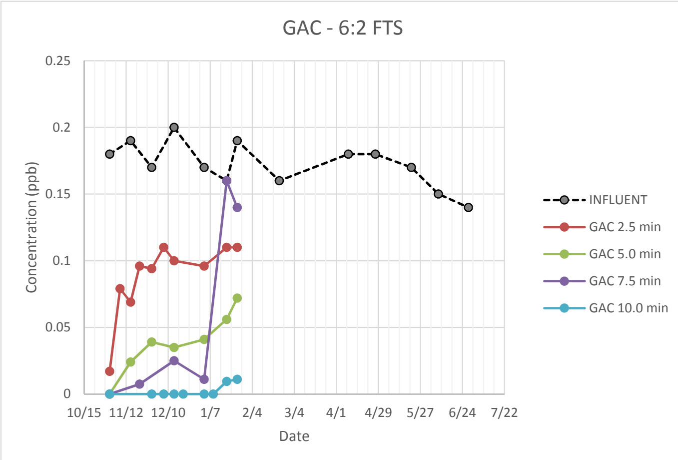


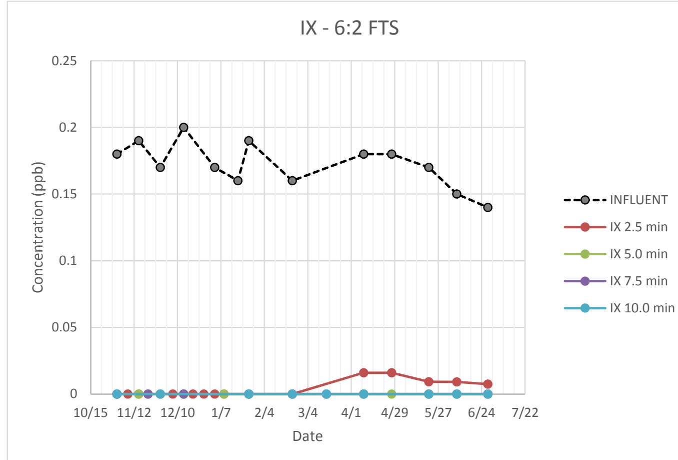


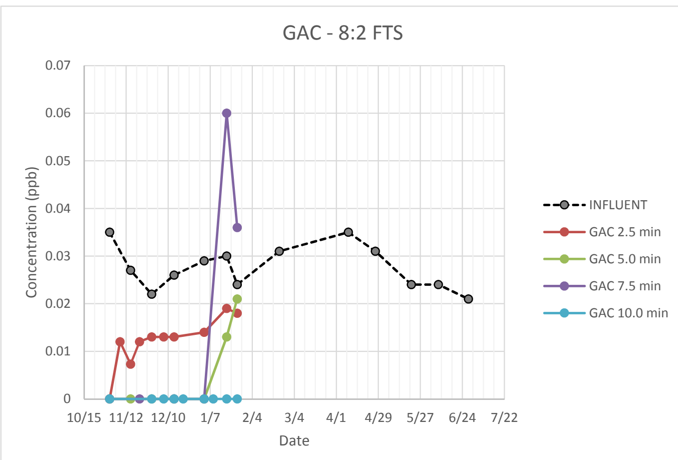


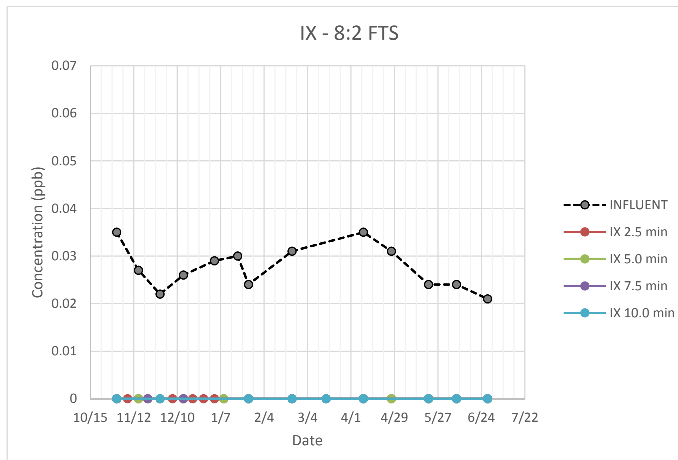


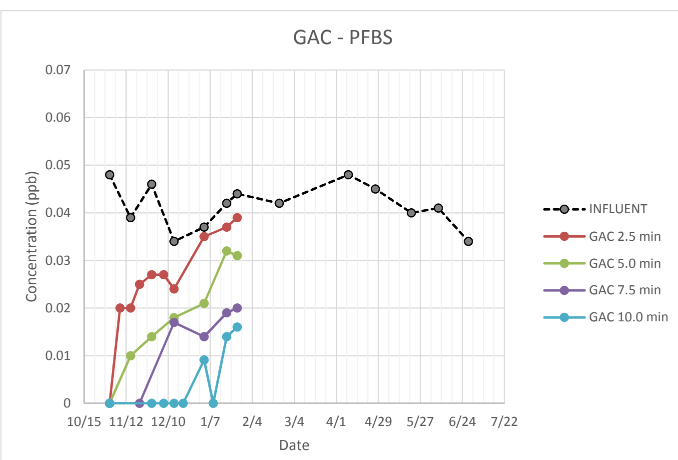
HAVEN WELL PRELIMINARY DATA - UPDATED 7/11/18

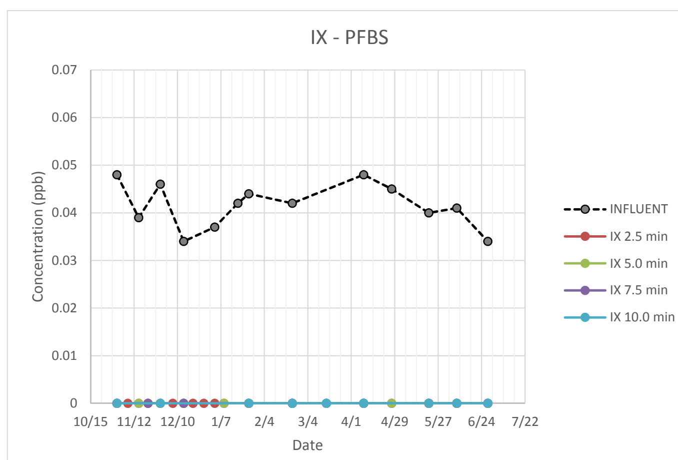




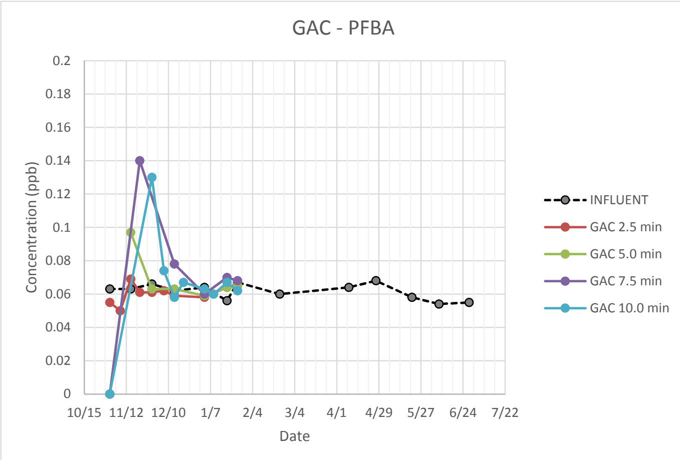


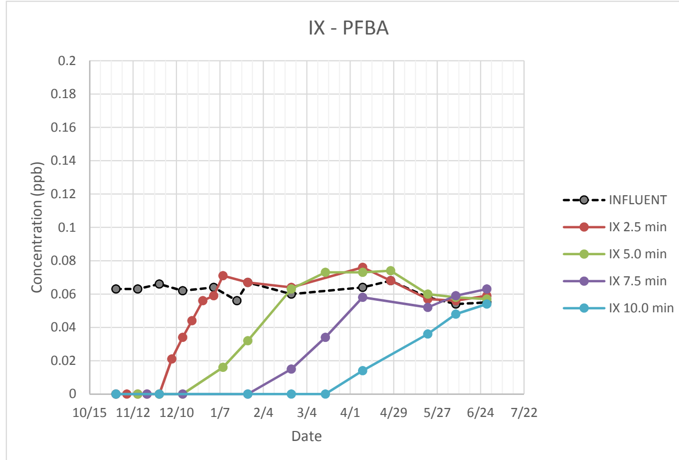


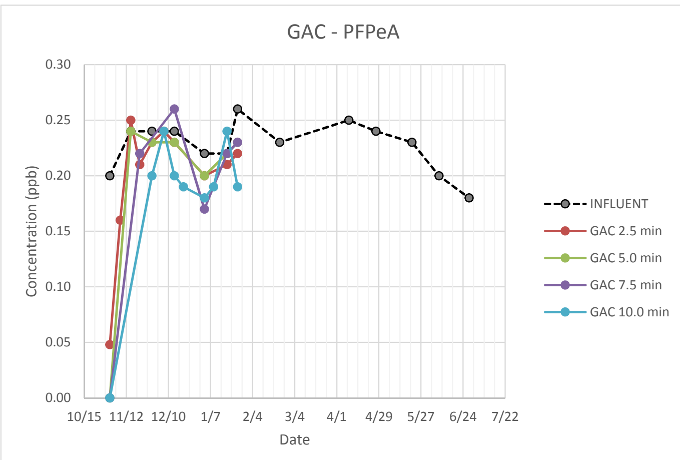


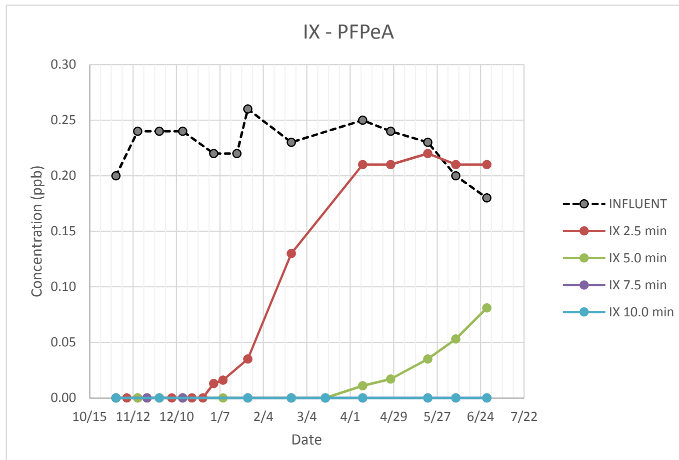


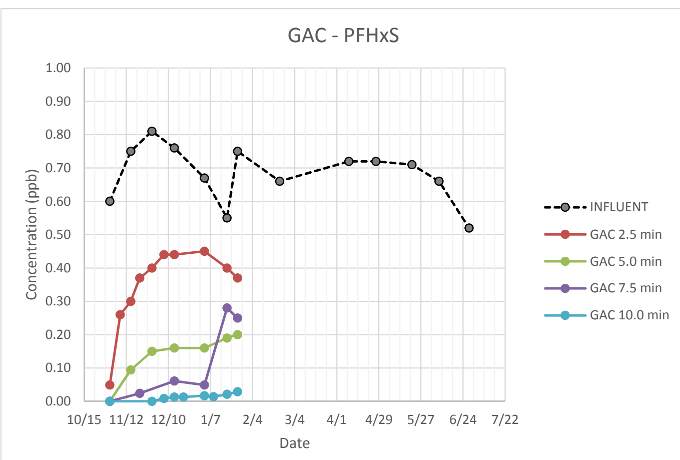
HAVEN WELL PRELIMINARY DATA - UPDATED 7/11/18

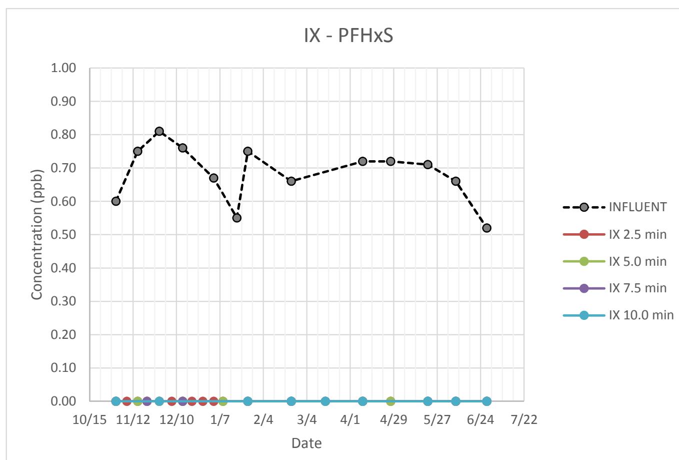




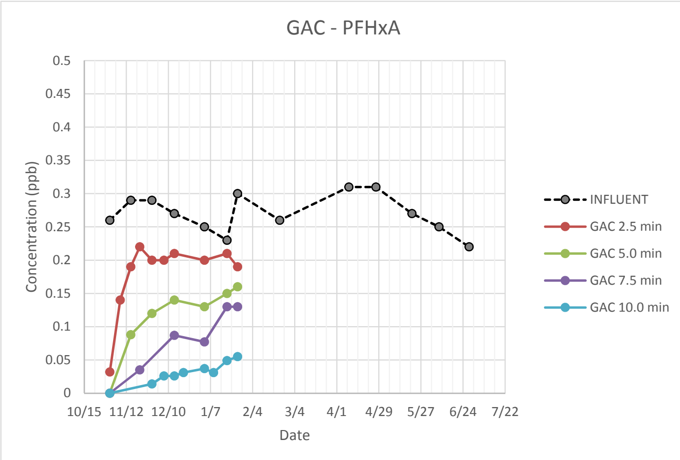


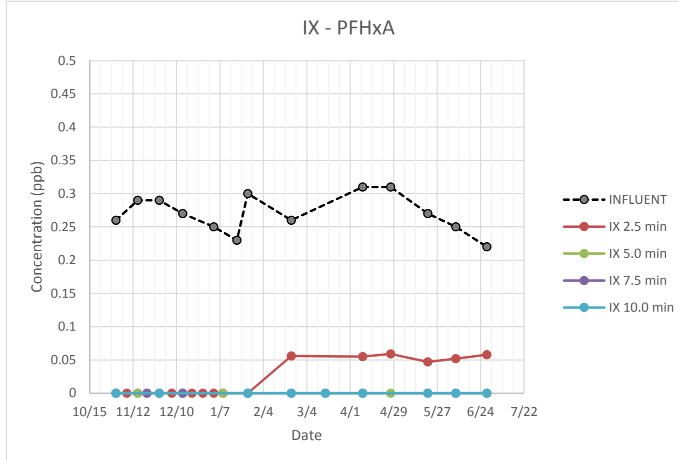


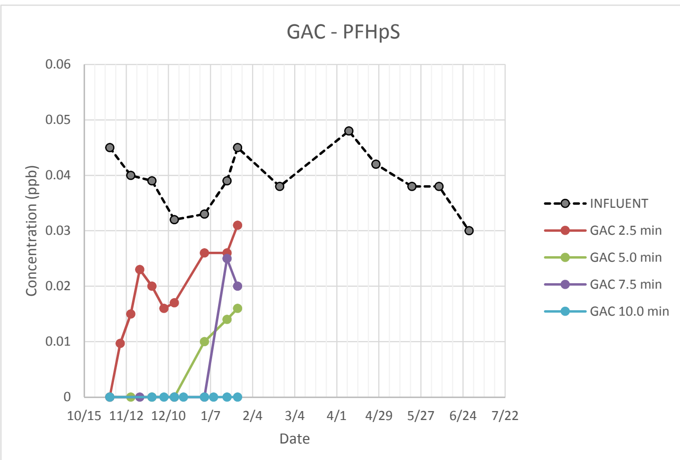


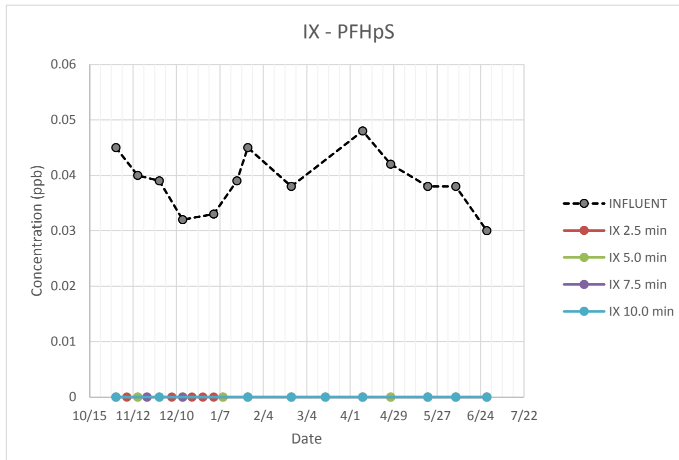


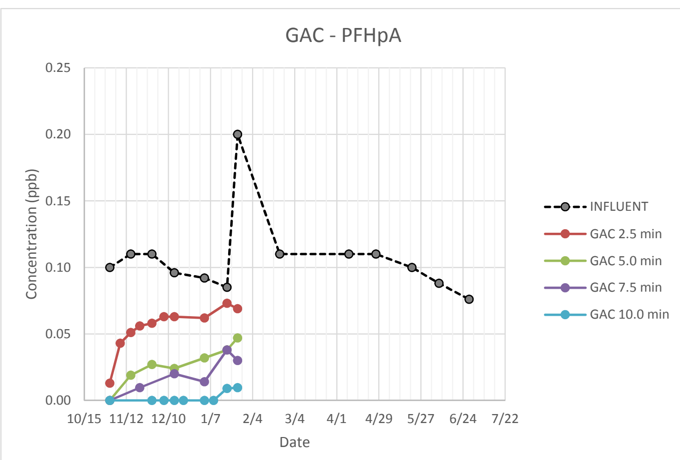
HAVEN WELL PRELIMINARY DATA - UPDATED 7/11/18

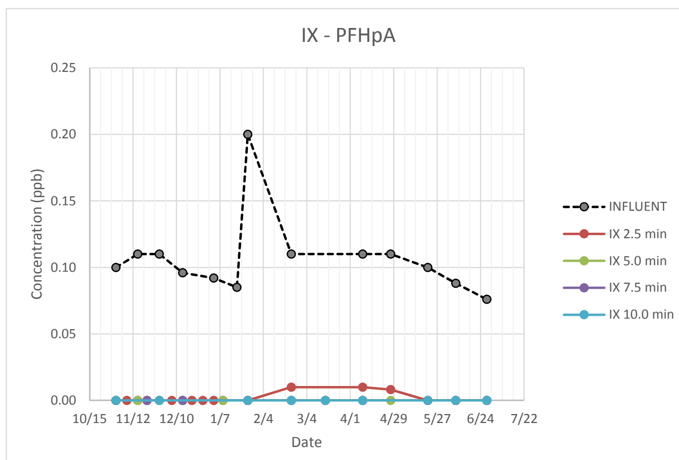




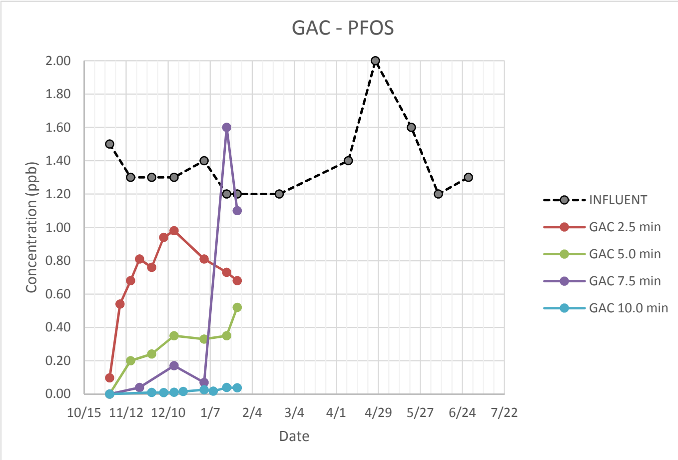


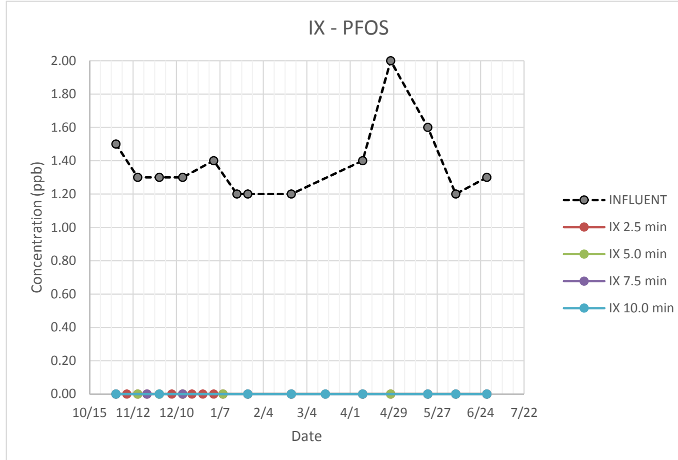


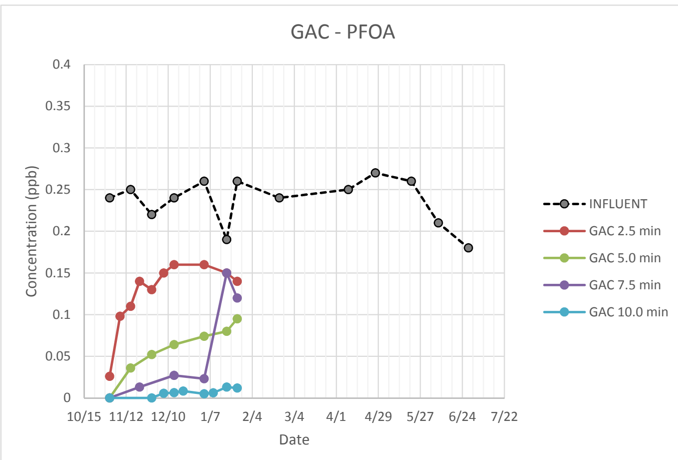


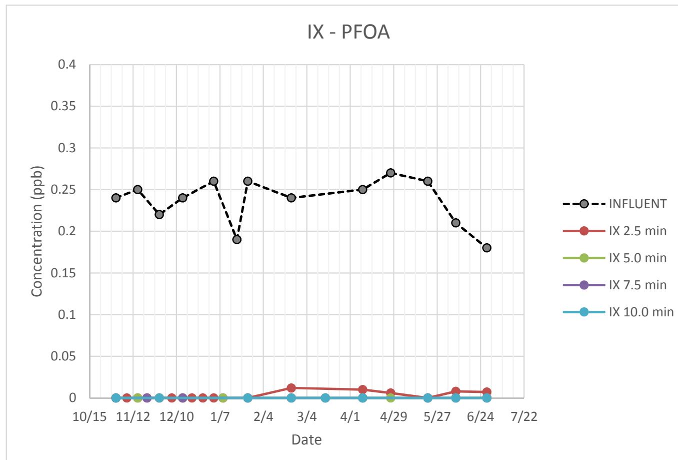


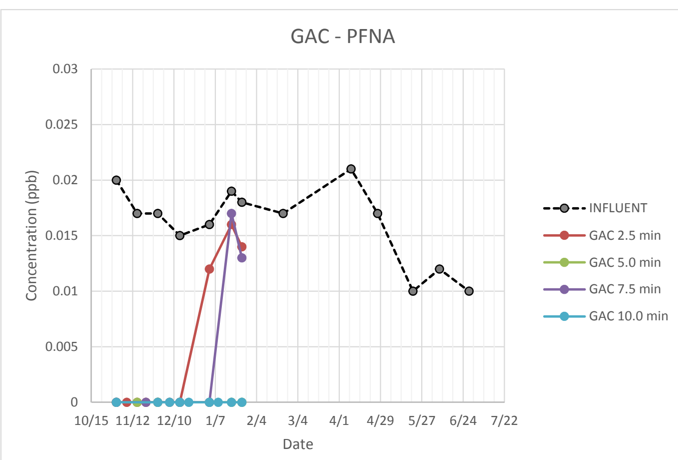
HAVEN WELL PRELIMINARY DATA - UPDATED 7/11/18

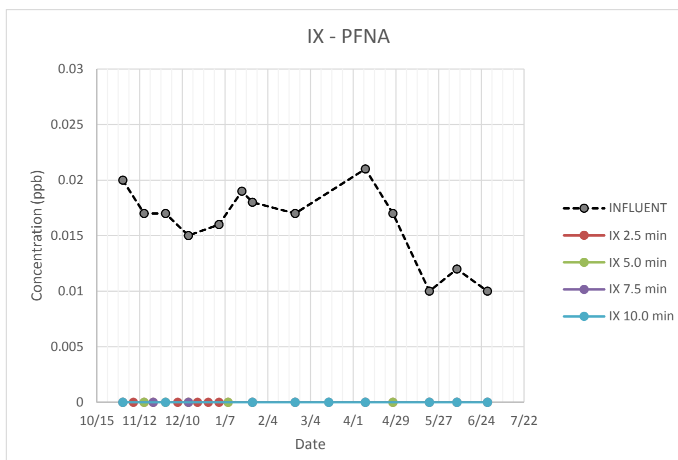












HAVEN WELL PILOT TEST ****** DRAFT *****

LAB RESULTS (MAXXAM)
(All values in ppb)

Sample Train	EBCT	Sample Label	Date	Time	Date and Time	Volume Treated		6:2 Fluoro telomer sulfonate	8:2 Fluoro telomer sulfonate	Perfluoro butane sulfonate	Perfluoro butanoic Acid	Perfluoro pentanoic Acid	Perfluoro hexane sulfonate	Perfluoro hexanoic acid	Perfluoro heptane sulfonate	Perfluoro heptanoic acid	Perfluoro octane sulfonate	Perfluoro octanoic acid	Perfluoro heptanoic acid	TOTAL PFAS	PFOS + PFOA
						gal	BVs	6:2 FTS	8:2 FTS	PFBS	PFBA	PFPeA	PFHxS	PFHxA	PFHpS	PFHpA	PFOS	PFOA	PFNA		
		START			10/27/2017 15:00																
INFLUENT		HW-GAC-INF-2017-1101	11/1/2017	14:11	11/1/2017 14:11			0.18	0.035	0.048	0.063	0.20	0.60	0.26	0.045	0.10	1.50	0.24	0.02	3.29	1.74
		HW-IX-INF-2017-1108	11/8/2017	14:23	11/8/2017 14:23			HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
		HW-IX-INF-2017-1115	11/15/2017	14:23	11/15/2017 14:23			0.19	0.027	0.039	0.063	0.24	0.75	0.29	0.04	0.11	1.30	0.25	0.017 J	3.32	1.55
		HW-IX-INF-2017-1122	11/21/2017	13:38	11/21/2017 13:38			HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
		HW-IX-INF-2017-1129	11/29/2017	13:38	11/29/2017 13:38			0.17	0.022	0.046	0.066	0.24	0.81	0.29	0.039	0.11	1.30	0.22	0.017 J	3.33	1.52
		HW-IX-INF-2017-1207	12/7/2017	8:56	12/7/2017 8:56			HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
		HW-IX-INF-2017-1214	12/14/2017	10:04	12/14/2017 10:04			0.2	0.026	0.034	0.062	0.24	0.76	0.27	0.032	0.096	1.30	0.24	0.015 J	3.28	1.54
		HW-IX-INF-2017-1220	12/20/2017	9:30	12/20/2017 9:30			HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
		HW-IX-INF-2017-1227	12/27/2017	11:19	12/27/2017 11:19			HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
		HW-IX-INF-2018-0103	1/3/2018	13:34	1/3/2018 13:34			0.17	0.029	0.037	0.064	0.22	0.67	0.25	0.033	0.092	1.4	0.26	0.016 J	3.24	1.66
	********** (Tube failure sometime between 1/3/18 and 1/9/18) ***********																				
		HW-IX-INF-2018-0109	1/9/2018		1/9/2018 0:00			HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
		HW-IX-INF-2018-0118	1/18/2018	13:34	1/18/2018 13:34			0.16	0.03	0.042	0.056	0.22	0.55	0.23	0.039	0.085	1.2	0.19	0.019 J	2.82	1.39
		HW-IX-INF-2018-0125	1/25/2018		1/25/2018 0:00			0.19	0.024	0.044	0.067	0.26	0.75	0.3	0.045	0.200	1.2	0.26	0.018 J	3.36	1.46
	********** (Pump failure sometime between 1/25/18 and 2/15/18) ***********																				
		HW-IX-INF-2018-0222	2/22/2018	10:20	2/22/2018 10:20			0.16	0.031	0.042	0.06	0.23	0.66	0.26	0.038	0.110	1.2	0.24	0.017 J	3.05	1.44
		HW-SYS-INF-2018-0409	4/9/2018	10:04	4/9/2018 10:04			0.18	0.035	0.048	0.064	0.25	0.72	0.31	0.048	0.110	1.4	0.25	0.021	3.44	1.65
		HW-SYS-INF-2018-0427	4/27/2018	9:24	4/27/2018 9:24			0.18	0.031	0.045	0.068	0.24	0.72	0.31	0.042	0.110	2.0	0.27	0.017 J	4.03	2.27
		HW-SYS-INF-2018-0521	5/21/2018	10:36	5/21/2018 10:36			0.17	0.024	0.04	0.058	0.23	0.71	0.27	0.038	0.100	1.6	0.26	0.010 J	3.51	1.86
		HW-SYS-INF-2018-0608	6/8/2018	10:30	6/8/2018 10:30			0.15	0.024	0.041	0.054	0.2	0.66	0.25	0.038	0.088	1.2	0.21	0.012 J	2.93	1.41
		HW-SYS-INF-2018-0628	6/28/2018	9:50	6/28/2018 9:50			0.14	0.021	0.034	0.055	0.18	0.52	0.22	0.03	0.076	1.3	0.18	0.010 J	2.77	1.48
		AVERAGE INFLUENT						0.17	0.03	0.04	0.06	0.23	0.68	0.27	0.04	0.11	1.38	0.24	0.016	3.26	1.61
GAC	2.5 min	HW-GAC1-EFF-2017-1101	11/1/2017	14:10	11/1/2017 14:10	574	2,860	0.017 J	0.0036 U	0.0048 U	0.055	0.048	0.049	0.032	0.0048 U	0.013 J	0.097	0.026	0.0038 U	0.34	0.12
	2.5 min	HW-GAC1-EFF-2017-1108	11/8/2017	14:18	11/8/2017 14:18	1,385	6,895	0.079	0.012 J	0.020 J	0.05	0.16	0.26	0.14	0.0097 J	0.043	0.54	0.098	0.0087 U	1.41	0.64
	2.5 min	HW-GAC1-EFF-2017-1115	11/15/2017	14:18	11/15/2017 14:18	2,194	10,927	0.069	0.0073 J	0.020	0.069	0.25	0.3	0.19	0.015 J	0.051	0.68	0.11	0.0087 U	1.76	0.79
	2.5 min	HW-GAC1-EFF-2017-1122	11/21/2017	13:33	11/21/2017 13:33	2,884	14,365	0.096	0.012 J	0.025	0.061	0.21	0.37	0.22	0.023	0.056	0.81	0.14	0.010 J	2.03	0.95
	2.5 min	HW-GAC1-EFF-2017-1129	11/29/2017	13:33	11/29/2017 13:33	3,810	18,973	0.094	0.013 J	0.027	0.061	0.23	0.4	0.2	0.020	0.058	0.76	0.13	0.011 J	2.00	0.89
	2.5 min	HW-GAC1-EFF-2017-1207	12/7/2017	8:43	12/7/2017 8:43	4,712	23,465	0.110	0.013 J	0.027	0.062	0.24	0.44	0.2	0.016 J	0.063	0.94	0.15	0.0087 U	2.26	1.09
	2.5 min	HW-GAC1-EFF-2017-1214	12/14/2017	9:51	12/14/2017 9:51	5,527	27,524	0.100	0.013 J	0.024	0.059	0.23	0.44	0.21	0.017 J	0.063	0.98	0.16	0.0087 U	2.30	1.14
	2.5 min	HW-GAC1-EFF-2017-1220	12/20/2017	9:56	12/20/2017 9:56	6,221	30,982	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	2.5 min	HW-GAC1-EFF-2017-1227	12/27/2017	11:13	12/27/2017 11:13	7,037	35,045	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	2.5 min	HW-GAC1-EFF-2018-0103	1/3/2018	13:28	1/3/2018 13:28	7,857	39,131	0.096	0.014 J	0.035	0.058	0.2	0.45	0.2	0.026	0.062	0.81	0.16	0.012 J	2.12	0.97
	********** (Tube failure sometime between 1/3/18 and 1/9/18) ***********																				
	2.5 min	HW-GAC1-EFF-2018-0103	1/9/2018	13:50	1/9/2018 13:50	8,553	42,596	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	2.5 min	HW-GAC1-EFF-2018-0118	1/18/2018	13:18	1/18/2018 13:18	9,591	47,767	0.11	0.019 J	0.037	0.064	0.21	0.4	0.21	0.026	0.073	0.73	0.15	0.016 J	2.05	0.88
	2.5 min	HW-GAC1-EFF-2018-0125	1/25/2018	10:23	1/25/2018 10:23	10,387	51,729	0.11	0.018 J	0.039	0.066	0.22	0.37	0.19	0.031	0.069	0.68	0.14	0.014 J	1.95	0.82
	2.5 min																				
	5 min	HW-GAC2-EFF-2017-1101	11/1/2017	14:09	11/1/2017 14:09	574	1,430	0.0032 U	0.0036 U	0.0048 U	0.0043 U	0.0027 U	0.0034 U	0.0029 U	0.0048 U	0.0033 U	0.0026 U	0.0046 U	0.0038 U	ND	ND
	5 min	HW-GAC2-EFF-2017-1108	11/8/2017	14:17	11/8/2017 14:17	1,384	3,447	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-GAC2-EFF-2017-1115	11/15/2017	14:17	11/15/2017 14:17	2,194	5,463	0.024	0.0066 U	0.010 J	0.097	0.24	0.094	0.088	0.0080 U	0.019 J	0.2	0.036	0.0087 U	0.81	0.24
	5 min	HW-GAC2-EFF-2017-1122	11/21/2017	13:32	11/21/2017 13:32	2,884	7,182	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-GAC2-EFF-2017-1129	11/29/2017	13:32	11/29/2017 13:32	3,810	9,486	0.039	0.0066 U	0.014 J	0.063	0.23	0.15	0.12	0.0080 U	0.027	0.24	0.052	0.0087 U	0.94	0.29
	5 min	HW-GAC1-EFF-2017-1207	12/7/2017	8:41	12/7/2017 8:41	4,711	11,732	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-GAC2-EFF-2017-1214	12/14/2017	9:49	12/14/2017 9:49	5,527	13,762	0.035	0.0066 U	0.018 J	0.063	0.23	0.16	0.14	0.0080 U	0.024	0.35	0.064	0.0087 U	1.08	0.41
	5 min	HW-GAC2-EFF-2017-1220	12/20/2017	9:18	12/20/2017 9:18	6,218	15,484	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-GAC2-EFF-2017-1227	12/27/2017	11:12	12/27/2017 11:12	7,037	17,522	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-GAC2-EFF-2018-0103	1/3/2018	13:27	1/3/2018 13:27	7,857	19,565	0.041	0.0066 U	0.021	0.059	0.2	0.16	0.13	0.010 J	0.032	0.33	0.074	0.0087 U	1.06	0.40
	********** (Tube failure sometime between 1/3/18 and 1/9/18) ***********																				
	5 min	HW-GAC2-EFF-2018-0109	1/9/2018	13:49	1/9/2018 13:49	8,553	21,298	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-GAC2-EFF-2018-0118	1/18/2018	13:17	1/18/2018 13:17	9,591	23,883	0.056	0.013 J	0.032	0.064	0.22	0.19	0.15	0.014 J	0.038	0.35	0.08	0.0087 U	1.21	0.43
	5 min	HW-GAC2-EFF-2018-0125	1/25/2018	10:22	1/25/2018 10:22	10,387	25,864	0.072	0.021	0.031	0.065	0.23	0.2	0.16	0.016 J	0.047	0.52	0.095	0.0087 U	1.46	0.62
	5 min																				

GAC	7.5 min	HW-GAC3-EFF-2017-1101	11/1/2017	14:08	11/1/2017 14:08	574	953	0.0032 U	0.0036 U	0.0048 U	0.0043 U	0.0027 U	0.0034 U	0.0029 U	0.0048 U	0.0033 U	0.0026 U	0.0046 U	0.0038 U	ND	ND
	7.5 min	HW-GAC3-EFF-2017-1108	11/8/2017	14:16	11/8/2017 14:16	1,384	2,298	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2017-1115	11/15/2017	14:16	11/15/2017 14:16	2,194	3,642	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2017-1122	11/21/2017	13:31	11/21/2017 13:31	2,884	4,788	0.008 J	0.0066 U	0.0054 U	0.14	0.22	0.024	0.035	0.0080 U	0.010 J	0.039	0.013 J	0.0087 U	0.49	0.052
	7.5 min	HW-GAC3-EFF-2017-1129	11/29/2017	13:31	11/29/2017 13:31	3,810	6,324	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2017-1207	12/7/2017	8:39	12/7/2017 8:39	4,711	7,821	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2017-1214	12/14/2017	9:47	12/14/2017 9:47	5,526	9,174	0.025	0.0066 U	0.017 J	0.078	0.26	0.061	0.087	0.0080 U	0.020 J	0.17	0.027	0.0087 U	0.75	0.197
	7.5 min	HW-GAC3-EFF-2017-1220	12/20/2017	9:16	12/20/2017 9:16	6,218	10,322	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2017-1227	12/27/2017	11:11	12/27/2017 11:11	7,037	11,681	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2018-0103	1/3/2018	13:26	1/3/2018 13:26	7,857	13,043	0.011 J	0.0066 U	0.014 J	0.06	0.17	0.049	0.077	0.0080 U	0.014 J	0.069	0.023	0.0087 U	0.49	0.092
	********** (Tube failure sometime between 1/3/18 and 1/9/18) ***********																				
	7.5 min	HW-GAC3-EFF-2018-0109	1/9/2018	13:48	1/9/2018 13:48	8,553	14,198	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-GAC3-EFF-2018-0118	1/18/2018	13:16	1/18/2018 13:16	9,591	15,922	0.16	0.06	0.019 J	0.07	0.22	0.28	0.13	0.025	0.038	1.6	0.15	0.017 J	2.77	1.75
	7.5 min	HW-GAC3-EFF-2018-0125	1/25/2018	10:21	1/25/2018 10:21	10,387	17,243	0.14	0.036	0.02	0.068	0.23	0.25	0.13	0.020 J	0.03	1.1	0.12	0.013 J	2.16	1.22
	7.5 min																				
	10 min	HW-GAC4-EFF-2017-1101	11/1/2017	14:07	11/1/2017 14:07	574	715	0.0032 U	0.0036 U	0.0048 U	0.0043 U	0.0027 U	0.0034 U	0.0029 U	0.0048 U	0.0033 U	0.0026 U	0.0046 U	0.0038 U	ND	ND
	10 min	HW-GAC4-EFF-2017-1108	11/8/2017	14:15	11/8/2017 14:15	1,384	1,724	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-GAC4-EFF-2017-1115	11/15/2017	14:15	11/15/2017 14:15	2,194	2,732	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-GAC4-EFF-2017-1122	11/21/2017	13:30	11/21/2017 13:30	2,884	3,591	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-GAC4-EFF-2017-1129	11/29/2017	13:30	11/29/2017 13:30	3,809	4,743	0.0066 U	0.0066 U	0.0054 U	0.13	0.2	0.0056 U	0.014 J	0.0080 U	0.0074 U	0.010 J	0.0033 U	0.0087 U	0.35	0.010
	10 min	HW-GAC4-EFF-2017-1207	12/7/2017	8:37	12/7/2017 8:37	4,711	5,866	0.0066 U	0.0066 U	0.0054 U	0.074	0.24	0.009 J	0.026	0.0080 U	0.0074 U	0.009 J	0.006 J	0.0087 U	0.36	0.014
	10 min	HW-GAC4-EFF-2017-1214	12/14/2017	9:45	12/14/2017 9:45	5,526	6,881	0.0066 U	0.0066 U	0.0054 U	0.058	0.2	0.013 J	0.026	0.0080 U	0.0074 U	0.011 J	0.006 J	0.0087 U	0.31	0.017
	10 min	HW-GAC4-EFF-2017-1220	12/20/2017	9:14	12/20/2017 9:14	6,218	7,741	0.0066 U	0.0066 U	0.0054 U	0.067	0.19	0.013 J	0.031	0.0080 U	0.0074 U	0.015 J	0.008 J	0.0087 U	0.32	0.023
	10 min	HW-GAC4-EFF-2017-1227	12/27/2017	11:10	12/27/2017 11:10	7,037	8,761	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-GAC4-EFF-2018-0103	1/3/2018	13:25	1/3/2018 13:25	7,857	9,783	0.0066 U	0.0066 U	0.009 J	0.063	0.18	0.017 J	0.037	0.0080 U	0.0074 U	0.026	0.005 J	0.0087 U	0.34	0.031
	********** (Tube failure sometime between 1/3/18 and 1/9/18) ***********																				
	10 min	HW-GAC4-EFF-2018-0109	1/9/2018	13:47	1/9/2018 13:47	8,553	10,649	0.0066 U	0.0066 U	0.0054 U	0.06	0.19	0.014 J	0.031	0.0080 U	0.0074 U	0.017 J	0.006 J	0.0087 U	0.32	0.023
	10 min	HW-GAC4-EFF-2018-0118	1/18/2018	13:15	1/18/2018 13:15	9,591	11,942	0.010 J	0.0066 U	0.014 J	0.067	0.24	0.021	0.049	0.0080 U	0.009	0.039	0.013 J	0.0087 U	0.46	0.052
	10 min	HW-GAC4-EFF-2018-0125	1/25/2018	10:20	1/25/2018 10:20	10,387	12,932	0.011 J	0.0066 U	0.016 J	0.062	0.19	0.029	0.055	0.0080 U	0.0096	0.037	0.012 J	0.0087 U	0.47	0.049
	10 min																				
IX RESIN	2.5 min	HW-IX1-EFF-2017-1101	11/1/2017	14:15	11/1/2017 14:15	575	2,862	0.0032 U	0.0036 U	0.0048 U	0.0043 U	0.0027 U	0.0034 U	0.0029 U	0.0048 U	0.0033 U	0.0026 U	0.0046 U	0.0038 U	ND	ND
	2.5 min	HW-IX1-EFF-2017-1108	11/8/2017	14:22	11/8/2017 14:22	1,385	6,897	0.0066 U	0.0066 U	0.0054 U	0.0055 U	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	2.5 min	HW-IX1-EFF-2017-1115	11/15/2017	14:22	11/15/2017 14:22	2,194	10,929	0.0066 U	0.0066 U	0.0054 U	0.0055 U	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	2.5 min	HW-IX1-EFF-2017-1122	11/21/2017	13:37	11/21/2017 13:37	2,885	14,367	0.0066 U	0.0066 U	0.0054 U	0.014 J	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	2.5 min	HW-IX1-EFF-2017-1129	11/29/2017	13:37	11/29/2017 13:37	3,810	18,975	0.0066 U	0.0066 U	0.0054 U	0.0055 U	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	2.5 min	HW-IX1-EFF-2017-1207	12/7/2017	8:54	12/7/2017 8:54	4,713	23,470	0.0066 U	0.0066 U	0.0054 U	0.021	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.021	ND
	2.5 min	HW-IX1-EFF-2017-1214	12/14/2017	10:02	12/14/2017 10:02	5,528	27,529	0.0066 U	0.0066 U	0.0054 U	0.034	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.034	ND
	2.5 min	HW-IX1-EFF-2017-1220	12/20/2017	9:28	12/20/2017 9:28	6,219	30,971	0.0066 U	0.0066 U	0.0054 U	0.044	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.044	ND
	2.5 min	HW-IX1-EFF-2017-1227	12/27/2017	11:18	12/27/2017 11:18	7,037	35,047	0.0066 U	0.0066 U	0.0054 U	0.056	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.056	ND
	2.5 min	HW-IX1-EFF-2018-0103	1/3/2018	13:33	1/3/2018 13:33	7,858	39,133	0.0066 U	0.0066 U	0.0054 U	0.059	0.013 J	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.072	ND
	2.5 min	HW-IX1-EFF-2018-0109	1/9/2018	13:29	1/9/2018 13:29	8,551	42,588	0.0066 U	0.0066 U	0.0054 U	0.071	0.016 J	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.087	ND
	2.5 min	HW-IX1-EFF-2018-0119	1/18/2018		1/18/2018 0:00	9,527	47,448	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	2.5 min	HW-IX1-EFF-2018-0125	1/25/2018	10:28	1/25/2018 10:28	10,387	51,731	0.0066 U	0.0066 U	0.0054 U	0.067	0.035	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.102	ND
	********** (Pump failure sometime between 1/25/18 and 2/15/18) ***********																				
	2.5 min	HW-IX1-EFF-2018-022	2/22/2018	10:19	2/22/2018 10:19	13,625	67,856	0.0066 U	0.0066 U	0.0054 U	0.064	0.13	0.0056 U	0.056	0.0080 U	0.010 J	0.0060 U	0.012 J	0.0087 U	0.272	0.012 J
	2.5 min	HW-IX1-EFF-2018-0409	4/9/2018	10:03	4/9/2018 10:03	18,944	94,345	0.016 J	0.0066 U	0.0054 U	0.076	0.21	0.0056 U	0.055	0.0080 U	0.010 J	0.0060 U	0.010 J	0.0087 U	0.377	0.010 J
	2.5 min	HW-IX1-EFF-2018-0427	4/27/2018	9:22	4/27/2018 9:22	21,022	104,697	0.016 J	0.0066 U	0.0054 U	0.068	0.21	0.0056 U	0.059	0.0080 U	0.008 J	0.0060 U	0.006 J	0.0087 U	0.367	0.006 J
	2.5 min	HW-IX1-EFF-2018-0521	5/21/2018	10:34	5/21/2018 10:34	23,804	118,550	0.009 J	0.0066 U	0.0054 U	0.057	0.22	0.0056 U	0.047	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.333	ND
	2.5 min	HW-IX1-EFF-2018-0608	6/8/2018	10:28	6/8/2018 10:28	25,885	128,915	0.009 J	0.0066 U	0.0054 U	0.056	0.21	0.0056 U	0.052	0.0080 U	0.0074 U	0.0060 U	0.008 J	0.0087 U	0.335	0.008 J
	2.5 min	HW-IX1-EFF-2018-0628	6/28/2018	9:49	6/28/2018 9:49	28,195	140,420	0.008 J	0.0066 U	0.0054 U	0.059	0.21	0.0056 U	0.058	0.0080 U	0.0074 U	0.0060 U	0.007 J	0.0087 U	0.342	0.007 J
IX RESIN	5 min	HW-IX2-EFF-2017-1101	11/1/2017	14:14	11/1/2017 14:14	575	1,431	0.0032 U	0.0036 U	0.0048 U	0.0043 U	0.0027 U	0.0034 U	0.0029 U	0.0048 U	0.0033 U	0.0026 U	0.0046 U	0.0038 U	ND	ND
	5 min	HW-IX2-EFF-2017-1108	11/8/2017	14:21	11/8/2017 14:21	1,385	3,448	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-IX2-EFF-2017-1115	11/15/2017	14:21	11/15/2017 14:21	2,194	5,464	0.0066 U	0.0066 U	0.0054 U	0.0055 U	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	5 min	HW-IX2-EFF-2017-1122	11/21/2017	13:36	11/21/2017 13:36	2,885	7,183	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-IX2-EFF-2017-1129	11/29/2017	13:36	11/29/2017 13:36	3,810	9,487	0.0066 U	0.0066 U	0.0054 U	0.0055 U	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	5 min	HW-IX2-EFF-2017-1207	12/7/2017	8:52	12/7/2017 8:52	4,712	11,734	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-IX2-EFF-2017-1214	12/14/2017	10:00	12/14/2017 10:00	5,527	13,764	0.0066 U	0.0066 U	0.0054 U	0.0055 U	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	ND	ND
	5 min	HW-IX2-EFF-2017-1220	12/20/2017	9:26	12/20/2017 9:26	6,219	15,485	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-IX2-EFF-2017-1227	12/27/2017	11:17	12/27/2017 11:17	7,037	17,523	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-IX2-EFF-2018-0103	1/3/2018	13:32	1/3/2018 13:32	7,858	19,566	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	5 min	HW-IX2-EFF-2018-0109	1/9/2018	13:28	1/9/2018 13:28	8,551	21,294	0.0066 U	0.0066 U	0.0054 U	0.016	0.0075 U	0.0056 U	0.0035 U	0.0080 U	0.0074 U	0.0060 U	0.0033 U	0.0087 U	0.016	ND
	5 min	HW-IX2-EFF-2018-0119	1/18/2018		1/18/2018 0:00	9,527	23,724	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD

	5 min	HW-IX2-EFF-2018-0125	1/25/2018	10:27	1/25/2018 10:27	10,387	25,865	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.032**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.032**	**ND**
	********** (Pump failure sometime between 1/25/18 and 2/15/18) ***********																			
	5 min	HW-IX2-EFF-2018-0222	2/22/2018	10:18	2/22/2018 10:18	13,625	33,928	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.063**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.063**	**ND**
	5 min	HW-IX2-EFF-2018-0316	3/16/2018	11:18	3/16/2018 11:18	16,174	40,276	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.073**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.073**	**ND**
	5 min	HW-IX2-EFF-2018-0409	4/9/2018	10:02	4/9/2018 10:02	18,944	47,172	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.073**	**0.011 J**	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.084**	**ND**
	5 min	HW-IX2-EFF-2018-0427	4/27/2018	9:20	4/27/2018 9:20	21,022	52,348	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.074**	**0.017 J**	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.091**	**ND**
	5 min	HW-IX2-EFF-2018-0521	5/21/2018	10:32	5/21/2018 10:32	23,804	59,274	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.06**	**0.035**	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.095**	**ND**
	5 min	HW-IX2-EFF-2018-0608	6/8/2018	10:26	6/8/2018 10:26	25,885	64,457	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.058**	**0.053**	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.111**	**ND**
	5 min	HW-IX2-EFF-2018-0628	6/28/2018	9:48	6/28/2018 9:48	28,195	70,210	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.057**	**0.081**	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.138**	**ND**

IX RESIN	7.5 min	HW-IX3-EFF-2017-1101	11/1/2017	14:13	11/1/2017 14:13	575	954	*0.0032 U*	*0.0036 U*	*0.0048 U*	*0.0043 U*	*0.0027 U*	*0.0034 U*	*0.0029 U*	*0.0048 U*	*0.0033 U*	*0.0026 U*	*0.0046 U*	*0.0038 U*	**ND**	**ND**
	7.5 min	HW-IX3-EFF-2017-1108	11/8/2017	14:20	11/8/2017 14:20	1,385	2,299	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2017-1115	11/15/2017	14:20	11/15/2017 14:20	2,194	3,643	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2017-1122	11/21/2017	13:35	11/21/2017 13:35	2,885	4,789	*0.0066 U*	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**ND**	**ND**
	7.5 min	HW-IX3-EFF-2017-1129	11/29/2017	13:35	11/29/2017 13:35	3,810	6,325	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2017-1207	12/7/2017	8:50	12/7/2017 8:50	4,712	7,823	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2017-1214	12/14/2017	9:58	12/14/2017 9:58	5,527	9,176	*0.0066 U*	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**ND**	**ND**
	7.5 min	HW-IX3-EFF-2017-1220	12/20/2017	9:24	12/20/2017 9:24	6,218	10,323	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2017-1227	12/27/2017	11:16	12/27/2017 11:16	7,037	11,682	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2018-0103	1/3/2018	13:31	1/3/2018 13:31	7,857	13,044	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2018-0109	1/9/2018	13:27	1/9/2018 13:27	8,551	14,196	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2018-0119	1/18/2018		1/18/2018 0:00	9,527	15,816	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	7.5 min	HW-IX3-EFF-2018-0125	1/25/2018	10:26	1/25/2018 10:26	10,387	17,243	*0.0066 U*	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**ND**	**ND**
	********** (Pump failure sometime between 1/25/18 and 2/15/18) ***********																			
	7.5 min	HW-IX3-EFF-2018-0222	2/22/2018	10:17	2/22/2018 10:17	13,625	22,618	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.015 J**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.015 J**	**ND**
	7.5 min	HW-IX3-EFF-2018-0316	3/16/2018	11:17	3/16/2018 11:17	16,174	26,850	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.034**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.034**	**ND**
	7.5 min	HW-IX3-EFF-2018-0409	4/9/2018	10:01	4/9/2018 10:01	18,944	31,448	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.058**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.058**	**ND**
	7.5 min	HW-IX3-EFF-2018-0521	5/21/2018	10:30	5/21/2018 10:30	23,804	39,516	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.052**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.052**	**ND**
	7.5 min	HW-IX3-EFF-2018-0608	6/8/2018	10:24	6/8/2018 10:24	25,885	42,971	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.059**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.059**	**ND**
	7.5 min	HW-IX3-EFF-2018-0628	6/28/2018	9:47	6/28/2018 9:47	28,195	46,806	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.063**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.063**	**ND**

	10 min	HW-IX4-EFF-2017-1101	11/1/2017	14:12	11/1/2017 14:12	574	715	*0.0032 U*	*0.0036 U*	*0.0048 U*	*0.0043 U*	*0.0027 U*	*0.0034 U*	*0.0029 U*	*0.0048 U*	*0.0033 U*	*0.0026 U*	*0.0046 U*	*0.0038 U*	**ND**	**ND**
	10 min	HW-IX4-EFF-2017-1108	11/8/2017	14:19	11/8/2017 14:19	1,385	1,724	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2017-1115	11/15/2017	14:19	11/15/2017 14:19	2,194	2,732	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2017-1122	11/21/2017	13:34	11/21/2017 13:34	2,885	3,591	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2017-1129	11/29/2017	13:34	11/29/2017 13:34	3,810	4,743	*0.0066 U*	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**ND**	**ND**
	10 min	HW-IX4-EFF-2017-1204	12/7/2017	8:48	12/7/2017 8:48	4,712	5,867	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2017-1214	12/14/2017	9:56	12/14/2017 9:56	5,527	6,882	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2017-1220	12/20/2017	9:22	12/20/2017 9:22	6,218	7,742	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2017-1227	12/27/2017	11:15	12/27/2017 11:15	7,037	8,762	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2018-0103	1/3/2018	13:30	1/3/2018 13:30	7,857	9,783	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2018-0109	1/9/2018	13:26	1/9/2018 13:26	8,551	10,647	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2018-0119	1/18/2018		1/18/2018 0:00	9,527	11,862	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD	HOLD
	10 min	HW-IX4-EFF-2018-0125	1/25/2018	10:25	1/25/2018 10:25	10,387	12,933	**0.020**	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.020**	**ND**
	********** (Pump failure sometime between 1/25/18 and 2/15/18) ***********																			
	10 min	HW-IX4-EFF-2018-0222	2/22/2018	10:16	2/22/2018 10:16	13,625	16,964	*0.0066 U*	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**ND**	**ND**
	10 min	HW-IX4-EFF-2018-0316	3/16/2018	11:16	3/16/2018 11:16	16,174	20,138	**0.015 J**	*0.0066 U*	*0.0054 U*	*0.0055 U*	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.015 J**	**ND**
	10 min	HW-IX4-EFF-2018-0409	4/9/2018	10:00	4/9/2018 10:00	18,944	23,586	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.014 J**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.014 J**	**ND**
	10 min	HW-IX4-EFF-2018-0521	5/21/2018	10:28	5/21/2018 10:28	23,803	29,637	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.036**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.036**	**ND**
	10 min	HW-IX4-EFF-2018-0608	6/8/2018	10:22	6/8/2018 10:22	25,885	32,228	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.048**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.048**	**ND**
	10 min	HW-IX4-EFF-2018-0628	6/28/2018	9:46	6/28/2018 9:46	28,195	35,105	*0.0066 U*	*0.0066 U*	*0.0054 U*	**0.054**	*0.0075 U*	*0.0056 U*	*0.0035 U*	*0.0080 U*	*0.0074 U*	*0.0060 U*	*0.0033 U*	*0.0087 U*	**0.054**	**ND**