Final Report

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Appendix E: Surface Active Foam Fractionation (SAFF®) Pilot Study Report

Project 1007 Feasibility Study
Minnesota Pollution Control Agency

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Referenced Figures (Found in Feasibility Study Appendix A)

Acronyms and Abbreviations

µg/L	microgram per liter
%	percent
$	United States Dollars
A	ampere
AOF	adsorbable organic fluorine
cBOD	carbonaceous biochemical oxygen demand
COD	chemical oxygen demand
EPA	United States Environmental Protection Agency
EPOC	EPOC Enviro
FS	Feasibility Study
ft	foot
GAC	granular activated carbon
gal	gallon
gpd	gallons per day
gpm	gallons per minute
HBV	Health-Based Value
HDPE	high-density polyethylene
HFPO-DA	hexafluoropropylene oxide-dimer acid
HI	Hazard Index
HRL	Health Risk Limit
Hz	Hertz
kVA	kilovolt-ampere
kW	kilowatt
L	liter
LPM	liters per minute
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Levels Goal
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
mg/L	milligram per liter
min	minutes
mm	millimeter
MPCA	Minnesota Pollution Control Agency
ng/L	nanograms per liter
NPDES	National Pollutant Discharge Elimination System
ODS	Oakdale Disposal Site
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid

PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFPeA	perfluoropentanoic acid
PFUnA	perfluoroundecanoic acid
RFP	Request for Proposal
RPM	revolutions per minute
SAFF®	Surface Active Foam Fractionation
SSC	Site-Specific Water Quality Criteria
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TOP	total oxidizable precursor
TSS	total suspended solids
V	Volt
VBWD	Valley Branch Watershed District
WCL	Washington County Landfill

E1 Introduction

The Project 1007 Feasibility Study (FS) was conducted to evaluate the prevalence and migration of per- and polyfluoroalkyl substances (PFAS) in the East Metropolitan (East Metro) area of the greater Twin Cities metropolitan area. PFAS contamination is widespread throughout groundwater, surface water, and sediment in this area stemming from historical waste disposal activities. As part of the wider Project 1007 FS, a pilot study was implemented to assess the feasibility of foam fractionation technology for treatment of PFAS-impacted surface water and groundwater.

To evaluate foam fractionation, the Minnesota Pollution Control Agency (MPCA) purchased a Surface Active Foam Fractionation (SAFF®) unit from EPOC Enviro (EPOC) in 2021. SAFF® was selected as a foam fractionation technology as EPOC was the only vendor to respond to the 2020 Request for Proposal (RFP) posted by the State of Minnesota and the technology demonstrated effective performance during bench-scale testing. More details on the bench-scale testing can be found in the SAFF® Bench Scale Summary Report from February 2021 (AECOM, 2021). This pilot study aimed to test the performance of SAFF® technology to physically remove PFAS from impacted water and to concentrate the PFAS into a small volume.

The pilot-scale treatment system was deployed at Tablyn Park in the City of Lake Elmo, Minnesota starting in November 2022. Technology performance was tested on the Shakopee and Jordan groundwater aquifers as well as on surface water from Raleigh Creek. This report documents the pilot study and the findings associated with the operational needs, optimization parameters, and analytical results. The PFAS concentrate generated as part of this pilot study was used for additional technology evaluation at both the bench- and pilot-scale. Appendix F (DE-FLUORO™ PFAS Destruction Pilot Study) describes the field study utilizing the DE-FLUORO™ electrochemical destruction technology and Appendix G (PFAS Destruction Technology Bench-Scale Study Summary and Analysis) describes the results of bench-scale studies performed by seven destruction technology vendors.

Overall, the goals of the pilot study were to:

- Operate the PFAS removal system using influent waters with varying PFAS concentrations and water chemistries;
- Determine the feasibility of operating the SAFF® unit with different surface water flow conditions and different groundwater aquifers;
- Evaluate the system's performance to determine optimal operational parameters; and
- Use results to evaluate potential effectiveness of technology for full-scale implementation.

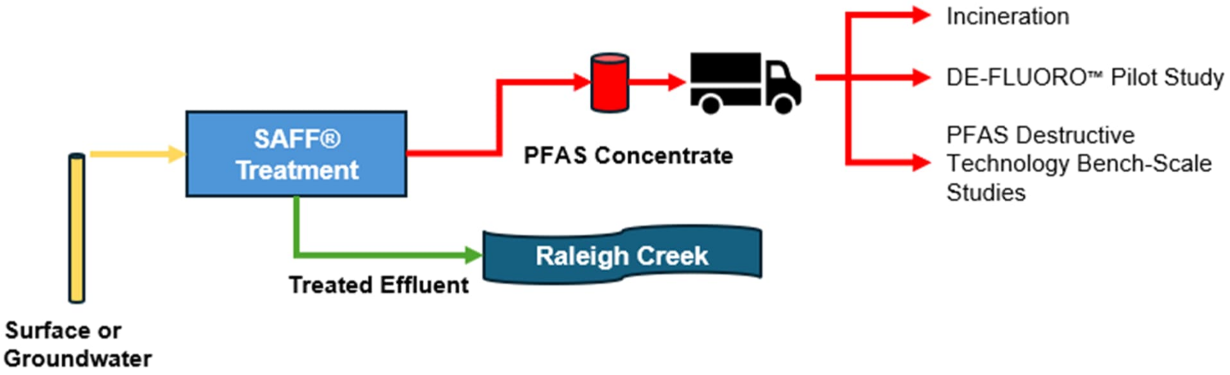

Figure E.1: Overview of SAFF® Pilot System.

E1.1 Site Background

Project 1007 is a flood mitigation system constructed in 1987 to address flooding of Lakes De Montreville, Olson, and Jane, together known as the Tri-Lakes, shown in Figure 2 of Appendix A. It utilizes both natural surface water bodies and constructed water conveyance structures to lower the water levels in the Tri-Lakes, ultimately discharging that water to the St. Croix River. Two historical PFAS disposal sites are connected by Project 1007. The Oakdale Disposal Site (ODS) is located in a wetland area at the approximate headwaters of Raleigh Creek, which flows intermittently into Project 1007 at Tablyn Park. The second disposal site, the Washington County Landfill (WCL), discharged groundwater from gradient control wells that likely contained PFAS between 1988 and 1995. In addition to surface water impacts, groundwater impacts have migrated from both disposal sites, including vertically into aquifers utilized for drinking water in the East Metro. Infiltration of PFAS impacted surface water, as conveyed by Project 1007, has resulted in a larger groundwater plume, including in the drinking water aquifers. The Jordan Aquifer is most commonly used for municipal drinking water in the East Metro; however, the Shakopee Aquifer, located vertically above the Jordan Aquifer also contains numerous private wells and is hydraulically connected to the Jordan Aquifer. The entire Project 1007 Site is defined by this larger resulting PFAS plume that has resulted from both surface water infiltration and leaching from both disposal sites and is referred to as the Site in this report. A more detailed Conceptual Site Model is included in Section 5 of the FS.

As this FS is focused on the protection of drinking water resources, removal of PFAS from surface water is an important part of preventing the migration of PFAS into the drinking water aquifers. Perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and perfluorobutanoic acid (PFBA) are the PFAS with the highest concentration across the Site. While PFBA does exceed the Minnesota Department of Health (MDH) Health Risk Limit (HRL) near WCL, across the rest of the Site, PFBA levels are below the current MDH HRL (7,000 nanograms per liter [ng/L]). As a result, this study focused on the ability of foam fractionation to remove PFOA and PFOS from groundwater and surface water.

E2 Technology Description

Foam fractionation relies on the surfactant nature of PFAS, which often contain a hydrophilic ("water-loving") head and hydrophobic ("water-hating") tail. As a result, the hydrophilic tail of some PFAS compounds adhere to gas-liquid interfaces, including that of air bubbles, and will promote the formation of foam. Foam fractionation utilizes these surfactant properties of PFAS to remove PFAS from the bulk water and concentrate it into a small aqueous volume of water. This is achieved through aeration of the water, which creates bubbles in the water column. PFAS molecules adhere to the bubbles, rise to the top of the column, and accumulate in a PFAS-rich foam, which is then separated from the bulk water. When the foam condenses, a small volume of water with high PFAS concentrations remains. While different foam fractionation vendors have slightly different applications of this, two to three concentration steps, often referred to as primary, secondary, and tertiary fractionation, are utilized to further concentrate the PFAS into a smaller volume. While the size and geometry of the vessels may differ at the second or third fractionation step compared to the primary fractionation step where PFAS is initially removed from the bulk water, the principle remains the same. Additional surfactants, sometimes referred to as boosters, can also be dosed during water treatment to promote foaming and improve PFAS removal. This was not implemented for this project because treated water was directly discharged to surface water (Raleigh Creek) and there were uncertainties around the aquatic toxicity of the commonly used surfactants.

SAFF® is a foam fractionation technology manufactured by EPOC Enviro that utilizes a batch system. Primary and secondary fractionation steps are standard with each system. A tertiary fractionation step can also be used to further concentrate the PFAS. These systems are built in 40-foot (ft) shipping containers to allow for mobility of the treatment system. The MPCA purchased a SAFF®20 for this pilot study which contains two primary fractionation vessels and a single secondary fractionation vessel. The SAFF®40 is EPOC's more commonly manufactured system and has twice the capacity of a SAFF®20 in the same footprint, with four primary fractionation vessels and two secondary fractionation vessels. Tertiary fractionation can also be implemented in the SAFF®40 to further reduce PFAS concentrate volumes.

Figure E.2 provides a schematic of the SAFF®20 treatment process. Impacted feedwater supplied to the system is filtered through bag filters before entering Tank 1, a 3,480 liter (L) supply tank that feeds the primary fractionation vessels. Primary fractionation, and the remainder of treatment steps, are described in greater detail below.

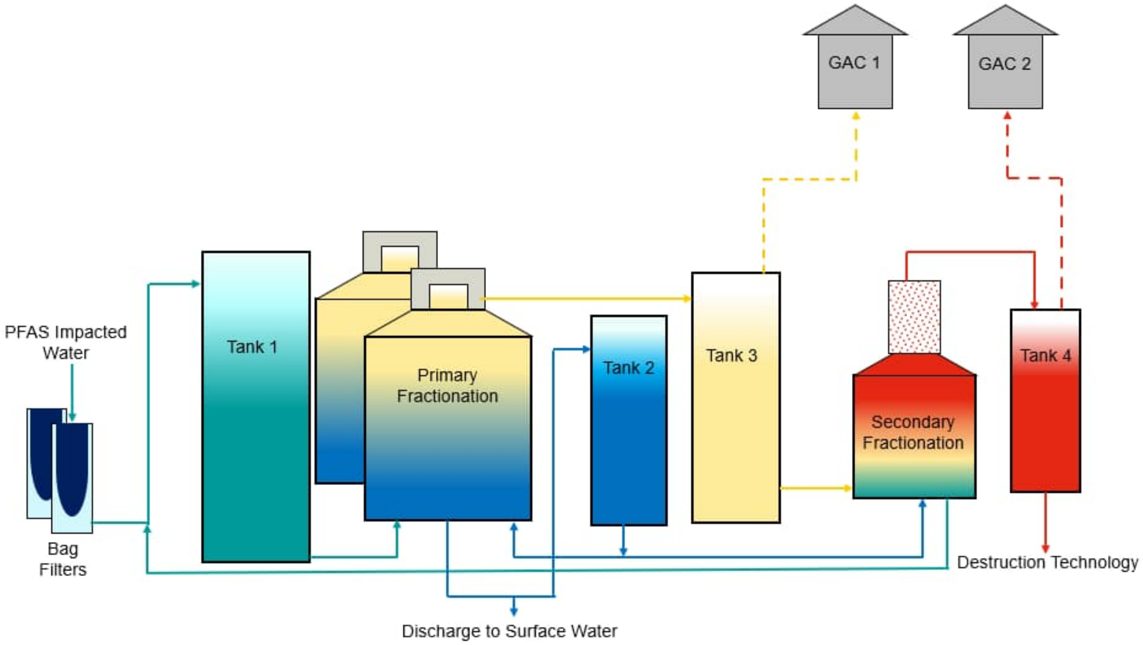

Figure E.2. SAFF® General Process Flow.

E2.1 Primary Fractionation

The primary fractionation tanks have a volume of 2,600 L and are batch systems that run in parallel for an adjustable length of time. Air is injected through ten venturis at the base of each primary fractionation vessel, generating PFAS-rich foam by sending the bubbles (to which PFAS molecules adhere) upwards. The foam, referred to as “primary fractionate” at this stage, collects at the top of the vessel, flows over a short cone into a viewing hood, and drains to Tank 3, a 1,600 L storage tank. At the end of each cycle, clean water stored in Tank 2 (1,000 L) is pumped at a constant rate into the bottom of the vessel during a stage referred to as “top-up”. This is to push remaining foam over the top of the cone. The treated water then discharges to Raleigh Creek and is also used to replenish Tank 2. The cleaned water stored in Tank 2, known as top-up feedwater, is also used by the sprinkler system which knocks down foam and rinses hoods, tanks, and level sensors. In Tank 3, the foam condenses before being processed in a single secondary fractionation vessel. From Tank 3, a dedicated vent line expels any air accumulated from the primary fractionation cycles through a granular activated carbon (GAC) filter located outside the container that vents to the atmosphere.

E2.2 Secondary Fractionation

The secondary fractionation vessel (950 L) operates similarly to the primary fractionation vessels, with the exception that foam concentrate is pulled from a taller viewing hood by vacuum rather than utilizing gravity-driven spill-over. Air is injected through ten venturis at the base of the vessel, and foam is collected and transferred to Tank 4 (820 L), where it condenses prior to disposal. The remaining water from the secondary fractionation process is recirculated back to Tank 1 so that it undergoes primary fractionation again. From Tank 4, a second dedicated vent line, separate from that attached to Tank 3, expels any air accumulated from the secondary fractionation cycles through a GAC filter located outside the container that vents to the atmosphere.

E2.3 Waste Removal

The final stage of SAFF® processing involves disposal of secondary fractionate from Tank 4, which can be gravity drained through an access panel at the side of the SAFF® container. This pilot study disposed of secondary fractionate via pilot-scale destruction, bench-scale destruction, and industrial incineration.

E3 Site Selection

Tablyn Park was selected as the location for the pilot study as it allowed for testing on both contaminated groundwater and surface water. Multiple monitoring wells had already been installed in the park as part of the Site investigation to confirm presence of PFAS in bedrock aquifers. This allowed pilot testing to occur using contaminated groundwater without the need to drill new wells. Additionally, Raleigh Creek runs along the north side of the park up to the confluence with the Project 1007 conveyance, which contains flow from the Tri-Lakes. The combined flow forms the eastern boundary of Tablyn Park. While water does not continuously flow through Raleigh Creek, surface water operations could only be implemented during the spring and larger rain events to test the effectiveness of foam fractionation treatment of surface water. Raleigh Creek could also be used as the discharge point for both groundwater and surface water (discharge point was downstream of the surface water intake), making Tablyn Park the ideal location for pilot testing. The location of the Site is shown in Figure 162 of Appendix A, and an aerial view of the Site is shown in Figure E.3.

Figure E.3: SAFF®20 Site Installation and Location of Tested Water Sources.

PFOS concentrations in Raleigh Creek at Tablyn Park typically range from 900 ng/L to 3,000 ng/L. Jordan Aquifer PFOS concentrations typically range from 3 to 700 ng/L and PFOA concentrations range from 8 to 700 ng/L. Pumping tests conducted before the SAFF® was installed indicated a hydraulic conductivity high enough to provide sufficient water to the SAFF® for continuous operations.

A St. Peter Aquifer well, which has PFOS and PFOA concentrations ranging from 70 to 900 ng/L and from 20 to 200 ng/L, was also considered for pilot testing. However, during a pumping test, water could not be pumped at a high enough rate to provide enough water to operate the SAFF® continuously.

A Shakopee Aquifer monitoring well was installed in October 2022 at Tablyn Park in anticipation of the pilot study. PFOS and PFOA concentrations in this well have been observed to range from 500 to 1,000 ng/L and 200 to 300 ng/L, respectively. The high PFOS and PFOA concentrations observed within the Shakopee Aquifer are similar to those observed further downgradient in the Jordan Aquifer. Slug testing also confirmed a sufficiently high hydraulic conductivity in the Shakopee Aquifer for operation of the SAFF®.

Prior to system installation, Raleigh Creek and the Jordan Aquifer well had been sampled several times for PFAS analysis. These results provided an indication of the variability in PFAS concentrations to be expected in the influent feedwater during operations. A sample from the Shakopee Aquifer was collected prior to system installation as well as additional samples during operations. Additional water quality parameters were analyzed to ensure the feedwater chemistry would be acceptable for the SAFF® system. While water hardness is characteristically high in the Jordan and Shakopee Aquifers across the Site, based on non-PFAS water chemistry results, EPOC Enviro recommended no additional pre-treatment for the pilot study. Water chemistry parameters for the Shakopee Aquifer, Jordan Aquifer, and Raleigh Creek are summarized in Table E.1; note that there was some variation in total organic carbon (TOC) values in Raleigh Creek throughout testing.

Generally, the groundwater portion of this pilot study occurred when dry or freezing conditions consistently prevented surface water flow in Raleigh Creek. When snowmelt or rainfall triggered continuous surface water flow from the headwaters of Raleigh Creek through Tablyn Park, the SAFF® system was switched over to treat surface water.

Table E.1: General Water Chemistry Parameters of Tested Waters.

Source Parameter		Shakopee Aquifer		Jordan Aquifer		Raleigh Creek	
		Tank 1	Effluent	Tank 1	Effluent	Tank 1	Effluent
TKN (mg/L)		<0.50	<0.50	<0.16	<0.16	0.51	<0.25
TOC (mg/L)		<1.0	<1.0	<0.47	<0.47	6.4	6.3
Metals (µg/L)	Cadmium	<3.0	<3.0	<0.46	<0.46	<0.46	<0.46
	Chromium	<10.0	<10.0	<1.4	<1.4	<1.4	<1.4
	Copper	<10.0	<10.0	<3.1	<3.1	<3.1	<3.1
	Iron	109	<50.0	<22.2	<22.2	85	72
	Lead	<10.0	<10.0	<2.6	<2.6	<2.6	<2.6
	Nickel	<20.0	<20.0	1.6	<1.6	<1.6	<1.6
	Zinc	38.6	35.3	87.1	<1.6	<4.5	<4.5
	Total Hardness (mg/L)	302	291	190	192	193	194
cBOD, 5 day (mg/L)		75.8	<2.0	<1.0	<3.0	<1.0	<3.0
Alkalinity (mg/L)		208	205	192	194	128	130
TSS (mg/L)		<10.0	<10.0	<5.0	<5.0	<5.0	<5.0
pH		7.2	7.4	8.4	7.9	8.2	8.6
Anions (mg/L)	Chloride	118	118	5	4.6	225	229
	Fluoride	0.079	0.078	0.12	0.12	0.093	0.093
	Nitrate as N	3.0	3.0	0.53	0.53	<0.023	<0.023
	Sulfate	16.0	15.9	5.1	5.3	10.8	11.7
Nitrogen, Ammonia (mg/L)		<0.10	<0.10	<0.015	<0.015	<0.015	0.28
Nitrogen, NO_2 + NO_3 (mg/L)		2.9	2.9	0.63	0.63	<0.021	<0.021
COD (mg/L)		<50.0	<50.0	<17.0	<17.0	<17.0	<17.0
Total Phosphorus (mg/L)		<0.10	<0.10	<0.024	<0.024	<0.024	<0.024

Legend: cBOD = carbonaceous biochemical oxygen demand; COD = chemical oxygen demand; mg/L = milligram per liter; TKN = total Kjeldahl nitrogen; TSS = total suspended solids; µg/L = microgram per liter.

E4 Site Preparation and System Installation

Site preparation and requirements for system installation are discussed in this section. All items discussed here may not be relevant to future installations, nor is this intended to be a comprehensive list of site-specific requirements. All sites must be considered individually prior to installation of a SAFF® unit.

E4.1 Permits

The following permits were issued to ensure compliance with State and local regulations:

- Minnesota Department of Natural Resources (MDNR) Water Appropriations Permit: The MDNR issued Appropriations Permits 2022-2858 and 2023-2984 for withdrawal of water from the St. Peter, Shakopee, and Jordan Aquifers. The MDNR also issued Appropriations Permits 2023-0043 and 2024-0348 for withdrawal of water from Raleigh Creek. To comply with these appropriations permits, the monthly volumes pumped from each influent source were reported on an annual basis.
- MDNR Public Water Work Permit: The MDNR issued Public Water Work Permit 2022-3121 for the intake and outfall structures in Raleigh Creek.

The MPCA's Industrial Permitting group applied for an exemption through the National Pollutant Discharge Elimination System (NPDES). The exemption is tied the Federal NPDES permit requirements under 40CFR Section 122.3 Exclusion – Part (d) to CERCLA/MERCLA, and no NPDES permits were required for this pilot study.

Construction activities near Raleigh Creek were also subject to Valley Branch Watershed District (VBWD) jurisdiction. To determine if wetland regulations would apply, VBWD conducted a wetland delineation of Raleigh Creek at Tablyn Park and found reed canary grass (a facultative wetland species but obligate upland species) but no other wetland species. As a result, pilot study activities were excluded from wetland regulations. The installation location within the 100-year flood plain required AECOM to provide a no-rise certification proving that the pilot study would not create a rise to the base flood elevation. VBWD approved the work, issuing permit 2022-54. The permit was approved for three years. Furthermore, upon request by VBWD, a silt fence was installed along the north side of the gravel access road constructed for this study between the road and Raleigh Creek. The fence was also extended along the eastern edge of the gravel to prevent sediment loading into Raleigh Creek.

To demonstrate compliance with water quality standards proposed by VBWD and the MDNR, monthly samples were collected from the SAFF® system's influent and effluent for a wide array of parameters; select effluent results are given in Table E.2. After demonstrating that SAFF® treatment did not negatively impact water quality in Raleigh Creek, it was determined that monthly water quality analyses could be reduced to pH and total suspended solids (TSS) only.

Table E.2: Select Effluent Permit Monitoring Results for Treated SAFF® Effluent.

Parameter	Limit	Effluent Sampling Results		
	Sample Date	*2/6/2023*	*5/2/2023*	*7/20/2023*
	Water Source	*Shakopee*	*Raleigh Creek*	*Jordan*
Flow (1)	Monitor (million gallons)	0.676	0.411	0.587
pH	6.0 SU to 9.0 SU	8.3	8.2	8.2
Total Hardness	Monitor only, mg/L	299	193	185
Total Suspended Solids	30 mg/L	<10.0	<5.0	<5.0
cBOD (5 Day, 20 Deg C)	Monitor only, mg/L	<2.0	<1.0	<1.0
Nitrite Plus Nitrate, Total (as N)	Monitor only, mg/L	3.1	<0.021	0.63
Nitrogen, Kjeldahl, Total	Monitor only, mg/L	<0.50	0.51	<0.16
Nitrogen, Total (as N) (2)	Monitor only, mg/L	3.6	0.531	0.79
Phosphorus, Total (as P)	Monitor only, mg/L	<0.10	<0.024	<0.024

(1) Flow is reported as the volume treated at the end of each month.

(2) Total Nitrogen is calculated as the sum of Total Kjeldahl Nitrogen and Nitrite Plus Nitrate. If either value was below the laboratory method detection limit, the method detection limit was used for the calculation of Total Nitrogen.

E4.2 Applicable PFAS Standards

Several PFAS regulatory standards exist, from both Federal and State regulatory agencies. The United States Environmental Protection Agency (EPA) has set enforceable Maximum Contaminant Levels (MCLs) for five PFAS species and the cumulative Hazard Index (HI). The EPA has also set unenforceable Maximum Contaminant Level Goals (MCLGs) for PFOS and PFOA. Due to Site characteristics, PFOS, PFOA, and perfluorohexanesulfonic acid (PFHxS) are the only relevant Site PFAS that exceed EPA MCLs; however, as of the publication of this report the EPA has announced its intention to rescind the MCL for PFHxS. In 2024, MDH set enforceable groundwater HRLs, as well as enforceable groundwater and unenforceable cancer Health-Based Values (HBVs). HBVs are generally lower than MCLs and HRLs and thus set the treatment target. MPCA Site-Specific Water Quality Criteria (SSC) also had to be considered for discharge to surface water. Relevant limits are summarized in Table E.3 and more information on regulatory limits, including a description of the HI, can be found in Section 9 of the FS.

Table E.3: Applicable PFAS Standards, in ng/L.

Compound	EPA MCLG	EPA MCL	MDH 2024 Groundwater HRL	MDH 2024 Groundwater HBV	MDH 2024 Cancer HBV	MPCA SSC
Enforceable	No	Yes	Yes	Yes	No	Yes
Unit	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
PFOA	Zero	4.0	35	0.24	0.0079	25
PFOS	Zero	4.0	300	2.3	7.6	0.05
PFHxS	10	10	47	-	-	20

E4.3 Site Access

To provide a level surface and consistent vehicle access for both installation and ongoing operations, a gravel road and leveled gravel pad were installed on November 14, 2022. The 6-inch thick, Class V aggregate access road, approximately 15-ft wide and 700-ft long, extended from the entrance road of Tablyn Park to the SAFF® system. An additional 3-inch deep layer of 1-inch rock was added to the existing gravel pad in July 2024 to improve ease of removing the trailer.

An 8-ft tall chain-link fence was installed around the gravel pad with a 20-ft double door swing gate on the western side of the fence and a 42-inch walking gate on the eastern side of the fence. A tan mesh privacy screen was also installed along the entire length of fence. After completion of operations and removal of the SAFF®, site restoration activities were performed, including removal of the fencing, removal of the gravel pad and road, and hydroseeding of the area to allow the area to again be used for recreation.

E4.4 Electrical Work

The SAFF® unit required 480 Volt (V), 3-phase power with a minimum of 63 ampere (A). To accommodate this, a new power drop was installed at Tablyn Park by Xcel Energy. To connect the transformer to the overhead power lines, an underground conduit was installed from the power drop to the transformer. Bloomington Electric conducted the remaining electrical work, including installation of a 100A, 277/480V, 3-phase, 3R power distribution panel and a 30 kilovolt-ampere (kVA), 1-100A, 120/208V, 3-phase, 3R panel transformer. Bloomington Electric also enabled the connection between the SAFF® system and the transformer, along with connection to a generator for initial operations. All electrical work was inspected and approved by an electrical inspector.

Schedule delays resulted in operations starting prior to the installation of the power drop and thus without permanent power. A generator and an auxiliary fuel tank were rented through Ziegler CAT to power the SAFF® system between November 2022 and early January 2023. These were staged on the west side of the SAFF® unit within the fenced perimeter to facilitate access for refueling. The generator and fuel tank were removed from Site on January 6, 2023, once permanent power was available.

In spring 2023, Bloomington Electric installed an additional outlet drawing power from the transformer approximately 5 ft south of Raleigh Creek. The outlet, mounted on a post approximately 3 ft above the ground, supplied power to the surface water pump. Bloomington Electric also installed a relay inside the SAFF® system to enable switching between the surface water pump and the groundwater pump without the need for any electrical rewiring. This allowed staff to alternate water sources during intermittent surface water flow months.

E4.5 Inlet System

The SAFF® system can accommodate an influent flow rate of up to 650 liters per minute (LPM) or approximately 172 gallons per minute (gpm). The submersible pumps selected to deliver groundwater and surface water to the system were sized to maximize flow under field limitations. During operations, each pump reached a flow rate of approximately 70 gpm. 2-inch black high-density polyethylene (HDPE) piping connected each submersible pump to the SAFF® inlet, where a reducer coupling connected this piping to the SAFF®'s 3-inch DN80 influent port. The piping was heat traced and insulated to prevent freezing during cold weather operations. Ball valves were configured to allow isolation of either surface water or groundwater sources when required. Pumps were wired to the main control panel to allow the SAFF® control programing to start and stop each pump; Bloomington Electric performed this portion of the work.

E4.5.1 Groundwater Pumps

Three submersible well pumps were installed by Traut Companies Inc. on October 18 and November 1, 2022 in Shakopee, Jordan, and St. Peter wells at Tablyn Park. Franklin Electric Model 60FH3S4-PE 4-inch High Capacity Submersible pumps were installed in the Shakopee and Jordan monitoring wells and were selected to accommodate the 4-inch well diameters and maximize pumping rates according to anticipated drawdown and head loss. One pump motor (Franklin Electric 2243022604G 4-inch Submersible Water Well Motor 3HP, 230V, Single Phase) was shared between the identical Shakopee and Jordan well pumps and transferred between wells by a licensed electrician as needed throughout the project. A similar Franklin Electric 3-inch submersible pump was installed in the St. Peter well, similarly selected to accommodate the 4-inch well diameters and maximize pumping rates according to anticipated drawdown.

A 2-inch to 1.5-inch reducer bushing was added to each submersible well pump outlet which was connected to a 1.5-inch HDPE drop pipe that extended to the well cap. Each well cap has two 0.5-inch openings for a transducer and a water level meter. The stainless-steel wellhead assembly tees off to a pressure gauge and to the discharge line. On the discharge line is a ball valve and a Badger Meter ModMAG M2000 flow meter. From the flow meter, the assembly flanges off to 2-inch black HDPE piping that connects to the SAFF® inlet port. A 4 ft by 4 ft insulated wooden enclosure was built around the wellhead assembly to protect the piping from freezing during cold weather operations. A space heater was also added to the enclosure during cold weather operations. Outside of the enclosure, the piping was heat traced and insulated. The wellhead assembly and wooden enclosure were transferred between wells as influent sources changed.

E4.5.2 Surface Water Pump

A 230V, single-phase, 17.1 A, Zoeller D295 model submersible pump with a 60 Hertz (Hz), 3450 revolutions per minute (RPM) motor was installed within a natural low point in Raleigh Creek on March 27, 2023, prior to spring snow melt and precipitation. This natural low point is approximately 30 ft upstream of the discharge point. The pump was housed by a fiberglass sump container which was perforated throughout its mid-section so that water could freely flow through it at a height which would limit entry of stream bed particulates. The pump was elevated approximately 8 inches from the floor of the sump container with concrete risers to limit suction of particulates accumulating on the sump floor. A float switch built into the pump operated at a shut-off point of 5 inches and a turn-on point of 14 inches (or a shut-off point of 13 inches and a turn-on point of 22 inches on the concrete risers). Because of the intake structure’s positioning within a natural low point in the stream, water levels below this shut-off point were indicative of non-continuous flow in Raleigh Creek. Metal stakes were placed into the creek bed around the sump container to stabilize the structure. A pipe spanning from the surface water pump to the SAFF® intake was set below the SAFF® trailer and contained a ball valve and a Seametrics WMP104-200 flow meter approximately 10 ft prior to the SAFF® intake location.

E4.6 Discharge System

Treated SAFF® effluent was discharged to Raleigh Creek just before the confluence of Raleigh Creek with the Project 1007 Conveyance System. Water discharged at a rate of approximately 400 LPM (or approximately 100 gpm); discharge typically took 5 to 6 minutes. The frequency of discharge cycles was dependent on the length of the primary fractionation cycles, with shorter primary fractionation cycles resulting in more frequent discharge events. 2-inch black SDR 11 HDPE piping was connected to the SAFF®’s flanged effluent port and secured to pipe hangers such that it ran at a slight decline towards the discharge point to facilitate complete draining and reduce the risk of freezing during cold weather operations. This piping was similarly wrapped with heat trace and insulation to further reduce the risk of freezing.

An erosion control structure was constructed at the discharge point into Raleigh Creek to prevent erosion of the streambank. The structure was approved by the MDNR and consisted of a 10 ft long by 8 ft wide geotextile fabric placed below 6-inch to 12-inch riprap. This structure began several feet from the stream bank and extended down the stream wall and halfway into the stream bed. The discharge pipe was placed on the stream bank so that water dissipated on the riprap before entering the stream, shown in Figure E.4.

Figure E.4: Treated Effluent Discharge Location and Erosion Control Structure.

E4.7 Waste Storage

Secondary fractionate waste (PFAS concentrate) generated by the SAFF® system was periodically transferred to 55-gallon steel drums, which were kept inside overpack drums. Drums were then transported to WCL for storage prior to final disposal or use in destructive technology bench-scale testing. Transportation of this waste was performed by a licensed waste hauler. A 10 ft x 20 ft locked and heated Tuff Shed was installed on a pre-existing asphalt pad at the northwest corner of WCL in October 2022 to allow for secure storage of the waste during the winter months.

E4.8 System Installation

The SAFF®20 system, which is contained within a 40-ft shipping container, was manufactured by EPOC in Australia and shipped to the Belair Sitework Services shipping yard in New Brighton, MN, where it arrived in November 2022. There, an EPOC representative installed an Ingersoll Rand 2340 air compressor and oversaw the transfer of the shipping container to a custom flatbed trailer. The trailer mounted SAFF® was then transported to Tablyn Park. Once positioned on the gravel pad at Tablyn Park, the container was properly leveled. Upon arrival, the heaters and transformer box were installed by a licensed electrician. Scaffolding (4 feet in height) with stairs and railings was affixed to a portion of the north side of the SAFF® in December 2022 for safe access to the system. Scaffolding was later expanded in December 2024 to allow access to all doors of the SAFF®. Mobile stairs were provided by EPOC to enable access to doors at the ends of the trailer and to access sampling ports.

Prior to starting operations, the SAFF®20 Onsite Setup Sequence was completed. This document was provided in the operations and maintenance manual supplied by EPOC. This included connecting the piping, filling Tank 2 with clean water, checking electrical connections, and bleeding system pumps. An EPOC operator directed the commissioning and training of AECOM operators.

Thermal trailer skirting was added to the trailer in December 2022 to block wind and provide a layer of insulation around the trailer. Insulation was also installed in any gaps between the container and the trailer.

E5 Tuning Methods

Successful operation of a foam fractionation system requires tuning of the system to optimize PFAS removal. Tuning is inherently an iterative process, where parameters are varied, samples are collected and analyzed, and then system parameters are further varied until PFAS removal is optimized. Tuning was required for both primary and secondary fractionation.

E5.1 Primary Fractionation Tuning

Primary fractionation tuning was accomplished by varying the below operational parameters. Numbers on each parameter correspond to the numbered relative locations in Figure E.5.

(1) Vessel fill level
(2) Venturi pump energy frequency (0 to 50 Hz)
(3) Stage duration
(4) Top-up rate
(5) Top-up time

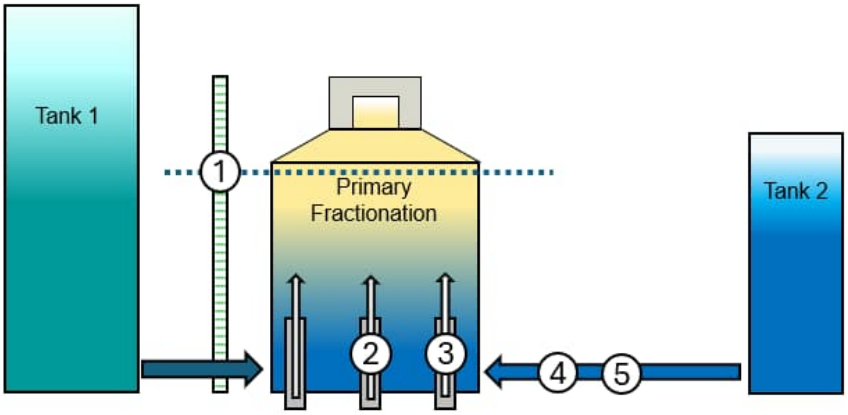

Figure E.5: Primary Fractionation Tuning Approach.

Vessel fill level was not tuned to the same extent as the other parameters. At the beginning of operations, the primary vessel fill pump often overshot the setpoint and the degree to which the pump overfilled was inconsistent. These inconsistencies indicated that extensive tuning according to fill level may not yield representative results. The aerosolization tuning required more fine-tuned fill levels, and after system programming was adjusted to minimize the gap between set points and actual fill levels, fill level was tuned and monitored more closely.

Once a primary fractionation vessel reaches the desired fill level, treatment occurs across a maximum of 10 stages, each of which has an adjustable duration and venturi pump frequency. The venturi pump frequency determines how much air is being injected into the primary vessel. As previously mentioned, during the tuning process for each influent water source, optimization focused on removal of PFOS and PFOA as these two compounds are consistently in exceedance of both groundwater and surface water standards across the Site. At the start of the project, PFHxS was not in exceedance of the MDH HRL (47 ng/L). In April 2024, EPA released new MCLs, including a lower standard for PFHxS (10 ng/L); however, this was after a majority of the tuning had occurred and the pilot test was then focused on long-term operations, so removal of PFHxS to below 10 ng/L was not prioritized.

The system was typically allowed to run for 24 hours at a particular setting before sampling to evaluate those settings. Allowing the system to run for this stretch of time allowed for stabilization of Tank 2 top-up water concentrations.

Because Tank 1 samples were collected intermittently, effluent concentrations typically guided parameter adjustment rather than removal efficiency calculations. Removal efficiency calculations could be relied upon more heavily during longer-term operations when corresponding influent samples were collected for each effluent sample.

In April 2023, it was observed that performance between the two primary fractionation vessels was variable despite identical settings. The suspected reason for variable performance was minor venturi pump damage from surface water debris introduced in April 2023. After this was discovered, most subsequent sampling occurred using the same primary fractionation vessel (SV1-20) which exhibited slightly improved removal efficiencies when compared to SV1-10. After a pinhole leak on SV1-20 paused that vessel's operation in December 2023, tuning continued using only SV1-10.

Four different treatment methods (stepwise, oscillation, continuous top-up, and concentrate dosing) were tested to evaluate their impact on PFAS removal. The parameters listed above were systematically adjusted with the goals of minimizing treatment times and energy consumption and maximizing removal efficiency and throughput. The different treatment methods are described in more detail in Section E6.

E5.2 Secondary Fractionation Tuning

The following parameters were adjustable for secondary fractionation, and each correspond to the numbers on the figure below:

(1) Vessel fill level
(2) Venturi pump energy frequency (0 to 50 Hz)
(3) Stage duration
(4) Blower energy frequency (0 to 50 Hz)
(5) Top-up rate
(6) Top-up time

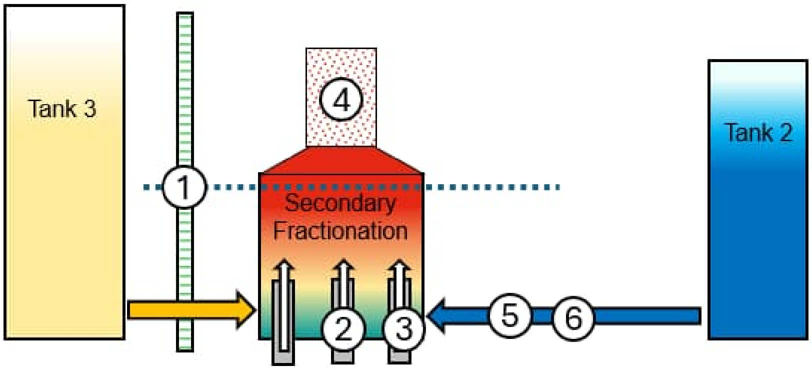

Figure E.6: Secondary Fractionation Tuning Approach.

Once the secondary fractionation vessel reaches the desired fill level, treatment occurs across a maximum of 10 stages, each of which has an adjustable duration, venturi pump frequency, and blower frequency. The venturi pump frequency determines how much air is being injected into the secondary vessel, while blower frequency determines the strength of the vacuum extracting foam from the top of the vessel.

The goal of secondary tuning was to maximize removal of PFAS from a high volume of primary fractionate and minimize the volume of highly concentrated PFAS product. As there is no way to directly sample the discharge from the secondary vessel to either Tank 4 or Tank 1, tuning could not be completed in the same manner as with primary fractionation. Instead, secondary tuning relied on visual observations of foam production and foam transfer during each stage of a cycle, along with recording the volume increase in Tank 4. The removal was generally evaluated by sampling Tank 3 as an influent sample, and Tank 1 after the secondary fractionation cycle discharged as an effluent sample to approximate the removal of PFAS. As suggested by EPOC, the general approach targeted foam generation in stages 1 through 8 with minimal transfer to tank 4 to allow for accumulation of a PFAS-rich foam. The venturi pump and blower frequencies were then increased during stages 9 and 10 and the top-up stage to transfer foam to Tank 4.

E5.3 Analytical Methods

Rapid short-list PFAS analytical sampling, full-suite PFAS sampling, and non-PFAS sampling were conducted during tuning with analyses being completed by SGS AXYS. A rapid turnaround time method (EPA Method 533) with analysis of 12 compounds including PFOS and PFOA was used for the tuning process to quickly evaluate how changes in operational settings affected PFAS removal. Full PFAS analysis of 40 compounds using method MLA-110 (based on EPA Method 1633) was completed with longer duration SAFF® testing to better characterize PFAS concentrations and removal. Adsorbable organic fluorine (AOF) and total oxidizable precursor (TOP) analyses were also completed to determine whether other PFAS compounds were present beyond the 40 compounds detected by MLA-110. To better characterize the system and to fulfill permitting requirements, additional general water chemistry parameters were analyzed by Pace Analytical including TOC, TSS, and metals.

Table E.4: PFAS Species Analyzed by Rapid Turnaround Time Method.

Name	Acronym	CAS #
Perfluorobutanoic acid	PFBA	375-22-4
Perfluoropentanoic acid	PFPeA	2706-90-3
Perfluorohexanoic acid	PFHxA	307-24-4
Perfluoroheptanoic acid	PFHpA	375-85-9
Perfluorooctanoic acid	PFOA	335-67-1
Perfluorononanoic acid	PFNA	375-95-1
Perfluorodecanoic acid	PFDA	335-76-2
Perfluoroundecanoic acid	PFUnA	2058-94-8
Perfluorododecanoic acid	PFDoA	307-55-1
Perfluorobutanesulfonic acid	PFBS	375-73-5
Perfluorohexanesulfonic acid	PFHxS	355-46-4
Perfluorooctanesulfonic acid	PFOS	1763-23-1

During tuning, samples for rapid PFAS turnaround time were collected from the primary fractionation effluent for each set of parameters to determine optimal operational conditions. Corresponding Tank 1 influent samples were not collected for every effluent sample to reduce analytical costs and were instead typically collected on a weekly basis. When longer-term testing to monitor variability in SAFF® performance occurred with full-suite MLA-110 analysis, the frequency of paired influent/effluent samples then increased. Tank 3 primary fractionation concentrate samples were collected to evaluate the extent of concentration by primary fractionation and to determine the influent concentration of secondary fractionation cycles. Tank 1 samples were also collected after completion of a secondary fractionation cycle to evaluate the PFAS concentrations in the secondary fractionation effluent as it is recycled back into Tank 1 for reprocessing. An isolated sampling point does not exist for the secondary fractionation effluent, thus the potential for PFAS recirculation had to be evaluated by collecting a combined sample in Tank 1. Tank 4 secondary fractionation concentrate was sampled to determine the extent of concentration of secondary fractionation. Tank 2, which is fed by effluent from the primary fractionation vessels, was not sampled because water in Tank 2 has the same concentration as the primary fractionation effluent.

This report contains summarized results of EPA Method 533 compounds for both rapid turnaround time samples and MLA-110 samples. Due to the number of sampling events, chains of custody, complete analytical results, and laboratory reports are not included in this appendix. Chains of custody, full analytical results, and laboratory reports are available upon request.

E6 Shakopee Aquifer Results

Results from the tuning efforts for the Shakopee Aquifer are discussed in this section. It is important to note that a corresponding Tank 1 influent sample was not collected with every effluent sample. Removal efficiencies were calculated using the corresponding influent and effluent concentrations where available. Where corresponding Tank 1 influent samples were not collected, influent concentrations were assumed to be equal to the most recent Tank 1 sample. Tuning focused on PFOS and PFOA removal as these were the species present above applicable regulatory standards at the time tuning occurred.

E6.1 Primary Fractionation Tuning Results - Shakopee

E6.1.1 Stepwise Method

Foam was not observed during primary fractionation at any venturi pump frequency tested on the Shakopee Aquifer. Based on discussions with EPOC Enviro, the optimal venturi pump frequencies are higher than are typically required at other sites, likely because of the low TOC content in the water.

Tuning to improve PFAS removal was initially tested with what is referred to in this report as the stepwise method. This method was recommended by EPOC Enviro to evaluate how systematic variation in the tuning parameters affected PFAS removal. The stepwise method consists of 10 stages that follow the general pattern of a linear increase in pump frequency, and thus the amount of air injected into the primary fractionation vessel, from stages 1 through 10 while stage duration remains constant. Table E.5 provides an example of a stepwise treatment cycle's settings. During the testing of this method venturi pump frequency, stage duration, and top-up rate were manipulated to evaluate which parameters have the greatest impact on PFOS and PFOA removal efficiencies. Top-up time was held constant at five minutes for all tuning methods besides continuous top-up.

Table E.5: Shakopee Aquifer Tuning Example of Stepwise Tuning Method Operational Parameters.

Fill Level (mm)	Stage	Stage Length (min)	Venturi Pump Frequency (Hz)	Top-Up Rate (LPM)
2080	1	5	30	10
	2	5	35	
	3	5	36	
	4	5	37	
	5	5	38	
	6	5	39	
	7	5	40	
	8	5	41	
	9	5	42	
	10	5	43	
	Top-Up	5	43	

Legend: min = minutes; mm = millimeter.

E6.1.1.1 Varying Venturi Pump Frequency

Figure E.7 presents the results of the stepwise method where the range of venturi pump frequencies was varied across trials, with stage lengths held constant at five minutes and top-up rate held constant at 10 LPM. The maximum pump frequency at stage 10 ranged from 26 Hz to 47 Hz across these trials. Lower PFAS removal was observed at lower pump frequencies with effluent concentrations of 688 ng/L (24.9 percent [%] removal efficiency) and 279 ng/L (7.60% removal efficiency) for PFOS and PFOA respectively, where the maximum pump frequency was 26 Hz. Higher pump frequencies resulted in improved removal with effluent concentrations of 13.1 ng/L (97.8% removal efficiency) and 35.7 ng/L (87.3% removal efficiency) for PFOS and PFOA respectively, where the maximum pump frequency was 47 Hz. This positive trend demonstrates that under the stepwise method, removal of PFOS and PFOA increases as pump frequency increases.

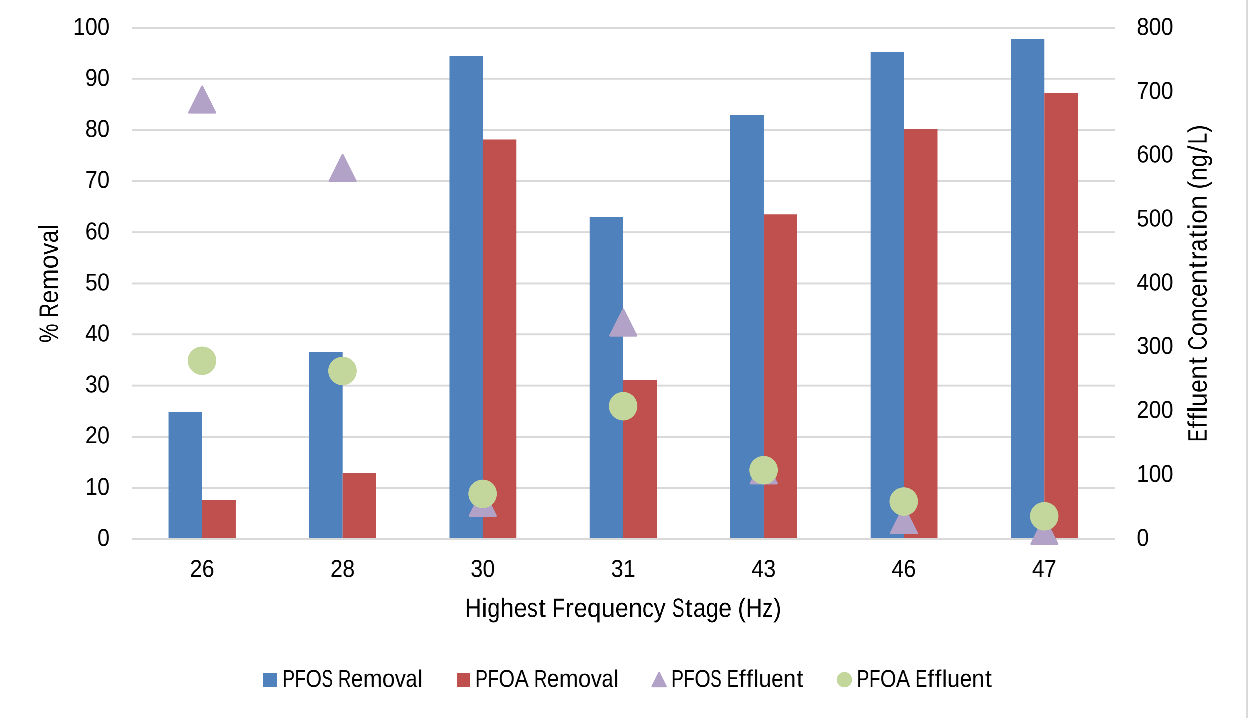

Figure E.7: Shakopee Aquifer Primary Fractionation Tuning - Stepwise Method: Varying Venturi Pump Frequency, PFOS and PFOA Removal.

E6.1.1.2 Varying Fractionation Stage Duration

Fractionation stage duration was also evaluated to determine its effects on PFOS and PFOA removal. During this testing, stage duration varied from 3 to 7 minutes while top-up rate and the range of venturi pump frequencies were held constant. Operating with a shorter treatment time increases the daily total throughput of the system, so these trials provided a basis for evaluating throughput capabilities. Figure E.8 demonstrates removal of PFOS and PFOA increased as stage length increased. The cycle with the shortest stage of 3 minutes yielded effluent concentrations of 626 ng/L (31.7% removal efficiency) and 277 ng/L (8.3% removal efficiency) for PFOS and PFOA respectively, while the longest stage length run of 7 minutes yielded effluent concentrations of 337 ng/L (63.2% removal efficiency) and 212 ng/L (29.8% removal efficiency) for PFOS and PFOA respectively. The stage duration testing was completed at a relatively low venturi pump frequency, as all trials had a maximum frequency of 30 Hz. Because duration testing was not completed at higher frequencies for the stepwise method, removal is lower than what is expected at the higher frequencies. The degree to which the same trends would be observed at higher frequencies is uncertain.

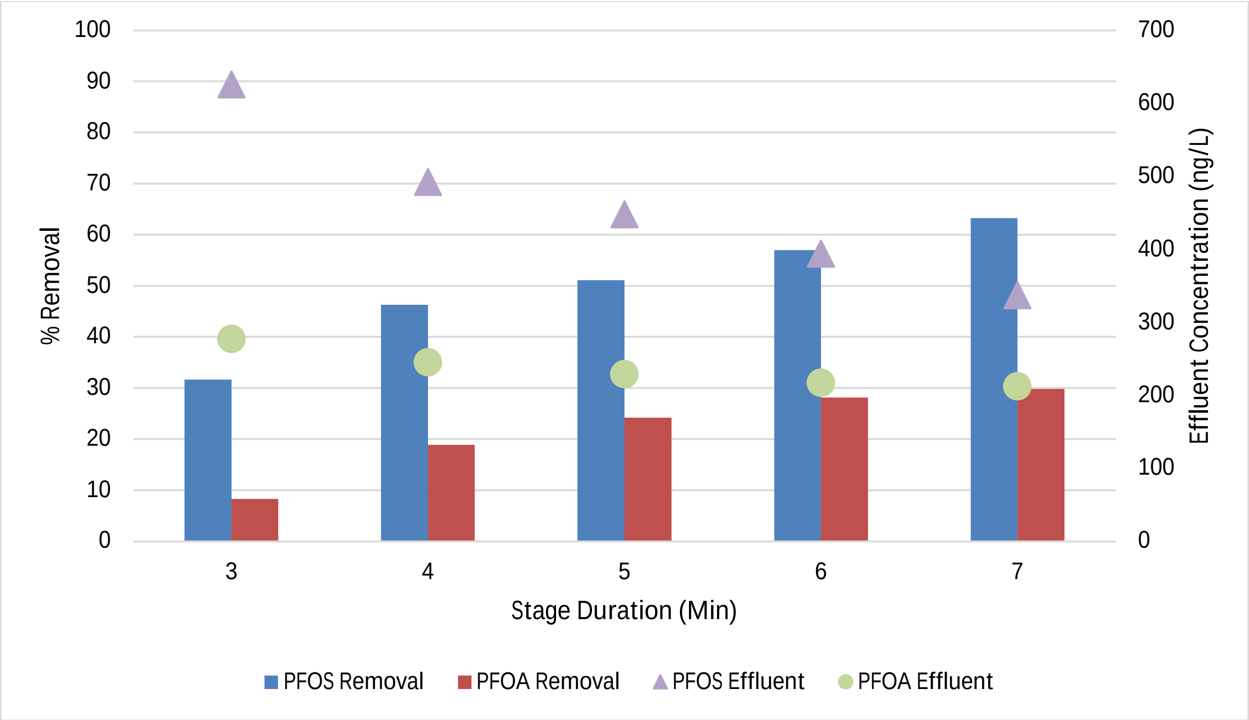

Figure E.8: Shakopee Aquifer Primary Fractionation Tuning - Stepwise Method: Varying Fractionation Stage Duration, PFOS and PFOA Removal.

E6.1.1.3 Varying Top-Up Rate

Top-up rate was manipulated to determine its effects on the removal of PFOS and PFOA. During this testing, top-up rates varied from 20 to 50 LPM over a 5-minute top up period while stage duration and venturi pump frequency were held constant. At these top-up rates, between 100 L and 250 L of clean Tank 2 water is pumped into the bottom of the primary fractionation vessel to push any foam or concentrated water that has accumulated at the top of the vessel over the top cone. Results are given in Figure E.9 and suggest that top-up rate had little to no impact on removal efficiency. Practically, this allows primary fractionation cycles to run at a minimal top-up rate to reduce the volume of water transferred to Tank 3. This in turn reduces the frequency of secondary fractionation cycles and potentially decreases the volume transferred to Tank 4.

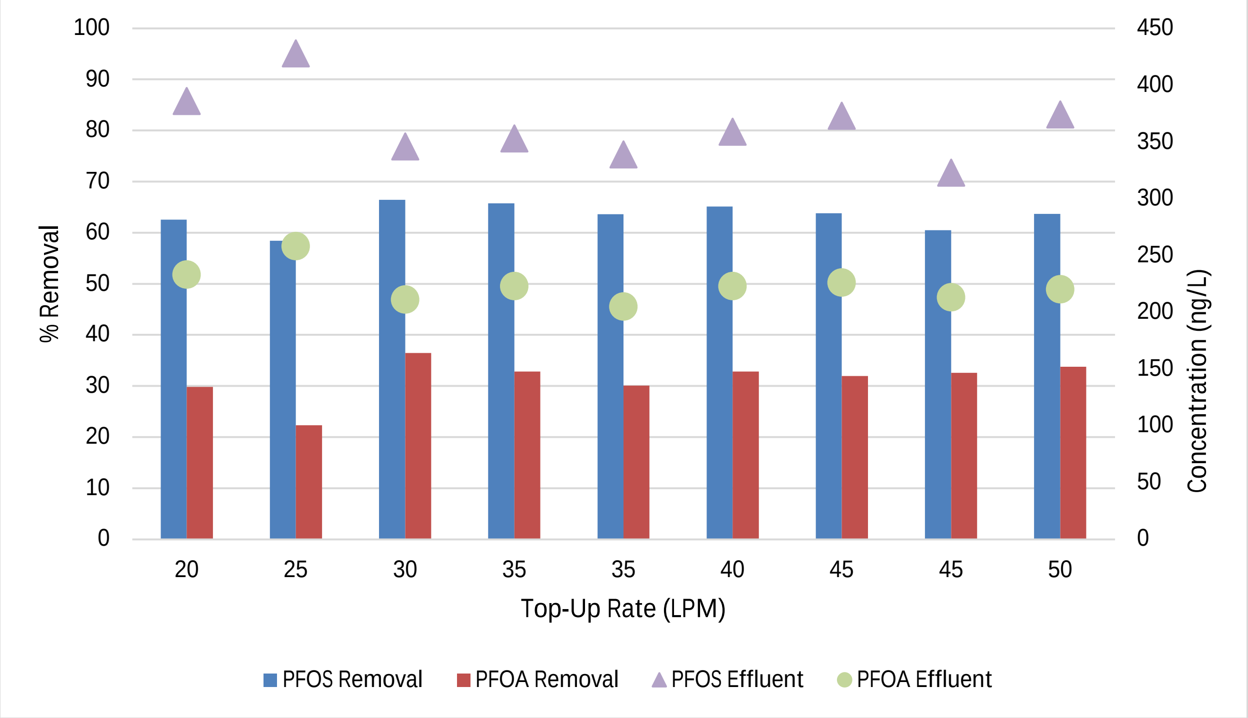

Figure E.9: Shakopee Aquifer Primary Fractionation Tuning - Stepwise Method: Varying Top-Up Rate, PFOS and PFOA Removal.

E6.1.2 Oscillation Method

The oscillation method for primary fractionation consists of batch treatment using 10 stages of different pump frequencies. The pump frequency followed an alternating pattern “oscillating” between low and high with an overall linear increase in pump energies from stage 1 through stage 10. Water would then be discharged after all stages and top up was completed. This method was proposed by EPOC to potentially improve PFOS and PFOA removal with water that has low foaming potential, as was the case with tested groundwater. As with the stepwise method testing, top-up time was held constant at five minutes for all oscillation trials. Table E.6 provides an example of oscillation method settings. As with the stepwise method and all other groundwater tuning methods, no foam was generated during primary fractionation.

Table E.6. Shakopee Aquifer Tuning Example of Oscillation Tuning Method Operational Parameters.

Fill Level (mm)	Stage	Stage Length (min)	Venturi Pump Frequency (Hz)	Top-Up Rate (LPM)
2080	1	5	27	10
	2	5	42.5	
	3	5	33	
	4	5	43.5	
	5	5	33	
	6	5	43.6	
	7	5	35	
	8	5	43.7	
	9	5	34	
	10	5	43.9	
	Top-Up	5	44	
Total Treatment Time		*55 Min*		

E6.1.2.1 Varying Venturi Pump Frequency

Varying venturi pump frequencies and stage durations were implemented during the testing of this method. Top-up rates were not independently manipulated after no trends were observed during the stepwise method’s top-up trials. As shown in Figure E.10 increasing pump frequencies for the oscillation method (while at constant stage lengths and top-up rates) did not always yield higher removal efficiencies for PFOS and PFOA. One reason for the inconsistent trend in this dataset may be that a relatively small range of energies was tested for this method (42.4 Hz to 47.3 Hz) compared to the stepwise method data set (28 Hz to 47 Hz). However, results suggest that with the oscillation method, high removal efficiencies can be achieved at more conservative pump energies than the stepwise method. For example, the lowest effluent concentration of 2.22 ng/L (99.8% removal efficiency) for PFOS was the result of a highest frequency stage run of 44.4 Hz. The lowest effluent concentration of 1.77 ng/L (99.4% removal efficiency) for PFOA was the result of a highest frequency stage run of 43.9 Hz. The highest frequency stage cycle that was performed during this testing was 47.3 Hz which yielded higher relative effluent concentrations of 33.9 ng/L (94.7% removal efficiency) and 32.7 ng/L (89.0% removal efficiency) for PFOS and PFOA respectively. Practically implementing these results could enable primary fractionation at reduced pump energy while still achieving high removal efficiency.

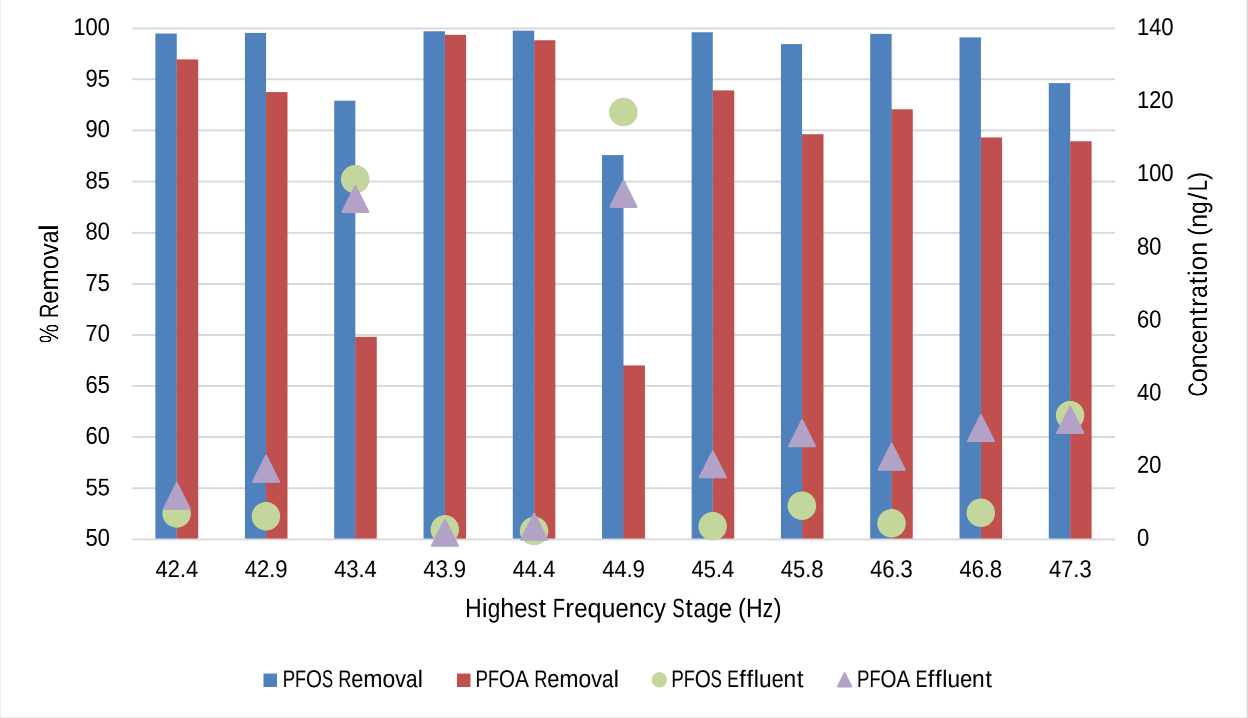

Figure E.10: Shakopee Aquifer Primary Fractionation Tuning - Oscillation Method: Varying Venturi Pump Frequency, PFOS and PFOA Removal.

E6.1.2.2 Varying Fractionation Stage Duration

Figure E.11 demonstrates that for the oscillation method, increasing stage duration (while holding number of stages per batch, top-up rates and the range of venturi pump frequencies constant) had a limited impact on removal efficiency. One possible explanation for this result may be that past a certain pump frequency the positive removal effect of time may become limited.

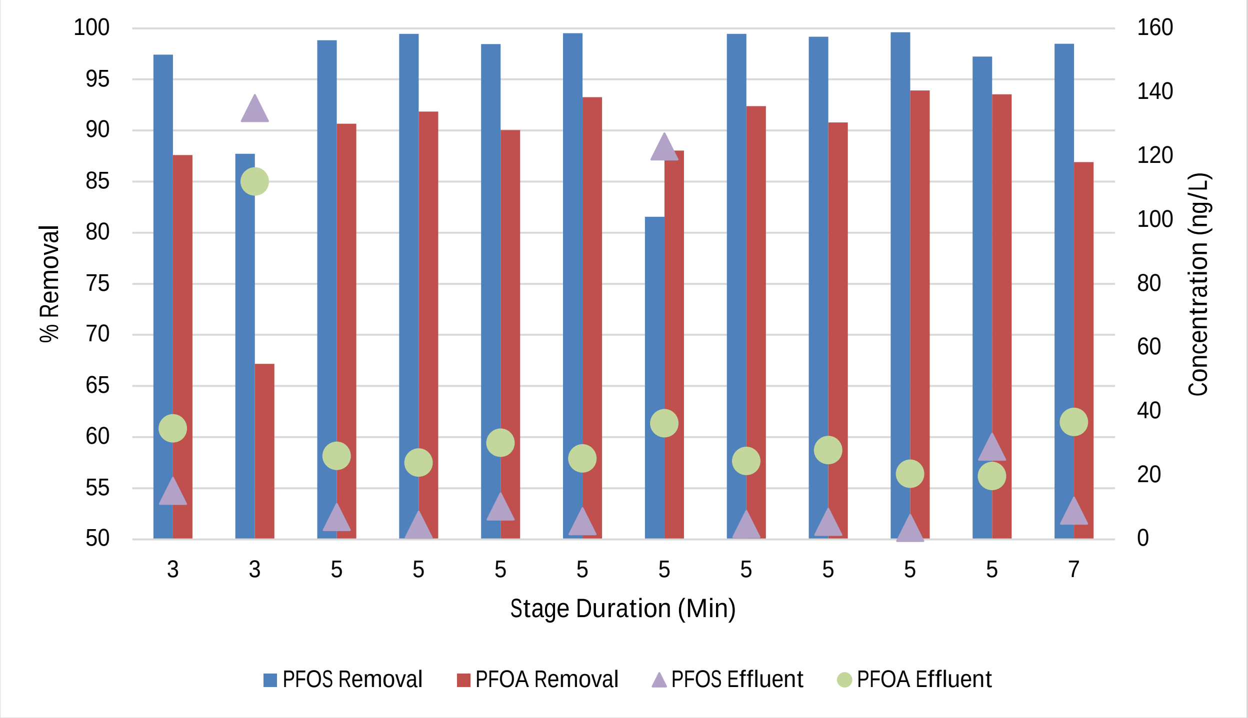

Figure E.11: Shakopee Aquifer Primary Fractionation Tuning - Oscillation Method: Varying Fractionation Stage Duration, PFOS and PFOA Removal.

E6.1.3 Continuous Top-Up Method

The continuous top-up method for SAFF® primary fractionation consisted of a 15-minute stage at a constant pump frequency followed by a 30-minute top-up cycle where the pump energy was identical to stage 1. Table E.7 provides an example of continuous top-up settings. Both primary fractionation vessels share the same top-up pump; therefore, only one primary fractionation vessel could operate at a time using the current system configuration.

Table E.7: Shakopee Aquifer Continuous Top-Up Tuning Method Operational Parameters.

Fill Level (mm)	Stage	Stage Length (min)	Venturi Pump Frequency (Hz)	Top-Up Rate (LPM)
2080	1	15	43	10
	Top-Up	30	43	

Varying pump frequencies were implemented during this round of testing. Figure E.12 shows there is a positive correlation between pump frequency and removal efficiency of PFOS and PFOA under the continuous top-up method. However, this correlation may no longer hold at frequencies above 40 Hz as removal efficiencies above 40 Hz level off. The lowest pump energy run was 24 Hz with PFOS and PFOA effluent concentrations of 636 ng/L (35.9% removal efficiency) and 323 ng/L (10.8% removal efficiency) respectively. The highest pump energy run was 46 Hz with PFOS and PFOA effluent concentrations of 14.7 ng/L (97.5% removal efficiency) and 21.6 ng/L (92.3% removal efficiency) respectively. However, the highest removal efficiencies were observed with the 40.0 Hz run yielding effluent concentrations of 1.54 ng/L (99.2% removal efficiency) and 5.55 ng/L (97.5% removal efficiency) for PFOS and PFOA respectively. These results indicate that the highest removal of PFOS and PFOA can be achieved at reduced pump energies. Top-up cycles transfer higher volumes of water to Tank 3 than other methods, thereby increasing the frequency of secondary fractionation cycles and potentially increasing waste sent to Tank 4.

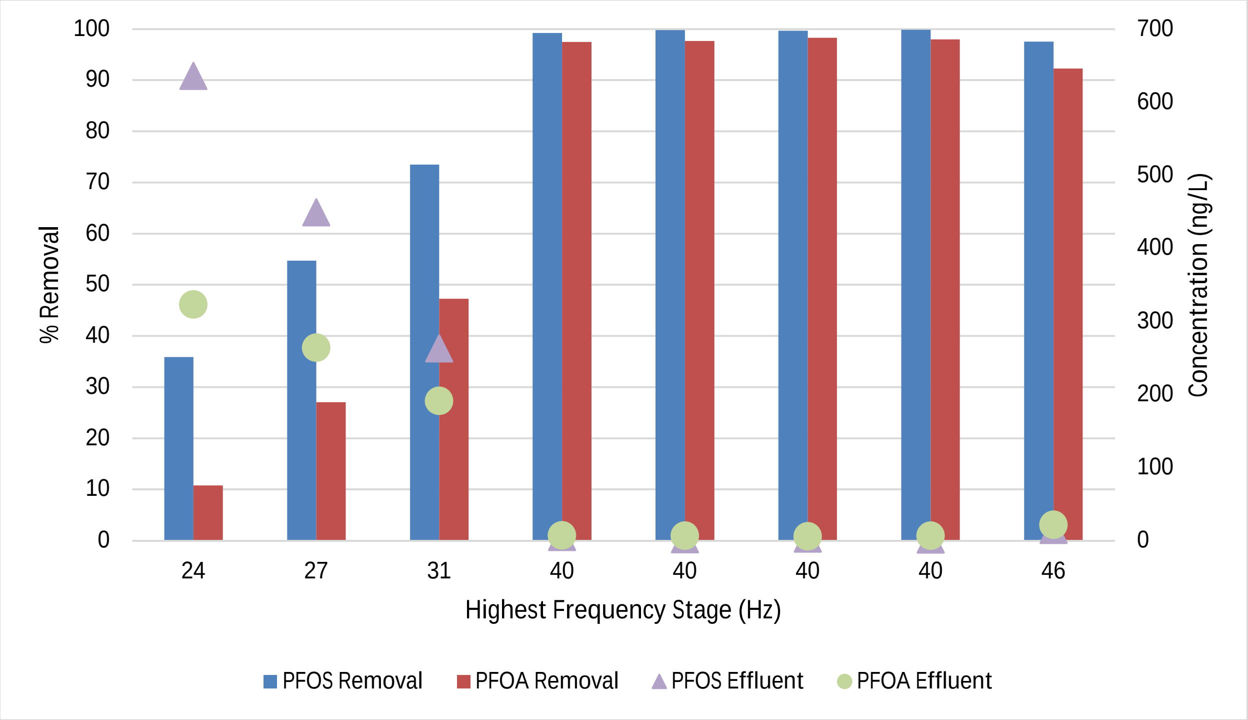

Figure E.12: Shakopee Aquifer Primary Fractionation Tuning – Continuous Top-Up: Varying Venturi Pump Speed, PFOS and PFOA Removal.

E6.1.4 Dosing with PFAS Concentrate

The Shakopee Aquifer has much lower total organic content than feedwaters for SAFF® units typically have, and as a result, foam did not form during primary fractionation. Dosing of secondary fractionate was tested to determine if increasing PFAS concentrations in the influent would increase overall foam formation, thereby attracting more PFAS and increasing PFAS removal. Although the SAFF® system is equipped with a dosing system which can dose surfactants into the fractionation vessels to promote foam formation and increase PFAS removal efficiencies, the dosing tank was not used to inject PFAS concentrate for these limited trials. It was decided to not contaminate the dosing tank in case of re-use during later operations. Although surfactant testing was not employed as a part of this pilot study due to the surface water discharge location and associated concerns with surfactant aquatic toxicity, future site configurations may allow for such testing.

To increase influent PFAS concentrations, a set volume of the concentrate in Tank 4 was manually reinjected back into the primary fractionation vessel during fractionation stage 1 via the vessel vent valve, or “snorkel”. Stage 1 for this test was set to a lower pump frequency and longer stage duration than the other stages to allow time for the concentrate to be poured back into the system and properly circulate. Table E.8 provides an example of these settings.

Table E.8: Shakopee Aquifer Dosing with Concentrate Tuning Method Operational Parameters Example.

Fill Level (mm)	Stage	Stage Length (min)	Venturi Pump Frequency (Hz)	Top-Up Rate (LPM)
2050	1	15	15	10
	2	5	31	
	3	5	32	
	4	5	33	
	5	5	34	
	6	5	35	
	7	5	36	
	8	5	37	
	9	5	38	
	10	5	39	
	Top-Up	5	39	

E6.1.4.1 Varying Concentrate Dosage

Figure E.13 displays a test where varying concentrate dosages of 2.3 L, 4.6 L, and 6.9 L were trialed under constant stepwise method parameters (5-minute stage length, maximum pump frequency of 39 Hz, top-up rate of 30 LPM). The results demonstrated a positive correlation between dosing volume and removal efficiency of PFOS and PFOA.

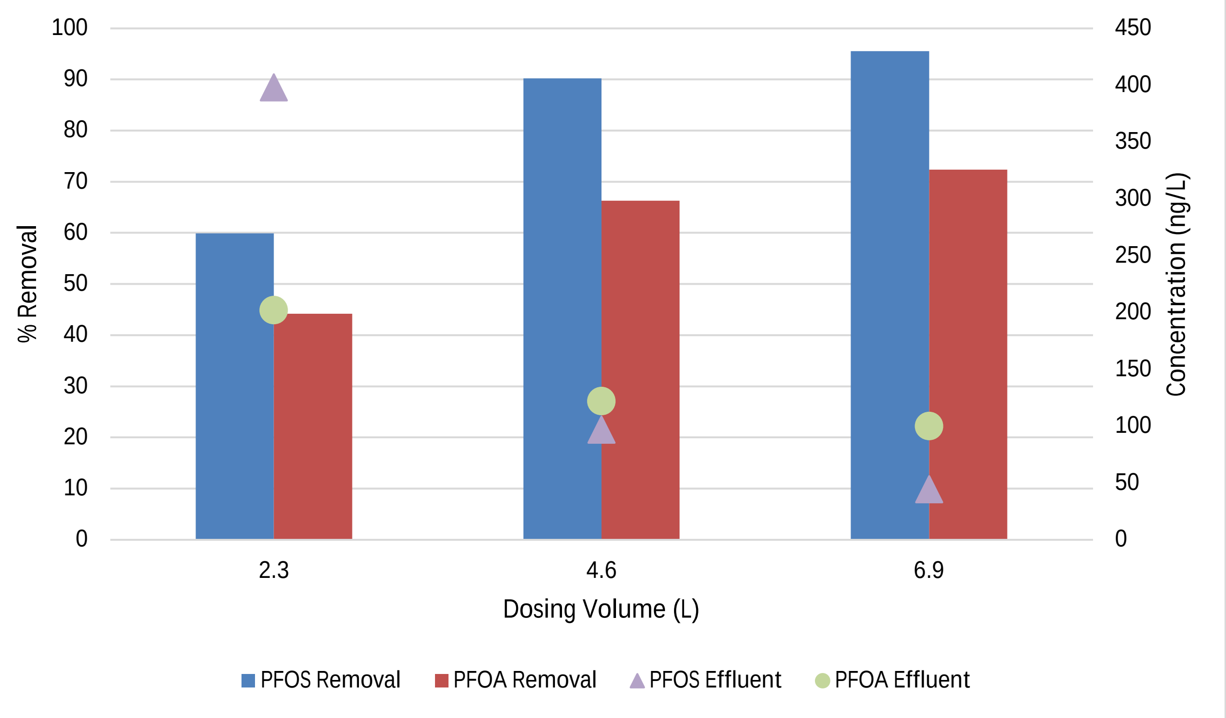

Figure E.13: Shakopee Aquifer Primary Fractionation Tuning – Dosing with PFAS Concentrate: Varying PFAS Concentrate Dosage, PFOS and PFOA Removal.

E6.1.4.2 Varying Venturi Pump Frequency

Varying venturi pump frequencies were tested while stage length, top-up rate, and concentrate dosage (2.9 L) were held constant. Figure E.14 demonstrates that dosing had a negative effect on removal efficiency at lower pump frequencies and a positive effect while at higher frequencies. This can be attributed to the additional PFAS loading from dosing and also demonstrates that insufficient treatment times will result in an overall net addition of PFAS to a sample. Overall, the highest PFOS and PFOA removal resulted from a 6.9 L dose at a highest energy stage of 39 Hz where effluent concentrations were 44.4 ng/L (95.5% removal efficiency) and 100 ng/L (72.4% removal efficiency) respectively. Dosing has the potential to aid in PFAS removal via primary fractionation, but this method is not sustainable for long-term operations, at least at the pilot scale, because the rate of Tank 4 concentrate production is lower than what would be required to maintain a high removal efficiency of PFOS and PFOA.

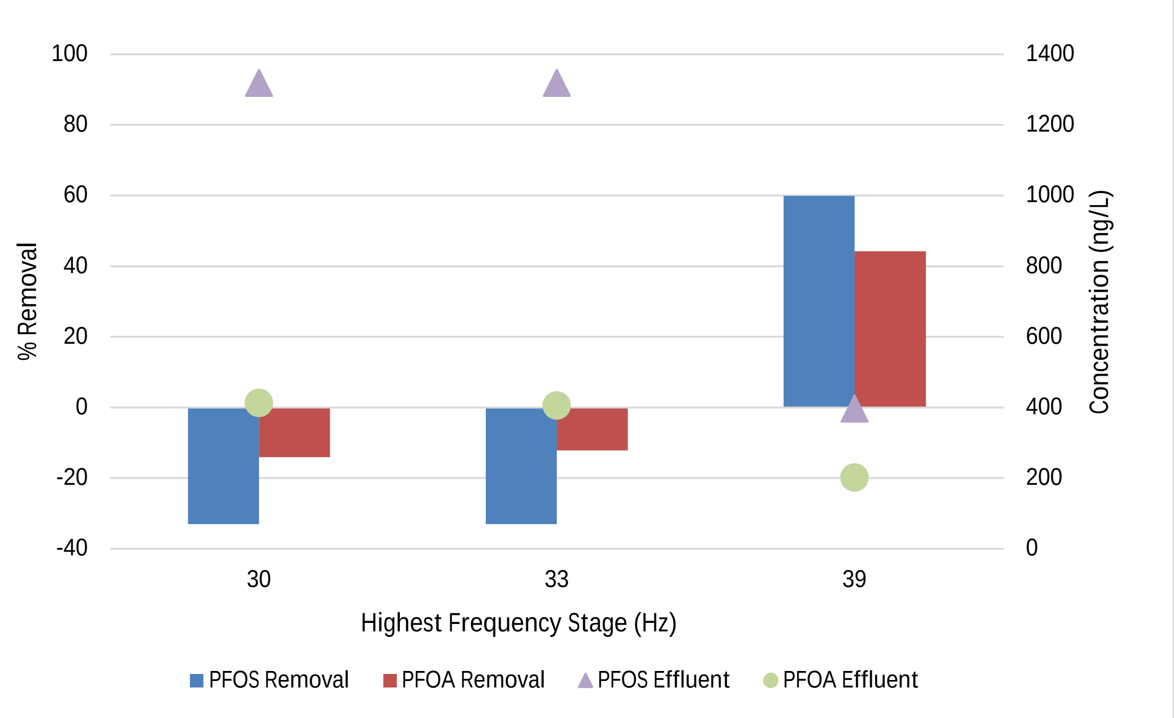

Figure E.14: Shakopee Aquifer Primary Fractionation Tuning – Dosing with PFAS Concentrate: Varying Venturi Pump Speed, PFOS and PFOA Removal.

E6.1.5 Regulated PFAS Results

While tuning focused on PFOA and PFOS removal, as previously mentioned, twelve PFAS compounds were analyzed in rapid turnaround time samples, and 40 compounds were analyzed for by EPA Method 1633. Example results are given in Table E.9 for PFAS subject to Federal and State regulations at the time of writing this report for different run styles tested during Shakopee Aquifer tuning with the exception of hexafluoropropylene oxide-dimer acid (HFPO-DA), as HFPO-DA was generally below detection limits at the Site and was not part of the rapid turnaround list. Results for all twelve compounds from the rapid turnaround time method for all runs can be found in Table E.30 (Tank 1), Table E.31 (Effluent), Table E.32 (Tank 3), and Table E.33 (Tank 4). Corresponding run settings are provided in Table E.34.

Table E.9: Shakopee Aquifer Tuning Regulated PFAS Results in ng/L.

Tuning Method	Compound	PFOA	PFOS	PFHxS	PFNA	PFBS	PFHxA	PFBA
	Treatment Target	ND	ND	< 5	< 5	< 50	< 100	< 3500
Stepwise - Venturi	Influent	280	590	42.6	2.05	20.0	55.6	419
	Effluent	35.7	13.1	11.5	<1.78	20.6	56.2	430
	Removal Efficiency (%)	*87.3*	*97.8*	*73.0*	*>13.2*	*-3.00*	*-1.08*	*-2.63*
Oscillation	Influent	281	939	34.1	2.12	15.4	44.3	372
	Effluent	<1.77	2.67	1.62	<1.77	13.5	36.1	361
	Removal Efficiency (%)	*99.4*	*99.7*	*95.2*	*>16.5*	*12.3*	*18.5*	*3.0*
Continuous Top-Up	Influent	318	872	29.2	1.94	18.1	47.8	521
	Effluent	6.54	1.54	3.14	<0.420	18.6	46.9	527
	Removal Efficiency (%)	*97.9*	*99.8*	*89.2*	*>78.4*	*-2.76*	*1.88*	*-1.15*
Concentrate Dosing	Influent	362	992	41.6	1.77	16.6	48.4	485
	Effluent	100	44.4	21.2	<1.81	14.4	43.7	482
	Removal Efficiency (%)	*72.4*	*95.5*	*49.0*	*NC*	*13.3*	*9.71*	*0.62*

Legend: NC = not calculated as effluent detection limit was greater than influent concentration; ND = non-detect.

E6.2 Secondary Fractionation Tuning Results - Shakopee

PFAS removal by secondary fractionation was generally evaluated by sampling Tank 3 as an influent sample and Tank 1 (after the secondary fractionation cycle discharged) as an effluent sample to approximate the removal of PFAS. For example, Figure E.15 provides a comparison between Tank 3 (influent), Tank 1 post-secondary discharge (effluent), and a Tank 1 sample under normal conditions on 11/29/2022. Because Tank 1 contains approximately 2100 L of influent water prior to the discharge of treated secondary fractionation effluent into Tank 1 (which increases Tank 1 volume to approximately 2650 L), secondary fractionation removal efficiency must be approximated using the blended Tank 1 water sample and the known range of typical influent concentrations. For example, the Tank 1 influent samples under normal conditions from November 29, 2022, had PFOS and PFOA concentrations of 984 ng/L and 304 ng/L respectively. The Tank 1 post-secondary discharge samples from November 29, 2022, had PFOS and PFOA concentrations of 807 ng/L and 262 ng/L respectively. Back calculating concentrations in Tank 3 would give an approximate PFOS concentration of 131 ng/L and a PFOA concentration of 102 ng/L in the Tank 3 effluent. While exact volumes of water in Tank 1 will vary and these back calculated numbers are only approximate, it can generally be assumed that Tank 1 post-secondary discharge concentrations are lower than the reported concentrations because the secondary discharge was mixed with higher concentration Tank 1 influent water. Calculating removal efficiencies based on these assumptions gives approximate removal efficiencies of 98% and 94% for PFOS and PFOA respectively during secondary fractionation.

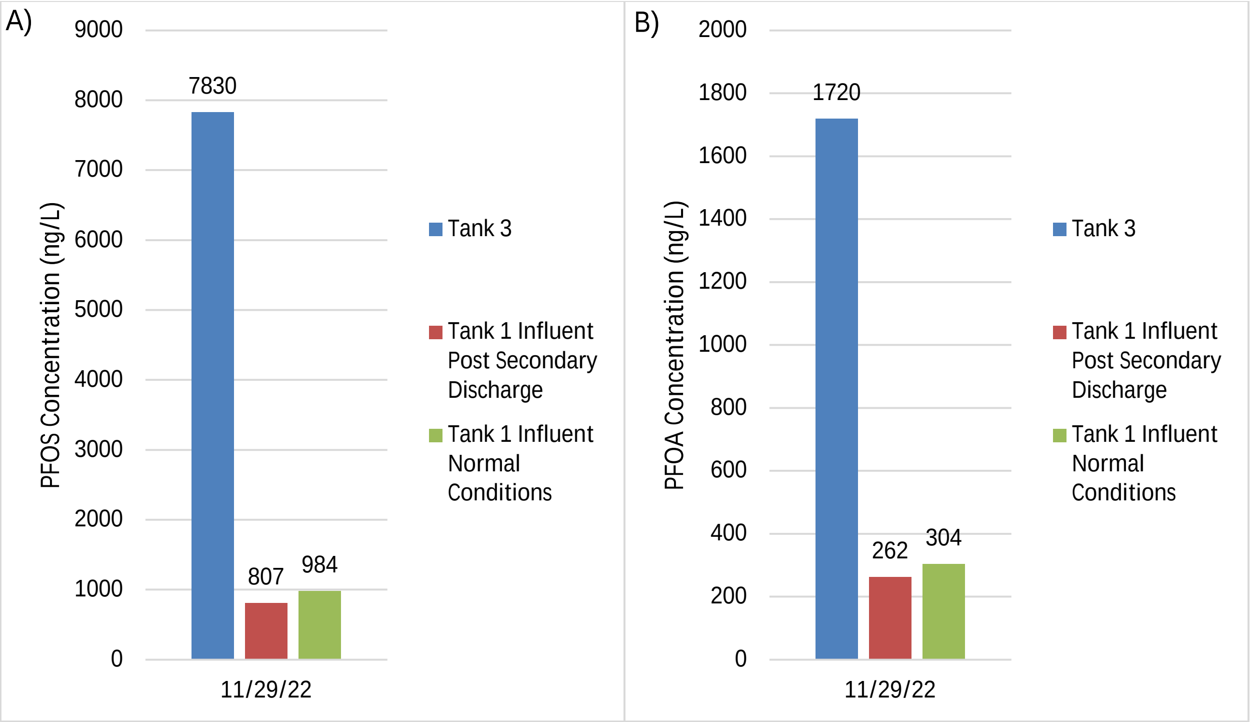

Figure E.15: Shakopee Aquifer Secondary Fractionation Discharge Testing: A) PFOS and B) PFOA Removal.

Tuning for secondary fractionation often relied on visual tuning in part due to the difficulty of collecting isolated secondary fractionation effluent samples. Visual tuning involved observing a secondary fractionation cycle's foam production and rate of volume inputs to Tank 4 and adjusting settings based on observations over several days. The Shakopee secondary cycles typically produced a low-density foam (comparable to that of dish soap bubbles) rather than the high-density foam (comparable to shaving cream) often observed at other SAFF® deployment sites and with the Raleigh Creek secondary cycles (discussed later), which was expected based on the overall low organic content in the water. A photo of this foam is shown in Figure E.16.

Optimal secondary settings varied according to corresponding primary settings and thus influent Tank 3 concentrations. An example of settings which generated about 5 L of secondary fractionate per day for Shakopee operations is provided in Table E.10.

Figure E.16: Shakopee Aquifer Secondary Fractionation Foam Production.

Table E.10: Shakopee Aquifer Secondary Fractionation Operational Parameters Example.

Stage	Stage Length (min)	Venturi Pump Frequency (Hz)	Blower Speed (Hz)	Top-Up Rate (LPM)
1	7	24.0	22.0	10
2	7	25.0	23.0	
3	7	26.0	24.0	
4	7	27.0	25.0	
5	4	27.0	25.0	
6	4	28.0	25.0	
7	4	28.0	26.0	
8	4	29.0	26.0	
9	4	29.0	27.0	
10	4	30.0	27.0	
Top-Up	5	30.0	28.0	

E6.3 Long-Term Operations - Shakopee

To evaluate variability in effluent concentrations, several cycles were run for weeks or months at a time following the tuning phase. By March 2023, Run 56 (45 minutes) had achieved the lowest effluent concentrations of the continuous top-up method trials, and Run 57 (55 minutes) had achieved the lowest concentrations of the oscillation method trials. These two cycles were therefore selected to operate for an extended period so that samples could be collected across several weeks. Following several months of continued tuning, oscillation cycles with reduced durations achieved effluent concentrations comparable to those of the previously optimized runs. Run 87 (35 minutes) and Run 90 (25 minutes) were then tested for extended periods to evaluate effluent variability for cycles with a higher daily throughput of water.

As previously stated, expedited turnaround PFAS analysis using EPA Method 533 was used for the tuning process, and a combination of this expedited analysis and the full-suite EPA Method 1633 analysis was applied for long-term testing. Some variability in results was observed between these two methods. Several samples were submitted for both EPA Method 533 and EPA Method 1633 analysis; percent difference between the samples was calculated using

Equation 1.

$$Percent\ Difference = \frac{[Method\ 533] - [Method\ 1633]}{\frac{[Method\ 533] + [Method\ 1633]}{2}} * 100\%$$

Percent difference in reported effluent concentrations is displayed in Table E.11.

Table E.11: Shakopee Aquifer PFOA and PFOS Analytical Method Comparison: EPA Method 533 vs. EPA Method 1633.

Sample Date	Run	Method	Species	Method 533 (ng/L)	Method 1633 (ng/L)	Percent Difference
3/6/2023	56	Continuous Top-Up	PFOA	36.4	6.66	447
			PFOS	121	1.87	6370
			PFHxS	5.99	3.86	-43.2
3/7/2023	56	Continuous Top-Up	PFOA	32.1	5.55	478
			PFOS	17.8	2.73	552
			PFHxS	5.14	3.61	-35.0
3/13/2023	57	Oscillation	PFOA	30.2	24	25.8
			PFOS	10.2	4.56	124
			PFHxS	10.6	6.81	-43.5
3/15/2023	57	Oscillation	PFOA	36.3	25.3	43.5
			PFOS	123	5.6	2100
			PFHxS	10.5	7.29	-36.1
3/17/2023	57	Oscillation	PFOA	27.9	24.5	13.9
			PFOS	5.46	4.74	15.2
			PFHxS	8.97	6.58	-30.7
3/5/2024	90	Oscillation	PFOA	48.1	53.4	-9.90
			PFOS	22.2	24	-7.50
			PFHxS	13.2	10.8	-20.0

The percentage difference between EPA Methods 533 and 1633 ranged from -9.9% to 480% for PFOA and from -7.50% to 6370% for PFOS. Method 1633 has more stringent quality control criteria than other methods and uses isotope dilution techniques to more accurately quantify PFAS. Expedited Method 533 results were therefore excluded from Figure E.17 and Figure E.18 when a paired Method 1633 sample was collected at the same time. To expand the dataset, however, expedited Method 533 results were included for dates where a paired 1633 sample was not taken. Where results indicated non-detect concentrations of a particular compound, the laboratory reporting limit has been used. Bold numbers indicate sample results, while non-bold numbers indicate statistical markers. The EPA MCLs (enforceable), MDH HRLs (enforceable), and MDH groundwater HBVs (not enforceable) for PFOS, PFOA, and PFHxS were plotted where relevant.

All extended run samples collected from Run 56, shown in Figure E.17, achieved the MDH HRLs for PFOA (35 ng/L), PFOS (300 ng/L), and PFHxS (47 ng/L). All samples achieved the EPA MCLs for PFOS (4 ng/L) and PFHxS (10 ng/L), but none achieved the MCL (4 ng/L) or groundwater HBV (0.24 ng/L) for PFOA. Two samples achieved the MDH groundwater HBV for PFOS (2.3 ng/L).

All extended run samples collected from Run 57, shown in Figure E.18 achieved the MDH HRLs for PFOS, PFOA, and PFHxS. All samples achieved the PFHxS MCL. One sample achieved the PFOS MCL of 4 ng/L, and no samples achieved the PFOA MCL of 4 ng/L.

Relevant PFAS regulatory limits are summarized in Table E.3. To summarize longer term testing relative to enforceable criteria:

- Effluent concentrations were consistently well below the HRLs for PFOS (300 ng/L) and PFHxS (47 ng/L)
- Approximately half of the extended run samples met the PFOA HRL (35 ng/L)
- Five samples were below the PFOS MCL (4 ng/L)
- More than two-thirds of extended runs samples achieved the PFHxS MCL (10 ng/L)
- No samples were below the PFOA MCL (4 ng/L)
- Run 56 achieved the lowest effluent concentrations most consistently

The effluent results demonstrate that SAFF® is capable of achieving several regulatory criteria with varying levels of consistency depending on operational parameters. Longer treatment times generally correspond to lower and more consistent effluent concentrations.

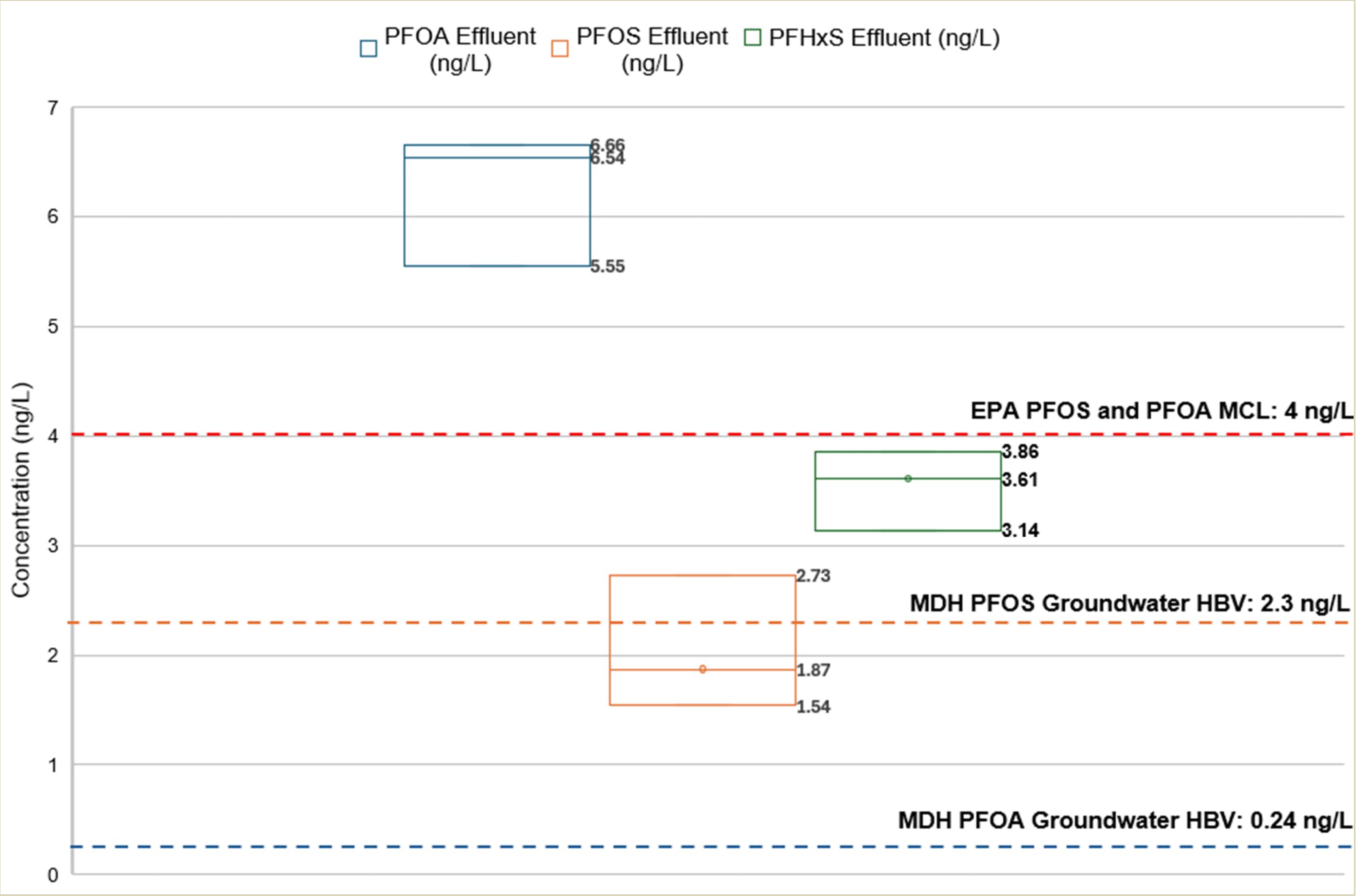

Figure E.17: Shakopee Aquifer Testing PFAS Concentration Variability, Run 56.

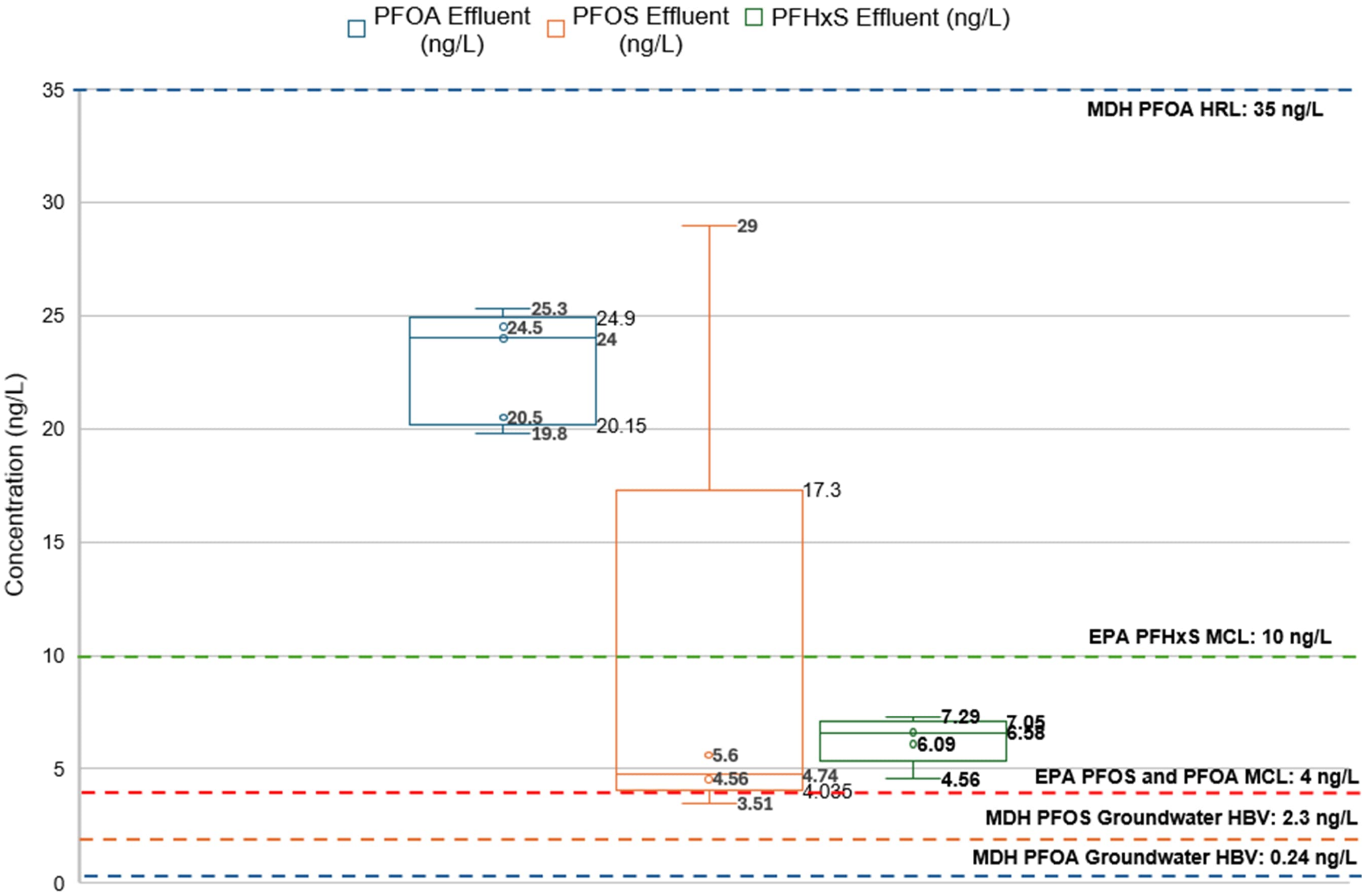

Figure E.18: Shakopee Aquifer Testing PFAS Concentration Variability, Run 57.

Table E.12: Shakopee Aquifer Testing Extended Run Effluent and Tank 3 Concentrations.

Method	Run	Lowest Effluent **Concentrations (ng/L)**			Associated Removal Efficiency (%)			**Median Tank 3 PFAS Concentrations** (ng/L)		
		PFOS	PFOA	PFHxS	PFOS	PFOA	PFHxS	PFOS	PFOA	PFHxS
Continuous Top-Up	56	1.54	5.55	3.14	99.8	98.3	89.2	6,970	2,750	275
Oscillation	57	3.51	19.8	4.56	99.6	93.6	88.1	32,200	10,650	900
	87	1.07	4.1	2.05	99.9	98.8	93.9	19,600	5,820	551
	90	10	17.5	6.84	99.1	95.1	86.9	29,400	9,485	674

Note: Optimized removal efficiencies and effluent concentrations stated above do not necessarily correspond to the same sample; the best results for each compound were individually selected.

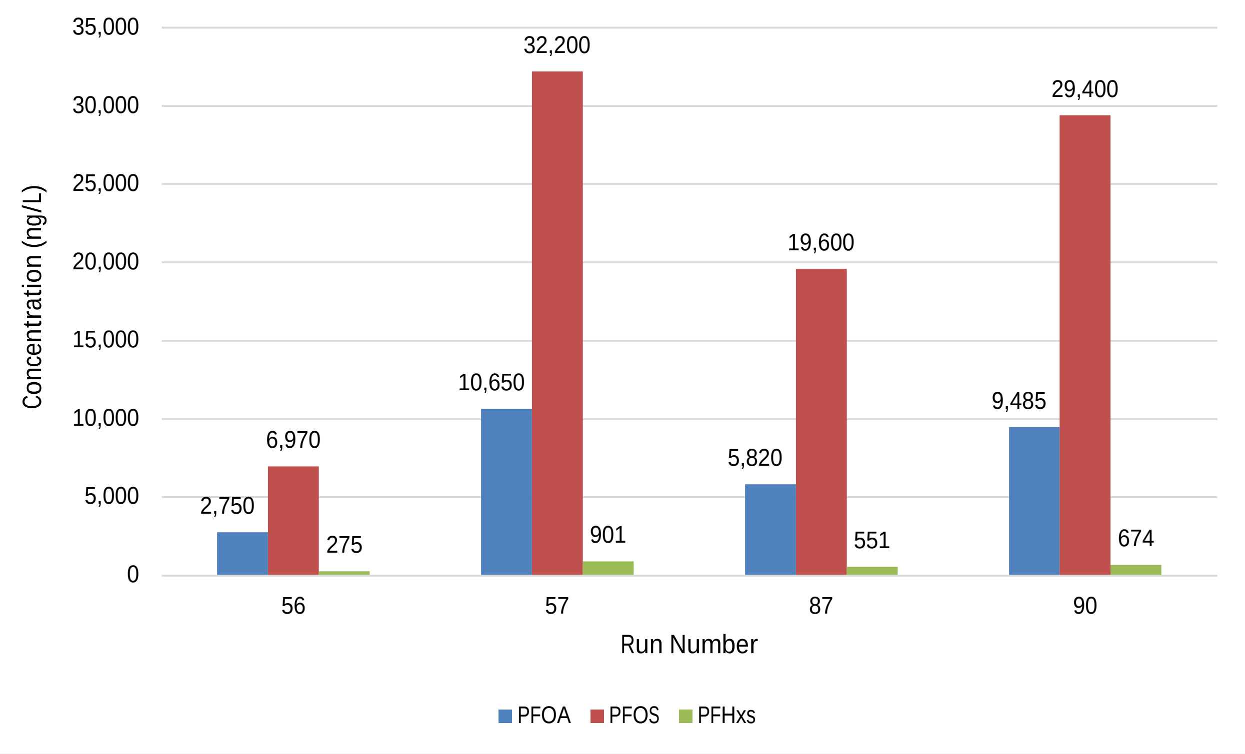

Figure E.19: Median Tank 3 (Primary Fractionation PFAS Concentrate) PFOS, PFOA, and PFHxS concentrations.

AOF was periodically sampled during Shakopee Aquifer operations; results are summarized in Table E.13. Generally, AOF influent results range from below the method detection limit to 3.7 µg/L and treated effluent concentrations were generally below method detection limits. Increases are seen from the influent to Tank 3 to Tank 4, which is to be expected given speciated PFAS results.

Table E.13: Shakopee Aquifer AOF Results Summary.

Date	Run Number	**AOF Concentrations (µg/L)**			
		Influent	Effluent	Tank 3	Tank 4
3/15/2023	57	2	<0.6	22	5,400
3/17/2023	57	<0.58	<0.58	36	5,600
3/9/2023	56 (with secondary fractionation treated effluent)	<0.59	1.5	NS	NS
3/10/2023	56	1.5	<0.6	9.9	4,400
3/7/2023	56	<0.47	<0.47	9.2	NS
3/20/2023	57	2.1	<0.47	NS	NS
12/15/2023	87 (1)	3.7	<0.3	20	24,000
12/15/2023	87	1.7	<0.3		
			<0.3		
12/15/2023	87	1.6	<0.3		

Legend: NS = not sampled.

(1) Sampling occurred after manual transfer of Tank 4 water into Tank 3 to reconcentrate Tank 4 waste.

Gray shading indicates sampling occurred after discharge from secondary fractionation back to Tank 1.

Concentration factors were also evaluated for PFOS, PFOA, and TOC during Shakopee Aquifer operations. Concentration factors were calculated using averaged, long-term operations results for PFOA and PFOS and are summarized in Table E.14. Concentration factors will vary depending on the influent concentration used, however, the results demonstrate significant volume reduction can be achieved on groundwater that does not foam.

Table E.14: Shakopee Aquifer PFOA, PFOS, and TOC Concentration Factors.

Species	Influent	Tank 3	Tank 3 **Concentration** Factor	Tank 4	Tank 4 **Concentration** Factor
PFOS	1.2 µg/L	32 µg/L	26x	21,000 µg/L	17,500x
PFOA	0.4 µg/L	10 µg/L	24x	9,600 µg/L	24,000x
TOC	1.1 mg/L	<1.0 mg/L	-	7.1 mg/L	6.5x

Table E.15 summarizes system throughput in gallons per day (gpd), energy consumption in kilowatts (kW) per 1000 gallons (gal), and calculated cost in United States Dollars ($) per 1000 gal. Energy consumption estimates from these select extended runs ranged from 4.4 to 6.6 kW per 1000 gal. Assuming an electrical cost of $0.10 per kW hour, electrical costs range from $0.44 to $0.66 per 1000 gallons treated. Note that this does not include labor nor initial capital cost of the equipment. Additionally, these estimates are based on operational energy consumption and exclude auxiliary energy consumption from items such as heaters. Throughput ranged from 14,000 gpd to 45,000 gpd using the SAFF®20 system.

Table E.15: Shakopee Aquifer Testing Extended Run Throughput, Energy Consumption, and Cost Estimates per 1000 gallons.

Method	Run	Batch Treatment Time (min)	Throughput (gpd)	**Energy Consumption** (kW per 1000 gal)	Cost ($) per 1000 gal
Continuous Top-Up	56	45	14,000	6.6	$1.19
Oscillation	57	55	26,000	5.6	$1.01
	87	35	35,000	5.2	$0.94
	90	25	45,000	4.4	$0.79

Note: Run 56 delivered significantly reduced throughput relative to the other runs due to the current pilot system configuration. One top-up pump is shared between both primary fractionation vessels, so the continuous top-up method can operate only one primary fractionation vessel at a time. A full-scale system could in theory adjust the pump and piping configuration to allow both vessels to operate simultaneously.

E6.4 Shakopee Aquifer Operations Summary

Shakopee operations occurred first and thus provided direction for future tuning during the Jordan and Raleigh Creek operations by revealing common trends and providing an example of what PFAS removal efficiencies could be expected. While the continuous top-up method did indicate removal efficiencies above 97% for both PFOA and PFOS, it was ruled out from further testing during Jordan and Raleigh Creek operations. Due to the shared top-up pump, throughput would be halved compared to other methods, reducing the volume of water that could be treated. Additionally, similar effluent standards were achieved using alternative methods (e.g. oscillation). Similarly, the concentrate dosing method was not tested during subsequent Jordan or Raleigh Creek operations. While good removal efficiencies of PFOA and PFOS were observed in some tests, dosing with concentrate was unsustainable due to the levels of concentrate needed for dosing. Similar or even better results could be achieved using a more sustainable method (e.g. oscillation).

Table E.16 highlights each method's best combined PFOS and PFOA effluent concentrations. The best PFOS and PFOA results achieved during the pilot study do not always align within the same run of a particular method. The Shakopee tuning results confirm that run style has a greater impact on PFAS removal than treatment time or cumulative energy input. The stepwise method had lower removal efficiencies of PFOS and PFOA relative to the oscillation method and continuous top-up method despite reaching the highest venturi pump frequencies. The oscillation method appears to be the most efficient method overall because it demonstrates effective removal efficiencies at decreased treatment times. At 42% reduced air injection rates and 36% reduced treatment times, the best oscillation method achieved lower PFOS and PFOA concentrations compared to the best stepwise method.

Table E.16: Shakopee Aquifer Operations – Comparison of Methods.

Method	Run	Highest Pump Energy Stage (Hz)	Effluent Concentration (ng/L)		Removal Efficiency (%) (1)		Cumulative Venturi Pump Energy Input (2)	Cycle Duration (min)
			PFOS	PFOA	PFOS	PFOA		
Stepwise	45	47	13.1	35.7	97.77	87.25	2350	55
Oscillation	87	44	1.07	4.1	99.89	98.82	1358	35
Continuous Top-Up	56	40	2.73	5.55	99.67	98.28	1800	45
Concentrate Dosing	29	39	44.4	100	95.52	72.38	1995	65

(1) Method 1633 results with paired influent samples are shown for the oscillation and continuous top-up results. Only Method 533 results are available for the stepwise and concentrate dosing results; paired influent samples were not collected for these, so removal efficiencies are approximated using influent concentrations from the prior week of testing. The reporting limit has been used where concentrations were below the detection limit.

(2) Cumulative Venturi Pump Energy Input is calculated as the sum of all products of pump frequency and time for each fraction stage. It illustrates the total energy applied and the relative volume of air injected during a run. A larger value indicates higher average venturi pump speed and thus a higher volume of air injected during a run.

E7 Jordan Aquifer Results

SAFF® tuning during Jordan Aquifer operations followed the same general principles as the Shakopee tuning did. Venturi pump frequencies, stage durations, and top-up rates were varied during tuning of the stepwise and oscillation methods. Jordan influent samples were collected more frequently, and influent PFOS and PFOA concentrations were highly variable and at times close to the reporting limit. Influent concentrations ranged from 0.801 ng/L to 63.7 ng/L for PFOS and from 21.1 ng/L to 73.9 ng/L for PFOA. All influent samples exceeded the PFOA MCL of 4 ng/L. 15 out of 26 influent samples exceeded the lowest PFOS MCL of 4 ng/L. No influent samples exceeded PFHxS standards.

The average Jordan influent concentration for PFOS was 12.2 (ng/L) during this study, whereas average concentrations of PFOS from the Shakopee and Raleigh creek operations were 839 (ng/L) and 1,360 (ng/L) respectively. As with Shakopee calculations, the laboratory reporting limit value was used in removal efficiency calculations where effluent concentrations were below the detection limit, resulting in some potentially under-reported removal efficiencies.

During Jordan operations 12 out of 26 effluent samples for PFOS and 3 out of 26 samples for PFOA were below the method detection limit of the lab. Despite the possibility of underestimated removal efficiencies where concentrations were below detection, this does not explain all low efficiencies where effluent concentrations were above detection limits. This supports the notion that higher influent PFAS concentrations support removal, and that it may be most practical to base tuning off target effluent concentrations rather than removal efficiency.

E7.1 Primary Fractionation Tuning Results - Jordan

E7.1.1 Stepwise Method

Testing of the stepwise method during Jordan operations used venturi pump frequency variations as the primary means of tuning. As demonstrated by Figure E.20, higher pump frequencies generally corresponded to decreased effluent PFOS concentrations, unlike Shakopee operational trends which indicated a positive correlation between these two variables. No trends were observed for PFOA removal. One factor that could be influencing the removal efficiency of PFOS in this case is the low influent concentrations.

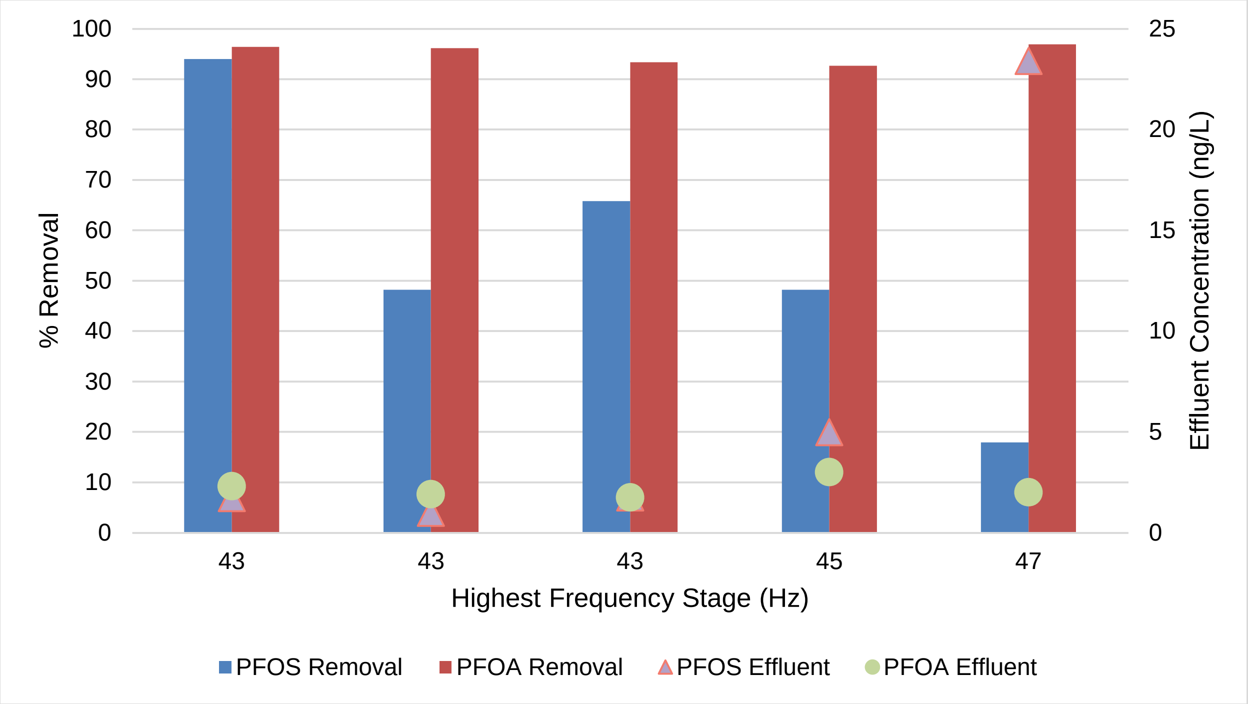

Figure E.20: Jordan Aquifer Primary Fractionation Tuning - Stepwise Method: Varying Venturi Pump Frequency, PFOS and PFOA Removal.

E7.1.2 Oscillation Method

Jordan Aquifer tuning varied venturi pump frequency, shown in Figure E.21 and fractionation stage duration, shown in Figure E.22. There was no significant correlation between energy variation and removal efficiency for the range of pump energies tested. This could have been due in part to the fluctuating and at times very low influent PFOS and PFOA concentrations. Influent concentrations of PFOS ranged from 1.41 (ng/L) to 63.7 (ng/L) while influent concentrations of PFOA ranged from 29.9 (ng/L) to 64.5 (ng/L). Additionally, results for varying venturi pump frequency indicate that operating closer to the maximum pump frequency may not be required to generate low effluent concentrations. Similarly, extending fractionation stage duration from 3 to 5 minutes did not necessarily improve results, though again, low influent concentrations did affect some results.

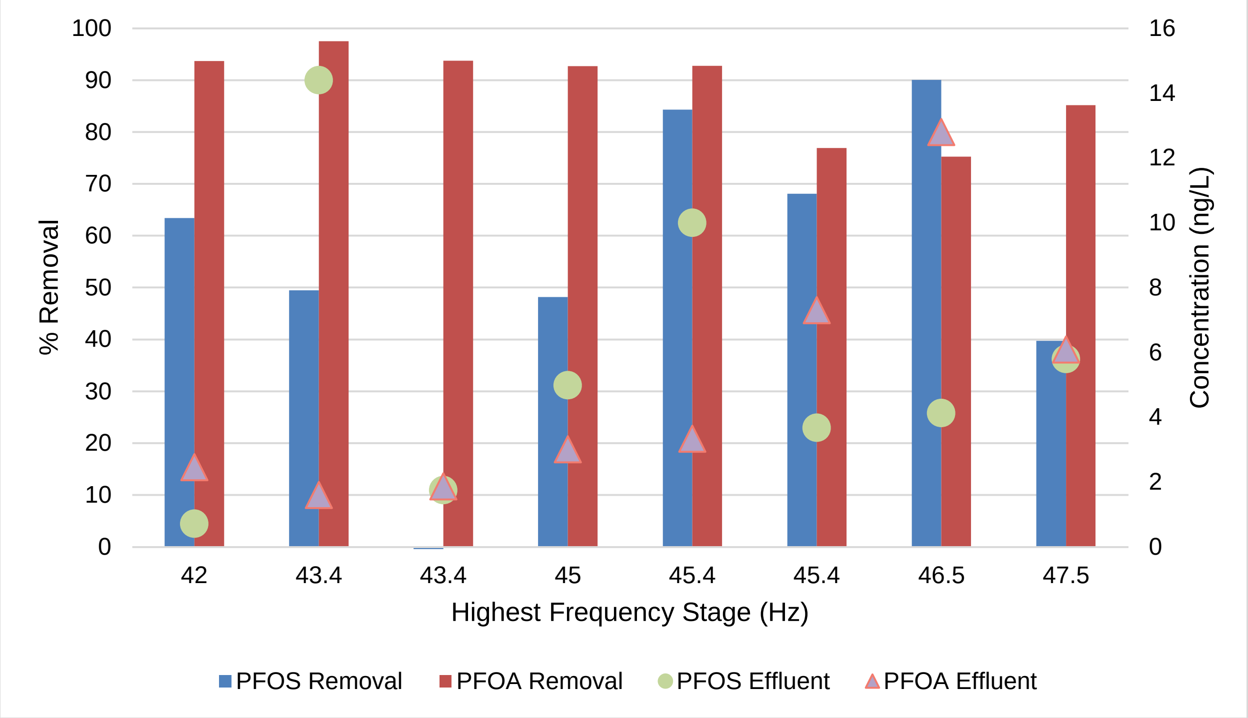

Figure E.21: Jordan Aquifer Primary Fractionation Tuning – Oscillation Method: Varying Venturi Pump Frequency, PFOS and PFOA Removal.

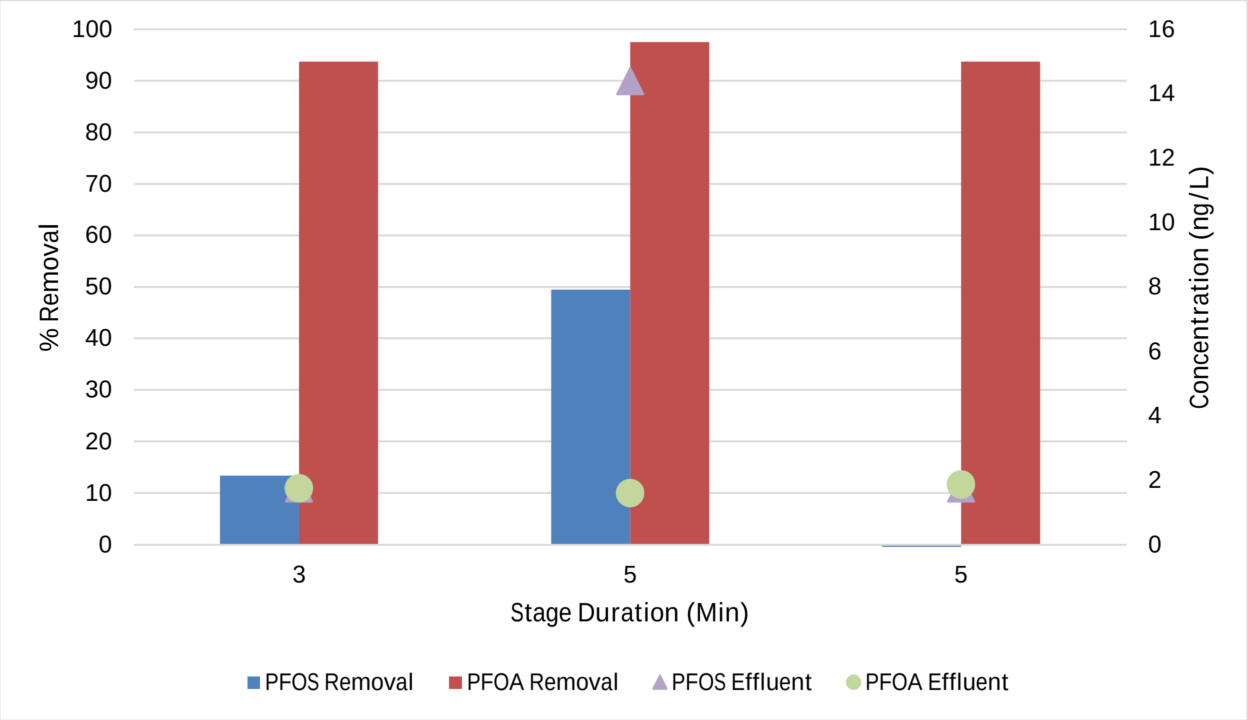

Figure E.22: Jordan Aquifer Primary Fractionation Tuning – Oscillation Method: Varying Fractionation Stage duration, PFOS and PFOA Removal.

E7.1.3 Regulated PFAS Results

While tuning focused on PFOA and PFOS removal, as previously mentioned, twelve PFAS compounds were analyzed in rapid turnaround time samples, and 40 compounds were analyzed for by EPA Method 1633. Example results are given in Table E.17 for PFAS subject to Federal and State regulations at the time of writing this report for different run styles tested during Jordan Aquifer tuning with the exception of HFPO-DA, as HFPO-DA was generally below detection limits at the Site and was not part of the rapid turnaround list. Results for all twelve compounds from the rapid turnaround time method for all runs can be found in Table E.35 (Tank 1), Table E.36 (Effluent), Table E.37 (Tank 3), and Table E.38 (Tank 4). Corresponding run settings are provided in Table E.39.

Table E.17: Jordan Aquifer Tuning Regulated PFAS Results in ng/L.

Tuning Method	Compound	PFOA	PFOS	PFHxS	PFNA	PFBS	PFHxA	PFBA
Stepwise - Venturi	Influent	26.3	5.12	1.04	<1.76	<1.76	6.24	362
	Effluent	<1.82	<1.82	<1.82	<1.82	<1.82	6.87	342
	Removal Efficiency (%)	93.1	64.5	*NC*	*NC*	*NC*	-10.1	5.52
Oscillation	Influent	64.5	28.5	2.43	<1.77	<1.77	7.7	444
	Effluent	2.3	<1.72	<1.72	<1.72	<1.72	6.73	431
	Removal Efficiency (%)	*97.2*	*94.0*	*29.2*	*NC*	*NC*	*12.6*	*2.93*

Legend: NC = Not Calculated as influent and/or effluent was below detection limits.

E7.2 Secondary Fractionation Tuning Results – Jordan

The secondary fractionation tuning approach for the Jordan Aquifer mirrored that of Shakopee tuning. Visual observations of foam production, foam transfer, and volume increases in Tank 4 influenced parameter adjustments. Generally, the foam produced during Jordan secondary fractionation was a low-density foam comparable to what was observed during Shakopee operations, likely due to reduced PFAS and TOC concentrations in the influent groundwater. Furthermore, all influent TOC samples collected from the Jordan Aquifer were below the detection limit of 0.47 (mg/L).

As with secondary fractionation during Shakopee operations, PFAS removal was evaluated by sampling Tank 3 as an influent sample and Tank 1 after the secondary fractionation cycle discharged as an effluent sample. For the samples displayed in Figure E.23, Tank 1 influent concentrations following secondary discharge were lower for PFOS and higher for PFOA when compared to Tank 1 concentrations under normal conditions. This translates to removal efficiencies of approximately 99.8% and 97.0% for PFOS and PFOA, respectively.

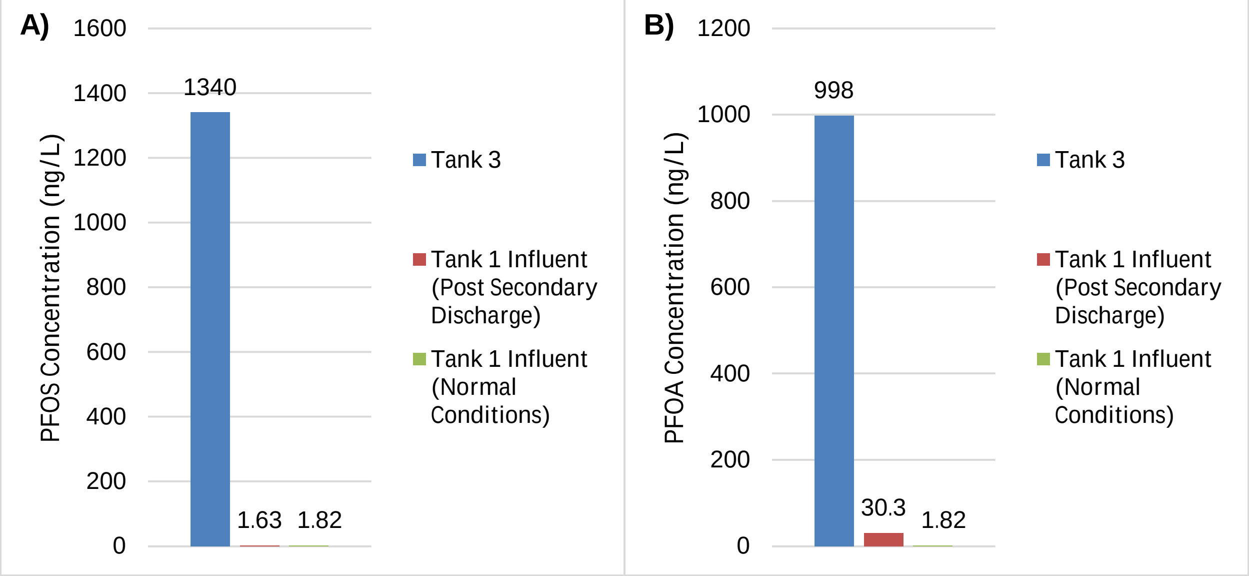

Figure E.23: Jordan Aquifer Secondary Fractionation Discharge Testing: A) PFOS and B) PFOA Removal.

E7.3 Long-Term Operations - Jordan

Jordan Aquifer Run 16 (35-min cycle time), an oscillation method, was run for several weeks to evaluate variability in effluent concentrations. All samples achieved the MDH PFOA HRL of 35 ng/L. All samples were analyzed using Method 1633. Where results indicated non-detect concentrations of a particular compound, the laboratory reporting limit was used. Table E.18 summarized extended run effluent concentrations and Tank 3 concentrations, and Table E.19 gives extended run throughput, energy consumption, and cost estimate per 1000 gallons.

Table E.18: Jordan Aquifer Testing Extended Run Effluent and Tank 3 Concentrations.

Method	Run	**Lowest Effluent Concentrations** (ng/L)			Associated Removal Efficiency (%)			Median Tank 3 PFAS **Concentrations (ng/L)**		
		PFOS	PFOA	PFHxS	PFOS	PFOA	PFHxS	PFOS	PFOA	PFHxS
Oscillation	16	0.402	1.75	0.402	56.3	93.75	42.4	87.7	828	18.7

Table E.19: Jordan Aquifer Testing Extended Run Throughput, Energy Consumption, and Cost Estimate per 1000 gallons.

Method	Run	Batch Treatment Time (min)	Throughput (gpd)	**Energy Consumption** (kW per 1000 gal)	Cost ($ per 1000 gal)
Oscillation	16	35	35,000	4.4	$0.79

AOF was periodically measured during Jordan Aquifer operations; results are summarized in Table E.20. Results are generally inconclusive, as the majority of the results are below the method detection limit. The Jordan Aquifer had the lowest influent PFAS concentrations of all water sources tested, thus these results are not surprising. AOF is generally more suitable for water sources with higher concentrations of Total PFAS (>1 µg/L), limiting the usefulness of AOF for this specific aquifer.

Table E.20: Jordan Aquifer AOF Results Summary.

Date	Run Number	AOF Concentrations (µg/L)			
		Influent	Effluent	Tank 3	Tank 4
8/15/2023	16	<0.54	<0.54	<0.54	NS
8/15/2023	16	<0.54	0.52		
8/15/2023	16	<0.54	<0.54		
*8/25/2023 **	*16*	*<0.33*	*0.53*	*NS*	*NS*
8/25/2023	16	<0.75	0.47	NS	NS

Legend: NS = not sampled.
* Indicates sample was collected after discharge from secondary fractionation was treated.

Concentration factors were also evaluated for PFOS and PFOA during Jordan Aquifer operations. Concentration factors were calculated for a single time point during Jordan Aquifer long-term operations due to the comparatively shorter period of time spent testing Jordan Aquifer groundwater. Rounded results are summarized in Table E.21. The results demonstrate that significant volume reduction can be achieved on groundwater that does not foam.

Table E.21: Shakopee Aquifer PFOA, PFOS, and TOC Concentration Factors.

Species	Influent	Tank 3	Tank 3 Concentration Factor	Tank 4	Tank 4 Concentration Factor
PFOS	0.001 µg/L	0.09 µg/L	95x	1,730 µg/L	1,800,000x
PFOA	0.023 µg/L	0.76 µg/L	32x	668 µg/L	29,000x
TOC	<1.0 mg/L	<1.0 mg/L	-	Not Measured	-

E7.4 Jordan Aquifer Operations Summary

Although Jordan tuning involved a much greater frequency of corresponding influent samples to calculate removal efficiencies, results indicated that focusing on effluent concentrations rather than removal efficiencies may provide greater value. The stepwise method’s highest removal efficiencies of PFOS and PFOA were 93.9% (effluent concentration of 1.72 ng/L) and 97.7% (effluent concentration of 1.71 ng/L) respectively. The oscillation method’s highest removal efficiencies for PFOS and PFOA were 90.0% (effluent concentration of 4.13 ng/L) and 97.5% (effluent concentration 1.6 ng/L) respectively. In both cases, these corresponded to runs with influent concentrations on the higher end of the observed range, indicating that correlation between higher influent concentrations and greater removal efficiencies may impact trend analysis. When filtering for the lowest effluent concentrations rather than highest removal efficiencies, the most successful runs achieved 0.414 ng/L and 1.10 ng/L for PFOS and PFOA respectively.

Due to lower relative influent concentrations, removal efficiencies were lower during Jordan operations than during Shakopee operations. Furthermore, as previously stated, the limiting factor of detection limits may result in underestimated removal efficiency. Table E.22 compares each method’s best combined PFOS and PFOA effluent concentrations.

Table E.22: Jordan Aquifer Operations – Comparison of Methods.

Method	Run	Highest Pump Energy Stage (Hz)	**Effluent Concentration** (ng/L)		Removal Efficiency (%)		**Cumulative** Venturi Pump Energy Input	**Cycle Duration** (min)
			PFOS	PFOA	PFOS	PFOA		
Stepwise	14	43	1.75	1.1	88.9	95.6	1755	45
Oscillation	16	43.4	1.75	1.75	13.4	93.8	1315	35

Note: Method 533 results with paired influent samples are shown for both methods above. The reporting limit has been used where concentrations were below the detection limit.

E8 Raleigh Creek Results

SAFF® tuning during Raleigh Creek operations followed the same general objectives as Shakopee Aquifer tuning did to minimize effluent concentrations and maximize throughput by varying venturi pump frequencies, stage durations, and top-up rates. During Raleigh Creek operations, a failing venturi pump, an intermittently failing surface water pump, high variability in the concentrations of PFAS and organic matter in Raleigh Creek, and periods of time when Raleigh Creek went dry, all limited the amount of tuning that could be performed. The failing venturi pump resulted in relatively low removal efficiencies which were not representative of normal operations, as well as system downtime to troubleshoot and replace the pump. Data collected before the pump was replaced is not included in this report. As there was a relatively short period of time during which water was flowing through Raleigh Creek each spring (April 17, 2023 – May 16, 2023, and April 4, 2024 – May 8, 2024), each system disruption resulting in downtime caused significant hurdles to tuning.

As a result of these factors, there was a limited number of approaches that were used for Raleigh Creek tuning. The stepwise method was used exclusively during Raleigh Creek operations because it had proven to be an effective method for previous influent sources. Oscillation was not tested due to the limited testing window and downtime from pump and electrical issues. As with Shakopee and Jordan Aquifer operations, tuning discussion focuses more heavily on effluent concentrations rather than removal efficiency because of the high influent variability and instances where influent samples were not collected.

E8.1 Primary Fractionation Tuning Results - Raleigh Creek

E8.1.1 Varying Venturi Pump Frequency

The maximum venturi pump frequencies varied from 29 Hz to 44 Hz during tuning. As seen in Figure E.24, increases in pump frequency may correlate to higher removal efficiencies of PFOS and PFOA. The lowest observed effluent concentrations for PFOS and PFOA were 9.13 ng/L and 4.84 ng/L at a maximum pump frequency of 41 Hz. These corresponded to removal efficiencies of 99.3% and 99.1% for PFOS and PFOA, respectively.

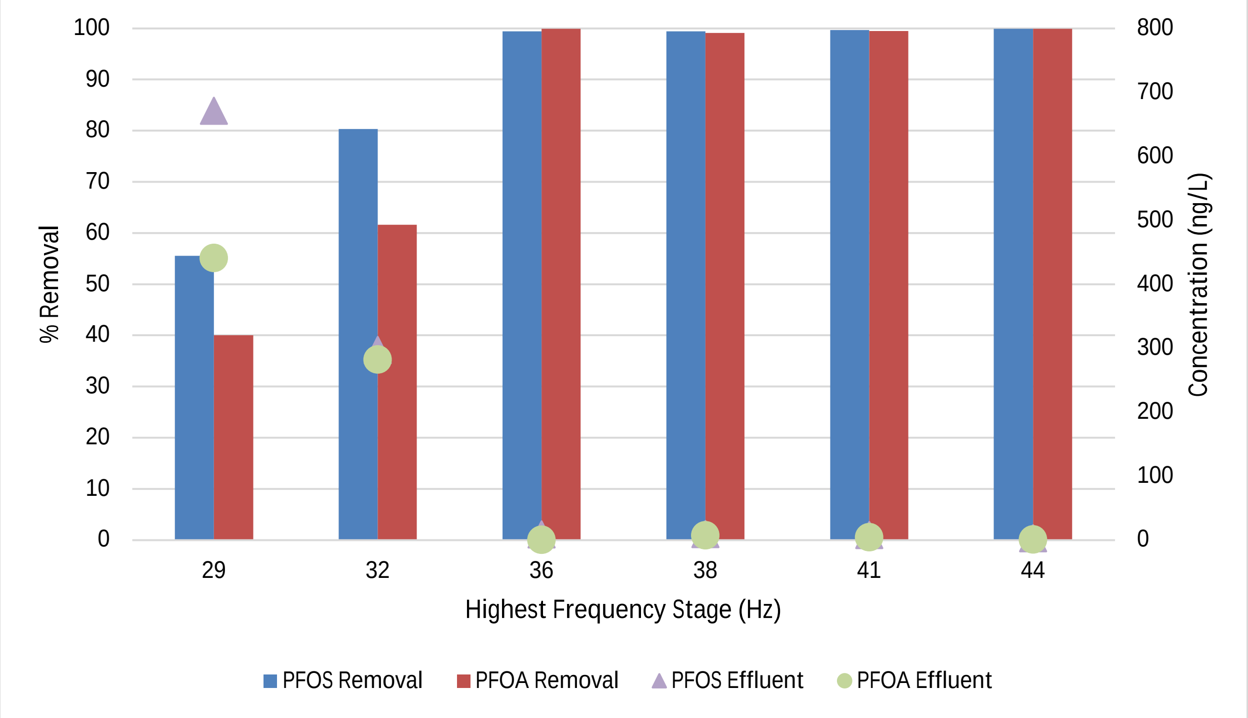

Figure E.24: Raleigh Creek Primary Fractionation Tuning - Stepwise Method: Varying Venturi Pump Frequency, PFOS and PFOA Removal.

E8.1.2 Varying Fractionation Stage Duration

Only two runs testing varied duration were completed due to operational disruptions caused by a failed venturi pump. As displayed in Figure E.25, the increased stage length from 3 minutes (35 minute cycle) to 5 minutes (55 minute cycle) in this case did not improve removal efficiency. However, more data should be collected from more time variations to define the trend for surface water treatment. For these two trials, the maximum venturi pump frequency was 38 Hz, and top-up rate was set to 30 LPM. It is possible that in this case pump frequency acted as the limiting factor, and if pump frequency was reduced, then trends driven by cycle duration may become significant again. These results indicate that similar removal efficiencies can be achieved in a shorter span of time, allowing for greater system throughput.

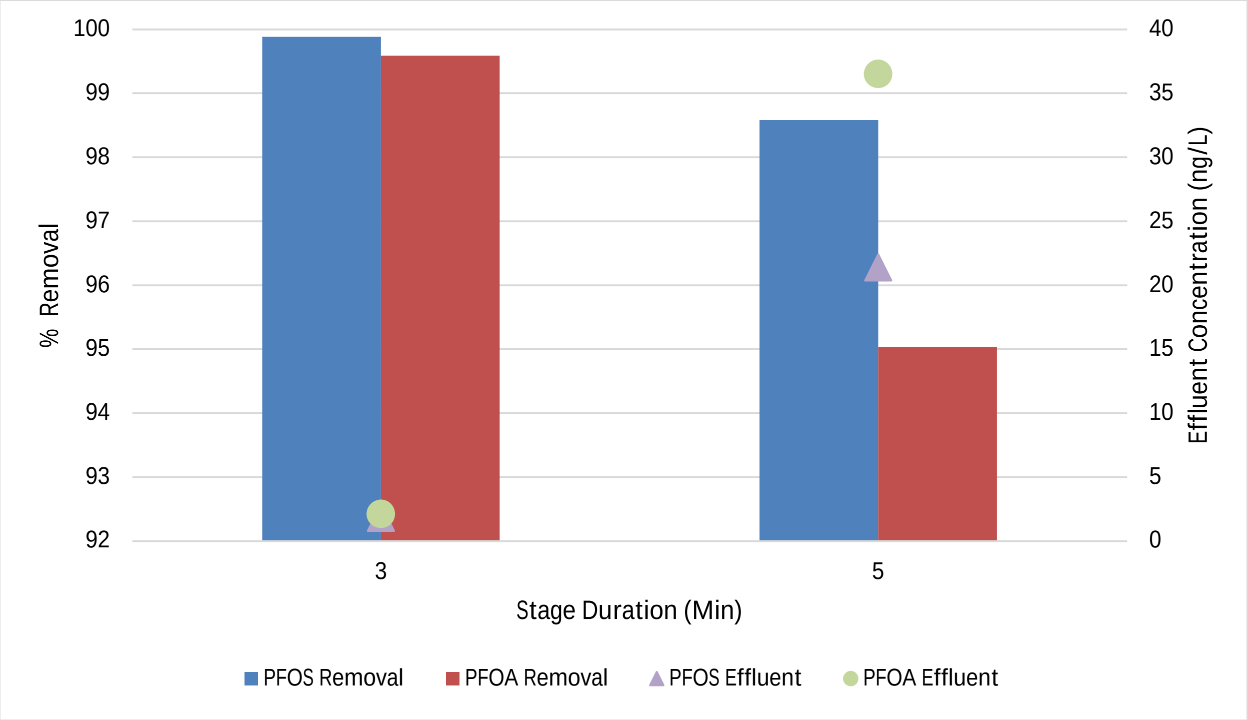

Figure E.25: Raleigh Creek Primary Fractionation Tuning - Stepwise Method: Varying Fractionation Stage Duration, PFOS and PFOA Removal.

E8.1.3 Varying Top-Up Rate

As shown in Figure E.26, increased top-up rate was correlated with increased removal efficiency. There were only two top-up variation runs that were included from when both the creek was flowing, and the venturi pump was operating correctly to ensure the analysis was representative of normal operating conditions. For the surface water top-up variation runs the pump energy was 41 Hz, and the stage length was 3 min.

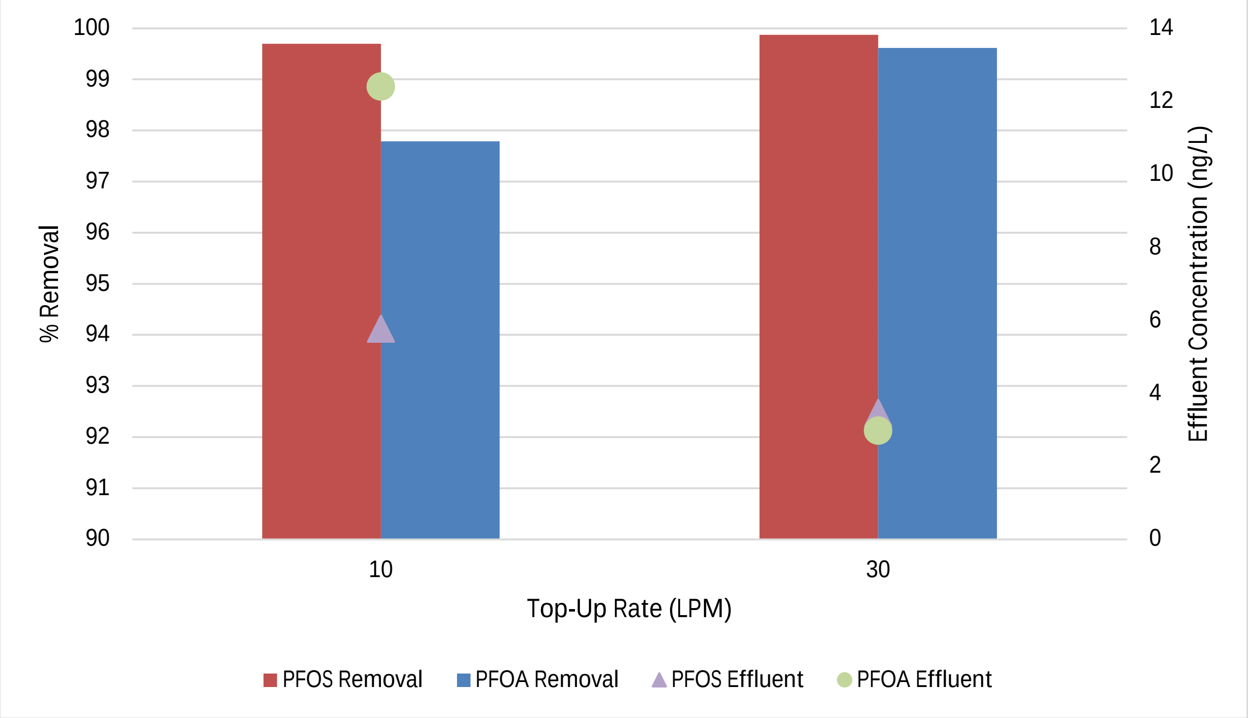

Figure E.26: Raleigh Creek Primary Fractionation Tuning - Stepwise Method: Varying Top-Up Rate, PFOS and PFOA Removal.

While tuning focused on PFOA and PFOS removal, as previously mentioned, twelve PFAS compounds were analyzed in rapid turnaround time samples, and 40 compounds were analyzed for by EPA Method 1633. Example are given in Table E.23 for PFAS subject to Federal and State regulations at the time of writing this report for different run styles tested during Raleigh Creek tuning with the exception of HFPO-DA, as HFPO-DA was generally below detection limits at the Site and was not part of the rapid turnaround list. Results from two dates are given, one with much higher PFOS concentrations for the influent than the other. Results for all twelve compounds from the rapid turnaround time method for all runs can be found in Table E.40 (Tank 1), Table E.41 (Effluent), Table E.42 (Tank 3), and Table E.43 (Tank 4). Corresponding run settings are provided in Table E.44.

Table E.23: Raleigh Creek Tuning Regulated PFAS Results in ng/L.

Tuning Method	Compound	PFOA	PFOS	PFHxS	PFNA	PFBS	PFHxA	PFBA
Stepwise - Venturi	Influent	9.19	17.7	4.88	<0.896	3.47	4.88	80.8
	Effluent	1.23	1.03	1.07	<0.916	2.74	4.89	77.1
	Removal Efficiency (%)	86.6	94.2	78.1	*NC*	21.0	-0.205	4.58
Stepwise - Venturi	Influent	655	1,540	75.4	8.87	24.8	75.4	293
	Effluent	28.1	93.7	11.0	<0.893	25.4	76.0	292
	Removal Efficiency (%)	95.7	93.9	85.4	89.9	-2.42	-0.796	0.341

Legend: NC = not calculated as influent and effluent were below detection limits.

Additional testing with the Stepwise – Venturi method allowed for increased removal efficiencies; results from a representative run are summarized in Table E.24.

Table E.24: Raleigh Creek Optimized Settings for Stepwise – Venturi Operations.

Compound	PFOA	PFOS	PFHxS	PFBS	PFHxA	PFBA
MPCA Site-Specific Water Quality Criteria (ng/L)	< 25	< 0.05	< 20	< 140	< 220	< 5700
Raleigh Creek Influent (ng/L)	515	1570	41.1	18.4	51.5	303
Raleigh Creek Effluent Achieved by Optimized Settings (ng/L)	2.12	1.8	1.69	8.08	22	175
Optimized Raleigh Creek Removal Efficiency (%)	99.6	99.9	95.9	56.1	57.3	42.2

E8.2 Secondary Fractionation Tuning Results - Raleigh Creek

The secondary fractionation tuning approach for Raleigh Creek operations mirrored that of groundwater operations, with the same goals of maximizing PFAS removal from primary fractionate while minimizing volume generation of the secondary fractionate product. Figure E.27 compares concentrations from Tank 3 (influent), Tank 1 post-secondary discharge (effluent), and Tank 1 under normal conditions on 5/11/2023. These results indicate that the effluent from secondary fractionation had lower concentrations than typical Tank 1 concentrations, suggesting removal efficiencies of >97.2% and >98.2% for PFOS and PFOA, respectively.

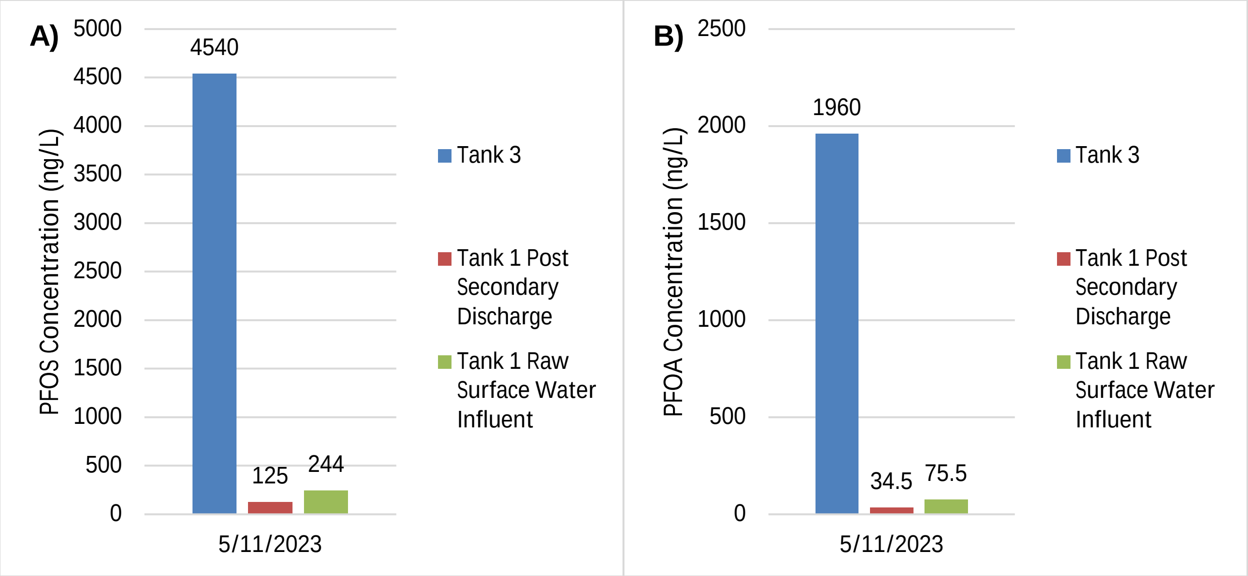

Figure E.27: Raleigh Creek Secondary Fractionation Discharge Testing: A) PFOS and B) PFOA Removal.

The Raleigh Creek secondary cycles produced a high-density foam (comparable to shaving cream) rather than the low-density foam (comparable to dish soap bubbles) which was observed during Shakopee treatment. The type of foam produced is likely due to high organic content of the influent water, and overall higher concentrations of PFAS. During Shakopee operations, TOC influent concentrations were consistently below the detection limit (≤1.0 mg/L) while TOC influent concentrations during Raleigh Creek operations ranged from 6.4 mg/L to 9.2 mg/L. Tank 3 PFAS concentrations during Raleigh Creek operations ranged from 951 to 15,100 ng/L and from 258 to 7,300 ng/L for PFOS and PFOA respectively. Tank 3 concentrations during Shakopee operations ranged from 7,460 to 9,220 ng/L and from 1,170 to 1,720 ng/L for PFOS and PFOA, respectively.

Figure E.28: Raleigh Creek Secondary Fractionation Foam Production.

E8.3 Raleigh Creek Operations Summary

High removal efficiencies of PFOS and PFOA were observed using the stepwise method to treat surface water from Raleigh Creek. Table E.25 summarizes the highest removal efficiencies observed during testing, which occurred using a venturi pump stage length of three minutes and a highest venturi pump energy of 41 Hz. Removal efficiencies of 99.7% and 99.5% for PFOS and PFOA, respectively, were observed. Intermittent surface water flow could pose operational challenges long term, though, should treatment of Raleigh Creek surface water be pursued.

Table E.25: Raleigh Creek Operations Highest Removal Efficiency.

Method	Highest Pump Energy Stage (Hz)	Stage Length (Min)	% PFOS Removal	% PFOA Removal
Stepwise - Venturi	41	3	99.7	99.5

Table E.26 compares the results of stepwise method runs with five minute stage lengths and varied pump energies between Raleigh Creek and Shakopee operations. Higher removal efficiencies were achieved at lower pump energies during Raleigh Creek operations relative to Shakopee Aquifer operations, likely due to higher foam production. During Raleigh Creek operations more foam was observed relative to Shakopee operations, likely because of higher organic contents in the Raleigh Creek water compared to the Shakopee. During Shakopee operations, TOC influent concentrations were generally below the detection limit (≤1.0 mg/L) while TOC influent concentrations during Raleigh Creek operations ranged from 5.9 mg/L to 7.5 mg/L. Another potential factor that may have aided in foam formation was higher concentrations of PFOS and PFOA that were found in Raleigh Creek relative to the Shakopee. PFOS influent concentrations ranged from 876 (ng/L) to 1730 (ng/L) and PFOA influent concentrations ranged from 349 (ng/L) to 928 (ng/L) for Raleigh Creek operations, while PFOS influent concentrations ranged from 590 (ng/L) to 1030 (ng/L) and PFOA influent concentrations ranged from 276 (ng/L) to 362 (ng/L) for Shakopee operations. Overall, Raleigh Creek had the highest observed removal efficiency of PFOS and PFOA between the three influent water sources.

Table E.26: Shakopee Aquifer vs. Raleigh Creek Operations Stepwise Method for PFOS and PFOA.

Shakopee			Raleigh Creek		
Highest Pump Energy Stage (Hz)	% PFOS Removal	% PFOA Removal	Highest Pump Energy Stage (Hz)	% PFOS Removal	% PFOA Removal
43	83.0	63.5	36	93.9	95.7
46	95.2	80.1	41	99.3	99.1
47	97.8	87.3	44	98.6	99.4

Similar to Shakopee Aquifer and Jordan Aquifer operations, AOF samples were periodically collected and analyzed during Raleigh Creek operations; AOF results are summarized in Table E.27. Initial concentrations of AOF were generally higher in Raleigh Creek samples compared to the Shakopee and Jordan Aquifers. Similarly, effluent concentrations of AOF are also higher in Raleigh Creek samples, though results generally demonstrate removal of AOF. The highest removal observed was on 5/13/2023, when greater than 82% of AOF was removed. Similar to Shakopee Aquifer results and speciated Raleigh Creek results, AOF concentrations from Tank 1 to Tank 3 to Tank 4 increased, further indicating concentration of PFAS occurred during operations.

Table E.27: Raleigh Creek AOF Results Summary.

Date	Run Number	**AOF Concentrations (ug/L)**			
		Influent	Effluent	Tank 3	Tank 4
*5/5/2023 *)*	*3*	*3.1*	*3*	*3.9*	*14,000*
5/7/2023	3	5.6	1.6	40	NS
5/5/2023	3	<0.46	1.8	NS	NS
5/13/2023	8	3.4	<0.6	13	NS
9/30/2023	12	3.5	1.5	NS	NS
			2.1		
5/8/2024	16	6.4	3.6	110	16,000

Legend: NS = not sampled.

* Indicates sample was collected after discharge from secondary fractionation was treated.

Concentration factors were also evaluated for PFOS and PFOA during Raleigh Creek operations. Concentration factors were calculated based on the averages of several time points. Results are summarized in Table E.28. Results will vary depending on the exact run used to calculate concentration factors, in large part due to varying influent conditions. Due to higher concentrations of TOC in the water and thus the more significant foaming observed during operations, lower concentration factors were observed than with groundwater. This indicates that while higher TOC will increase foaming and may decrease treatment time, the achievable concentration factor may be lower in water sources with higher TOC. Observed concentration factors still demonstrate a significant volume reduction though.

Table E.28: Shakopee Aquifer PFOA, PFOS, and TOC Concentration Factors.

Species	Influent	Tank 3	**Tank 3 Concentration** Factor	Tank 4	**Tank 4 Concentration** Factor
PFOS	2.2 µg/L	65 µg/L	30x	16,700 µg/L	8,000x
PFOA	0.8 µg/L	23 µg/L	30x	5,500 µg/L	7,000x
TOC	8.1 mg/L	11.7	1.4x	160	20x

E9 Aerosolization Results

Testing was conducted to evaluate the extent to which PFAS removal occurred through aerosolization rather than fractionation. If aerosolization occurred, this could result in increased loading of PFAS to the GAC filter rather than transfer of PFAS to the concentrate. Aerosolized PFAS either condenses in the pipe routed to Tank 3 or is captured by GAC air filters as the air vents outside. The process of aerosolization testing for primary fractionation consisted of setting the primary vessel fill level low enough to prevent any spill-over or transfer to Tank 3 at the pump frequency being tested. Fill levels used were lower than what was typically used in other methods and was determined through visual observations of the primary vessels. The pump frequency was then held constant for the length of time being tested, and the top-up stage was eliminated to prevent any spill over and transfer of water to Tank 3. Aerosolization testing was not conducted for surface water operations, as foam formation was expected to inhibit aerosolization from the water surface. During testing for the non-foaming Shakopee and Jordan Aquifers, Tank 3 levels were observed to increase slightly, despite no visual observations of spill-over, suggesting that some condensation of aerosolized PFAS could have occurred.

Venturi pump frequency and cycle duration were varied as part of this testing. Figure E.29 (PFOS) and Figure E.30 (PFOA) show results of Shakopee aerosolization trials at pump frequencies of 30 Hz and 40 Hz ranging from 5 minutes to 240 minutes. While 240 minutes is an unrealistically long fractionation time for normal treatment, it was selected to allow for adequate time to observe potential aerosolization. Aerosolization trials at a pump frequency at 30 Hz saw a maximum removal of 25.8% and 9.9% for PFOS and PFOA respectively. For the 30 Hz frequency trials, duration did not have a notable impact on removal. Trials at a pump frequency of 40 Hz saw a maximum removal of 97.2% and 75.5% for PFOS and PFOA respectively. For these 40 Hz trials, removal generally increased as duration increased.

Testing on the Jordan Aquifer also occurred at pump frequencies of 30 Hz and 40 Hz with test durations ranging from five minutes to 240 minutes. Figure E.31 (PFOS) and Figure E.32 (PFOA) give aerosolization results for Jordan Aquifer tests. Aerosolization trials at a pump frequency at 30 Hz saw a maximum removal of 59.6% and 46.5% for PFOS and PFOA respectively. For the 30 Hz frequency trials, duration did not have a notable impact on removal. Trials at a pump frequency of 40 Hz saw a maximum removal of 62.5% and 44.8% for PFOS and PFOA respectively. For PFOS, removal at 40 Hz generally increased as duration increased, though this was generally not true at 30 Hz. Removal of PFOA did not appear to increase as duration increased, neither at 30 Hz nor 40 Hz.

The minimal Tank 3 volume increase indicates that some PFOS and PFOA are likely vented through the GAC filter and therefore not collected to undergo secondary fractionation; however, the amounts of concentrated PFAS transferred to Tank 3 via condensation as opposed to through the GAC system is unclear. To clarify understanding of how PFOS and PFOA move through the system during primary fractionation, additional aerosolization testing could be performed in conjunction with air and GAC sampling. Because several influent sources and a wide variety of treatment methods were tested, mass balances based on individual trials were not feasible, and GAC samples were therefore not collected during this pilot study. Future testing should monitor the volume inputs to Tank 3 via condensation and incorporate sampling of the GAC filter before and after testing. If high concentrations of aerosolized PFAS are being captured by the GAC, modifications such as addition of a condenser, increase in GAC vessel size, or increase in the number of GAC vessels (i.e. addition of a lead/lag pair) may be required to maximize PFAS capture in Tank 3.

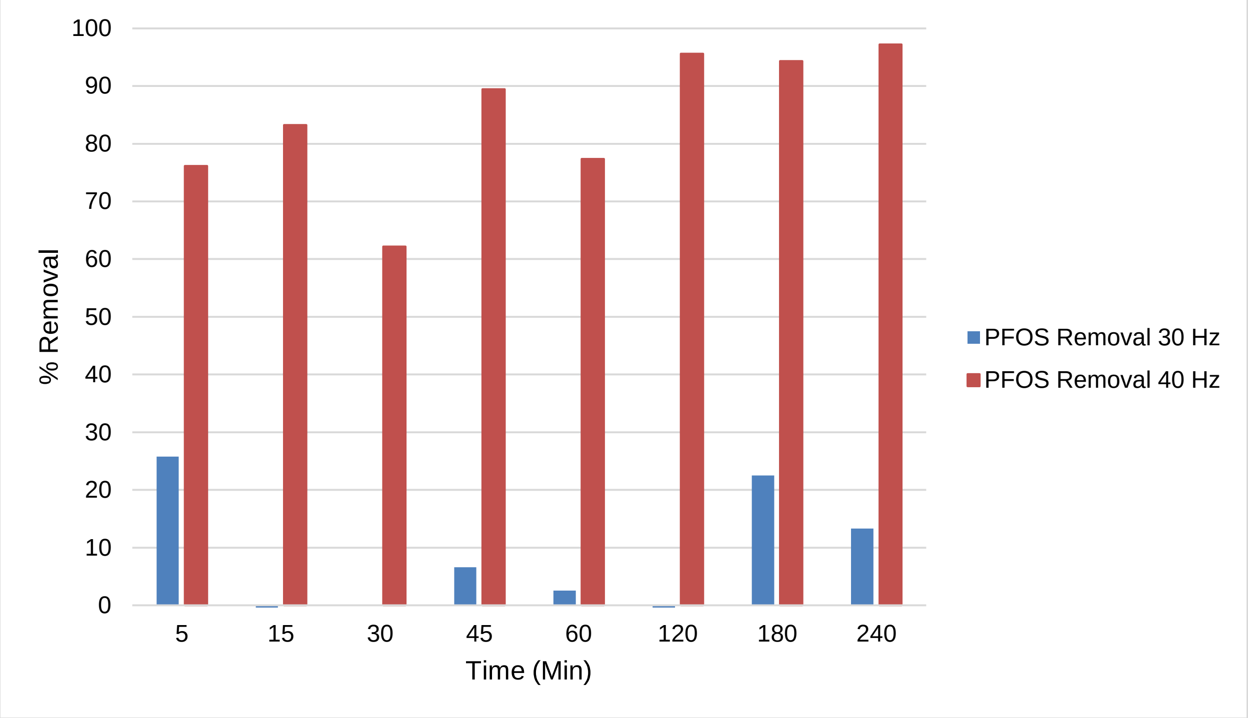

Figure E.29: Shakopee Aquifer Aerosolization Analysis - PFOS Removal.

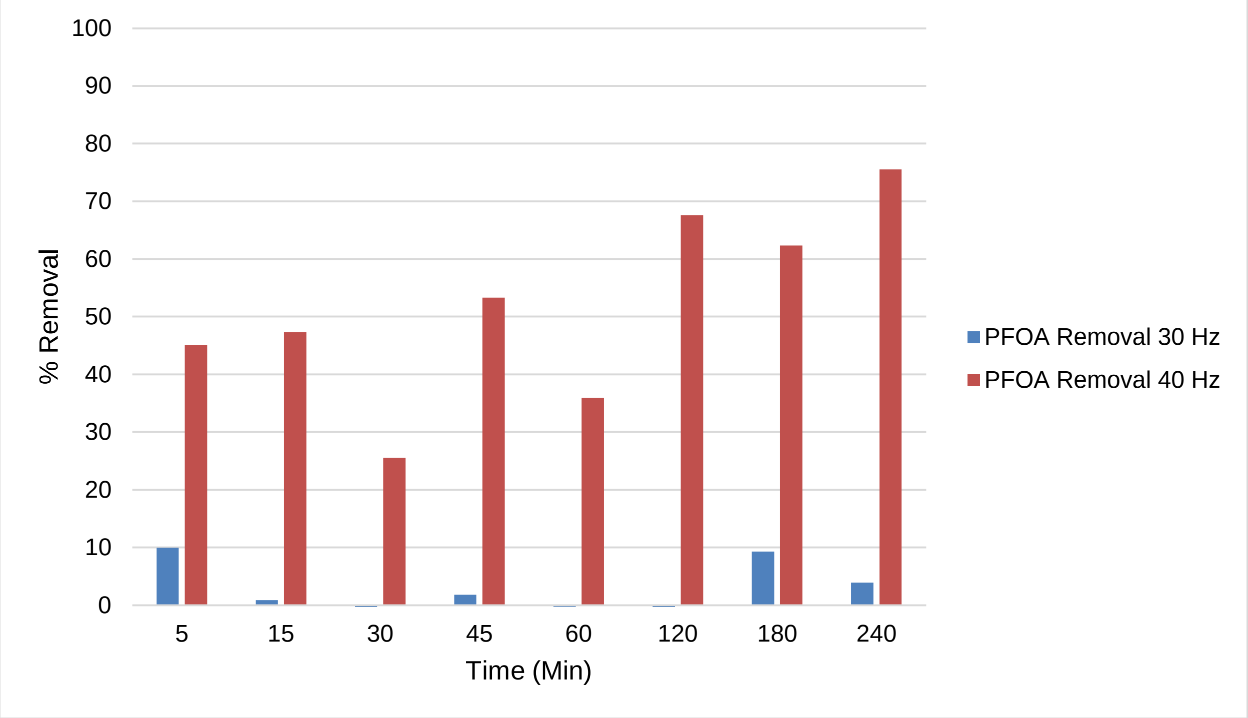

Figure E.30: Shakopee Aquifer Aerosolization Analysis - PFOA Removal.

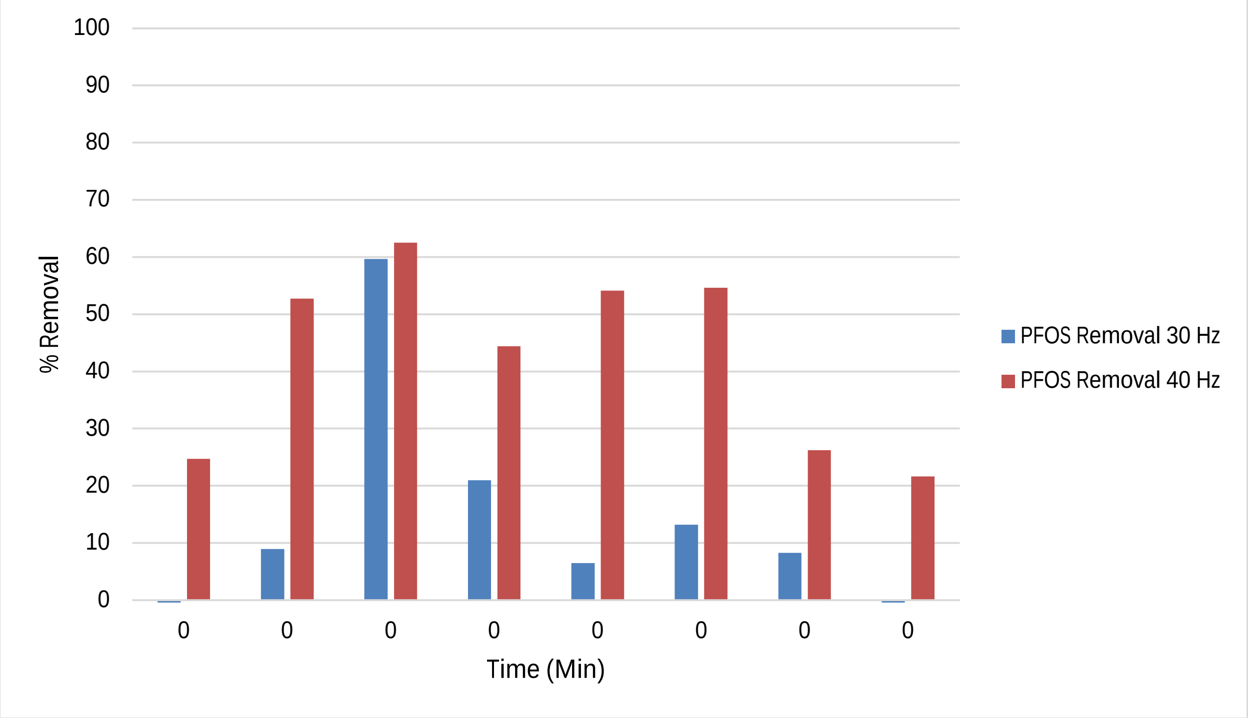

Figure E.31: Jordan Aquifer Aerosolization Analysis - PFOS Removal.

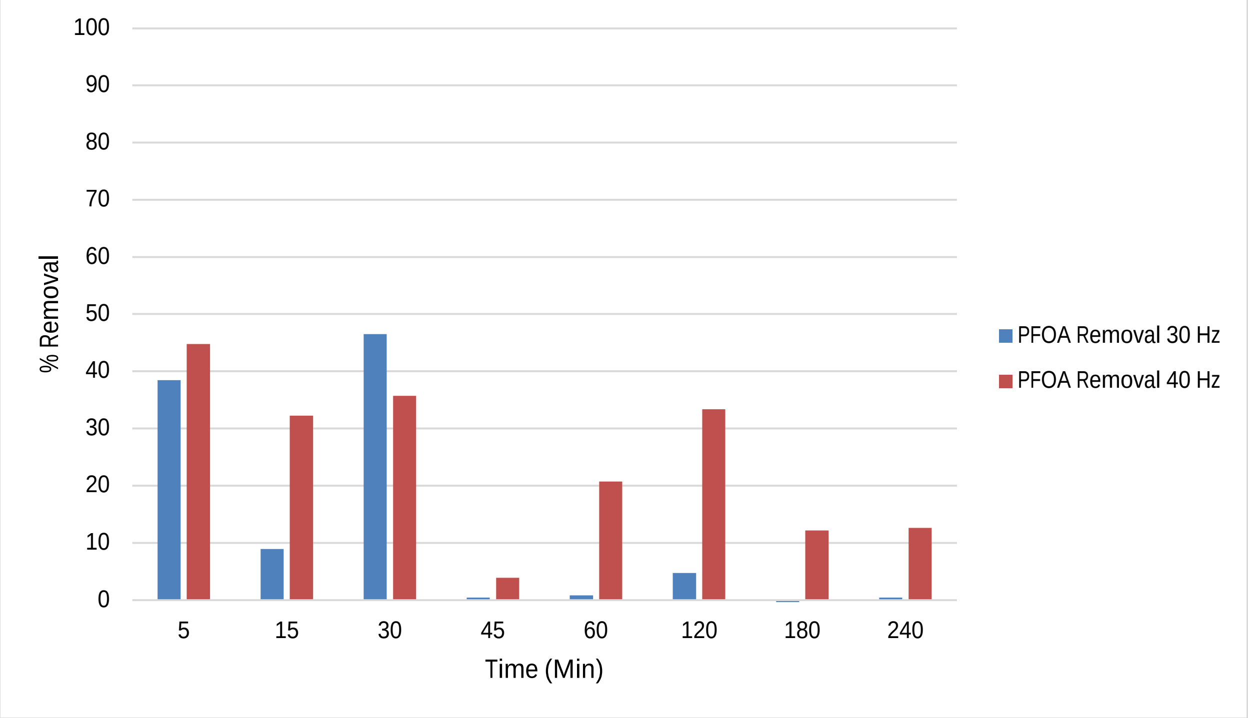

Figure E.32: Jordan Aquifer Aerosolization Analysis - PFOA Removal.

E10 Operations and Maintenance

The following section summarizes the operations and maintenance needs of the piloted SAFF® with the intent of documenting pilot study activities, informing future operators, and suggesting process modifications to improve performance. It has been divided into the following categories:

- Programming (automation, telemetry, alarms, primary vessel fill levels/other programming adjustment)
- Maintenance
  - Routine (generator, bag filters, cleaning of hoods and solenoid valves, air compressor, reconcentration/transfer)
  - Non-Routine (level sensor mismatch, flow switch dislodging)
- Repairs & Replacements (pump replacements, leaks)
- Site-Specific Considerations

The time and effort required to perform maintenance activities were often dependent on the season and influent water source. The SAFF® system was run continuously to the extent possible, with some extended shutdowns occurring due to weather and equipment repairs as described in detail below. The SAFF® was primarily operated by AECOM staff, although EPOC maintained remote access to the unit, allowing full control remotely. EPOC provided input and operators as needed to troubleshoot system issues and improve operations.

E10.1 Programming

System operation is controlled by various automated sequences that can be stopped at any time. A sequence will only proceed if all drives, instruments, valves, and other equipment required for the sequence are healthy.

E10.1.1 Alarms

When problems arise with the SAFF® system, there are three levels of alarms to alert operators. The highest level of alarm will shut down the entire system; for example, if there is a system leak and the bund alarm is triggered, all system operations are stopped. The next level of alarm is equipment specific and will only shut down the relevant equipment, while the third level of alarm is an indicator only alarm to notify the operator of a fault or piece of equipment that requires maintenance.

E10.1.2 On-Site Programming Modifications

The following program modifications were made during the pilot study:

- Continuous Top-Up (temporary)
- Primary Vessel Fill Levels (permanent)

When tuning primary vessel fill levels, consistent overfilling of both primary vessels by the fill pump (P1-01) with inconsistent fill levels between each vessel were observed. SV1-01 filled slower and drained faster than SV1-02. Possible explanations for the difference in fill levels between vessels include different distances from the shared fill pump or a valve being slow to close for the SV1-02 filling port. EPOC adjusted system programming so that the fill pump rate could be slowed down after reaching a specified level within the primary vessel to allow for greater precision near the end of the filling process. To minimize overfilling and variation between vessels, the level at which the fill pump slowed down, the energy it slowed to, and fill time and level were adjusted. Fill levels were more consistent after implementing these adjustments.

E10.2 Routine Maintenance

The following items required regular maintenance during various phases of the pilot study:

E10.2.1 Bag Filters

Influent water was filtered with 150-micron bag filters during Shakopee Aquifer, Raleigh Creek, and Jordan Aquifer operations. Bag filters were changed out as needed based on the pressure differential across the filter. In an effort to remove the additional particulates present in Raleigh Creek compared to the drinking water aquifers, 50-micron bag filters were used during a portion of Raleigh Creek operations but clogged easily, causing frequent high pressure differential alarms and shutting down the influent supply of water and thereby pausing the system. EPOC recommended switching back to 150-micron bag filters which were used without issue.

E10.2.2 Cleaning of Hoods

To maintain visibility into the hoods on the primary and secondary fractionation vessels, the hoods were periodically cleaned. Routine cleaning involved removing the top flange of the vessels and scrubbing the inside of the hood with white vinegar. This task was completed as needed to maintain visibility into the hoods. The Shakopee Aquifer and Jordan Aquifer were not high in organics; therefore, residue buildup was minimal and less frequent cleaning was required. Raleigh Creek's high organics concentrations generated frequent buildup of organic residue therefore required more frequent cleaning.

E10.2.3 Air Compressor Maintenance

The air compressor pump requires an oil change and a belt check/replacement annually. Water also needs to be regularly drained from the air compressor to remove accumulated condensation to prevent rust and damage within the compressor tank.

E10.3 Non-Routine Maintenance

The following irregular maintenance activities occurred periodically after minor system faults and process disruptions.

E10.3.1 Solenoid Valve Cleaning

High iron concentrations in the source water resulted in fouling at the diaphragm holes of the sprinkler system solenoid valves. Fouling caused a variety of minor process disruptions such as preventing the sprinkler pump from reaching or maintaining adequate pressure in the sprinkler lines. This caused some minor leaks through the sprinklers into various tanks and treatment vessels. Disassembling the solenoid valve and cleaning the fouled diaphragm remedied the problem.

E10.3.2 Level Sensor Mismatch Correction

"Level sensor mismatch" errors at the Tank 1 magnetic level sensors frequently paused operations. This error typically occurred after the filling of a primary fractionation vessel when Tank 1 levels were nearly empty. The issue persisted following sensor programming adjustments by EPOC. However, manually sliding a magnet along the low-level sensor typically cleared the error. A possible explanation for these errors includes sediment buildup near the magnetic float, programming issues, or loose wiring. Because this alarm occurred when Tank 1 levels were nearly empty, EPOC suggested that the sensor be swapped with the Tank 4 level sensor, as a Tank 4 level sensor mismatch alarm would not disrupt operations. The level sensor mismatch errors stopped occurring altogether after the Tank 1 and Tank 4 sensors were swapped.

E10.3.3 Secondary Fractionate Reconcentration and Transfer

Secondary fractionate production was variable during the tuning process due to constantly changing primary fractionation parameters and changing influent water sources. To maximize the concentration factor of the treatment process and minimize waste volumes/transfer efforts, the secondary fractionate in Tank 4 was periodically dosed into Tank 3 to process it via secondary fractionation for a second time to further concentrate the secondary fractionate. When the consistency of Tank 4 fractionate appeared too foamy to successfully concentrate into a smaller volume, secondary fractionate accumulating in the Tank 4 storage tank within the SAFF® was transferred to 55-gallon steel drums contained within overpack drums and transported by a licensed waste hauler from Tablyn Park to WCL for storage. Table E.29 lists the dates of waste mobilization and the number of drums transported. The volume of fractionate in each drum varied from approximately 35 gallons to 50 gallons.

Table E.29: Secondary Fractionation PFAS Concentrate Transfers.

Influent Water Source	Date of Transport	Number of 55-Gallon Drums Transported
Shakopee	1/3/2023	3
Shakopee	1/18/2023	3
Shakopee	3/1/2023	1
Raleigh Creek, Shakopee	5/17/2023	3
Jordan	8/10/2023	3
Shakopee, Jordan, Raleigh Creek	5/1/2024	4
Shakopee	5/7/2025	4

Approximately 800 gallons of secondary fractionate were transported to the landfill staging area between January 2023 and May 2025, of which a portion was used for various destruction technologies' bench- and field-scale pilot studies. The DE-FLUORO™ mobile electrochemical oxidation system was pilot-tested onsite using both groundwater and surface water secondary fractionate generated by the SAFF® pilot-study. Seven other destruction technology companies applied for an MPCA grant to complete bench-scale testing using SAFF® generated secondary fractionate. Results from these studies are available in Appendix F and Appendix G, respectively. An additional MPCA RFP was issued in April 2025 to distribute more SAFF® concentrate to destruction vendors; the remaining secondary fractionate not used for bench- and pilot-scale studies will be transported offsite by Clean Harbors for industrial incineration.

E10.4 Repairs & Replacements

E10.4.1 Miscellaneous Leaks

- Primary Fractionation Vessels: Leaks began appearing at different points on the primary fractionation vessels in January 2024. A pinhole leak at the base of SV1-20 was repaired by APR Plastic Fabricating in January 2024 but began leaking again shortly after. Two elbow joints connecting venturi pumps to flexible hosing also began leaking on the same vessel and were repaired by removing the piping and reapplying thread tape. Leaks were also noticed at the base of two venturi pumps in January 2024 – one on SV1-10 and one on SV1-20. These leaks were mitigated by reapplying sealant to the base of the venturi where it meets the vessel.

In July 2024, EPOC moved the original SV1-10 tank into SV1-20's position and removed the original, leaky SV1-20 vessel. They installed a new vessel in SV1-10's place. A pinhole leak appeared at the base of the new SV1-10 vessel in October 2024, and in December 2024, new welding specifications were applied to both primary fractionation vessels. A pinhole leak appeared once again in January 2025. After completion of pilot test, repair of the vessel during warmer weather was completed. During this repair, the contractor performing the testing indicated the previous attempt had not been successful due to temperature differences between the weld material and the vessel, even with additional efforts to heat the vessel during the winter.

E10.4.2 Pump Replacements

- Secondary Fractionation Vessel Fill Pump: The pump used to fill the secondary fractionation vessel from Tank 3 (P3-01) stopped working. When the pump was taken apart, a nut and small pieces of plastic were found, presumably from manufacturing. This pump was replaced, and normal operations resumed.
- Sprayer Pump Controller: The controller for the sprayer pump to clean the hoods and level gauges between each cycle stopped functioning properly. The pump could be turned on manually for periodic washing. However, the pump would not run automatically after each cycle so a buildup of organic matter on the hoods resulted. The controller was replaced, and normal operations resumed.
- Venturi Pumps: The venturi pump on Primary Fractionation Vessel 1 (SV1-10) stopped working as efficiently due to sediment buildup. Poor removal efficiencies were observed along with a visual difference in foam production between the two vessels. The new pump was observed to be more efficient and did result in slightly higher removal efficiencies. Data from before the pump was replaced was not included in this report.
- Flow Meter Transmitter/Top-Up Pump: The Primary Top-Up Flow Meter (FM1-01) faulted for an unknown reason during operations, and after a hard reset, failed to trigger top-up pump P1-03 to start. The transmitter was replaced to restore P1-03's functionality. After continued issues with primary vessels top-up cycles the top-up pump (P1-03) was found to be the issue and was replaced. Since the top-up pump replacement there have been no issues with top-up.

E10.5 Site-Specific Considerations

E10.5.1 Winter Weather Operations

Portable heaters were installed in the trailer to prevent freezing. Prior to the connection to main power, these heaters were powered by diesel or gasoline generators. Heaters were still used after connecting the unit to permanent power and were placed near doorways and smaller pipes along the floor to minimize cold air pockets which could cause localized freezing.

Water inside the storage tanks, vessels, and internal piping did not freeze; however, level sensors on Tanks 2, 3, and 4 located near the doors at the end of the container were prone to freezing. Air circulation in this area is minimal because of the tanks, and temperatures near the bottom of the door where the level sensors are located can be significantly lower than in the rest of the container. The level sensor on Tank 3 was especially prone to freezing which prevented proper filling and emptying of the tank to the secondary fractionation vessel. A heater and fan were placed on top of Tank 3 to move warm air into this area and additional insulation was also added to the door. Heat trace wiring was also installed around the level sensors for Tanks 2, 3, and 4.

Placing the SAFF® container on a trailer likely exacerbated winter weather challenges to operations. Insulation blankets were wrapped around the trailer and insulation was placed in gaps between the trailer and the shipping container. Even with these efforts, a large temperature differential could be observed inside the unit, with ice sometimes forming on the floor of the shipping container while the air near the top of the container could be 60 to 70° Fahrenheit. This temperature differential may have contributed to the pinhole leaks that occurred in vessels. Future installations should consider adding additional insulation, placing the container on the ground, adding fans to increase air and heat circulation, and potentially additional heaters to reduce temperature variation within the trailer.

E10.5.2 Summer Weather Operations

Once the influent source was switched from Raleigh Creek to the Jordan Aquifer, pooled water was observed on the floor of the SAFF® and triggered the bund alarm. The hot and humid air reacting with the groundwater-cooled vessels and piping caused the moist air to condense and collect on the floor. This problem was eliminated by installing a dehumidifier and a floor fan inside the trailer. Air conditioning was not required; water inside the treatment system provided enough of a heat sink to prevent the trailer from getting excessively warm. No other issues presented during summertime operations.

E10.5.3 Sump and Submersible Pump

During Raleigh Creek operations, the area around the in-creek sump was routinely checked, especially during high flow events. Sticks, leaves, and other debris were removed to protect the pump. Additionally, silt built up at the bottom of the sump over time and was manually removed to protect the pump.

The submersible pump stopped functioning after a relatively short period of operations. After checking pump internals and general condition it was found to be an electrical issue at the SAFF® junction box. Bloomington Electric replaced the junction box and there were no further issues with the submersible pump.

E11 Conclusions

Foam fractionation, and specifically SAFF® treatment as a standalone technology, is unlikely to be a comprehensive treatment solution for effluent fated for drinking water distribution or aquifer reinjection. Effluent PFOS concentrations from the Shakopee Aquifer and PFOA concentrations from the Jordan Aquifer exceeded the remedial target of non-detect. If SAFF®-treated groundwater or surface water is discharged to surface water, it is expected to meet surface water target concentrations for all compounds except PFOS.

Foam fractionation broadly, and SAFF® specifically, is not an approved treatment for PFAS in drinking water in the State of Minnesota at the time of writing this report. However, this pilot study demonstrated bulk removal of PFOA and PFOS with effluent concentrations approaching regulatory standards, demonstrating foam fractionation could play an important role within a treatment train approach. Polishing by an adsorptive media such as GAC or ion exchange resin is expected to be required to meet Site effluent standards. Use of a polishing media could allow for reduced treatment times, if the subsequent increase in effluent concentrations and increased use of adsorptive media was nominal compared to the increased throughput per SAFF® unit. SAFF® was ineffective at removal of short-chain PFAS, particularly PFBA, which is present at high concentrations near WCL. However, the use of a surfactant was not explored in this pilot study, and surfactants have been used in other applications by foam fractionation vendors to improve short-chain PFAS removal.

These results indicate that if foam fractionation is to be incorporated in a full-scale remedial alternative, the following items should occur:

- Further demonstration of scalability;
- Piloting of novel modifications to SAFF® technology that could improve PFBA removal, throughput, and overall efficiency;
- Evaluation of other foam fractionation vendors and their technology, as additional companies offer commercially available equipment compared to when the initial RFP was issued; and
- Piloting additional PFAS separation technologies before or after SAFF® to assess their removal capability within other treatment trains.

The current treatment capacity of foam fractionation systems may not be sufficient to meet the expected treatment requirements for groundwater and surface water. For example, a SAFF®40 has an advertised maximum capacity of ~250,000 gpd, but operation at the settings used in this pilot would result in a throughput of approximately 70,000-90,000 gpd per unit. To achieve the expected treatment capacity required for surface water and groundwater, a prohibitory number of SAFF®40's would be required. With new vendors and offerings available, non-container-based units may be available that could better reach treatment capacities required for groundwater remediation. New offerings from vendors may allow for increased throughput as well. Operations and maintenance challenges posed by limited space in the container-based system could also be improved with a skid-based system.

Further pilot tests using the SAFF®20 unit used in this pilot test are also recommended. Modifications to the unit by EPOC and Allonia (the US distributor of SAFF® units) have been proposed which could potentially improve short-chain PFAS removal. The SAFF®20 unit used in testing also has a dosing pump which could be utilized to dose surfactant during testing. While surfactants were not used during this pilot test as long-chain PFAS were the targets, additional investigation with surfactants, particularly in areas with high short-chain PFAS concentrations could provide valuable information on the applicability of foam fractionation and SAFF® to short-chain PFAS removal.

Evaluation of other foam fractionation vendors and their respective technologies is also recommended. Since the RFP was initially issued in 2020, more foam fractionation vendors have brought units to market. Further evaluation of these additional vendors is recommended, as capacities and capabilities of new offerings may differ than the SAFF®20 used in this pilot test. Additional bench-scale or pilot-scale testing may be warranted to select the most appropriate technology for Site conditions, particularly in areas with high short-chain concentrations.

Finally, additional pilot- and bench-scale studies are recommended to evaluate the use of foam fractionation within other treatment trains. SAFF® may also be effective in the treatment of RO reject water to reduce the volume of this waste stream.

In summary, the results discussed above are expected to broaden understanding of SAFF® technology's full capabilities and to identify the treatment trains best suited to the Site and the project's remedial objectives.

E12 References

AECOM, 2021. Project 1007 Surface Active Foam Fractionation Bench Scale Test Results. Prepared for Minnesota Pollution Control Agency. February 16, 2021.

E13 Additional Tables

Table E.30: Shakopee Aquifer Tank 1 PFAS Results.

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
11/22/2022	N/A	Method 533	496	26.6	47.1	32.6	325	1.77	3.05	<1.77	<1.77	15.5	41.9	1030
11/28/2022	Run 2	Method 533	493	27.7	47.5	31.3	304	1.79	2.69	<1.74	<1.74	16.4	38.8	984
11/29/2022 *	Run 1	Method 533	501	27.0	46.8	27.5	262	1.39	2.41	<1.77	<1.77	15.7	31.1	807
12/5/2022	Run 1	Method 533	459	25.5	45.4	27.4	276	1.73	2.62	<1.73	<1.73	14.6	33.1	891
12/13/2022	Run 1	Method 533	515	26.6	45.8	28.1	302	1.59	2.98	<1.77	<1.77	15.2	34.7	916
1/10/2023	Run 90	Method 1633	413	23.5	45.3	32.3	398	3.18	3.55	<3.04	<2.44	13.9	32.0	1140
1/11/2023	Run 9	Method 533	511	27.3	48.3	30.8	332	1.69	3.27	<1.74	<1.74	16.0	37.1	1030
1/12/2023 *	Run 11	Method 533	518	28.0	48.7	31.5	316	1.29	2.32	<1.80	<1.80	16.6	35.7	818
1/16/2023 *	Run 13	Method 533	539	28.0	49.7	31.4	293	1.58	3.24	<1.75	<1.75	17.5	34.6	931
1/26/2023	Run 17	Method 533	485	25.9	48.4	31.0	362	1.77	3.38	<1.74	<1.74	16.6	41.6	992
2/6/2023	Run 38	Method 533	602	30.5	59.4	43.3	309	2.05	3.81	<1.80	<1.80	21.0	47.6	656
2/13/2023	Run 37B	Method 533	419	32.5	55.6	38.0	280	2.05	3.43	<1.74	<1.74	20.0	42.6	590
2/15/2023 *	Run 42	Method 533	429	34.1	71.3	41.7	280	1.98	3.21	<1.79	<1.79	22.1	42.6	580
2/20/2023 *	Run 46	Method 533	400	31.4	82.2	41.9	264	1.79	3.2	<1.80	<1.80	22.2	38.5	591
2/27/2023	Run 51	Method 1633	502	24.9	43.3	30.3	285	2.15	3.25	<0.404	<0.323	14.6	31.8	810
2/27/2023 *	Run 51	Method 533	406	32.0	52.8	37.0	296	2.25	3.48	<1.76	<1.76	19.9	41.5	634
3/7/2023	Run 56	Method 1633	553	27.8	46.3	35.5	323	2.12	3.32	<0.402	<0.322	16.5	33.5	838
3/9/2023	Run 56	Method 1633	516	27.7	51.0	41.2	310	1.83	3.3	<0.405	<0.324	19.5	35.4	842
3/10/2023	Run 56	Method 1633	521	27.8	47.8	28.3	318	1.94	3.42	<0.397	<0.317	18.1	29.2	872
3/13/2023	Run 57	Method 1633	455	23.8	39.9	28.2	295	2.09	3.18	<0.414	<0.331	13.5	31.3	854
3/13/2023	Run 57	Method 533	432	33.7	57.9	44.1	303	2.14	3.63	<1.79	<1.79	21.9	44.9	667
3/15/2023	Run 57	Method 1633	516	27.9	49.3	32.7	376	<3.03	4.95	<3.03	<2.43	17.4	34.6	1160
3/17/2023	Run 57	Method 1633	490	27.1	45.4	27.4	322	1.99	3.19	<0.415	<0.332	17.5	29.0	869
3/20/2023 *	Run 57	Method 1633	511	26.7	54.9	45.8	275	1.88	3.11	<0.408	<0.326	16.3	32.6	743
3/22/2023	Run 57	Method 1633	508	27.5	46.6	28.0	337	2.01	3.56	<0.41	<0.328	18.5	30.9	933
9/13/2023	Run 57	Method 533	406	27.8	49.1	37.0	307	2.27	3.23	<1.80	<1.80	15.4	38.3	1050

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
9/14/2023	Run 58	Method 533	385	25.7	45.3	34.9	287	1.66	3.74	<1.84	<1.84	14.9	35.2	944
9/15/2023	Run 59	Method 533	386	25.6	44.9	31.5	296	1.95	4.17	<1.77	<1.77	15.1	35.9	969
9/18/2023 *	Run 60	Method 533	375	25.6	48.3	46.0	267	2.13	3.38	<1.75	<1.75	16.2	37.7	828
9/18/2023	Run 60	Method 533	372	24.8	44.3	33.1	281	2.12	3.62	<1.73	<1.73	15.4	34.1	939
9/21/2023	Run 61	Method 533	479	28.6	51.2	35.9	341	2.08	3.50	<1.74	<1.74	17.0	41.1	1100
9/26/2023 *	Run 62	Method 533	462	28.9	58.7	68.0	303	1.63	3.15	<1.74	<1.74	17.7	54.7	920
9/26/2023	Run 62	Method 533	456	27.1	51.3	44.0	324	1.81	3.86	<1.77	<1.77	16.3	43.7	1080
10/9/2023	Run 66	Method 533	398	26.5	43.9	30.7	309	2.54	4.85	<1.75	<1.75	14.9	35.2	1390
10/16/2023	Run 68	Method 533	483	28.8	55.6	47.8	392	2.49	4.92	<1.77	<1.77	17.4	49.9	1340
10/27/2023	Run 86	Method 1633	446	27.2	45.5	29.7	341	2.43	3.64	<1.12	<0.896	15.3	31.4	1040
10/27/2023	Run 85	Method 1633	458	27.7	47.4	28.5	348	2.62	3.73	<1.15	<0.923	15.9	31.3	1020
10/27/2023	Run 84	Method 1633	461	27.5	46.8	29.8	337	1.89	4.06	<1.18	<0.944	16.2	31.2	1010
10/27/2023	Run 83	Method 1633	441	26.7	46.4	28.5	347	2.36	4.12	<1.13	<0.901	15.7	31.8	985
10/27/2023	Run 82	Method 1633	454	26.9	45.9	30.6	336	2.02	3.63	<1.14	<0.911	16.0	30.8	1010
10/27/2023	Run 81	Method 1633	454	26.7	44.8	28.8	338	2.16	3.99	<1.14	<0.908	15.0	30.1	967
10/27/2023	Run 80	Method 1633	451	27.2	46.0	28.5	335	2.30	3.32	<1.13	<0.906	15.4	31.6	984
10/27/2023	Run 79	Method 1633	462	27.2	48.9	31.6	338	2.48	4.11	<1.14	<0.913	16.0	33.0	1020
10/30/2023	Run 87	Method 533	497	29.2	57.9	59.8	355	2.10	4.20	<1.81	<1.81	17.6	48.4	1210
11/1/2023	Run 88	Method 533	468	27.3	52.6	55.2	346	1.97	3.75	<1.79	<1.79	17.5	48.5	1120
11/3/2023	Run 89	Method 533	491	29.1	58.2	66.8	366	2.23	3.89	<1.85	<1.85	18.0	52.4	1160
11/7/2023	Run 90	Method 533	475	28.1	52.6	53.8	360	2.17	4.08	<1.77	<1.77	17.5	47.0	1170
12/15/2023	Run 87	Method 1633	248	15.5	32.6	35.5	290	1.81	3.8	<0.802	<0.641	9.51	28.2	971
12/15/2023	Run 87	Method 1633	470	27.4	47.1	29.1	336	2.47	4.19	<0.374	<0.299	15.2	32.1	949
12/15/2023	Run 87	Method 1633	492	29.3	80.8	43.2	409	2.87	2.97	<0.450	<0.360	19.3	36.7	943
12/20/2023	Run 87	Method 1633	483	27.8	49.0	36.0	348	2.43	3.96	<0.384	<0.307	16.4	33.6	987
12/20/2023	Run 87	Method 1633	484	28.5	86.2	241	1380	3.76	7.20	<3.10	<2.48	18.7	208	1510
1/10/2024	Run 90	Method 1633	492	28.2	51.6	47.1	655	4.24	6.43	<3.06	<2.45	16.6	50.6	1730
1/29/2024	Run 90	Method 533	550	31.6	59.3	48.3	494	3.29	6.58	<1.76	<1.76	18.2	52.3	1730

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
3/5/2024	Run 90	Method 1633	483	26.3	46.3	28.9	332	2.33	3.23	<0.378	<0.303	14.2	30.8	912
3/5/2024	Run 90	Method 533	547	29.9	50.2	35.5	361	2.40	4.45	<1.77	<1.77	18.5	41.6	1100
3/7/2024	Run 90	Method 1633	489	27.1	51.6	51.2	412	2.99	3.72	<0.422	<0.338	15.5	38.8	1120
3/7/2024	Run 90	Method 1633	484	27.1	54.6	58.2	482	3.06	4.33	<0.389	<0.311	14.9	43.1	1310
3/13/2024	Run 90	Method 1633	502	26.7	53.8	39.4	314	2.22	3.29	<0.373	<0.299	15.3	30.9	801
3/13/2024	Run 90	Method 1633	555	29.4	54.1	35.7	373	2.44	4.31	<0.37	<0.296	16.1	35.0	1060
3/14/2024	Run 91	Method 533	556	31.0	53.3	44.0	393	2.73	5.16	<1.74	<1.74	18.9	45.3	1130
3/15/2024	Run 92	Method 533	521	29.4	52.9	42.6	374	2.05	4.73	<1.74	<1.74	16.9	43.9	1090
3/21/2024	Run 93	Method 533	516	29.5	53.2	55.0	379	3.39	5.35	<1.92	<1.92	17.8	49.3	1220
10/23/2024	Run 71	Method 1633	428	25.3	45.5	37.2	313	2.16	3.55	<1.14	<0.911	15.4	33.2	914
10/24/2023	Run 73	Method 1633	452	26.8	45.1	30.3	324	1.70	3.94	<1.19	<0.956	15.2	30.1	935
10/24/2023	Run 72	Method 1633	449	27.6	45.8	32.1	316	2.02	4.48	<1.12	<0.900	15.4	30.5	925
10/25/2023	Run 75	Method 1633	456	26.4	45.1	29.6	323	2.00	4.02	<1.11	<0.891	16.0	30.4	964
10/25/2023	Run 74	Method 1633	492	29.2	50.2	31.9	359	1.76	4.66	<1.18	<0.944	16.8	35.1	1100
10/26/2023	Run 78	Method 1633	447	26.9	46.7	34.3	334	2.01	3.35	<1.10	<0.878	16.2	34.0	964
10/26/2023	Run 77	Method 1633	449	26.6	46.2	37.2	330	2.03	3.89	<1.06	<0.851	15.7	35.6	1010
10/26/2023	Run 76	Method 1633	447	27.1	53.8	66.1	352	2.07	4.08	<1.16	<0.927	16.8	46.6	998

* Indicates sample was collected after discharge from secondary fractionation occurred.

Table E.31: Shakopee Aquifer Effluent PFAS Results.

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
11/23/2022	Run 0	Stepwise - Venturi	SV1-10	Method 533	493	38.0	52.4	29.6	71.0	9.00	7.32	5.28	4.77	13.1	9.94	57.2
11/28/2022	Run 3	Stepwise - Venturi	SV1-10	Method 533	496	26.7	48.2	29.9	224	1.07	1.58	<1.73	<1.73	16.3	29.7	454
11/28/2022	Run 4	Stepwise - Venturi	SV1-10	Method 533	496	26.9	48.0	29.2	222	0.947	1.43	<1.80	<1.80	16.1	28.8	464
11/28/2022	Run 2	Stepwise - Venturi	SV1-10	Method 533	492	27.1	46.1	30.1	223	1.56	1.93	<1.81	<1.81	15.1	29.4	479
11/29/2022	Run 3	Stepwise - Venturi	SV1-10	Method 533	551	30.1	50.5	32.9	212	0.845	1.11	<1.78	<1.78	18.00	30.3	333
11/29/2022	Run 1	Stepwise - Venturi	SV1-10	Method 533	488	26.8	44.5	25.4	177	0.755	1.08	<1.75	<1.75	15.7	25.4	355
11/29/2022	Run 2	Stepwise - Venturi	SV1-10	Method 533	491	27.0	46.7	29.1	207	0.899	1.10	<1.81	<1.81	16.4	28.0	394
11/29/2022	Run 1	Stepwise - Venturi	SV1-10	Method 533	501	26.8	46.3	30.4	252	1.26	1.81	<1.75	<1.75	16.1	33.0	558
12/5/2022	Run 1	Stepwise - Venturi	SV1-10	Method 533	450	25.4	45.3	27.7	235	1.09	1.61	<1.77	<1.77	13.9	28.9	579
12/13/2022	Run 3	Stepwise - Venturi	SV1-10	Method 533	510	26.5	44.8	28.0	208	0.723	0.857	<1.76	<1.76	16.3	28.5	339
12/13/2022	Run 2	Stepwise - Venturi	SV1-10	Method 533	507	26.1	46.2	29.6	263	1.03	1.68	<1.79	<1.79	14.8	32.8	581
12/13/2022	Run 1	Stepwise - Venturi	SV1-10	Method 533	514	26.1	46.2	29.8	279	1.22	2.03	<1.77	<1.77	15.9	33.5	688
12/28/2022	Run 5	Stepwise - Time	SV1-10	Method 533	496	27.8	48.1	30.5	245	0.866	1.37	<1.73	<1.73	16.1	31.4	492
12/28/2022	Run 4	Stepwise - Time	SV1-10	Method 533	508	27.6	48.3	31.9	277	1.17	1.72	<1.74	<1.74	15.9	34.4	626
12/29/2022	Run 8	Stepwise - Time	SV1-10	Method 533	464	25.1	44.9	27.0	212	0.717	0.823	<1.74	<1.74	14.8	28.8	337
12/29/2022	Run 7	Stepwise - Time	SV1-10	Method 533	470	26.1	44.9	28.1	217	0.799	1.01	<1.74	<1.74	14.5	29.6	394
12/29/2022	Run 6	Stepwise - Time	SV1-10	Method 533	484	26.5	46.2	29.6	229	0.843	1.18	<1.74	<1.74	15.4	30.3	448
1/11/2023	Run 9	Stepwise - Top-Up	SV1-10	Method 533	499	27.9	47.2	28.2	211	0.751	0.926	<1.73	<1.73	16.1	28.9	346
1/11/2023	Run 10	Stepwise - Top-Up	SV1-10	Method 533	495	27.0	45.3	28.9	220	0.792	0.928	<1.76	<1.76	15.7	29.4	374
1/12/2023	Run 11	Stepwise - Top-Up	SV1-10	Method 533	537	28.0	48.8	30.6	213	<1.74	0.905	<1.74	<1.74	17.1	30.8	323
1/12/2023	Run 11	Stepwise - Top-Up	SV1-10	Method 533	530	28.4	50.7	31.3	226	0.712	1.01	<1.73	<1.73	17.2	30.8	373
1/13/2023	Run 12	Stepwise - Top-Up	SV1-10	Method 533	506	27.1	46.2	29.4	223	0.702	0.923	<1.80	<1.80	15.5	31.0	359
1/16/2023	Run 13	Stepwise - Top-Up	SV1-10	Method 533	574	29.1	49.6	31	205	0.668	0.932	<1.74	<1.74	18.3	30.8	339
1/16/2023	Run 13	Stepwise - Top-Up	SV1-10	Method 533	540	26.4	47.8	28.7	223	0.669	0.977	<1.76	<1.76	16.8	32.0	353
1/17/2023	Run 14	Stepwise - Top-Up	SV1-10	Method 533	609	30.2	52.6	32.1	258	0.786	1.14	<1.75	<1.75	18.6	35.5	428
1/18/2023	Run 15	Stepwise - Top-Up	SV1-10	Method 533	529	27.0	44.7	27.6	233	0.809	1.04	<1.75	<1.75	16.7	32.8	386
1/20/2023	Run 16	Aerosolization	SV1-10	Method 533	531	25.9	46.8	31.0	204	<1.74	1.00	<1.74	<1.74	16.5	32.0	351

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
1/26/2023	Run 17	Aerosolization	SV1-10	Method 533	485	25.3	46.0	28.3	108	<1.71	<1.71	<1.71	<1.71	16.8	23.4	41.8
1/30/2023	Run 20	Aerosolization	SV1-10	Method 533	526	29.4	46.7	28.4	110	<1.78	<1.78	<1.78	<1.78	15.9	23.3	54.3
1/30/2023	Run 18	Aerosolization	SV1-10	Method 533	532	28.6	49.0	30.8	159	<1.85	<1.85	<1.85	<1.85	16.2	29.5	86.3
1/30/2023	Run 19	Aerosolization	SV1-10	Method 533	535	28.7	46.6	27.0	134	<1.89	<1.89	<1.89	<1.89	17.7	24.4	103
1/31/2023	Run 22	Aerosolization	SV1-10	Method 533	537	28.5	47.5	30.6	211	<1.71	<1.71	<1.71	<1.71	16.4	31.9	209
1/31/2023	Run 21	Aerosolization	SV1-10	Method 533	508	26.2	46.3	29.3	220	<1.71	<1.71	<1.71	<1.71	15.4	31.4	268
1/31/2023	Run 23	Aerosolization	SV1-10	Method 533	495	25.5	45.6	27.7	207	<1.69	<1.69	<1.69	<1.69	14.8	30.3	289
2/1/2023	Run 28	Dosing	SV1-10	Method 533	485	25.0	42.9	27.7	122	<1.73	<1.73	<1.73	<1.73	14.7	23.8	97.0
2/1/2023	Run 27	Dosing	SV1-10	Method 533	496	25.5	46.1	31.2	202	0.898	1.46	<1.76	<1.76	15.9	30.8	398
2/1/2023	Run 24	Aerosolization	SV1-10	Method 533	496	26.2	45.9	29.4	279	1.42	1.85	<1.79	<1.79	15.5	33.6	669
2/1/2023	Run 26	Dosing	SV1-10	Method 533	490	26.2	42.4	31.0	406	2.25	3.82	<1.77	<1.77	16.3	43.1	1320
2/1/2023	Run 25	Dosing	SV1-10	Method 533	519	27.2	46.0	32.2	413	2.22	3.70	<1.81	<1.81	15.7	44.4	1320
2/2/2023	Run 29	Dosing	SV1-10	Method 533	482	25.7	43.7	28.6	100	<1.81	<1.81	<1.81	<1.81	14.4	21.2	44.4
2/2/2023	Run 33	Continuous Top-Up	SV1-10	Method 533	603	30.9	60.1	41.5	191	0.690	1.13	<1.75	<1.75	20.5	38.3	263
2/2/2023	Run 32	Continuous Top-Up	SV1-10	Method 533	603	30.7	60.7	46.2	264	1.57	2.19	<1.79	<1.79	21.5	48.3	449
2/2/2023	Run 31	Continuous Top-Up	SV1-10	Method 533	622	32.1	60.5	42.9	323	2.71	3.89	<1.71	<1.71	21.6	50.9	636
2/2/2023	Run 30	Dosing	SV1-10	Method 533	520	27.3	46.4	36.4	373	1.82	2.29	<1.82	<1.82	15.9	43.0	926
2/3/2023	Run 35	Oscillation	SV1-10	Method 533	601	30.9	57.9	30.8	85.2	<1.74	<1.74	<1.74	<1.74	21.0	21.2	54.6
2/3/2023	Run 34	Oscillation	SV1-10	Method 533	610	31.4	57.8	29.8	72.2	<1.80	<1.80	<1.80	<1.80	21.2	18.6	58.4
2/3/2023	Run 36	Dosing	SV1-10	Method 533	582	29.7	58.6	42.5	129	<1.83	<1.83	<1.83	<1.83	20.9	33.8	65.8
2/4/2023	Run 37	Oscillation	SV1-10	Method 533	600	30.7	59.2	35.9	101	<1.72	<1.72	<1.72	<1.72	20.0	25.6	51.0
2/4/2023	Run 38	Dosing	SV1-10	Method 533	597	30.7	57.7	41.1	234	0.710	<1.75	<1.75	<1.75	21.7	44.9	234
2/13/2023	Run 39	Oscillation	SV1-10	Method 533	417	32.9	52.7	21.7	26.1	<1.75	<1.75	<1.75	<1.75	18.9	9.05	6.95
2/13/2023	Run 37B	Oscillation	SV1-10	Method 533	419	32.1	53.6	29.8	83.6	<1.77	<1.77	<1.77	<1.77	17.8	18.6	35.4
2/14/2023	Run 40	Oscillation	NR	Method 533	429	33.1	53.3	24.1	36.7	<1.72	<1.72	<1.72	<1.72	19.4	11.8	8.99
2/15/2023	Run 41	Oscillation	NR	Method 533	419	32.0	51.7	22.5	36.1	<1.79	<1.79	<1.79	<1.79	19.3	11.2	9.80
2/15/2023	Run 42	Oscillation	NR	Method 533	408	31.6	52.0	22.7	34.7	<1.76	<1.76	<1.76	<1.76	18.8	9.67	15.2
2/15/2023	Run 42	Oscillation	NR	Method 533	419	32.8	70.3	21.1	25.9	<1.78	<1.78	<1.78	<1.78	21.4	8.90	25.8

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
2/16/2023	Run 43	Oscillation	NR	Method 533	411	31.9	53.8	25.1	57.3	<1.75	<1.75	<1.75	<1.75	19.7	14.5	27.2
2/17/2023	Run 44	Oscillation	NR	Method 533	413	31.9	53.0	20.5	18.8	<1.79	<1.79	<1.79	<1.79	19.1	7.19	15.0
2/20/2023	Run 46	Continuous Top-Up	NR	Method 533	471	32.4	96.7	15.5	4.57	<3.68	<3.68	<3.68	<3.68	24.0	1.86	10.9
2/20/2023	Run 46	Continuous Top-Up	NR	Method 533	425	33.8	61.1	12.7	4.57	<1.81	<1.81	<1.81	<1.81	20.8	2.24	11.5
2/20/2023	Run 45	Stepwise - Venturi	NR	Method 533	430	33.5	56.2	27.9	35.7	<1.78	<1.78	<1.78	<1.78	20.6	11.5	13.1
2/21/2023	Run 49	Continuous Top-Up	NR	Method 533	413	32.5	50.6	14.6	7.14	<1.79	<1.79	<1.79	<1.79	18.7	3.77	4.72
2/21/2023	Run 48	Continuous Top-Up	NR	Method 533	413	32.3	50.5	11.2	21.6	<1.81	<1.81	<1.81	<1.81	17.9	5.22	14.7
2/21/2023	Run 47	Oscillation	NR	Method 533	414	32.1	53.2	27.0	79.6	<1.75	<1.75	<1.75	<1.75	18.8	17.7	58.3
2/24/2023	Run 50	Oscillation	NR	Method 533	403	30.3	49.5	22.2	29.0	<1.78	<1.78	<1.78	<1.78	17.8	9.06	9.14
2/27/2023	Run 51	Oscillation	NR	Method 1633	524	26.0	41.1	16.9	22.6	<0.399	<0.399	<0.399	<0.319	14.8	7.17	4.34
2/27/2023	Run 51	Oscillation	NR	Method 533	405	31.0	48.7	22.6	30.3	<1.76	<1.76	<1.76	<1.76	17.7	9.44	90.2
2/28/2023	Run 52	Oscillation	NR	Method 1633	443	23.0	36.4	17.7	30.4	<0.405	<0.405	<0.405	<0.324	13.7	8.28	7.22
2/28/2023	Run 52	Oscillation	NR	Method 533	397	31.1	48.9	23.1	36.2	<1.76	<1.76	<1.76	<1.76	18.3	10.3	25.3
3/1/2023	Run 53	Oscillation	NR	Method 533	405	31.2	49.6	23.0	32.7	<1.83	<1.83	<1.83	<1.83	18.5	9.28	33.9
3/2/2023	Run 54	Stepwise - Venturi	NR	Method 533	414	31.7	51.4	29.7	108	<1.81	<1.81	<1.81	<1.81	18.2	20.2	108
3/3/2023	Run 55	Stepwise - Venturi	NR	Method 1633	556	26.8	45.8	19.8	48.0	<0.404	<0.404	<0.404	<0.323	15.8	11.3	19.1
3/3/2023	Run 55	Stepwise - Venturi	NR	Method 533	399	30.6	50.7	25.2	58.8	<1.81	<1.81	<1.81	<1.81	18.3	13.7	30.4
3/6/2023	Run 56	Continuous Top-Up	NR	Method 1633	520	27.5	48.3	20.6	6.66	<0.399	<0.399	<0.399	<0.319	18.4	3.86	1.87
3/7/2023	Run 56	Continuous Top-Up	NR	Method 1633	512	26.0	45.2	20.2	5.55	<0.415	<0.415	<0.415	<0.332	15.3	3.61	2.73
3/7/2023	Run 56	Continuous Top-Up	NR	Method 533	418	34.6	61.3	29.9	32.1	<1.74	<1.74	<1.74	<1.74	21.6	5.14	17.8
3/9/2023	Run 56	Continuous Top-Up	NR	Method 1633	505	26.9	48.6	24.0	7.25	<0.408	<0.408	<0.408	<0.326	18.1	4.52	2.11
3/10/2023	Run 56	Continuous Top-Up	NR	Method 1633	527	28.2	46.9	14.3	6.54	<0.420	<0.420	<0.420	<0.336	18.6	3.14	1.54
3/13/2023	Run 57	Oscillation	NR	Method 1633	474	25.5	45.5	17.9	24	<0.401	<0.401	<0.401	<0.321	16.9	6.81	4.56
3/13/2023	Run 57	Oscillation	NR	Method 533	424	32.8	53.8	26.9	30.2	<1.74	<1.74	<1.74	<1.74	20.0	10.6	10.2
3/15/2023	Run 57	Oscillation	NR	Method 1633	510	27.2	46.6	18.3	25.3	<2.89	<2.89	<2.89	<2.31	18.3	7.29	5.60
3/15/2023	Run 57	Oscillation	NR	Method 533	434	33.7	52.5	23.9	36.3	<1.72	1.03	<1.72	<1.72	21.8	10.5	123
3/17/2023	Run 57	Oscillation	NR	Method 1633	511	27.3	44.9	16.6	24.5	<0.436	<0.436	<0.436	<0.349	18.0	6.58	4.74
3/17/2023	Run 57	Oscillation	NR	Method 1633	435	33.7	52.5	22.9	27.9	<1.81	<1.81	<1.81	<1.81	21.1	8.97	5.46

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
3/20/2023	Run 57	Oscillation	NR	Method 1633	535	28.0	52.6	28.6	15.5	<0.409	<0.409	<0.409	<0.327	16.9	6.66	4.2
3/22/2023	Run 57	Oscillation	NR	Method 1633	508	26.4	44.6	16.6	20.5	<0.408	<0.408	<0.408	<0.326	17.4	6.09	3.51
9/13/2023	Run 57	Oscillation	NR	Method 533	379	25.8	41.2	14.2	19.8	<1.83	<1.83	<1.83	<1.83	14.6	4.56	29.0
9/14/2023	Run 58	Oscillation	NR	Method 533	381	27.1	43.7	25.5	94.7	<1.81	<1.81	<1.81	<1.81	14.7	17.2	117
9/15/2023	Run 59	Oscillation	NR	Method 533	388	27.1	40.4	9.89	3.44	<1.82	<1.82	<1.82	<1.82	15.0	2.04	2.22
9/18/2023	Run 60	Oscillation	SV1-20	Method 533	361	24.4	36.1	9.49	<1.77	<1.77	<1.77	<1.77	<1.77	13.5	1.62	2.67
9/18/2023	Run 60	Oscillation	SV1-20	Method 533	371	24.9	44.2	15.2	3.75	<1.70	<1.70	<1.70	<1.70	15.7	1.86	4.50
9/21/2023	Run 61	Oscillation	SV1-10	Method 533	461	27.5	48.8	28.5	112	<1.71	<1.71	<1.71	<1.71	16.5	20.6	135
9/26/2023	Run 62	Oscillation	SV1-20	Method 533	473	28.7	50.7	22.3	5.61	<1.75	<1.75	<1.75	<1.75	16.7	3.56	3.03
9/26/2023	Run 62	Oscillation	SV1-20	Method 533	443	26.0	43.7	14.8	16.6	<1.74	<1.74	<1.74	<1.74	14.5	5.03	11.9
9/27/2023	Run 63	Oscillation	SV1-10	Method 533	468	28.4	50.0	26.2	26.1	<1.79	<1.79	<1.79	<1.79	17.0	10.1	12.2
9/28/2023	Run 64	Oscillation	SV1-20	Method 533	474	27.2	46.6	19.2	22.9	<1.77	<1.77	<1.77	<1.77	15.4	7.56	25.8
9/29/2023	Run 65	Oscillation	SV1-10	Method 533	463	27.3	47.0	24.1	38.3	<1.72	<1.72	<1.72	<1.72	15.3	10.7	16.6
10/9/2023	Run 66	Oscillation	SV1-10	Method 533	515	32.0	54.4	29.6	93.3	<1.75	<1.75	<1.75	<1.75	19.4	17.0	98.6
10/12/2023	Run 67	Oscillation	SV1-20	Method 533	490	29.5	49.3	22.8	19.3	<1.76	<1.76	<1.76	<1.76	17.4	8.16	6.27
10/12/2023	Run 67	Oscillation	SV1-10	Method 533	510	31.4	61.6	44.2	61.8	<1.75	<1.75	<1.75	<1.75	18.3	19.4	27.7
10/16/2023	Run 68	Oscillation	SV1-20	Method 533	470	27.8	48.2	16.1	11.9	<1.73	<1.73	<1.73	<1.73	15.7	5.32	7.02
10/17/2023	Run 69	Oscillation	SV1-20	Method 533	472	28.5	47.2	14.8	6.22	<1.75	<1.75	<1.75	<1.75	16.1	3.36	4.35
10/18/2023	Run 70	Oscillation	SV1-20	Method 533	473	28.9	43.1	12.7	3.57	<1.76	<1.76	<1.76	<1.76	15.6	2.87	1.42
10/26/2023	Run 76	Aerosolization	SV1-20	Method 1633	452	27.8	56.9	81.7	369	2.30	4.39	<1.11	<0.888	17.6	63.5	1060
10/27/2023	Run 79	Aerosolization	SV1-20	Method 1633	486	27.9	41.7	33.0	347	2.58	4.10	<1.11	<0.887	15.4	35.9	1020
10/30/2023	Run 87	Oscillation	SV1-20	Method 533	485	28.7	50.6	21.9	19.2	<1.82	<1.82	<1.82	<1.82	16.6	6.17	20.0
11/1/2023	Run 88	Oscillation	SV1-20	Method 533	482	28.1	47.8	23.0	19.6	<1.81	<1.81	<1.81	<1.81	17.0	6.40	23.9
11/3/2023	Run 89	Oscillation	SV1-10	Method 533	470	27.8	51.1	37.7	37.7	<1.86	<1.86	<1.86	<1.86	17.3	14.1	17.5
11/7/2023	Run 90	Oscillation	SV1-20	Method 533	464	27.0	44.2	17.2	17.5	<1.80	<1.80	<1.80	<1.80	15.8	5.73	10.0
12/15/2023	Run 87	Oscillation	SV1-20	Method 1633	351	20.7	41.1	24.4	5.53	<0.451	<0.451	<0.451	<0.361	11.9	3.16	4.15
12/15/2023	Run 87	Oscillation	SV1-20	Method 1633	457	26.2	42.4	12.8	16.0	<0.427	<0.427	<0.427	<0.341	14.3	3.73	12.6
12/15/2023	Run 87	Oscillation	SV1-10	Method 1633	468	26.7	45.3	19.6	39.3	<0.389	<0.389	<0.389	<0.311	16.0	8.45	13.0

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
12/15/2023	Run 87	Oscillation	SV1-20	Method 1633	478	28.8	69.2	13.7	4.26	<0.392	<0.392	<0.392	<0.314	16.8	1.67	27.7
12/20/2023	Run 87	Oscillation	SV1-20	Method 1633	489	27.4	44.8	11.4	4.10	<0.381	<0.381	<0.381	<0.305	14.1	2.05	1.07
12/20/2023	Run 87	Oscillation	SV1-10	Method 1633	468	27.1	45.0	20.2	41.2	<0.384	<0.384	<0.384	<0.307	15.0	9.52	13.1
12/20/2023	Run 87	Oscillation	SV1-20	Method 1633	473	28.1	78.4	44.2	6.29	<0.388	<0.388	<0.388	<0.31	17.5	2.56	51.5
1/10/2024	Run 90	Oscillation	SV1-10	Method 1633	491	28.4	48.3	20.2	51.7	<0.372	<0.372	<0.372	<0.298	15.7	10.2	20.2
1/10/2024	Run 90	Oscillation	SV1-10	Method 1633	497	29.5	51.0	33.8	127	<0.371	<0.371	<0.371	<0.297	16.5	18.0	54.7
1/29/2024	Run 90	Oscillation	SV1-20	Method 533	523	29.7	48.6	17.2	21.7	<1.81	<1.81	<1.81	<1.81	17.2	6.84	10.3
1/29/2024	Run 90	Oscillation	SV1-10	Method 533	513	29.5	48.4	24.2	53.4	<1.80	<1.80	<1.80	<1.80	16.4	12.9	28.5
3/5/2024	Run 90	Oscillation	SV1-10	Method 533	510	29.9	48.1	23.6	48.1	<1.84	<1.84	<1.84	<1.84	17.9	13.2	22.2
3/5/2024	Run 90	Oscillation	SV1-10	Method 1633	504	26.6	45.2	19.8	53.4	<0.383	<0.383	<0.383	<0.306	14.6	10.8	24.0
3/7/2024	Run 90	Oscillation	SV1-10	Method 1633	488	26.6	54.1	41.4	66.5	<0.393	<0.393	<0.393	<0.315	15.2	13.8	26.6
3/7/2024	Run 90	Oscillation	SV1-10	Method 1633	493	27.0	50.4	43.9	68.9	<0.393	<0.393	<0.393	<0.314	15.2	15.9	26.7
3/13/2024	Run 90	Oscillation	SV1-10	Method 1633	491	26.8	50.9	28.7	35.0	<0.378	<0.378	<0.378	<0.303	14.6	9.71	14.5
3/13/2024	Run 90	Oscillation	SV1-10	Method 1633	545	29.3	48.7	20.9	47.5	<0.382	<0.382	<0.382	<0.305	15.7	10.6	18.8
3/14/2024	Run 91	Oscillation	SV1-10	Method 533	509	29.4	48.9	26.0	42.9	<1.76	<1.76	<1.76	<1.76	18.0	12.2	16.6
3/15/2024	Run 92	Oscillation	SV1-10	Method 533	529	30.5	50.2	22.6	37.8	<1.78	<1.78	<1.78	<1.78	17.2	11.5	13.6
3/21/2024	Run 93	Oscillation	SV1-10	Method 533	507	29.6	49.0	23.1	27.6	<1.87	<1.87	<1.87	<1.87	17.5	10.6	11.7
10/23/2023	Run 71	Aerosolization	SV1-20	Method 1633	447	26.4	48.0	31.8	76.6	<0.373	<0.373	<0.373	<0.298	15.5	18.0	25.3
10/24/2023	Run 73	Aerosolization	SV1-20	Method 1633	446	26.7	44.8	26.3	105	<0.376	<0.376	<0.376	<0.301	15.5	18.4	41.0
10/24/2023	Run 72	Aerosolization	SV1-20	Method 1633	213	13.7	30.4	24.5	119	<0.381	<0.381	<0.381	<0.305	8.71	19.9	52.5
10/25/2023	Run 74	Aerosolization	SV1-20	Method 1633	451	26.6	46.4	26.6	230	0.723	0.623	<0.370	<0.296	15.8	25.6	249
10/25/2023	Run 75	Aerosolization	SV1-20	Method 1633	441	26.1	45.1	27.7	293	1.61	2.10	<1.14	<0.912	14.8	29.9	747
10/26/2023	Run 78	Aerosolization	SV1-20	Method 1633	362	22.7	41.8	34.4	321	1.67	2.71	<1.02	<0.815	14.1	33.3	836
10/26/2023	Run 77	Aerosolization	SV1-20	Method 1633	445	26.9	49.7	49.6	331	1.80	3.27	<1.08	<0.865	15.6	41.1	984
10/27/2023	Run 83	Aerosolization	SV1-20	Method 1633	451	26.1	46.2	26.7	162	0.384	<0.377	<0.377	<0.301	15.6	22.0	104
10/27/2023	Run 82	Aerosolization	SV1-20	Method 1633	392	24.2	41.6	25.5	177	0.464	<0.372	<0.372	<0.298	14.6	22.7	169
10/27/2023	Run 85	Aerosolization	SV1-20	Method 1633	458	27.1	47.5	27.6	191	0.637	0.705	<0.392	<0.313	15.8	23.6	243
10/27/2023	Run 84	Aerosolization	SV1-20	Method 1633	400	24.8	44.8	27.5	251	0.904	0.813	<0.373	<0.299	14.8	27.5	382

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
10/27/2023	Run 86	Aerosolization	SV1-20	Method 1633	458	27.1	47.1	30.0	307	1.87	3.18	<1.14	<0.914	15.7	30.1	772
10/27/2023	Run 80	Aerosolization	SV1-20	Method 1633	455	26.5	45.9	30.5	329	1.99	3.37	<1.11	<0.891	15.2	30.2	919
10/27/2023	Run 81	Aerosolization	SV1-20	Method 1633	455	26.7	46.3	29.8	335	2.19	3.68	<1.14	<0.908	16.3	32.1	996

Legend: NR = not recorded.

Table E.32: Shakopee Aquifer Tank 3 PFAS Results.

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
11/29/2022	Run 1	Method 533	426	27.3	49.0	61.7	1,720	13.5	22.6	<12.8	<11.8	16.1	143	7,830
12/5/2022	Run 1	Method 533	339	<13.6	42.1	48.9	1,500	13.6	23.1	<12.8	<11.8	<12.8	124	7,460
1/11/2023	Run 9	Method 533	326	20.7	34.1	36.1	1,170	13.7	40.2	<3.99	<3.69	10.6	86.6	9,220
3/6/2023	Run 56	Method 1633	447	<27.5	71.2	194	2,430	<13.8	22.7	<13.8	<11.0	20.9	261	6,550
3/7/2023	Run 56	Method 1633	474	32.4	81.1	218	2,750	17.8	30.4	<14.8	<11.9	19.9	306	6,970
3/13/2023	Run 57	Method 1633	<784	<392	<196	579	11,500	<196	236	<196	<157	<196	1,010	39,500
3/15/2023	Run 57	Method 1633	<792	<396	209	562	10,700	<198	<198	<198	<158	<198	886	30,700
3/17/2023	Run 57	Method 1633	<792	<396	<198	477	10,300	<198	<198	<198	<158	<198	878	31,700
3/22/2023	Run 60	Method 1633	<800	<400	<200	603	10,600	<200	<200	<200	<160	<200	915	32,700
9/18/2023	Run 60	Method 1633	236	<9.80	<9.80	<9.80	991	<9.80	36.6	<9.80	<9.80	<9.80	24.5	4,840
9/26/2023	Run 62	Method 1633	394	16.2	44.6	127	2,740	24.8	147	<9.62	<9.62	9.03	233	24,400
12/15/2023	Run 87	Method 1633	477	32.2	111	414	5,820	45.9	70.6	<2.92	<2.33	23.8	551	19,600
1/10/2024	Run 90	Method 1633	498	<79.2	107	415	12,000	94.4	221	<39.6	<31.7	<39.6	832	43,700
3/5/2024	Run 90	Method 1633	492	<80.1	103	371	9,950	90.8	110	<40.0	<32.0	<40.0	673	32,100
3/7/2024	Run 90	Method 1633	542	<80.2	103	352	9,020	76.1	98.8	<40.1	<32.1	<40.1	675	26,700
3/13/2024	Run 90	Method 1633	516	<80.3	106	314	8,110	58.9	92.8	<40.1	<32.1	<40.1	603	23,900

Table E.33: Shakopee Aquifer Tank 4 PFAS Results.

Sample Date	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
11/29/2022	Method 533	418	49.8	165	900	26,100	196	319	<33.3	<33.3	30.2	2,400	119,000
12/13/2022	Method 533	346	25.9	121	622	19,800	139	234	<33.3	<33.3	23.4	1,700	89,000
1/12/2023	Method 533	487	46.9	186	740	26,700	215	394	<33.3	<33.3	43.6	2,110	147,000
1/18/2023	Method 533	503	40.5	402	3,180	207,000	1,550	4,900	59.4	<33.3	57.9	11,700	1,150,000
2/15/2023	Method 533	512	43.2	473	7,250	124,000	5,660	8,600	80.3	<33.3	60.2	24,800	220,000
2/20/2023	Method 533	626	52.8	586	9,890	145,000	6,680	10,200	97.5	<35.7	73.2	30,200	210,000
3/1/2023	Method 533	589	59.0	1,260	32,300	242,000	14,100	15,700	301	<33.3	100.0	63,800	1,980,000
3/3/2023	Method 1633	<80,000	<40,000	<20,000	93,200	3,570,000	24,800	108,000	<20,000	<16,000	<20,000	265,000	15,500,000
3/15/2023	Method 1633	<40,000	<20,000	<10,000	43,600	1,360,000	<10,000	11,800	<10,000	<8,000	<10,000	108,000	3,670,000
3/17/2023	Method 1633	<40,000	<20,000	<10,000	48,000	1,700,000	<10,000	17,900	<10,000	<8,000	<10,000	130,000	4,350,000
3/20/2023	Method 1633	<40,000	<20,000	<10,000	67,800	2,350,000	14,800	43,500	<10,000	<8,000	<10,000	190,000	9,220,000
3/22/2023	Method 1633	<80,000	<40,000	<20,000	191,000	6,360,000	37,100	60,600	<20,000	<16,000	<20,000	452,000	19,100,000
10/4/2023	Method 1633	<8,000	<4,000	<2,000	33,300	941,000	6,890	10,600	<2,000	<1,600	<2,000	71,200	2,610,000
12/15/2023	Method 1633	<235,000	<118,000	<58,800	123,000	5,380,000	<58,800	85,700	<58,800	<47100	<58,800	398,000	19,300,000
1/10/2024	Method 1633	<85,100	<42,600	<21,300	222,000	7,560,000	54,800	53,300	<21,300	<17000	<21,300	649,000	17,000,000
3/7/2024	Method 1633	<82,500	<41,200	<20,600	222,000	8,260,000	56,300	73,900	<20,600	<16500	<20,600	679,000	18,600,000
3/13/2024	Method 1633	<79,200	<39,600	<19,800	341,000	13,000,000	92,900	95,500	<19,800	<15800	<19,800	983,000	28,200,000

Table E.34: Shakopee Aquifer Run Settings.

Sample Date	Run	Run Style	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
11/23/2022	Run 0	Stepwise - Venturi	2100	30, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
11/29/2022	Run 1	Stepwise - Venturi	2050	25, 27	5	2	26	1	26.5	1	27	1	27.5	5	28	3	28.5	2	29	2	29.5	2	29.8	1	30
11/29/2022	Run 1	Stepwise - Venturi	2100	0, 27	5	2	26	1	26.5	1	27	1	27.5	5	28	3	28.5	2	29	2	29.5	2	29.8	1	30
12/5/2022	Run 1	Stepwise - Venturi	2065	25, 27	5	2	24	1	26	1	27	1	27.5	5	28	3	28.5	2	29	2	29.5	2	29.8	1	30
12/13/2022	Run 1	Stepwise - Venturi	2075	10, 30	5	5	17	5	18	5	19	5	20	5	21	5	22	5	23	5	24	5	25	5	26
11/28/2022	Run 2	Stepwise - Venturi	2150	25, 27	5	2	28	1	28.5	1	29	1	29.5	5	30	3	30.5	2	31	2	31.5	2	31.8	1	32
11/29/2022	Run 2	Stepwise - Venturi	2100	25, 27	5	2	30	1	30.5	1	31	1	31.5	5	32	3	32.5	2	33	2	33.5	2	33.8	1	34
12/13/2022	Run 2	Stepwise - Venturi	2075	10, 30	5	5	19	5	20	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28
11/28/2022	Run 3	Stepwise - Venturi	2150	0, 27	5	2	28	1	28.5	1	29	1	29.5	5	30	3	30.5	2	31	2	31.5	2	31.8	1	32
11/29/2022	Run 3	Stepwise - Venturi	2100	0, 27	5	2	30	1	30.5	1	31	1	31.5	5	32	3	32.5	2	33	2	33.5	2	33.8	1	34
12/13/2022	Run 3	Stepwise - Venturi	2075	10, 30	5	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30	5	31
11/28/2022	Run 4	Stepwise - Venturi	2100	25, 27	5	2	26	1	26.5	1	27	1	27.5	5	28	3	28.5	2	29	2	29.5	2	29.8	1	30
12/28/2022	Run 4	Stepwise - Time	2075	10, 30	5	3	21	3	22	3	23	3	24	3	25	3	26	3	27	3	28	3	29	3	30
12/28/2022	Run 5	Stepwise - Time	2075	10, 30	5	4	21	4	22	4	23	4	24	4	25	4	26	4	27	4	28	4	29	4	30
12/29/2022	Run 6	Stepwise - Time	2075	10, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
12/29/2022	Run 7	Stepwise - Time	2075	10, 30	5	6	21	6	22	6	23	6	24	6	25	6	26	6	27	6	28	6	29	6	30
12/29/2022	Run 8	Stepwise - Time	2075	10, 30	5	7	21	7	22	7	23	7	24	7	25	7	26	7	27	7	28	7	29	7	30
1/11/2023	Run 9	Stepwise - Top-Up	2100	30, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/11/2023	Run 10	Stepwise - Top-Up	2100	50, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/12/2023	Run 11	Stepwise - Top-Up	2100	45, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/12/2023	Run 11	Stepwise - Top-Up	2100	45, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/13/2023	Run 12	Stepwise - Top-Up	2100	40, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/16/2023	Run 13	Stepwise - Top-Up	2100	35, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/16/2023	Run 13	Stepwise - Top-Up	2100	35, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/17/2023	Run 14	Stepwise - Top-Up	2100	25, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/18/2023	Run 15	Stepwise - Top-Up	2100	20, 30	5	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
1/20/2023	Run 16	Aerosolization	1950	52, 40	5	5	20	5	30	15	40	10	40	-	-	-	-	-	-	-	-	-	-	-	-
1/26/2023	Run 17	Aerosolization	2075	52, 40	5	30	30	30	40	30	40	30	40	30	40	30	40	30	40	20	40	-	-	-	-
1/30/2023	Run 18	Aerosolization	2085	0,40	5	30	30	30	40	30	40	30	40	30	40	30	40	30	40	20	40	-	-	-	-
1/30/2023	Run 19	Aerosolization	2085	30,40	5	30	30	30	40	30	40	30	40	30	40	30	40	30	40	20	40	-	-	-	-
1/30/2023	Run 20	Aerosolization	2085	10,40	5	30	30	30	40	30	40	30	40	30	40	30	40	30	40	20	40	-	-	-	-
1/31/2023	Run 21	Aerosolization	2085	0,40	5	30	40	30	40	30	40	30	40	30	40	30	40	-	-	-	-	-	-	-	-
1/31/2023	Run 22	Aerosolization	2085	0,40	5	30	40	30	40	30	40	30	40	-	-	-	-	-	-	-	-	-	-	-	-
1/31/2023	Run 23	Aerosolization	2085	0,40	5	30	40	30	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/1/2023	Run 24	Aerosolization	2085	0, 40	5	30	30	30	30	30	30	30	30	30	30	30	30								

Sample Date	Run	Run Style	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
2/1/2023	Run 25	Dosing	2075	30, 30	5	10	15	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
2/1/2023	Run 26	Dosing	2000	30, 30	5	10	15	5	25	5	26	5	27	5	28	5	29	5	30	5	31	5	32	5	33
2/1/2023	Run 27	Dosing	2050	30, 39	5	15	15	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39
2/1/2023	Run 28	Dosing	2050	30, 39	5	15	15	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39
2/2/2023	Run 29	Dosing	2050	30, 39	5	15	15	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39
2/2/2023	Run 30	Dosing	2050	30, 30	5	15	15	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30
2/2/2023	Run 31	Continuous Top-Up	2050	10, 24	30	15	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/2/2023	Run 32	Continuous Top-Up	2050	10, 27	30	15	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/2/2023	Run 33	Continuous Top-Up	2050	10, 31	30	15	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/3/2023	Run 34	Oscillation	2085	5, 45	5	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.3	5	45.4
2/3/2023	Run 35	Oscillation	2095	10, 45	5	5	43.5	5	31	5	44.5	5	31	5	44.6	5	33	5	44.7	5	32	5	44.8	5	44.9
2/3/2023	Run 36	Dosing	2095	5, 45	5	20	20	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	31	10	45.3
2/4/2023	Run 37	Oscillation	2095	5, 40	5	20	20	5	39	5	26	5	40	5	26	5	40.1	5	28	5	40.2	5	26	10	40.3
2/4/2023	Run 38	Dosing	2095	5, 40	5	20	20	5	39	5	26	5	40	5	26	5	40.1	5	28	5	40.2	5	26	10	40.3
2/13/2023	Run 39	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
2/14/2023	Run 40	Oscillation	2055	10, 45	5	7	25	7	44	7	31	7	45	7	31	7	45.1	7	33	7	45.2	7	32	7	45.4
2/15/2023	Run 41	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.4	30	43						
2/15/2023	Run 42	Oscillation	2055	10, 45	5	3	25	3	44	3	31	3	45	3	31	3	45.1	3	33	3	45.2	3	32	3	45.4
2/15/2023	Run 42	Oscillation	2055	10, 45	5	3	25	3	44	3	31	3	45	3	31	3	45.1	3	33	3	45.2	3	32	3	45.4
2/16/2023	Run 43	Oscillation	2055	10, 45	5	5	25	5	30	5	35	5	37	5	32	5	39	5	34	5	46.3	5	34	5	46.5
2/17/2023	Run 44	Oscillation	2055	10, 45	5	5	25	5	30	5	37	5	43	5	31	5	43.5	5	32	5	44	5	33	5	44.5
2/20/2023	Run 45	Stepwise - Venturi	2055	10, 45	5	5	38	5	39	5	40	5	41	5	42	5	43	5	44	5	45	5	46	5	47
2/20/2023	Run 46	Continuous Top-Up	2055	30, 43	5	15	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/20/2023	Run 46	Continuous Top-Up	2055	30, 43	5	15	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/21/2023	Run 47	Oscillation	2095	10, 45	5	5	46	5	31	5	47	5	31	5	47.1	5	33	5	47.2	5	32	5	47.3	5	47.4
2/21/2023	Run 48	Continuous Top-Up	2050	10, 46	30	15	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/21/2023	Run 49	Continuous Top-Up	2050	10, 40	30	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/24/2023	Run 50	Oscillation	2055	10, 45	5	5	25	5	44.5	5	31	5	45.5	5	31	5	45.6	5	33	5	45.7	5	32	5	45.8
2/27/2023	Run 51	Oscillation	2055	10, 45	5	5	25	5	45	5	31	5	46	5	31	5	46.1	5	33	5	46.2	5	32	5	46.3
2/27/2023	Run 51	Oscillation	2055	10, 45	5	5	25	5	45	5	31	5	46	5	31	5	46.1	5	33	5	46.2	5	32	5	46.3
2/28/2023	Run 52	Oscillation	2055	10, 45	5	5	25	5	45.5	5	31	5	46.5	5	31	5	46.6	5	33	5	46.7	5	32	5	46.8
2/28/2023	Run 52	Oscillation	2055	10, 45	5	5	25	5	45.5	5	31	5	46.5	5	31	5	46.6	5	33	5	46.7	5	32	5	46.8
3/1/2023	Run 53	Oscillation	2055	10, 45	5	5	25	5	46	5	31	5	47	5	31	5	47.1	5	33	5	47.2	5	32	5	47.3
3/2/2023	Run 54	Stepwise - Venturi	2055	10, 45	5	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43
3/3/2023	Run 55	Stepwise - Venturi	2055	10, 45	5	5	37	5	38	5	39	5	40	5	41	5	42	5	43	5	44	5	45	5	46
3/3/2023	Run 55	Stepwise - Venturi	2055	10, 45	5	5	37	5	38	5	39	5	40	5	41	5	42	5	43	5	44	5	45	5	46
3/6/2023	Run 56	Continuous Top-Up	2050	10, 40	30	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample Date	Run	Run Style	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
3/7/2023	Run 56	Continuous Top-Up	2050	10, 40	30	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/7/2023	Run 56	Continuous Top-Up	2050	10, 40	30	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/9/2023	Run 56	Continuous Top-Up	2050	10, 40	30	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/10/2023	Run 56	Continuous Top-Up	2050	10, 40	30	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/13/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/13/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/15/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/15/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/17/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/17/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/20/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
3/22/2023	Run 57	Oscillation	2055	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
9/13/2023	Run 57	Oscillation	2080	10, 45	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
9/14/2023	Run 58	Oscillation	2080	10, 45	5	5	25.0	5	43.5	5	31.0	5	44.5	5	31.0	5	44.6	5	33.0	5	44.7	5	32.0	5	44.9
9/15/2023	Run 59	Oscillation	2080	10, 45	5	5	25.0	5	43.0	5	31.0	5	44.0	5	31.0	5	44.1	5	33.0	5	44.2	5	32.0	5	44.4
9/18/2023	Run 60	Oscillation	2080	10, 44	5	5	25.0	5	42.5	5	31.0	5	43.5	5	31.0	5	43.6	5	33.0	5	43.7	5	32.0	5	43.9
9/18/2023	Run 60	Oscillation	2080	10, 44	5	5	25.0	5	42.5	5	31.0	5	43.5	5	31.0	5	43.6	5	33.0	5	43.7	5	32.0	5	43.9
9/21/2023	Run 61	Oscillation	2080	10, 45	5	3	25	3	44	3	31	3	45	3	31	3	45.1	3	33	3	45.2	3	32	3	45.4
9/26/2023	Run 62	Oscillation	2080	10, 44	5	3	25	3	42.5	3	31	3	43.5	3	31	3	43.6	3	33	3	43.7	3	32	3	43.9
9/26/2023	Run 62	Oscillation	2080	10, 44	5	3	25	3	42.5	3	31	3	43.5	3	31	3	43.6	3	33	3	43.7	3	32	3	43.9
9/27/2023	Run 63	Oscillation	2080	10, 44	5	2	25	5	42.5	2	31	5	43.5	2	31	5	43.6	2	33	5	43.7	2	32	5	43.9
9/28/2023	Run 64	Oscillation	2080	10, 44	5	2	25	3	42.5	2	31	3	43.5	2	31	3	43.6	2	33	3	43.7	2	32	3	43.9
9/29/2023	Run 65	Oscillation	2080	10, 44	5	0	0	0	0	5	31	5	43.5	5	31	5	43.6	5	33	5	43.7	5	32	5	43.9
10/9/2023	Run 66	Oscillation	2080	10, 44	5	5	25	5	42	5	31	5	43	5	31	5	43.1	5	33	5	43.2	5	32	5	43.4
10/12/2023	Run 67	Oscillation	2080	10, 43	5	5	25	5	41.5	5	31	5	42.5	5	31	5	42.6	5	33	5	42.7	5	32	5	42.9
10/12/2023	Run 67	Oscillation	2080	10, 43	5	5	25	5	41.5	5	31	5	42.5	5	31	5	42.6	5	33	5	42.7	5	32	5	42.9
10/16/2023	Run 68	Oscillation	2080	10, 43	5	5	25	5	41	5	31	5	42	5	31	5	42.1	5	33	5	42.2	5	32	5	42.4
10/17/2023	Run 69	Oscillation	2080	10, 44	5	5	23	5	42.5	5	29	5	43.5	5	29	5	43.6	5	31	5	43.7	5	30	5	43.9
10/18/2023	Run 70	Oscillation	2080	10, 44	5	5	27.0	5	42.5	5	33.0	5	43.5	5	33.0	5	43.6	5	35.0	5	43.7	5	34.0	5	43.9
10/23/2023	Run 71	Aerosolization	2065	0, 40	5	30	40.0	30	40	30	40.0	30	40	30	40.0	30	40	30	40.0	25	40	-	-	-	-
10/24/2023	Run 72	Aerosolization	2065	0, 40	5	30	40.0	30	40	30	40.0	30	40	30	40.0	25	40	-	-	-	-	-	-	-	-
10/24/2023	Run 73	Aerosolization	2065	0, 40	5	30	40.0	30	40	30	40.0	25	40	-	-	-	-	-	-	-	-	-	-	-	-
10/25/2023	Run 74	Aerosolization	2065	0, 40	5	30	40.0	25	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/25/2023	Run 75	Aerosolization	2065	0, 30	5	30	30.0	30	30	30	30.0	30	30	30	30.0	25	30								
10/26/2023	Run 76	Aerosolization	2065	0, 30	5	30	30.0	30	30	30	30.0	25	30												
10/26/2023	Run 77	Aerosolization	2065	0, 30	5	30	30.0	25	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/26/2023	Run 78	Aerosolization	2065	0, 30	5	30	30.0	30	30	30	30.0	30	30	30	30.0	30	30	30	30.0	25	30				

Sample Date	Run	Run Style	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
10/27/2023	Run 79	Aerosolization	2065	0, 30	5	25	30.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 80	Aerosolization	2065	0, 30	5	30	30.0	10	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 81	Aerosolization	2065	0, 30	5	10	30.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 82	Aerosolization	2065	0, 40	5	10	40.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 83	Aerosolization	2065	0, 40	5	30	40.0	10	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 84	Aerosolization	2065	0, 40	5	25	40.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 85	Aerosolization	2065	0, 40	5	0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/27/2023	Run 86	Aerosolization	2065	0, 30	5	0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10/30/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/15/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/15/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/15/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/15/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/20/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/20/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
12/20/2023	Run 87	Oscillation	2080	10, 44	5	3	27.0	3	42.5	3	33.0	3	43.5	3	33.0	3	43.6	3	35.0	3	43.7	3	34.0	3	43.9
11/1/2023	Run 88	Oscillation	2080	10, 44	5	3	27.0	4	42.5	3	33.0	4	43.5	3	33.0	4	43.6	3	35.0	4	43.7	3	34.0	4	43.9
11/3/2023	Run 89	Oscillation	2080	10, 44	5	2	27.0	3	42.5	2	33.0	3	43.5	2	33.0	3	43.6	2	35.0	3	43.7	2	34.0	3	43.9
11/7/2023	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
1/10/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
1/10/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
1/29/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
1/29/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/5/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/5/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/7/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/7/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/13/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/13/2024	Run 90	Oscillation	2080	10, 44	5	2	27.0	2	42.5	2	33.0	2	43.5	2	33.0	2	43.6	2	35.0	2	43.7	2	34.0	2	43.9
3/14/2024	Run 91	Oscillation	2080	10, 44	5	2	27.0	2	42.5	-	-	2	43.5	-	-	2	43.6	-	-	2	43.7	-	-	2	43.9
3/15/2024	Run 92	Oscillation	2080	10, 44	5	3	27.0	3	42.5	-	-	3	43.5	-	-	3	43.6	-	-	3	43.7	-	-	3	43.9
3/21/2024	Run 93	Oscillation	2080	10,44	5	5	27.0	5	42.5	-	-	5	43.5	-	-	5	43.6	-	-	5	43.7	-	-	5	43.9
2/13/2023	Run 37B	Oscillation	2055	5, 40	5	2	20	5	39	5	26	5	40	5	26	5	40.1	5	28	5	40.2	5	26	10	40.3

Legend: NR = not recorded.
Notes: Stepwise - Venturi = Venturi Pump Frequency was varied; Stepwise - Time = Fractionation Stage Duration was varied; Stepwise - Top-Up = Top-Up Rate was varied.

Table E.35: Jordan Aquifer Tank 1 PFAS Results.

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
6/6/2023	Run 1	Method 533	368	9.37	9.19	3.53	46.1	<1.72	<1.72	<1.72	<1.72	1.2	3.03	63.7
6/9/2023	Run 2	Method 533	512	7.68	8.71	2.13	41.1	<1.75	<1.75	<1.75	<1.75	<1.75	1.37	9.61
6/14/2023	Run 4	Method 533	444	7.02	7.7	2.64	64.5	<1.77	<1.77	<1.77	<1.77	<1.77	2.43	28.5
6/19/2023	Run 7	Method 533	383	6.27	7.24	2.55	51.7	<1.75	<1.75	<1.75	<1.75	<1.75	1.82	41.4
6/23/2023	Run 8	Method 533	377	6.29	7.72	1.91	31.6	<1.77	<1.77	<1.77	<1.77	<1.77	1.13	11.5
7/10/2023	Run 9	Method 533	398	6.06	6.79	2.16	73.9	<1.80	<1.80	<1.80	<1.80	<1.80	2.13	35.5
7/11/2023	Run 10	Method 533	377	5.74	6.41	1.95	38.2	<1.75	<1.75	<1.75	<1.75	<1.75	1.39	9.94
7/12/2023	Run 11	Method 533	373	5.72	6.44	1.69	29.7	<1.76	<1.76	<1.76	<1.76	<1.76	1.27	4.97
7/13/2023	Run 12	Method 533	399	6.46	6.75	2.02	38.8	<1.75	<1.75	<1.75	<1.75	0.506	1.48	1.95
7/17/2023	Run 13	Method 533	355	5.80	6.59	2.51	49.4	<1.79	<1.79	<1.79	<1.79	0.449	1.88	1.89
7/21/2023	Run 6	Method 533	367	5.88	5.94	1.16	24.9	<1.85	<1.85	<1.85	<1.85	<1.85	0.993	16.2
7/21/2023	Run 6	Method 533	362	5.98	6.24	1.32	26.3	<1.76	<1.76	<1.76	<1.76	<1.76	1.04	5.12
7/21/2023 *	Run 6	Method 533	341	5.46	7.19	3.16	30.3	<1.79	<1.79	<1.79	<1.79	<1.79	1.49	1.63
7/24/2023	Run 14	Method 533	366	5.84	5.90	1.39	25.2	<1.74	<1.74	<1.74	<1.74	<1.74	0.924	15.7
7/25/2023	Run 15	Method 533	339	5.66	6.29	1.26	22.8	<1.74	<1.74	<1.74	<1.74	<1.74	<1.74	2.18
7/26/2023	Run 11B	Method 533	340	5.56	6.38	1.48	22.8	<1.79	<1.79	<1.79	<1.79	<1.79	<1.79	1.24
7/27/2023	Run 4B	Method 533	347	6.20	6.44	1.93	29.9	<1.82	<1.82	<1.82	<1.82	<1.82	1.14	1.41
7/28/2023	Run 16	Method 533	336	5.91	6.58	1.68	28.0	<1.87	<1.87	<1.87	<1.87	<1.87	1.08	2.02
8/2/2023	Run 18B	Method 1633	312	4.83	5.36	1.09	21.1	<0.378	<0.378	<0.378	<0.302	<0.378	0.490	0.876
8/2/2023	Run 19B	Method 1633	365	5.59	6.09	1.33	23.8	<0.378	<0.378	<0.378	<0.302	<0.378	0.642	1.03
8/2/2023	Run 20B	Method 1633	324	4.96	5.88	1.04	23.0	<0.391	<0.391	<0.391	<0.312	<0.391	0.704	1.29
8/4/2023	Run 17B	Method 1633	371	5.45	6.15	1.28	23.9	<0.382	<0.382	<0.382	<0.306	<0.382	0.599	1.31
8/4/2023	Run 21B	Method 1633	255	4.10	4.78	1.17	21.7	<0.381	<0.381	<0.381	<0.305	<0.381	0.633	1.12

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
8/7/2023	Run 22B	Method 1633	370	5.85	6.23	1.17	24.3	<0.375	<0.375	<0.375	<0.300	0.419	0.748	1.44
8/8/2023	Run 31B	Method 1633	385	5.90	5.55	1.15	22.5	<0.378	<0.378	<0.378	<0.303	<0.378	0.729	1.09
8/9/2023	Run 32B	Method 1633	383	5.72	5.44	1.15	22.9	<0.370	<0.370	<0.370	<0.296	0.441	0.701	0.879
8/11/2023	Run 16A	Method 1633	368	5.57	6.21	1.21	26.7	<0.408	<0.408	<0.408	<0.326	<0.408	0.702	1.39
8/11/2023	Run 16B	Method 1633	387	5.67	5.97	1.22	22.6	<0.371	<0.371	<0.371	<0.297	0.416	0.777	1.18
8/15/2023	Run 16B	Method 1633	392	5.91	6.35	1.26	26.5	<0.384	<0.384	<0.384	<0.307	<0.384	0.791	0.920
8/15/2023	Run 16A	Method 1633	358	5.51	5.70	1.03	24.3	<0.406	<0.406	<0.406	<0.325	<0.406	0.698	0.801
8/25/2023	Run 16B	Method 1633	351	5.47	5.82	1.26	21.4	<0.387	<0.387	<0.387	<0.310	0.433	0.674	0.975
8/25/2023	Run 16A	Method 1633	357	5.45	5.81	1.18	21.9	<0.425	<0.425	<0.425	<0.340	<0.425	0.692	0.978
8/7/2023	Run 23B	Method 1633	343	5.43	5.55	1.21	23.0	<0.379	<0.379	<0.379	<0.379	<0.379	0.78	1.03
8/7/2023	Run 24B	Method 1633	363	5.55	6.02	1.13	23.0	<0.373	<0.373	<0.373	<0.299	<0.373	0.697	0.919
8/7/2023	Run 25B	Method 1633	372	5.63	6.04	1.28	24.2	<0.376	<0.376	<0.376	<0.300	0.420	0.624	0.869
8/8/2023	Run 26B	Method 1633	369	5.46	6.39	1.18	23.5	<0.371	<0.371	<0.371	<0.297	0.391	0.637	0.848
8/7/2023	Run 27B	Method 1633	361	5.57	5.90	1.12	23.0	<0.384	<0.384	<0.384	<0.307	0.414	0.671	0.944
8/8/2023	Run 28B	Method 1633	365	5.53	6.05	1.27	22.8	<0.376	<0.376	<0.376	<0.301	<0.376	0.654	1.01
8/9/2023	Run 29B	Method 1633	368	5.60	6.12	1.18	24.0	<0.372	<0.372	<0.372	<0.297	<0.372	0.609	0.999
8/9/2023	Run 30B	Method 1633	370	5.59	6.18	1.22	23.2	<0.368	<0.368	<0.368	<0.294	0.372	0.694	0.870
8/11/2023	Run 16B	Method 1633	388	5.68	5.72	1.24	23.3	<0.380	<0.380	<0.380	<0.304	<0.380	0.738	0.832
8/11/2023	Run 16A	Method 1633	375	5.61	6.43	1.13	23.3	<0.410	<0.410	<0.410	<0.328	<0.410	0.830	0.904
8/11/2023 *	Run 16A	Method 1633	395	5.92	6.35	2.31	64.3	<0.390	<0.390	<0.390	<0.312	0.521	1.76	6.76
8/15/2023 *	Run 16A	Method 1633	397	5.86	7.59	4.44	173	<0.376	<0.376	<0.376	<0.301	<0.376	4.91	4.71
8/16/2023	Run 16B	Method 533	317	5.09	5.53	1.24	21.1	<1.73	<1.73	<1.73	<1.73	<1.73	0.885	0.995
8/16/2023	Run 16A	Method 533	316	5.17	5.55	1.35	21.4	<1.81	<1.81	<1.81	<1.81	<1.81	<1.81	1.16
8/16/2023	Run 16A	Method 533	313	5.68	5.34	1.29	21.6	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	0.999
8/16/2023	Run 16B	Method 533	337	5.75	5.89	1.26	24.2	<1.79	<1.79	<1.79	<1.79	<1.79	<1.79	1.26

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
8/16/2023 *	Run 16B	Method 533	312	5.35	6.21	2.95	119	<1.78	<1.78	<1.78	<1.78	<1.78	3.67	5.84
8/25/2023	Run 16A	Method 1633	357	5.45	5.81	1.18	21.9	<0.425	<0.425	<0.425	<0.340	<0.425	0.692	0.978

* Indicates sample was collected after discharge from secondary fractionation occurred.

Table E.36: Jordan Aquifer Effluent PFAS Results.

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
6/6/2023	Run 1	Oscillation	SV1-20	Method 533	388	8.62	8.62	1.17	3.34	<1.77	<1.77	<1.77	<1.77	<1.77	<1.77	10.0
6/9/2023	Run 2	Stepwise - Venturi	SV1-10	Method 533	531	8.54	8.59	1.38	3.01	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	4.98
6/12/2023	Run 3	Oscillation	SV1-20	Method 533	460	6.94	7.74	1.80	6.09	<1.76	<1.76	<1.76	<1.76	<1.76	<1.76	5.79
6/14/2023	Run 4	Oscillation	SV1-20	Method 533	449	6.69	6.85	<1.72	1.60	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72	14.4
6/15/2023	Run 5	Stepwise - Venturi	SV1-20	Method 533	450	7.08	6.54	<1.86	2.01	<1.86	<1.86	<1.86	<1.86	<1.86	<1.86	23.4
6/16/2023	Run 6	Stepwise - Venturi	SV1-20	Method 533	431	7.04	6.73	0.887	2.30	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72
6/19/2023	Run 7	Oscillation	SV1-20	Method 533	382	6.55	6.94	1.27	12.8	<1.68	<1.68	<1.68	<1.68	<1.68	<1.68	4.13
6/23/2023	Run 8	Oscillation	SV1-20	Method 533	379	6.50	6.25	<1.75	7.30	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	3.67
7/10/2023	Run 9	Stepwise - Venturi	SV1-20	Method 533	395	5.73	5.76	<1.76	1.71	<1.76	<1.76	<1.76	<1.76	<1.76	<1.76	8.23
7/11/2023	Run 10	Stepwise - Venturi	NR	Method 533	400	6.29	6.46	0.905	3.32	<1.74	<1.74	<1.74	<1.74	<1.74	<1.74	4.15
7/12/2023	Run 11	Stepwise - Venturi	NR	Method 533	372	5.72	6.14	0.995	5.73	<1.79	<1.79	<1.79	<1.79	<1.79	<1.79	5.91
7/13/2023	Run 12	Oscillation	SV1-20	Method 533	381	6.19	6.11	1.00	2.46	<1.76	<1.76	<1.76	<1.76	0.507	<1.76	0.713
7/17/2023	Run 13	Stepwise - Venturi	SV1-20	Method 533	354	5.90	5.46	0.69	1.90	<1.74	<1.74	<1.74	<1.74	0.428	<1.74	0.979
7/21/2023	Run 6	Stepwise - Venturi	SV1-20	Method 533	350	5.20	5.57	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75
7/21/2023	Run 6	Stepwise - Venturi	SV1-20	Method 533	342	5.76	6.87	1.11	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82
7/24/2023	Run 14b	Stepwise - Venturi	SV1-20	Method 533	349	5.63	5.47	<1.75	1.10	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75
7/25/2023	Run 15	Stepwise - Venturi	SV1-20	Method 533	335	5.38	5.49	<1.72	1.56	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72
7/26/2023	Run 11B	Stepwise - Venturi	SV1-20	Method 533	342	5.35	5.00	<1.83	3.20	<1.83	<1.83	<1.83	<1.83	<1.83	<1.83	11.5
7/27/2023	Run 4B	Oscillation	SV1-20	Method 533	326	5.63	5.53	<1.75	1.87	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75
7/28/2023	Run 16	Oscillation	SV1-20	Method 533	332	5.47	5.42	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75
8/2/2023	Run 18B	Aerosolization	SV1-20	Method 1633	364	5.63	5.96	1.21	14.3	<0.377	<0.377	<0.377	0.448	0.383	0.510	0.414
8/2/2023	Run 20B	Aerosolization	SV1-10	Method 1633	363	5.61	5.98	1.09	15.3	<0.386	<0.386	<0.386	<0.309	0.419	0.577	<0.386
8/2/2023	Run 19B	Aerosolization	SV1-20	Method 1633	368	5.69	6.33	1.22	22.1	<0.382	<0.382	<0.382	0.335	0.440	0.711	0.717
8/4/2023	Run 21B	Aerosolization	SV1-20	Method 1633	370	5.78	6.30	1.14	13.2	<0.394	<0.394	0.547	0.644	0.427	<0.394	0.986
8/4/2023	Run 17B	Aerosolization	SV1-20	Method 1633	357	5.38	6.18	1.35	17.2	<0.385	<0.385	<0.385	<0.308	0.402	0.619	0.514
8/7/2023	Run 22B	Aerosolization	SV1-20	Method 1633	374	5.68	6.22	1.26	16.2	<0.382	<0.382	<0.382	<0.306	<0.382	0.564	0.653
8/7/2023	Run 24B	Aerosolization	SV1-20	Method 1633	366	5.64	6.17	1.13	20.2	0.378	0.378	0.378	0.302	0.457	0.588	0.760

Sample Date	Run	Run Style	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
8/7/2023	Run 23B	Aerosolization	SV1-20	Method 1633	367	5.64	6.13	1.26	20.1	<0.385	<0.385	<0.385	<0.308	0.386	0.608	0.720
8/7/2023	Run 25B	Aerosolization	SV1-20	Method 1633	363	5.53	5.90	1.08	14.9	<0.389	<0.389	<0.389	<0.311	<0.389	<0.389	1.27
8/7/2023	Run 27B	Aerosolization	SV1-20	Method 1633	365	5.72	6.02	1.01	12.3	<0.381	<0.381	<0.381	<0.305	0.391	0.473	<0.381
8/8/2023	Run 26B	Aerosolization	SV1-20	Method 1633	381	5.45	5.93	1.17	23.0	<0.375	<0.375	<0.375	<0.300	0.465	0.756	1.00
8/8/2023	Run 28B	Aerosolization	SV1-20	Method 1633	368	5.54	5.98	1.32	21.4	<0.375	<0.375	<0.375	<0.300	0.404	0.545	0.772
8/8/2023	Run 31B	Aerosolization	SV1-20	Method 1633	369	5.58	6.39	1.27	22.7	<0.371	<0.371	<0.371	<0.297	0.443	0.659	0.798
8/9/2023	Run 30B	Aerosolization	SV1-20	Method 1633	386	5.59	5.71	1.20	22.8	<0.373	<0.373	<0.373	<0.298	0.422	0.744	0.893
8/9/2023	Run 32B	Aerosolization	SV1-20	Method 1633	365	5.45	6.16	1.16	23.8	<0.375	<0.375	<0.375	<0.300	<0.375	0.564	0.934
8/9/2023	Run 29B	Aerosolization	SV1-20	Method 1633	352	5.40	5.82	1.18	22.1	<0.384	<0.384	<0.384	<0.307	<0.384	0.697	0.755
8/11/2023	Run 16A	Oscillation	SV1-10	Method 1633	365	5.70	6.29	1.23	12.7	<0.401	<0.401	<0.401	<0.320	0.468	0.615	0.436
8/11/2023	Run 16A	Oscillation	SV1-20	Method 1633	393	5.81	5.62	0.891	5.45	<0.373	<0.373	<0.373	<0.298	<0.373	<0.373	<0.373
8/11/2023 *	Run 16B	Oscillation	SV1-10	Method 1633	394	5.76	6.70	3.19	68.2	<0.399	<0.399	<0.399	<0.319	0.456	2.25	5.63
8/15/2023	Run 16A	Oscillation	SV1-20	Method 1633	391	5.75	5.84	0.958	4.95	<0.402	<0.402	<0.402	<0.322	<0.402	<0.402	<0.402
8/15/2023	Run 16A	Oscillation	SV1-20	Method 1633	358	5.58	5.73	1.03	7.66	<0.424	<0.424	<0.424	<0.339	<0.424	<0.424	<0.424
8/15/2023 *	Run 16B	Oscillation	SV1-20	Method 1633	394	5.72	7.26	3.85	151	<0.390	<0.390	<0.390	<0.312	0.502	4.31	3.63
8/16/2023	Run 16B	Oscillation	SV1-20	Method 1633	313	5.36	5.18	<1.75	2.69	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75	<1.75
8/16/2023	Run 16A	Oscillation	SV1-10	Method 1633	314	5.48	5.54	1.05	11.8	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82	<1.82
8/16/2023	Run 16B	Oscillation	SV1-20	Method 1633	324	5.48	6.49	2.71	37.1	<1.78	<1.78	<1.78	<1.78	<1.78	2.13	<1.78
8/20/2023	Run 16B	Oscillation	SV1-20	Method 1633	350	5.95	6.52	1.08	5.6	<0.419	<0.419	<0.419	<0.335	<0.419	<0.419	2.30
8/25/2023	Run 16A	Oscillation	SV1-10	Method 1633	387	5.67	6.36	<1.41	10.8	<1.41	<1.41	<1.41	<1.12	<1.41	<1.41	<1.41

* Indicates sample was collected after discharge from secondary fractionation was treated.

Table E.37: Jordan Aquifer Tank 3 PFAS Results.

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
7/21/2023	Run 6	Method 533	326	<100	<100	<100	998	<100	<100	<100	<100	<100	52.5	1340
8/11/2023	Run 16	Method 1633	399	6.37	9.77	9.04	563	0.603	1.07	<0.371	<0.297	0.516	11.3	124
8/15/2023	Run 16	Method 1633	400	6.02	10.9	13.0	828	0.698	<0.368	<0.368	<0.294	<0.368	18.7	66.7
8/16/2023	Run 16	Method 533	335	5.98	10.4	14.3	880	<1.78	<1.78	<1.78	<1.78	<1.78	23.9	87.7

Table E.38: Jordan Aquifer Tank 4 PFAS Results.

Sample Date	Method	SAFF Vessel	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
7/12/2023	Method 533	Tank 4	376	53.0	928	33,100	1,070,000	5,290	5,890	<100	<100	64.6	65,200	2,630,000
8/10/2023	Method 1633	Tank 4	<7,210	<3,600	<1,800	20,200	668,000	6,270	6,370	<1,800	<1,440	<1,800	37,500	1,730,000

Table E.39: Jordan Aquifer Run Settings.

Sample Date	Run	Run Style	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
6/6/2023	Run 1	Oscillation	2100	20, 43	5	5	25	5	44	5	31	5	45	5	31	5	45.1	5	33	5	45.2	5	32	5	45.4
6/9/2023	Run 2	Stepwise - Venturi	2100	20, 43	5	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43	5	44	5	45
6/12/2023	Run 3	Oscillation	2100	20, 43	5	5	25	5	46	5	31	5	47	5	31	5	47.1	5	31	5	47.2	5	32	5	47.5
6/14/2023	Run 4	Oscillation	2100	20, 43	5	5	25	5	42	5	31	5	43	5	31	5	43.1	5	33	5	43.2	5	32	5	43.4
6/15/2023	Run 5	Stepwise - Venturi	2100	20, 43	5	5	38	5	39	5	40	5	41	5	42	5	43	5	44	5	45	5	46	5	47
6/16/2023	Run 6	Stepwise - Venturi	2100	20, 43	5	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43
6/19/2023	Run 7	Oscillation	2100	20, 43	5	5	25	5	44	5	31	5	45	5	31	5	45.5	5	33	5	46	5	32	5	46.5
6/23/2023	Run 8	Oscillation	2100	20, 43	5	5	25	5	44	5	35	5	45	5	35	5	45.1	5	36	5	45.2	5	36	5	45.4
7/10/2023	Run 9	Stepwise - Venturi	2100	10, 43	5	7	34	7	35	7	36	7	37	7	38	7	39	7	40	7	41	7	42	7	43
7/11/2023	Run 10	Stepwise - Venturi	2100	10, 41	5	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41
7/12/2023	Run 11	Stepwise - Venturi	2100	10, 43	5	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42	3	43
7/13/2023	Run 12	Oscillation	2100	10, 42	5	5	25	5	38	5	28	5	39	5	28	5	40	5	29	5	41	5	30	5	42
7/17/2023	Run 13	Stepwise - Venturi	2100	20, 43	5	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43
7/21/2023	Run 6	Stepwise - Venturi	2100	20, 43	5	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43
7/21/2023	Run 6	Stepwise - Venturi	2100	20, 43	5	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43
7/24/2023	Run 14B	Stepwise - Venturi	2100	20, 43	5	4	34	4	35	4	36	4	37	4	38	4	39	4	40	4	41	4	42	4	43
7/25/2023	Run 15	Stepwise - Venturi	2100	10, 43	5	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42	3	43
7/26/2023	Run 11B	Stepwise - Venturi	2100	20, 43	5	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42	3	43
7/27/2023	Run 4B	Oscillation	2100	20, 43	5	5	25	5	42	5	31	5	43	5	31	5	43.1	5	33	5	43.2	5	32	5	43.4
7/28/2023	Run 16	Oscillation	2100	10, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/2/2023	Run 18B	Aerosolization	2100	0, 43	0	240	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/2/2023	Run 19B	Aerosolization	2100	0, 43	0	180	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/2/2023	Run 20B	Aerosolization	2100	0, 43	0	120	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/4/2023	Run 17B	Aerosolization	2100	0, 43	0	60	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/4/2023	Run 21B	Aerosolization	2100	0, 43	0	45	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/7/2023	Run 27B	Aerosolization	2100	0, 43	0	30	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/7/2023	Run 25B	Aerosolization	2100	0, 43	0	15	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/7/2023	Run 22B	Aerosolization	2100	0, 43	0	5	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/7/2023	Run 24B	Aerosolization	2100	0, 43	0	240	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/7/2023	Run 23B	Aerosolization	2100	0, 43	0	180	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/8/2023	Run 26B	Aerosolization	2100	0, 43	0	120	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample Date	Run	Run Style	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
8/8/2023	Run 28B	Aerosolization	2100	0, 43	0	60	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/8/2023	Run 31B	Aerosolization	2100	0, 43	0	45	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/9/2023	Run 30B	Aerosolization	2100	0, 43	0	30	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/9/2023	Run 32B	Aerosolization	2100	0, 43	0	15	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/9/2023	Run 29B	Aerosolization	2100	0, 43	0	5	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8/11/2023	Run 16A	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/11/2023	Run 16B	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/11/2023	Run 16A	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/15/2023	Run 16B	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/15/2023	Run 16A	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/15/2023	Run 16A	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/16/2023	Run 16B	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/16/2023	Run 16A	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/16/2023	Run 16B	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/20/2023	Run 16B	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4
8/25/2023	Run 16B	Oscillation	2100	0, 43	5	3	25	3	42	3	31	3	43	3	31	3	43.1	3	33	3	43.2	3	32	3	43.4

Table E.40: Raleigh Creek Tank 1 PFAS Results.

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
4/18/2023	Run 3	Method 533	310	47.3	92.9	112	735	8.37	8.68	<0.887	<0.847	31.1	89.3	1,510
4/20/2023	Run 3	Method 533	182	24.6	44.1	53.2	383	4.17	5.47	<0.877	<0.877	15.7	41.2	918
4/21/2023	Run 4	Method 533	273	47.2	91.6	107	705	7.22	6.64	<0.909	<0.909	33.1	92.2	1,360
4/25/2023	Run 7	Method 533	342	61.1	122	145	928	9.88	8.69	<0.868	<0.868	42.9	131	1,730
5/2/2023	Run 8	Method 533	341	56.8	110	129	796	8.87	8.19	<0.880	<0.880	39.8	100	1,610
5/4/2023	Run 11	Method 533	85.4	8.62	6.77	3.99	20.4	<0.903	<0.903	<0.903	<0.903	4.43	3.57	53
5/5/2023	Run 3	Method 533	80.8	7.06	4.88	2.37	9.19	<0.896	<0.896	<0.896	<0.896	3.47	2.3	17.7
5/7/2023	Run 3	Method 533	293	47.4	75.4	90.3	655	8.87	8.53	<0.868	<0.868	24.8	76.7	1,540
5/11/2023	Run 7	Method 533	130	15.9	19.7	7.52	34.5	<0.871	<0.871	<0.871	<0.871	7.96	5.02	125
5/11/2023	Run 7	Method 1633	135	12.2	15.6	11.6	55.9	0.892	1.31	<0.382	<0.305	6.2	6.85	180
5/11/2023	Run 7	Method 533	138	17.2	21.6	18.5	75.5	1.36	1.36	<0.936	<0.936	8.02	11.8	244
5/11/2023	Run 7	Method 1633	140	13.4	16.3	6.59	30.7	0.713	0.775	<0.385	<0.308	6.65	4.17	94
5/13/2023	Run 8	Method 533	228	33.2	48.6	55.7	349	3.66	5.9	<0.883	<0.883	19.4	40.9	876
5/13/2023	Run 8	Method 1633	303	34	51.5	52.5	515	3.29	7.14	<2.93	<2.35	18.4	41.4	1,570
5/15/2023	Run 7	Method 1633	327	38.1	61.8	67.8	724	5.64	6.53	<2.97	<2.38	19.9	55	2,240
5/15/2023	Run 7	Method 533	265	40.1	64.1	75.1	543	6.06	7.02	<0.890	<0.890	24.3	64.5	1,310
5/15/2023	Run 12	Method 1633	338	39.1	68.3	54.3	619	5.08	6.46	<2.85	<2.28	21.7	42.9	2,030
5/15/2023	Run 12	Method 1633	346	38.4	65.2	69.2	775	7.1	9	<2.91	<2.33	23.4	56.1	2,660
5/16/2023	Run 13	Method 1633	397	43.8	73.8	80.2	903	7.22	9.25	<3.04	<2.44	23	60.2	2,940
5/16/2023	Run 13	Method 533	293	43.2	70.6	80.9	793	7.12	8.33	<1.76	<1.76	26.2	67.7	1,380
9/30/2023	Run 12	Method 533	144	11.4	17.4	11.7	124	2.64	4.5	<1.74	<1.74	7.51	16	1,230
4/4/2024	Run 12	Method 1633	448	48.6	85.6	75.7	708	4.23	3.46	<0.404	<0.323	27.4	50.8	1,390
4/8/2024	Run 17A	Method 533	270	28.7	44.5	44.2	515	4.74	5.66	<0.896	<0.896	14.4	39.4	1,720

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
4/9/2024	Run 14A	Method 533	303	34.1	56.7	54.4	560	5.11	6.07	<0.880	<0.880	18.9	45.9	1,920
4/10/2024	Run 15A	Method 533	442	47.6	92.6	94.7	847	6.19	6.23	<0.906	<0.906	29.7	66.5	2,130
4/10/2024	Run 16A	Method 533	508	57.9	115	120	1,060	6.84	7.37	<0.903	<0.903	36.8	84.7	2,390
4/17/2024	Run 19A	Method 533	344	37.5	64.8	65.5	684	6.09	5.58	<0.926	<0.926	21.3	52.8	2,140
4/18/2024	Run 16A	Method 1633	319	35.3	62.2	59.7	699	5.53	4.1	<0.586	<0.469	19.4	47.8	1,780
4/18/2024	Run 16A	Method 1633	325	36.8	76.4	62	606	5.17	4.36	<0.614	<0.491	21.2	40.1	1,710
4/18/2024	Run 16A	Method 1633	392	41.3	72.2	74.5	709	5.41	4.82	<2.96	<2.37	22.8	54.1	2,060
4/18/2024	Run 16A	Method 1633	407	38.7	72.3	78.3	772	5.26	6.48	<2.91	<2.33	22	55.3	2,250
4/18/2024	Run 16A	Method 1633	401	40.2	71.1	79.6	735	5.91	6.2	<3.02	<2.42	22.5	58	2,170
4/18/2024	Run 16A	Method 533	352	41.7	71.4	74.2	761	6.35	5.5	<0.903	<0.903	24.6	58.8	2,280
4/18/2024	Run 16A	Method 533	388	44.9	81.1	85.3	833	6.26	6.91	<0.916	<0.916	27.2	66.6	2,530
4/19/2024	Run 16A	Method 1633	583	56.8	113	116	1,040	5.63	7.24	<2.91	<2.33	35.1	81.1	2,450
4/19/2024	Run 16A	Method 533	518	58.1	115	118	1,100	7.68	7.42	<0.893	<0.893	37.9	89.7	2,820
4/30/2024	Run 16A	Method 1633	345	33.1	60	59.6	592	4.22	3.8	<3.04	<2.43	18	40.8	1,830
4/30/2024	Run 16A	Method 1633	317	31.7	63.3	56	487	4.15	3.94	<0.386	<0.309	16.6	35.6	1,440
9/30/2024	Run 12	Method 1633	97	10.1	14	9.74	101	4.7	4.81	<1.2	<0.959	3.9	10.1	936
5/8/2024	Run 16	Method 1633	456	54.1	88.2	95.6	1,130	8.74	9.01	<3.03	<2.43	26	73.9	3,020
5/8/2024	Run 16	Method 1633	434	53.4	79.5	91.5	1,040	10.1	9.06	<3.14	<2.51	24.4	71.4	2,800

Table E.41: Raleigh Creek Effluent PFAS Results.

Sample Date	Run	Method	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
4/17/2023	Run 1	Stepwise - Venturi	SV1-20	Method 533	314	49.8	86.5	94.4	441	3.12	3.00	<0.923	<0.923	30.1	58.2	671
4/18/2023	Run 2	Stepwise - Venturi	SV1-20	Method 533	304	47.4	89.9	89.9	282	1.01	0.916	<0.890	<0.890	31.3	40.8	297
4/18/2023	Run 3A	Stepwise - Venturi	SV1-10	Method 533	299	47.4	87.7	74.8	74.6	<0.906	<0.906	<0.906	<0.906	32.6	19.4	29.1
4/18/2023	Run 3B	Stepwise - Venturi	SV1-20	Method 533	302	44.9	89.0	79.1	115	<0.903	<0.903	<0.903	<0.903	30.5	26.8	81.5
4/19/2023	Run 4	Stepwise - Venturi	SV1-20	Method 533	301	44.0	85.7	52.9	36.5	<0.906	<0.906	<0.906	<0.906	31.6	9.22	21.4
4/20/2023	Run 3	Stepwise - Venturi	SV1-20	Method 533	180	24.1	41.9	48.9	345	3.24	4.48	<0.896	<0.896	15.1	36.7	831
4/21/2023	Run 4A	Stepwise - Venturi	SV1-10	Method 533	283	50.4	93.8	108	680	6.21	5.82	<0.903	<0.903	35.2	93.6	1190
4/21/2023	Run 4B	Stepwise - Venturi	SV1-20	Method 533	290	51.7	99.9	114	590	3.81	2.88	<0.906	<0.906	36.0	81.8	801
4/25/2023	Run 7A	Stepwise - Venturi	SV1-10	Method 533	340	58.5	121	136	897	9.92	7.96	<0.893	<0.893	42.6	115	1650
4/25/2023	Run 7B	Stepwise - Venturi	SV1-20	Method 533	361	63.9	128	128	388	1.65	1.38	<0.874	<0.874	44.4	65.2	435
5/1/2023	Run 9	Stepwise - Venturi	SV1-20	Method 533	348	57.7	109	114	358	1.52	1.09	<0.883	<0.883	40.5	57.6	337
5/2/2023	Run 8	Stepwise - Venturi	SV1-20	Method 533	353	60.4	113	121	455	2.23	1.53	<0.883	<0.883	40.1	70.9	500
5/3/2023	Run 10	Stepwise - Venturi	SV1-20	Method 533	90.1	8.66	8.86	4.97	6.94	<0.903	<0.903	<0.903	<0.903	4.53	2.03	9.39
5/4/2023	Run 11	Stepwise - Venturi	SV1-20	Method 533	85.7	8.61	6.33	2.39	3.68	<0.893	<0.893	<0.893	<0.893	4.17	1.26	20.8
5/5/2023	Run 3	Stepwise - Venturi	NR	Method 533	77.1	6.80	4.89	1.82	1.23	<0.916	<0.916	<0.916	<0.916	2.74	1.07	1.03
5/7/2023	Run 3	Stepwise - Venturi	NR	Method 533	292	45.9	76.0	55.5	28.1	<0.893	<0.893	<0.893	<0.893	25.4	11.0	93.7
5/8/2023	Run 3	Stepwise - Venturi	NR	Method 533	377	47.7	75.1	38.7	<0.366	<0.366	<0.366	<0.366	<0.293	26.8	8.14	8.90
5/11/2023	Run 7	Stepwise - Venturi	SV1-20	Method 533	136	16.9	21.1	15.2	20.9	<0.862	1.95	<0.862	<0.862	7.99	4.89	304
5/11/2023	Run 7	Stepwise - Venturi	SV1-20	Method 533	139	16.5	21.4	8.89	5.38	<0.880	<0.880	<0.880	<0.880	8.30	2.61	4.60
5/11/2023	Run 7	Stepwise - Venturi	NR	Method 1633	172	17.5	23.2	15.3	13.7	<0.373	<0.373	<0.373	<0.299	8.61	4.15	15.4
5/11/2023	Run 7	Stepwise - Venturi	NR	Method 1633	152	14.3	18.4	7.21	4.51	<0.372	<0.372	<0.372	<0.297	7.46	1.83	3.72
5/13/2023	Run 8	Stepwise - Venturi	NR	Method 1633	109	9.28	9.63	6.36	7.57	<0.391	<0.391	<0.391	<0.313	4.38	2.22	5.29
5/13/2023	Run 8	Stepwise - Venturi	NR	Method 1633	175	17.6	22.0	11.2	2.12	<0.39	<0.39	<0.39	<0.312	8.08	1.69	1.80
5/13/2023	Run 8	Stepwise - Venturi	SV1-20	Method 533	155	20.4	24.8	12.7	4.41	<0.909	<0.909	<0.909	<0.909	9.98	2.19	7.57

Sample Date	Run	Method	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
5/13/2023	Run 8	Stepwise - Venturi	SV1-10	Method 533	106	12.0	12.3	7.61	8.70	<0.909	<0.909	<0.909	<0.909	5.95	2.79	8.79
5/15/2023	Run 7	Stepwise - Venturi	NR	Method 1633	301	33.3	52.5	24.5	3.95	<0.373	<0.373	<0.373	<0.298	18.3	2.43	7.80
5/15/2023	Run 7	Stepwise - Venturi	SV1-10	Method 533	249	36.7	56.7	31.2	4.84	<0.859	<0.859	<0.859	<0.859	21.6	2.86	9.13
5/15/2023	Run 12	Stepwise - Venturi	NR	Method 1633	327	35.2	51.9	19.7	2.97	<0.369	<0.369	<0.369	<0.295	19.0	2.08	3.46
5/15/2023	Run 12	Stepwise - Venturi	NR	Method 1633	334	36.6	58.8	30.1	9.67	<0.376	<0.376	<0.376	<0.301	20.2	5.42	9.28
5/15/2023	Run 12	Stepwise - Venturi	NR	Method 1633	321	37.2	59.1	25.2	8.31	<0.375	<0.375	<0.375	<0.375	20.9	3.75	10.4
5/15/2023	Run 12	Stepwise - Venturi	SV1-10	Method 533	260	37.5	60.2	36.4	10.0	<0.896	<0.896	<0.896	<0.896	22.2	6.64	10.8
5/15/2023	Run 12	Stepwise - Venturi	SV1-20	Method 533	250	36.7	54.1	20.0	2.57	<0.839	<0.839	<0.839	<0.839	21.1	2.05	3.92
5/16/2023	Run 13A	Stepwise - Venturi	SV1-10	Method 1633	405	43.6	66.1	22.0	1.85	<0.367	<0.367	<0.367	<0.293	23.7	1.65	5.84
5/16/2023	Run 13B	Stepwise - Venturi	SV1-20	Method 1633	392	41.9	55.4	5.10	0.836	<0.373	<0.373	<0.373	<0.299	21.8	<0.373	2.90
5/16/2023	Run 13A	Stepwise - Venturi	SV1-10	Method 533	296	45.2	67.0	19.8	5.28	<0.906	<0.906	<0.906	<0.906	25.8	1.70	19.8
5/16/2023	Run 13B	Stepwise - Venturi	SV1-20	Method 533	291	42.3	57.2	6.09	4.68	<0.906	<0.906	<0.906	<0.906	25.6	<0.906	24.4
9/30/2024	Run 12A	Stepwise - Venturi	SV1-10	Method 1633	140	11.1	18.3	7.27	8.34	<0.507	0.687	<0.507	<0.406	6.39	2.44	20.4
9/30/2024	Run 12B	Stepwise - Venturi	SV1-20	Method 1633	61.4	6.10	7.76	2.89	6.44	1.23	1.40	0.876	<0.447	2.68	<0.559	14.3
9/30/2023	Run 12A	Stepwise - Venturi	SV1-10	Method 533	185	13.7	23.0	7.48	4.14	<1.76	<1.76	<1.76	<1.76	11.0	2.86	13.3
9/30/2023	Run 12B	Stepwise - Venturi	SV1-20	Method 533	146	11.1	14.0	3.63	<1.84	<1.84	<1.84	<1.84	<1.84	8.34	1.02	3.73
4/4/2024	Run 12A	Stepwise - Venturi	SV1-10	Method 1633	476	53.0	90.3	29.9	12.9	<0.417	<0.417	<0.417	<0.334	29.0	3.19	9.76
4/8/2024	Run 17A	Stepwise - Venturi	SV1-10	Method 533	333	35.1	56.6	25.1	20.2	<0.909	<0.909	<0.909	<0.909	19.5	4.80	11.3
4/9/2024	Run 14A	Stepwise - Venturi	SV1-10	Method 533	314	34.5	59.0	29.3	12.4	<0.883	<0.883	<0.883	<0.883	19.7	5.18	5.77
4/10/2024	Run 15A	Stepwise - Venturi	SV1-10	Method 533	428	47.5	91.4	43.1	21.4	<0.916	<0.916	<0.916	<0.916	31.6	6.07	15.7
4/10/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 533	496	55.9	105	45.7	12.7	<0.912	<0.912	<0.912	<0.912	34.8	5.25	6.93
4/17/2024	Run 19A	Stepwise - Venturi	SV1-10	Method 533	320	36.1	53.5	33.6	39.1	<0.909	<0.909	<0.909	<0.909	18.1	8.97	19.7
4/18/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	316	34.0	60.7	24.6	10.9	<0.478	<0.478	<0.478	<0.383	19.5	3.39	5.68
4/18/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	329	36.5	74.0	27.2	8.79	<0.503	<0.503	<0.503	<0.403	21.3	2.88	4.85
4/18/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	406	40.3	69.1	35.9	14.5	<0.382	<0.382	<0.382	<0.306	21.9	5.14	4.09

Sample Date	Run	Method	SAFF Vessel	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFUnA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
4/18/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	384	37.7	67.4	34.3	12.7	<0.393	<0.393	<0.393	<0.315	21.3	4.75	4.37
4/18/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 533	347	39.4	68.2	31.4	14.4	<0.899	<0.899	<0.899	<0.899	22.7	3.94	11.4
4/18/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 533	368	42.4	74.1	34.6	13.3	<0.893	<0.893	<0.893	<0.893	25.5	5.07	5.48
4/19/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 533	497	54.5	101	48.3	28.4	<0.893	<0.893	<0.893	<0.893	35.3	6.73	11.7
4/19/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	510	51.7	94.1	45.1	22.4	<0.378	<0.378	<0.378	<0.302	30.1	6.06	7.48
4/30/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	355	35.3	60.4	27.3	12.5	<0.384	<0.384	<0.384	<0.307	17.9	3.66	6.14
4/30/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	332	34.4	65.0	23.8	6.32	<0.38	<0.38	<0.38	<0.304	17.0	1.76	6.31
5/8/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	452	50.0	81.1	48.4	21.2	<0.544	<0.544	<0.544	<0.435	25.3	10.2	7.10
5/8/2024	Run 16A	Stepwise - Venturi	SV1-10	Method 1633	453	52.0	82.1	48.9	20.2	<0.381	<0.381	<0.381	<0.305	24.7	10.5	7.17

Legend: NR = not recorded.

Table E.42: Raleigh Creek Tank 3 PFAS Results.

Sample Date	Run	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
5/5/2023	Run 3	Method 533	77.5	8.58	8.4	17.4	258	8.61	5.68	<4.90	<4.90	<4.90	40.5	951
5/7/2023	Run 3	Method 533	352	51.7	122	710	7,300	119	107	<4.72	<4.72	33.2	945	15,100
5/11/2023	Run 7	Method 533	199	28.5	50.3	163	1,960	50.2	90.5	1.78	<0.859	17.4	247	4,540
5/11/2023	Run 7	Method 1633	<402	<201	<101	165	4,690	<101	<101	<101	<80.4	<101	286	18,500
5/13/2023	Run 8	Method 533	118	20.0	32.3	151	2,860	30.0	39.8	<15.6	<15.6	<15.6	274	7,310
5/13/2023	Run 8	Method 1633	123	<35.0	30.6	153	3,330	32.3	43.1	<17.5	<14.0	<17.5	215	8,500
5/15/2023	Run 12	Method 1633	<808	<404	<202	534	9,170	<202	<202	<202	<162	<202	585	26,000
4/18/2024	Run 16A	Method 1633	<412	<206	178	1,080	20,300	146	136	<103	<82.5	<103	1,200	54,100
4/18/2024	Run 16A	Method 1633	451	<198	228	1,260	19,800	161	157	<99	<79.2	<99	1,410	55,000
4/18/2024	Run 16A	Method 1633	452	<198	220	1,180	19,400	154	160	<99	<79.2	<99	1,440	54,600
4/18/2024	Run 16A	Method 533	350	48.8	205	1,340	21,900	175	170	<5.00	<5.00	39.6	1,620	70,200
4/18/2024	Run 16A	Method 533	348	50.3	203	1,360	22,300	175	169	<4.90	<4.90	41.2	1,730	69,900
4/19/2024	Run 16A	Method 1633	557	<199	266	1,750	25,700	149	204	<99.5	<79.6	<99.5	1,960	64,800
4/19/2024	Run 16A	Method 533	442	64.4	287	1,910	28,600	196	192	<5.10	<5.10	61.8	2,200	76,600
4/30/2024	Run 16A	Method 1633	394	197	194	1,020	15,800	116	134	<98.5	<78.8	<98.5	1,070	49,600
5/8/2024	Run 16A	Method 1633	583	<202	196	1,500	31,300	224	251	<101	<80.8	<101	1,900	81,100
5/8/2024	Run 16A	Method 1633	573	<202	225	1,580	32,300	237	179	<101	<80.8	<101	2,080	80,000

Table E.43: Raleigh Creek Tank 4 PFAS Results.

Sample Date	Lab Analysis	PFBA (ng/L)	PFPeA (ng/L)	PFHxA (ng/L)	PFHpA (ng/L)	PFOA (ng/L)	PFNA (ng/L)	PFDA (ng/L)	PFuNA (ng/L)	PFDoA (ng/L)	PFBS (ng/L)	PFHxS (ng/L)	PFOS (ng/L)
5/4/2023	Method 533	500	55	1,160	46,400	335,000	22,200	25,900	674	75.7	86	83,500	515,000
5/5/2023	Method 533	532	116	3,290	41,600	280,000	14,100	16,200	24.4	<16.7	256	67,500	449,000
5/17/2023	Method 533	463	136	2,540	30,200	2,540,000	8,750	10,400	28.0	<33.3	204	43,700	308,000
4/19/2024	Method 533	674	165	4,140	267,000	9,020,000	65,400	117,000	571	<19.2	324	767,000	20,300,000
4/19/2024	Method 1633	<80,000	<40,000	<20,000	228,000	7,130,000	43,400	72,300	<20,000	<16000	<20,000	578,000	18,500,000
4/19/2024	Method 1633	<80,000	<40,000	<20,000	240,000	7,580,000	48,900	73,900	<20,000	<16000	<20,000	638,000	19,300,000
5/8/2024	Method 1633	<40,000	<20,000	<10,000	164,000	3,880,000	37,800	64,600	<10,000	<8,000	<10,000	271,000	14,900,000
5/8/2024	Method 1633	<40,000	<20,000	<10,000	155,000	3,570,000	27,600	60,800	<10,000	<8,000	<10,000	250,000	12,700,000
5/17/2024	Method 1633	<40,000	<20,000	<10,000	78,400	1,880,000	14,600	19,800	<10,000	<8,000	<10,000	141,000	4,900,000

Table E.44: Raleigh Creek Run Settings.

Sample Date	Run	Method	Fill Level (mm)	Top-Up (LPM, Hz)	Top-Up Length (Min)	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5		Stage 6		Stage 7		Stage 8		Stage 9		Stage 10	
						Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)	Time (min)	Venturi Pump Frequency (Hz)
4/17/2023	Run 1	Stepwise - Venturi	2075	30, 29	5	5	20	5	21	5	22	5	23	5	24	5	25	5	26	5	27	5	28	5	29
4/18/2023	Run 2	Stepwise - Venturi	2100	30, 32	5	5	23	5	24	5	25	5	26	5	27	5	28	5	29	5	30	5	31	-	-
4/18/2023	Run 3a	Stepwise - Venturi	2100	30, 35	5	5	26	5	27	5	28	5	29	5	30	5	31	5	32	5	33	5	34	5	36
4/19/2023	Run 4	Stepwise - Venturi	2100	30, 38	5	5	29	5	30	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38
4/20/2023	Run 3	Stepwise - Venturi	2100	30, 35	5	5	26	5	27	5	28	5	29	5	30	5	31	5	32	5	33	5	34	5	36
4/21/2023	Run 4a	Stepwise - Venturi	2100	30, 38	5	5	29	5	30	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38
4/21/2023	Run 4b	Stepwise - Venturi	2100	30, 38	5	5	29	5	30	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38
4/25/2023	Run 7a	Stepwise - Venturi	2100	30, 41	5	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41
4/25/2023	Run 7b	Stepwise - Venturi	2100	30, 41	5	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41
5/1/2023	Run 9	Stepwise - Venturi	2100	30, 38	5	7	29	7	30	7	31	7	32	7	33	7	34	7	35	7	36	7	37	7	38
5/2/2023	Run 8	Stepwise - Venturi	2100	30, 38	5	3	29	3	30	3	31	3	32	3	33	3	34	3	35	3	36	3	37	3	38
5/3/2023	Run 10	Stepwise - Venturi	2100	10, 38	5	5	29	5	30	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38
5/4/2023	Run 11	Stepwise - Venturi	2100	20, 38	5	5	29	5	30	5	31	5	32	5	33	5	34	5	35	5	36	5	37	5	38
5/5/2023	Run 3	Stepwise - Venturi	2100	30, 35	5	5	26	5	27	5	28	5	29	5	30	5	31	5	32	5	33	5	34	5	36
5/7/2023	Run 3	Stepwise - Venturi	2100	30, 35	5	5	26	5	27	5	28	5	29	5	30	5	31	5	32	5	33	5	34	5	36
5/8/2023	Run 3	Stepwise - Venturi	2100	30, 35	5	5	26	5	27	5	28	5	29	5	30	5	31	5	32	5	33	5	34	5	36
5/11/2023	Run 7	Stepwise - Venturi	2100	30, 41	5	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41
5/13/2023	Run 8	Stepwise - Venturi	2100	30, 38	5	3	29	3	30	3	31	3	32	3	33	3	34	3	35	3	36	3	37	3	38
5/15/2023	Run 7	Stepwise - Venturi	2100	30, 41	5	5	32	5	33	5	34	5	35	5	36	5	37	5	38	5	39	5	40	5	41
5/15/2023	Run 12	Stepwise - Venturi	2100	30, 41	5	3	32	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41
5/16/2023	Run 13a	Stepwise - Venturi	2100	30, 41	5	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43	5	44
5/16/2023	Run 13b	Stepwise - Venturi	2100	30, 41	5	5	35	5	36	5	37	5	38	5	39	5	40	5	41	5	42	5	43	5	44
9/30/2023	Run 12A	Stepwise - Venturi	2080	30, 41	5	3	32	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41
9/30/2023	Run 12B	Stepwise - Venturi	2080	30, 41	5	3	32	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41
4/4/2024	Run 12A	Stepwise - Venturi	2080	30, 41	5	3	32	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41
4/8/2024	Run 17A	Stepwise - Venturi	2100	10, 41	5	2	32	2	33	2	34	2	35	2	36	2	37	2	38	2	39	2	40	2	41
4/9/2024	Run 14A	Stepwise - Venturi	2100	10, 41	5	3	32	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41
4/10/2024	Run 15A	Stepwise - Venturi	2100	10, 40	5	3	31	3	32	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40
4/10/2024	Run 16A	Stepwise - Venturi	2100	10, 42	5	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42
4/17/2024	Run 19A	Stepwise - Venturi	NR	NR	5	3	32	3	35	3	38	3	39	3	40	3	41	-	-	-	-	-	-	-	-
4/18/2024	Run 16A	Stepwise - Venturi	2100	10, 42	5	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42
4/19/2024	Run 16A	Stepwise - Venturi	2100	10, 42	5	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42
4/30/2024	Run 16A	Stepwise - Venturi	2100	10, 42	5	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42
5/8/2024	Run 16A	Stepwise - Venturi	2100	10, 42	5	3	33	3	34	3	35	3	36	3	37	3	38	3	39	3	40	3	41	3	42