Per- and Polyfluoroalkyl Substances (PFAS) in the Nueces, Corpus Christi and Oso Bays

Annual Report

Publication CBBEP - 175
Project Number –2206
August 2023

Prepared By:

J. David Felix, Ph.D., Principal Investigator
And
Erin Taylor, Field Assistant
Department of Physical and Environmental Sciences
Center for Water Supply Studies
Texas A&M University – Corpus Christi
6300 Ocean Drive, Unit 5850
Corpus Christi, Texas 78412
(361) 825-4180
joseph.felix@tamucc.edu

SUBMITTED TO:

Adrien Hilmy
Coastal Bend Bays & Estuaries Program
1305 N Shoreline Blvd, Suite 205
Corpus Christi, TX, 78401

The views expressed herein are those of the authors and do not necessarily reflect the views of CBBEP or other organizations that may have provided funding for this project.

PREPARED IN COOPERATION WITH THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
The preparation of this report was financed through funding from the Texas Commission on Environmental Quality.

Table of Contents

Executive Summary

Per- and polyfluoroalkyl substances (PFAS) are used in a number of commercial (e.g., firefighting foams, plastic manufacturing) and household (e.g., cookware, food packaging) products leading to a ubiquitous accumulation of these compounds in nature. Despite this, little data is available about the current status of PFAS concentrations in estuaries and groundwater of the Texas Coastal Bend. To address this, six surface water sites and three wells were sampled monthly in the Corpus Christi Bay watershed from May 2022 to April 2023. Using a modified EPA method 537.1 with isotope dilution quantification, 70 PFAS were targeted for measurement, and 21 and 15 of the 70 compounds were detected in surface and well samples, respectively. Total PFAS (ΣPFAS) in the surface samples ranged from 2.1 to 126.1 ng/L with an average of 21.7 ± 17.9 ng/L. ΣPFAS in the well samples ranged from 1.2 to 41.6 ng/L with an average of 15.7 ± 13.3 ng/L. PFOS was the dominate PFAS species in surface water samples contributing 28% of ΣPFAS while PFHxS was the dominate species in well water contributing 44% of ΣPFAS.

Surface water sites S1 to S4 and S6 did not have significantly different ΣPFAS concentrations (ANOVA, $p > 0.05$) but site S5 located in Oso Bay had significantly higher concentrations (ANOVA, $p < 0.05$) driven primarily by PFOS. Well 1 had significantly higher ΣPFAS than the other two wells (ANOVA, $p < 0.05$) and this was due to PFHxS (62%) being the major contributor while PFOS (25%) was also a substantial contributor. Surface waters as a whole showed no significant temporal trend in ΣPFAS (ANOVA, $p > 0.05$). However, site S5 had noticeable fluctuations with peaks in July, October and April driven primarily by PFOS variations. Wells 2 and 3 concentrations were relatively consistent throughout the sampling period while well 1 concentrations varied and were driven by fluctuations in PFHxS.

The PFOA+PFOS concentrations are within the range of other US estuary sites and surface water averages are ~ two orders of magnitude higher than that of the open ocean. In 2016 the EPA introduced a drinking water health advisory for PFOA+PFOS of 70 ppt but recently replaced this with an interim advisory of 0.004 ppt for PFOA and 0.02 ppt for PFOS. The average PFOA+PFOS for surface and well samples were 8.0 ± 12.3 and 2.7 ± 4.0, respectively and all surface and well sample concentrations were higher than the 2022 interim health advisory. This year, a National Primary Drinking Water Regulation (NPDWR) was proposed for six PFAS including PFOA, PFOS, PFNA, HFPO-DA, PFHxS and PFBS which recommends maximum contaminant levels (MCLs) for PFOA and PFOS and a Hazard Index (HI) for combined PFNA, HFPO-DA, PFHxS, and PFBS. If this study's surface and well samples were indicative of levels that could be found in drinking water in the region, there would have been 47 samples with MCL exceedances and 11 samples with HI exceedances. It must be noted in this comparison the study samples are not drinking water but indicate ambient environmental levels in the Coastal Bend region and the advisory levels are compared as a point of reference.

Consistently elevated surface and well concentrations were observed in the Oso Bay/Naval Air Station region and suggest a potential risk of PFAS bioaccumulation in local marine life, possibly serving as a significant pathway of PFAS exposure for humans. Future research should focus on sediment and biota PFAS composition, with targeted sampling in the Oso Bay and Naval Base area. As the U.S. establishes consumption guidelines for contaminated foods and sets advisories, assessing potential PFAS concentrations in marine life will be essential in safeguarding public health.

Acknowledgements

We thank Abril Garcia Lunar for assisting in the field and Kristen Lincoln and Sofia Miatello for aiding in data organization. We thank Eurofins for PFAS analysis and the Coastal Bend Bays & Estuaries Program for supporting this project.

List of Figures

List of Tables

Per- and polyfluoroalkyl substances (PFAS) in the Nueces, Corpus Christi and Oso Bays

INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) were historically and are currently used in a number of commercial (e.g., firefighting foams, plastic manufacturing) and household (e.g., cookware, food packaging) products leading to a ubiquitous accumulation of these compounds in nature (NAS 2022). Due to their known links to reproductive, developmental, and immunological effects in humans, these compounds have received increased national attention (Fenton et al., 2020). Despite this, little data is available about the current status of PFAS concentrations in estuaries and groundwater of the Texas Coastal Bend.

Due to direct ingestion by humans, drinking PFAS contaminated water has been the primary focus of the EPA and state governments, thus they often ignore coastal water contamination that leads to accumulation in marine food webs. In turn, seafood consumption is a primary pathway of PFAS exposure for adults (Fair et al., 2019, Domingo and Nadal 2017). Due to historical and current PFAS production and household/commercial uses, present loading and legacy effects could be leading to accumulation in the Coastal Bend's water resources. For instance, the Corpus Christi Naval Air Station located on Oso and Corpus Christi Bays is known to have used PFAS firefighting products and groundwater testing at this station revealed PFOS + PFOA (perfluorooctane sulfonate + perfluorooctanoic acid) concentrations up to 510 ppt (USDON 2018). For reference, this is ~7 times the 2016 EPA drinking water health advisory guidelines of 70 ppt and several orders of magnitude higher than the 2022 interim EPA health advisory of 0.004 and 0.02 ppt for PFOA and PFOS, respectively (USEPA 2023). This type of environmental concentration data is scarce, so the regional health risk is unclear. With continued focus on industrial growth in the coastal bend (i.e., Chemours Company facility located on Corpus Christi Bay is the world's largest producer of the PFAS refrigerant, HFO-1234yf), local PFAS production and use will increase making it essential to understand the current state of PFAS contamination and locate potential hotspots of PFAS accumulation.

Monthly sampling (5/2022 to 4/2023) was conducted at six surface water and three groundwater sites in the Corpus Christi Bay watershed and 70 PFAS compounds were measured including PFOS and PFOA. The primary objective was to provide an assessment of the current PFAS levels so stakeholders can discern potential human and ecosystem risk of PFAS exposure in the Coastal Bend. Evaluating this risk is the first step to creating informed mitigation strategies and determining potential PFAS contamination issues will help alleviate future economic strains associated with remediation. In addition, the Texas Department of State Health Services has expressed interest in the project's PFAS data as they are currently undergoing a 4-year study investigating PFAS in fish throughout Texas and this project will help identify PFAS hot spots for future sampling.

METHODS

Site Description

Sampling sites were located in the Corpus Christi Bay watershed. Corpus Christ Bay is a shallow primary bay contained within the Nueces Estuary System. It is separated from the Gulf of Mexico by a barrier island and is connected to two secondary bays, Oso and Nueces, which are fed by rivers. The city of Corpus Christi's population is ~330,000 and its anthropogenic activities including airports, petroleum industry, wastewater treatment plants, fire-fighting training areas and military bases provide various potential PFAS sources to the watershed.

There were six surface water and three well water sampling sites (Table 1, Figure 1, S denotes surface and W denotes well). Site S1 (Campus Beach) is located in Corpus Christi Bay off the coast of Texas A&M University – Corpus Christi (TAMU-CC). Site S2 (McGee Park) is located directly of the seawall in McGee Park in downtown Corpus Christi. Site S3 (Indian Point) is located in Corpus Christi Bay off the coast of Indian Point, a public recreation area separating Nueces and Corpus Christi Bays and located on the border between Nueces and San Patricio Counties. Site S4 (Ingleside Beach Club) is located directly off the coast of the northeast shore of Corpus Christi Bay in a residential area, Ingleside on the Bay. Site S5 (Oso Bay) is located in Oso Bay just adjacent to the Oso Bay bridge. Site S6 (Nueces River at Hazel Bazemore Park), is a Nueces River sampling site located in a 30 ha public park just west of Nueces Bay. Site W1 (Campus Well) is a monitoring well located on the north side of TAMU-CC campus adjacent to Corpus Christi Bay. Site W2 (Botanical Gardens Well) is a monitoring well located in a 73 ha botanical garden in the southern outskirts of Corpus Christi and adjacent to the Oso River which flows into the Oso Bay. Site W3 (Hazel Bazemore Park Well) is located in the same public park as S6 near the Nueces River which flows to the Nueces Bay.

Table 1. Well and surface sampling site names and locations.

Site	Site Name	latitude	longitude
S1	Campus Beach	27.71406	-97.319
S2	McGee Park Beach	27.78589	-97.3934
S3	Indian Point	27.85185	-97.3583
S4	Ingleside Beach Club	27.82684	-97.2255
S5	Oso Bay	27.68158	-97.3142
S6	Nueces River at Hazel Bazemore Park	27.86711	-97.6396
W1	Campus Well	27.71476	-97.3226
W2	Botanical Gardens Well	27.65832	-97.4069
W3	Hazel Bazemore Park Well	27.86564	-97.6393

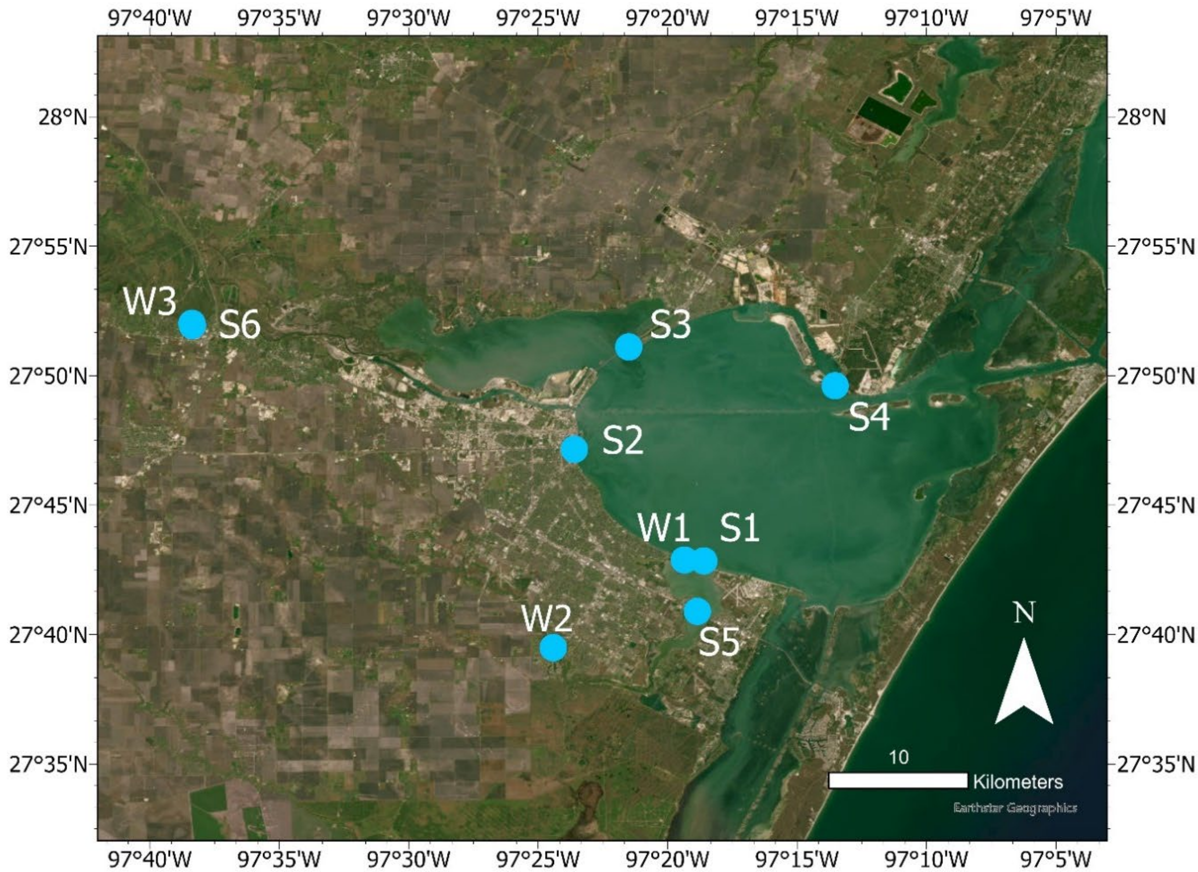

Figure 1: Surface water and well water sampling locations represented as blue circles. Surface = S# ; Well = W#. These sites are currently based on existing wells and surface water access.

Sample Collection

Monthly sampling of surface and ground water followed the general PFAS sampling guidance as outlined by the Michigan Department of Environment (EGLE 2020). On the day of sampling, no perfumes, lotions, cosmetics, sunscreens, or bug sprays were worn. Fabric softener was not used on field clothing. All handling of sampling equipment and samples was done while wearing a fresh pair of nitrile gloves. For each sample, two 250-mL HDPE bottles were used for sample collection, and a fine-point sharpie was used to mark the bottles.

Before going into the field, a blank was created using HPLC water. The blank was collected the morning of sampling using a 250-mL HDPE bottle and stored in a Styrofoam cooler filled with fresh, loose ice (no chemical ice packs) in a plastic bag with the rest of the collection bottles. As samples were collected, they were labelled and then placed back into the cooler. Surface water was collected at 20 cm below the air-water interface. Groundwater sampling was from surficial monitoring wells and followed the standard procedure as set forth in the TCEQ Surface Water Quality Monitoring Procedures Volume 1: Chemical Monitoring Methods for Water, Sediment, and Tissue (October 2008). Before groundwater samples were collected, the well was purged by three well volumes. To determine the amount of stagnant water necessary to purge, the amount of standing water was first calculated by measuring the diameter of the well, total depth of the water column, and the water level at the time of sampling. The groundwater elevation at the time of sampling was calculated by subtracting depth to water from the ground elevation (taken in the field with measuring tape). According to the EPA, the calculation for the volume of water to purge is:

$$V = 3(\pi\ d2\ h)$$

Where: h = height of water in the well in feet, d = diameter of well in inches, and V = volume of water in gallons. A 20-L bottle was used for collecting the purged water and discarded. Groundwater was then sampled at the wellhead using a peristaltic pump after all YSI readings were stable. After all samples were collected, they were brought back to the lab where they were double-bagged and placed in the refrigerator until overnight shipment to Eurofins Environmental Testing Northern California, LLC (EETNC).

PFAS analysis

There are thousands of PFAS compounds (Buck et al., 2021) and most studies focus on two predominate PFAS compounds, PFOA and PFOS. This study targeted 70 specific PFAS compounds including PFOA and PFOS. PFAS determination was performed by EETNC following Eurofins SOP WS_LC_0025 (Eurofins Sacramento 2021), which is based upon EPA Method 537.1 (Shoemaker and Tettenhorst 2020) but incorporates isotope dilution quantitation. This method is termed "modified EPA method 537.1" for the purposes of this report. In summary, water samples were extracted using a solid phase extraction (SPE) cartridge. PFAS were eluted from the cartridge with an organic solution. The final 80:20 methanol:water extracts were analyzed by LC/MS/MS. PFAS were separated from other components on a C18 column with a solvent gradient program. The mass spectrometer was operated in the electrospray (ESI) negative ion mode for the analysis of PFAS. An isotope dilution technique was employed with this method for the compounds of interest. The isotope dilution analytes (IDA) consisted of carbon-13 labeled analogs, oxygen-18 labeled analogs, or deuterated analogs of the compounds of interest, and they were fortified into the samples at the time of extraction. This technique allows for the correction for analytical bias encountered when analyzing more chemically complex environmental samples. The isotopically labeled compounds were chemically similar to the compounds of concern and are therefore affected by sample-related interferences to the same extent as the compounds of concern. Compounds that do not have an identically labeled analog are quantitated by the IDA method using a closely related labeled analog.

RESULTS

Overall PFAS concentrations

Twenty-one of the 70 targeted PFAS compounds were detected in the surface samples and 15 were detected in the well samples (Figure 2, 3, Table 2). Total PFAS (ΣPFAS) in the surface samples ranged from 2.1 to 126.1 ng/L with an average of 21.7 ± 17.9 ng/L and the minimum and maximum both occurred in S5 samples. ΣPFAS in the well samples ranged from 1.2 to 41.6 ng/L with an average of 15.7 ± 13.3 ng/L and the minimum and maximum occurred in W3 and W1 samples, respectively. PFOS was the dominate species in surface water samples contributing 28% of ΣPFAS while PFHxS was the dominate species in well water contributing 44% of ΣPFAS (Figure 4). Many of the detected PFAS compounds have the same source and/or are degradation products of each other so many were significantly correlated throughout the surface and well samples. The individual correlations along with their correlation coefficient and level of significance are given in Appendix B (surface) and Appendix C (wells).

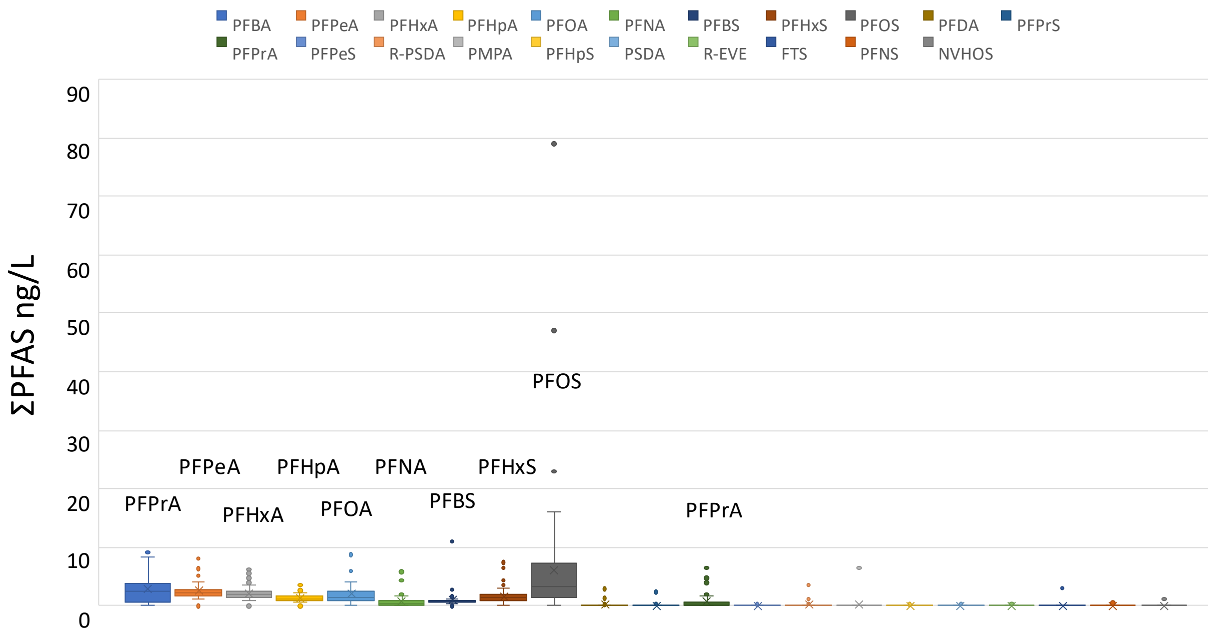

Figure 2. Box and whisker plots of detected PFAS compound concentrations across all surface samples (n = 72) for the entire sample period May 2022 to April 2023.

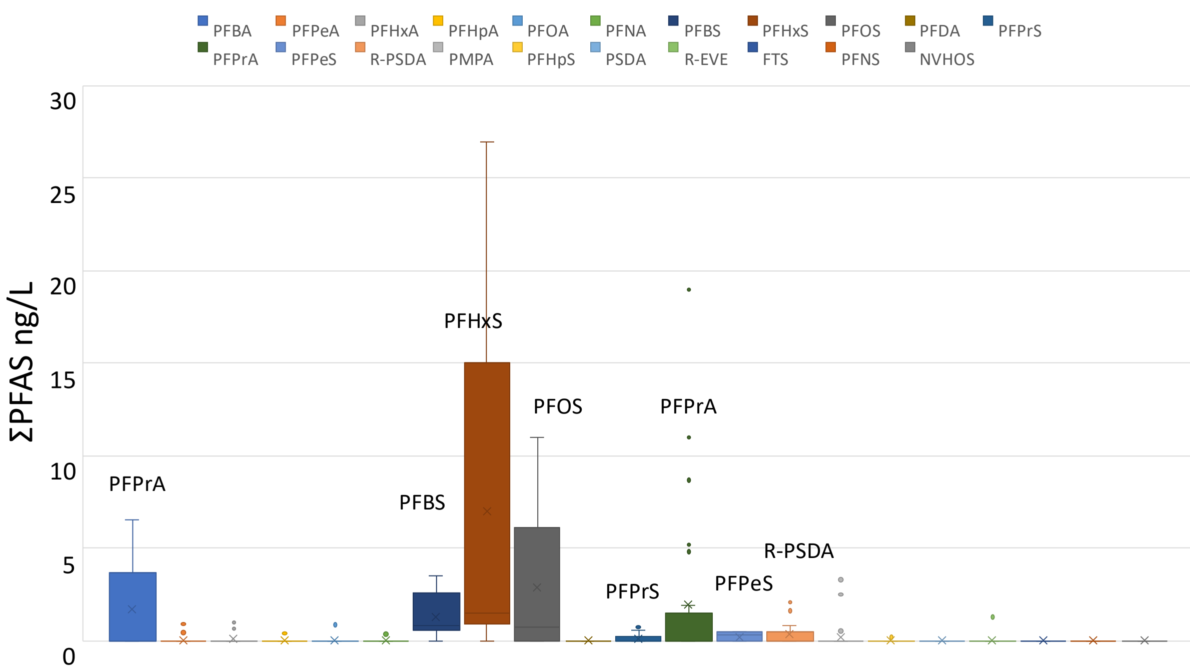

Figure 3. Box and whisker plots of detected PFAS compound concentrations across all well samples (n = 36) for the entire sample period May 2022 to April 2023.

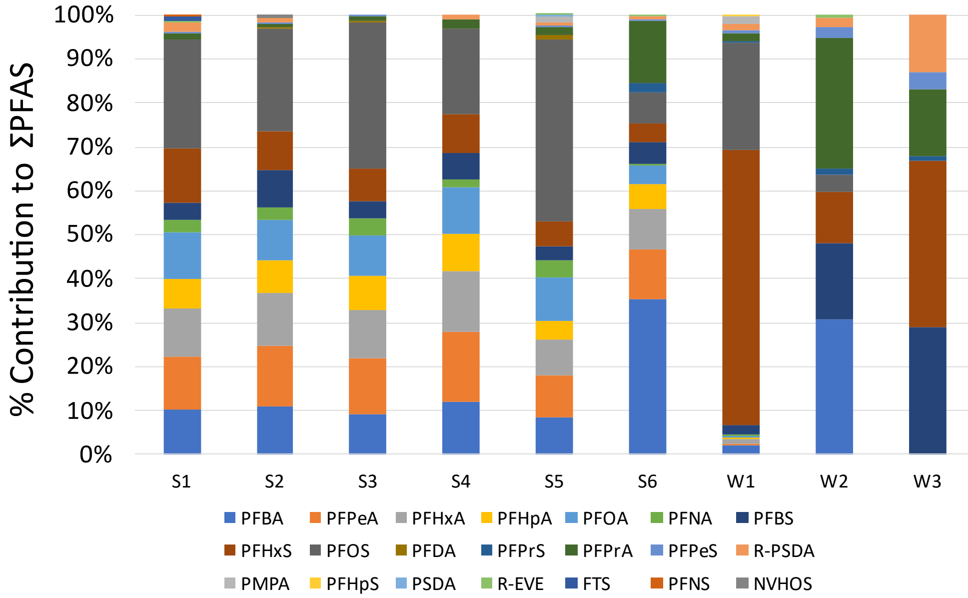

Figure 4. Percent contribution of detected PFAS compound concentrations to ΣPFAS across all surface (n = 72) and well samples (n = 36) for the entire study period May 2022 to April 2023.

Table 2. 21 of the 70 measured PFAS compounds were above the detection limit in at least one of the surface or well samples. They are listed below with their minimum, maximum and average concentrations across all well and surface samples. nd = no detect. The entire list of 70 measured compounds is in Appendix A.

PFAS compound	Surface Min (ng/L)	Surface Max (ng/L)	Surface Ave (ng/L)	Well Min (ng/L)	Well Max (ng/L)	Well Ave (ng/L)
PFBA	nd	9.1	2.9 ± 2.4	nd	8.5	1.8 ± 2.2
PFPeA	nd	8.1	2.6 ± 1.3	nd	0.9	0.04 ± 0.2
PFHxA	nd	6.2	2.2 ± 1.1	nd	1.0	0.09 ± 0.3
PFHpA	nd	3.6	1.6 ± 0.6	nd	0.5	0.05 ± 0.1
PFOA	nd	9.0	1.9 ± 1.7	nd	0.9	0.05 ± 0.2
PFNA	nd	5.8	0.6 ± 0.9	nd	0.4	0.01 ± 0.06
PFBS	nd	11	1.0 ± 1.3	nd	3.5	1.3 ± 1.1
PFHxS	nd	6.5	1.6 ± 1.1	nd	27	7.0 ± 9.8
PFOS	nd	79	6.1 ± 11	nd	11	2.8 ± 4.1
PFDA	nd	2.9	0.1 ± 0.4	nd	0	0 ± 0
PFPrS	nd	2.3	0.1 ± 0.3	nd	0.7	0.1 ± 0.2
PFPrA	nd	6.5	1.1 ± 2.6	nd	19	1.8 ± 3.9
PFPeS	nd	0.6	0.1 ± 0.2	nd	0.5	0.2 ± 0.2

R-PSDA	nd	3.5	0.3 ± 0.6	nd	2.2	0.4 ± 0.7
PMPA	nd	6.5	0.7 ± 1.5	nd	3.3	0.2 ± 0.7
PFHpS	nd	0.5	0.06 ± 0.1	nd	0.4	0.02 ± 0.1
PSDA	nd	0.4	0.005 ± 0.04	nd	0	0 ± 0
R-EVE	nd	0.4	0.02 ± 0.08	nd	1.3	0.04 ± 0.2
FTS	nd	3.0	0.04 ± 0.4	nd	0	0 ± 0
PFNS	nd	0.4	0.006 ± 0.04	nd	0	0 ± 0
NVHOS	nd	1.2	0.02 ± 0.1	nd	0	0 ± 0

Spatial and temporal PFAS concentrations

Surface water sites S1 to S4 and S6 did not have significantly different ΣPFAS concentrations (ANOVA, $p > 0.05$) across the duration of the study but site S5 located in Oso Bay had significantly higher concentrations (ANOVA, $p < 0.05$) driven primarily by PFOS (41%) (Figure 4, 5). PFOS was the primary contributor to ΣPFAS at surface sites 1 to 5, while the primary contributor to ΣPFAS at S6 was PFBA (35%) (Figure 4). Well 1 had significantly higher ΣPFAS than the other two wells (ANOVA, $p < 0.05$) and this was due to PFHxS (62%) being the major contributor while PFOS (25%) was still a substantial contributor (Figure 4, 5). PFHxS was also the major contributor to well 3 (38%) but ΣPFAS were lowest (2.2 ng/L) of all surface or well sites. Well 2 located at the Botanical Gardens percent PFAS composition was different from the other wells with PFBA (31%) and PFPrA (29%) being the primary contributors. Despite being in a different region of the sampling area, W2 percent contributions were similar to the outlier surface site, S6, which also had similar large contributions from PFBA and PFPrA.

Surface waters as a whole show no significant temporal trend (ANOVA, $p > 0.05$) (Figure 7). However, when observed individually, S5 had noticeable fluctuations with high peaks in July, October and April driven primarily by PFOS variations while peaks in May and July were driven by PFOS, PFOA, PFBA and PFPeA. S1 and S2 had small but noticeable peaks in November supported by increases in PFOS at S1 and PFOS and PFBS at S2. Small December peaks were observed at S3 and S6 as a product of increased PFOS. (Figure 8, Appendix D and E). Temporal well trends were further investigated individually (Figure 9). Wells 2 and 3 concentrations were relatively consistent while well 1 concentrations varied throughout the sampling driven by fluctuations in PFHxS. For a more in-depth portrayal of temporal breakdown of individual PFAS contribution at each site for each month, the complete data set and percent contribution figures are given monthly in Appendix D and E.

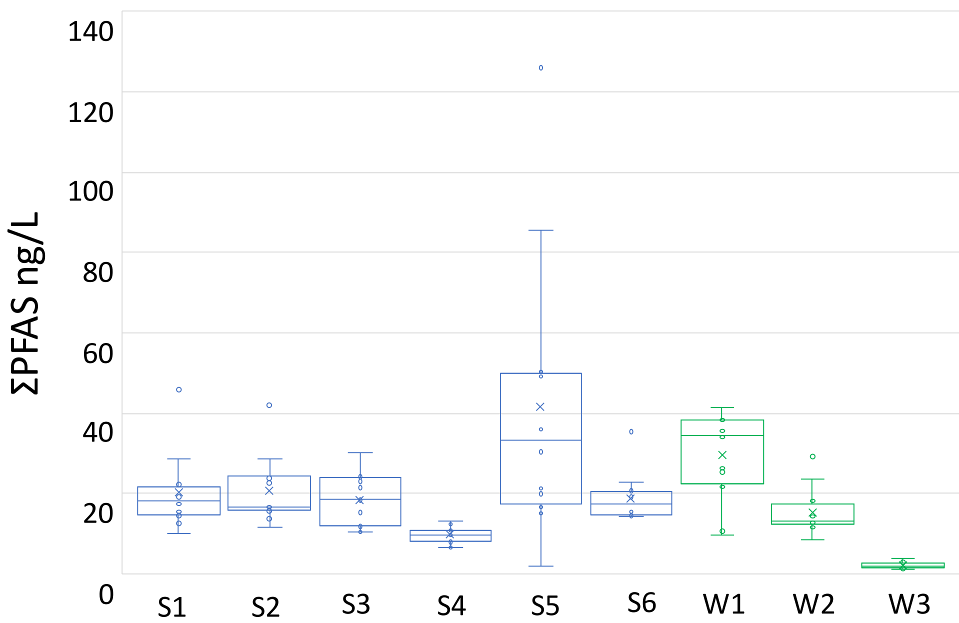

Figure 5. Box and whisker plot of ΣPFAS for each surface and well site over the entire sampling period May 2022 to April 2023.

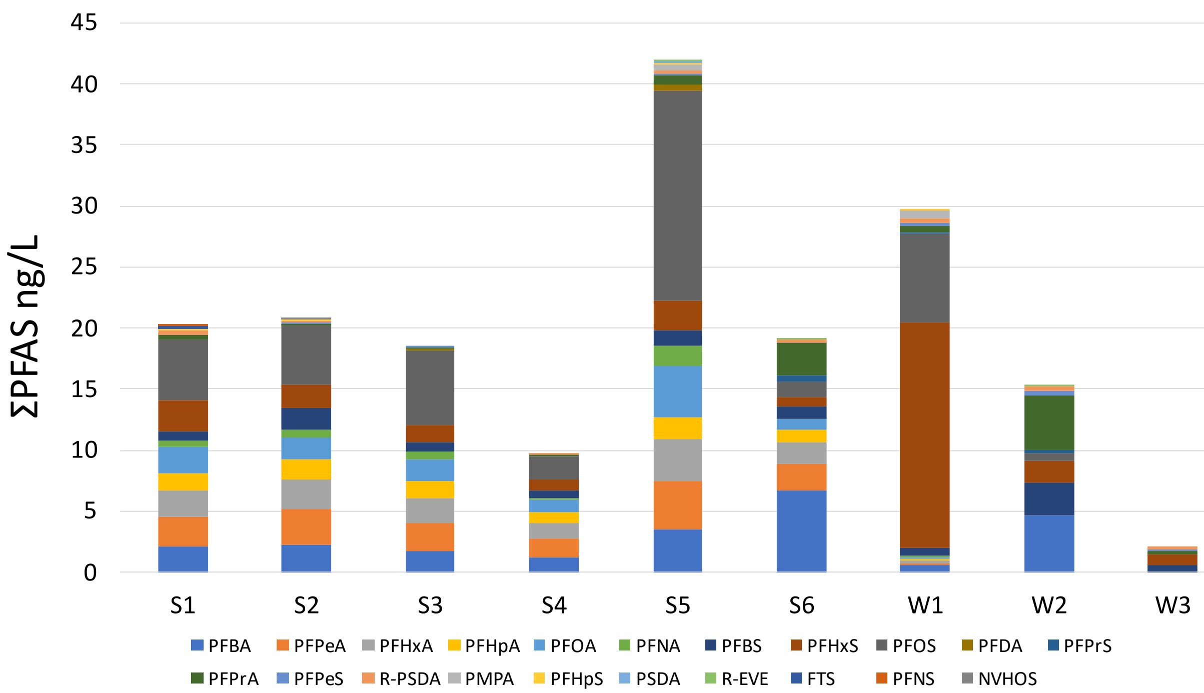

Figure 6. Stacked column plots of PFAS compound average concentrations for each surface and well site for the entire study period May 2022 to April 2023.

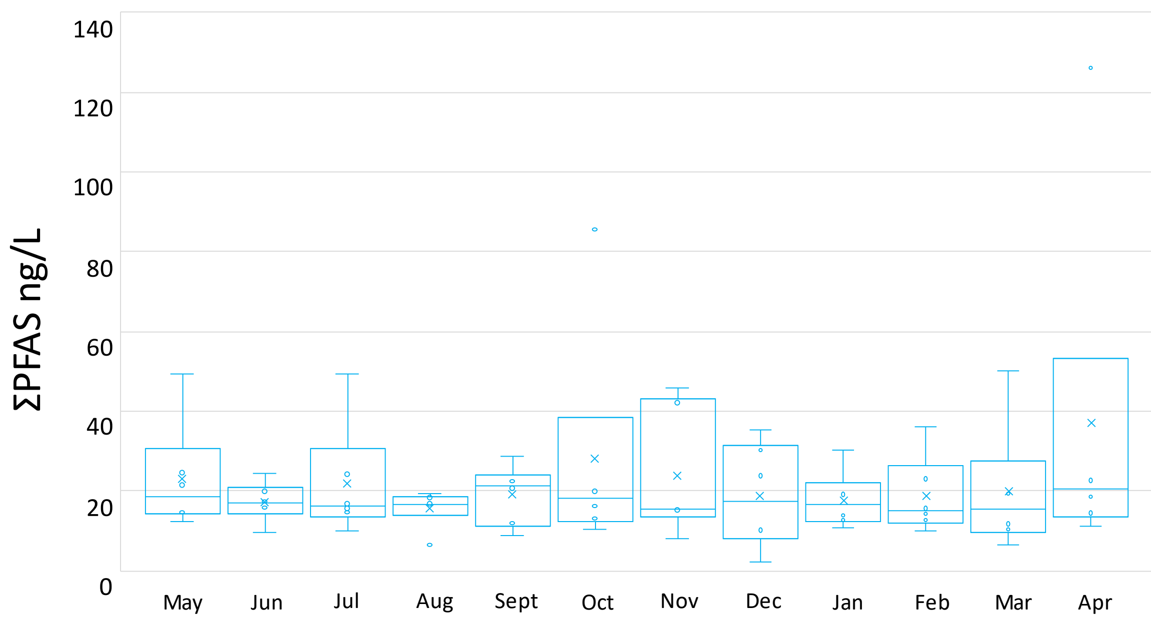

Figure 7. Monthly box plots of PFAS concentrations at all wells combined during the study period May 2022 to April 2023.

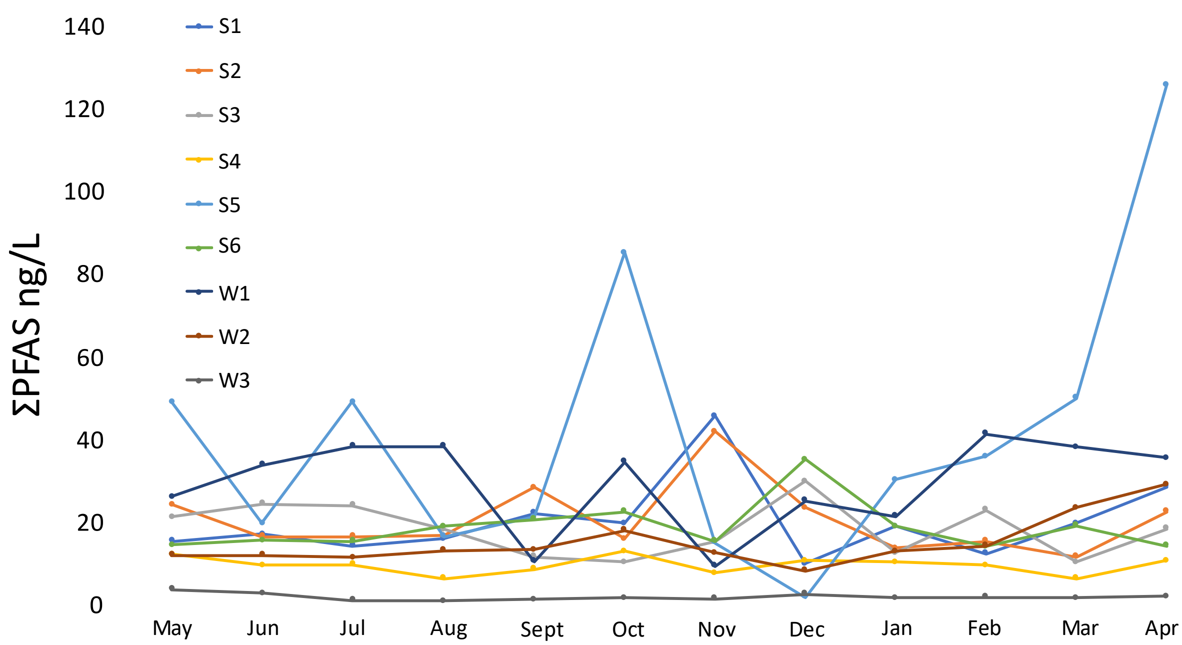

Figure 8. Monthly PFAS concentrations at all surface and well sites during the study period May 2022 to April 2023.

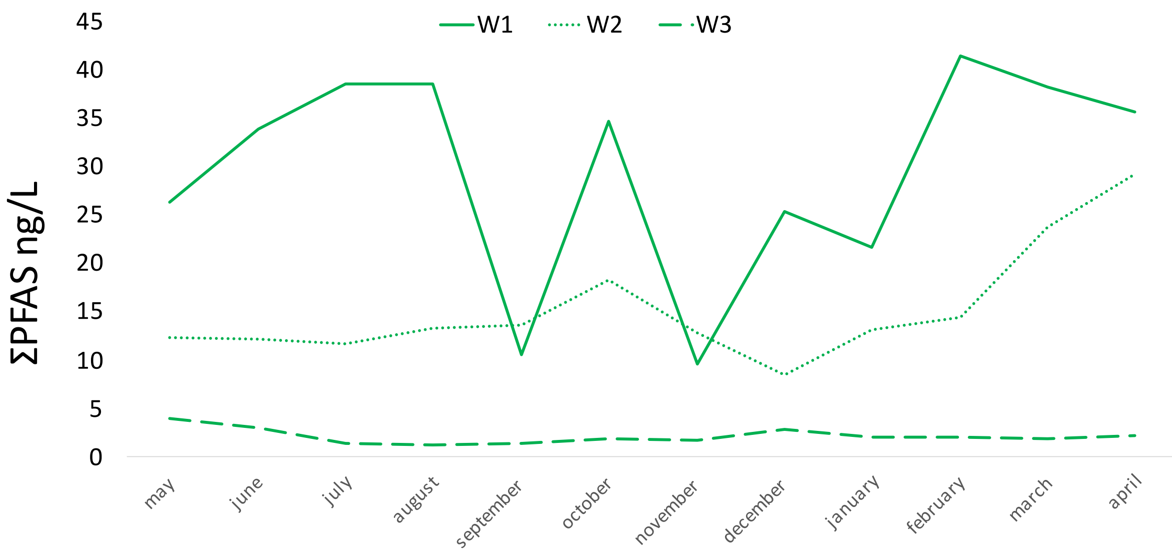

Figure 9. Monthly ΣPFAS concentrations at each well during the study period May 2022 to April 2023.

PFOS/PFOA concentrations

In 2016 the EPA introduced a drinking water health advisory for PFOA+PFOS of 70 ppt but recently replaced this with an interim advisory of 0.004 ppt for PFOA and 0.02 ppt for PFOS. The average PFOA+PFOS for surface and well samples were 8.0 ± 12.3 and 2.7 ± 4.0, respectively with S5 and W1 being significantly higher than their site counterparts and all surface and well sample concentrations were higher than the 2022 interim health advisory. It must be noted in this comparison that the study samples are not drinking water but indicate ambient environmental levels in the Coastal Bend region. The observed PFOA+PFOS levels are within the higher range when compared to average PFOS + PFOA at other estuary related sites in the US and surface water averages are ~ two orders of magnitude higher than that of the open ocean. However, not many estuary-based studies exist in the US or worldwide, so this comparison is not comprehensive. A summary of just these two compounds in previous coastal US PFAS studies is provided to enable comparison to other regions of the US (Table 3).

Table 3. PFOS and PFOA average concentrations reported in other US estuary-associated surface water body studies. Several of these references are found in reviews of PFAS in water bodies by Jarvis et al., 2021 and Kudwadkar et al., 2022.

Location	PFOS	PFOA	Reference
Sarasota Bay, FL	0.90	-	Houde et al., 2006

Staten Island, NY	1.66	4.05	Zhang et al., 2016
Lower NY Harbor, NY	0.755	2.02	Zhang et al., 2016
Cape Fear River, NC	31.2	-	Nakayama et al. (2007)
Narragansett Bay, RI	2.2	1.2	Benskin et al. 2012
Bristol Harbor, RI	0.508	1.2	Zhang et al., 2016
South Ferry Road Pier, RI	0.161	0.267	Zhang et al., 2016
Woonasquatucket River, RI	14.6	7.03	Zhang et al., 2016
Charleston Harbor, SC	12.0	-	Houde et al., 2006
Puget Sound, WA	2.3	2.3	Dinglasan-Panlilio 2014
Clayoquot Sound, WA	0.32	1.2	Dinglasan-Panlilio 2014
Biscayne Bay and canals	11.04	2.92	Li et al., 2022
Western Pacific Ocean	0.078	0.142	González-Gaya et al. 2014
North Atlantic Ocean	0.036	0.338	Yamashita et al., 2005
Mid Atlantic Ocean	0.073	0.439	Yamashita et al., 2005
Corpus Christi watershed surface	1.9 ± 1.7	6.1 ± 11	This study
Corpus Christi watershed well	2.6 ± 4.0	0.05 ± 0.2	This study

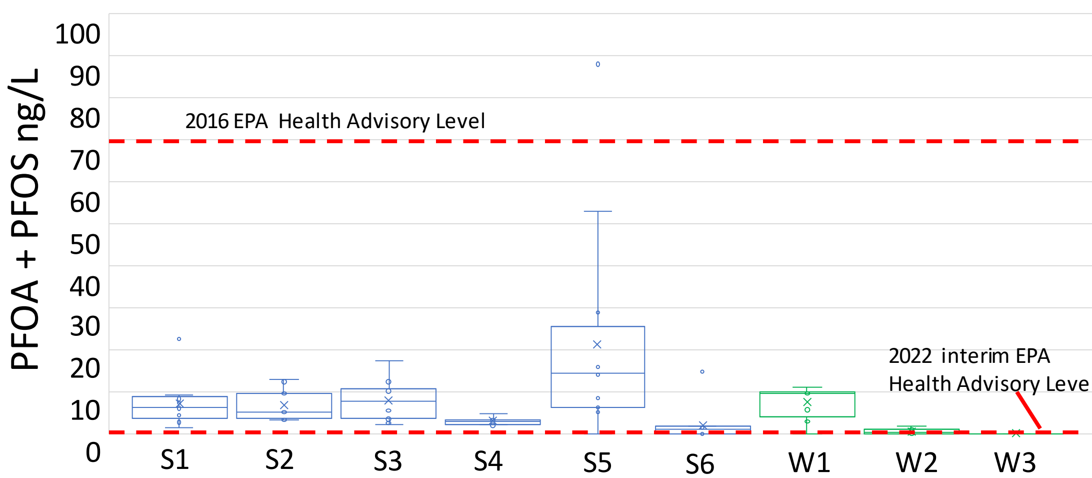

Figure 10. Box and whisker plot of PFOA + PFOA concentrations for individual surface and well sites for the entire sample period May 2022 to April 2023.

DISCUSSION/IMPLICATIONS

The EPA has taken significant strides to address PFAS contamination through a strategic road map focused on cleanup acceleration, prevention of new contamination, and advancing scientific understanding of PFAS (USEPA 2021). Notably, specific drinking water health advisories for PFOA and PFOS in drinking water were set at 70 ppt in 2016, but a 2022 interim health advisory has drastically reduced this to 0.004 ppt for PFOA and 0.02 ppt for PFOS. This year, a National Primary Drinking Water Regulation (NPDWR) was proposed for six PFAS including PFOA, PFOS, PFNA, HFPO-DA, PFHxS, and PFBS. The regulation recommends a maximum contaminant level (MCL) for PFOS and PFOA of 4 ppt and a hazard index (HI) of 1.0 as a maximum contaminant level goal (MCLG) for the other four compounds combined (USEPA 2023b). For reference, HI was calculated for each of the study samples, and if these surface and well water samples were indicative of levels that could be found in drinking water sources in the region, there would have been 47 samples with MCL exceedances and 11 samples with HI exceedances under the proposed NPDWR (Table 4).

In this study, all PFAS covered in the proposed NPDWR drinking water regulation except, HFPO-DA were detected at significant levels, with PFOS and PFHxS being the dominant PFAS present and occurring at the highest concentrations at sites S5 and W1. These sites are located near Oso Bay and the Corpus Christi Naval Air Station (NAS), which reported a spill of approximately 55 thousand liters of an aqueous film-forming foam (AFFF) fire suppressant containing PFAS in 2015 (USEPA 2022). Moreover, a previous groundwater sampling project at the NAS reported PFOS + PFOA concentrations as high as 510 ppt (USDON 2018). These elevated concentrations in the Oso Bay/Air Station region suggest a potential risk of PFAS bioaccumulation in local marine life, possibly serving as a significant pathway of PFAS exposure for humans. Studies in other areas, such as Tampa Bay, have shown that high PFAS levels in sediments are reflected in the fish population, with fish mirroring the high percentage of PFOS contributions found in sediments (Pulster et al., 2022). To better understand this potential pathway in the Corpus region, future research should focus on sediment and biota composition, with particular attention to the higher values observed at sites S5 and W1, warranting targeted sampling in the Oso Bay and Naval Base area. As the U.S. establishes consumption guidelines for contaminated foods and sets advisories, assessing potential PFAS concentrations in marine life will be essential in safeguarding public health.

Table 4. A National Primary Drinking Water Regulation (NPDWR) was proposed this year (2023) for six PFAS including PFOA, PFOS, PFNA, HFPO-DA, PFHxS and PFBS. The table displays the concentrations and ranges of these six PFAS compounds in the study samples. The associated hazard index (HI) for PFNA+HFPO-DA+ PFHxS+ PFBS is reported as well as HI and MCL exceedances if the samples were treated as drinking water. *nd= no detect.

Surface (n = 72)	**Range ng/L**	**Average ng/L**	**# of MCL exceedances (> 4 ppt)**	**Range HI**	**Ave HI**	**# of HI exceedances > 1.0**
PFOA	9.0	1.9 ± 1.7	6			
PFOS	79	6.1 ± 11	31			
PFNA	5.8	0.6 ± 0.9				
HFPO-DA	nd	nd				
PFHxS	6.5	1.6 ± 1.1				
PFBS	11	1.0 ± 1.3				
PFNA+HFPO-DA+ PFHxS+ PFBS				0 to 1.07	0.24	1
Wells (n = 36)						
PFOA	0.9	0.05 ± 0.2	0			
PFOS	11	2.8 ± 4.1	10			
PFNA	0.01 ± 0.06	0.01 ± 0.06				
HFPO-DA	nd	nd				
PFHxS	27	7.0 ± 9.8				
PFBS	3.5	1.3 ± 1.1				

PFNA+HFPO-DA+ PFHxS+ PFBS		0.0003 to 3.001	0.78	10

Reference

Benskin, J.P., Muir, D.C., Scott, B.F., Spencer, C., De Silva, A.O., Kylin, H., Martin, J.W., Morris, A., Lohmann, R., Tomy, G. and Rosenberg, B., 2012. Perfluoroalkyl acids in the Atlantic and Canadian Arctic oceans. *Environmental science & technology*, *46*(11), pp.5815-5823.

Buck, R.C., Korzeniowski, S.H., Laganis, E. and Adamsky, F., 2021. Identification and classification of commercially relevant per-and poly-fluoroalkyl substances (PFAS). *Integrated environmental assessment and management*, *17*(5), pp.1045-1055.

Domingo, J.L. and Nadal, M., 2017. Per-and polyfluoroalkyl substances (PFASs) in food and human dietary intake: a review of the recent scientific literature. *Journal of agricultural and food chemistry*, *65*(3), pp.533-543.

Dinglasan-Panlilio, M.J., Prakash, S.S. and Baker, J.E., 2014. Perfluorinated compounds in the surface waters of Puget Sound, Washington and Clayoquot and Barkley Sounds, British Columbia. *Marine pollution bulletin*, *78*(1-2), pp.173-180.

EGLE 2020. Michigan Department of Environment, Great Lakes, and Energy. Private residential well PFAS sampling Guidance. Michigan.gov/PFASResponse.

Eurofins Sacramento. 2021. SOP No. WS-LC-0025, Rev. 4.0. Title: Per- and Polyfluorinated Alkyl Substances (PFAS) in Water, Soils, Sediments and Tissue [Method 537 (Modified), Method PFAS by LCMSMS Compliant with QSM Table B-15, Revision 5.3 and higher] Effective Date: 01/27/2021

Fair, P.A., Wolf, B., White, N.D., Arnott, S.A., Kannan, K., Karthikraj, R. and Vena, J.E., 2019. Perfluoroalkyl substances (PFASs) in edible fish species from Charleston Harbor and tributaries, South Carolina, United States: Exposure and risk assessment. *Environmental research*, *171*, pp.266-277.

Fenton, S.E., Ducatman, A., Boobis, A., DeWitt, J.C., Lau, C., Ng, C., Smith, J.S. and Roberts, S.M., 2021. Per-and polyfluoroalkyl substance toxicity and human health review: Current state of knowledge and strategies for informing future research. *Environmental toxicology and chemistry*, *40*(3), pp.606-630.

González-Gaya, B., Dachs, J., Roscales, J.L., Caballero, G., Jiménez, B., Perfluoroalkylated substances in the global tropical and subtropical surface oceans. Environ. Sci. Technol. 2014, 48, 13076–13084.

Houde M, Bujas TA, Small J, Wells RS, Fair PA, Bossart GD, Solomon KR, Muir DC. 2006a. Biomagnification of perfluoroalkyl compounds in the bottlenose dolphin (tursiops truncatus) food web. Environ Sci Technol 40:4138–4144.

Houde M, Martin JW, Letcher RJ, Solomon KR, Muir DCG. 2006. Biological monitoring of polyfluoroalkyl substances: A review. Environ Sci Technol 40:3463–3473

Jarvis, A.L., Justice, J.R., Elias, M.C., Schnitker, B. and Gallagher, K., 2021. Perfluorooctane sulfonate in US ambient surface waters: A review of occurrence in aquatic environments and comparison to global concentrations. *Environmental toxicology and chemistry*, *40*(9), pp.2425-2442.

Jiang, W., Zhang, Y., Yang, L., Chu, X. and Zhu, L., 2015. Perfluoroalkyl acids (PFAAs) with isomer analysis in the commercial PFOS and PFOA products in China. *Chemosphere*, *127*, pp.180-187.

Kurwadkar, S., Dane, J., Kanel, S.R., Nadagouda, M.N., Cawdrey, R.W., Ambade, B., Struckhoff, G.C. and Wilkin, R., 2022. Per-and polyfluoroalkyl substances in water and wastewater: A critical review of their global occurrence and distribution. *Science of The Total Environment*, *809*, p.151003.

Li, X., Fatowe, M., Cui, D. and Quinete, N., 2022. Assessment of per-and polyfluoroalkyl substances in Biscayne Bay surface waters and tap waters from South Florida. *Science of the Total Environment*, *806*, p.150393.

Pulster, E.L., Rullo, K., Gilbert, S., Ash, T.M., Goetting, B., Campbell, K., Markham, S. and Murawski, S.A., 2022. Assessing per-and polyfluoroalkyl substances (PFAS) in sediments and fishes in a large, urbanized estuary and the potential human health implications. *Frontiers in Marine Science*, *9*, p.1046667.

NAS. 2022. National Academies of Sciences, Engineering, and Medicine, 2022. Potential Health Effects of PFAS. In *Guidance on PFAS Exposure, Testing, and Clinical Follow-Up*. National Academies Press (US).

Shoemaker, J. and Dan Tettenhorst. Method 537.1 Determination of Selected Per- and Polyflourinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS). U.S. Environmental Protection Agency, Washington, DC, 2020.

TCEQ Surface Water Quality Monitoring Procedures Volume 1: Chemical Monitoring Methods for Water, Sediment, and Tissue (October 2008).

USDON. 2018. US Department of the Navy. Final phase I and II - per - and polyfluoroalkyl substances groundwater investigation report at solid waste management unit 4 firefighting training area NAS Corpus Christi, TX. Resolution Consultants. Contract Number N62470-11-D-8013.

USEPA. 2021. PFAS strategic roadmap: EPA's Commitments to Action 2021–2024. October 2021. EPA-100-K-21-002

USEPA. 2022. Environmental Protection Agency. National Response Center. https://echo.epa.gov/system/files/Initial_Calls_Reported_to_NRC_Indicating_AFFF_Usage_02-23-2022.xlsx

USEPA. 2023. Per- and Polyfluoroalkyl Substances (PFAS). https://www.epa.gov/pfas. Accessed July 2023.

USEPA. 2023. PFAS National Primary Drinking Water Regulation Rulemaking. Environmental Protection Agency. 40 CFR Parts 141 and 142, EPA–HQ–OW–2022–0114; FRL 8543–01– OW.

Yamashita, N., Kannan, K., Taniyasu, S., Horii, Y., Petrick, G., Gamo, T., 2005. A global survey of perfluorinated acids in oceans. Marine Pollution Bulletin 51, 658–668.

Zhang, X., Lohmann, R., Dassuncao, C., Hu, X.C., Weber, A.K., Vecitis, C.D. and Sunderland, E.M., 2016. Source attribution of poly-and perfluoroalkyl substances (PFASs) in surface waters from Rhode Island and the New York Metropolitan Area. *Environmental science & technology letters*, *3*(9), pp.316-321.

APPENDICES

Appendix A: List of 70 targeted PFAS compounds using an approach modified from EPA 537 that is a user-defined LC-MS/MS isotope dilution method. *This modified EPA 537.1 method will follow SOP WS_LC_0025 (Eurofins Sacramento 2021), which is based upon Method 537.1, but incorporates isotope dilution quantitation.

Parameter	**Units**	**Method**	**Method Description**
PFAS (Per- and polyfluoroalkyl substances)	ng/L	*537.1	Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)
Perfluorobutanoic acid (PFBA)	ng/L	*537.1	LC/MS/MS
Perfluoropentanoic acid (PFPeA)	ng/L	*537.1	LC/MS/MS
Perfluorohexanoic acid (PFHxA)	ng/L	*537.1	LC/MS/MS
Perfluoroheptanoic acid (PFHpA)	ng/L	*537.1	LC/MS/MS
Perfluorooctanoic acid (PFOA)	ng/L	*537.1	LC/MS/MS
Perfluorononanoic acid (PFNA)	ng/L	*537.1	LC/MS/MS
Perfluorodecanoic acid (PFDA)	ng/L	*537.1	LC/MS/MS
Perfluoroundecanoic acid (PFUnA)	ng/L	*537.1	LC/MS/MS

Perfluorododecanoic acid (PFDoA)	ng/L	*537.1	LC/MS/MS
Perfluorotridecanoic acid (PFTriA)	ng/L	*537.1	LC/MS/MS
Perfluorotetradecanoic acid (PFTeA)	ng/L	*537.1	LC/MS/MS
Perfluoro-n-hexadecanoic acid (PFHxDA)	ng/L	*537.1	LC/MS/MS
Perfluoro-n-octadecanoic acid (PFODA)	ng/L	*537.1	LC/MS/MS
Perfluorobutanesulfonic acid (PFBS)	ng/L	*537.1	LC/MS/MS
Perfluoropentanesulfonic acid (PFPeS)	ng/L	*537.1	LC/MS/MS
Perfluorohexanesulfonic acid (PFHxS)	ng/L	*537.1	LC/MS/MS
Perfluoroheptanesulfonic Acid (PFHpS)	ng/L	*537.1	LC/MS/MS
Perfluorooctanesulfonic acid (PFOS)	ng/L	*537.1	LC/MS/MS
Perfluorononanesulfonic acid (PFNS)	ng/L	*537.1	LC/MS/MS
Perfluorodecanesulfonic acid (PFDS)	ng/L	*537.1	LC/MS/MS
Perfluorododecanesulfonic acid (PFDoS)	ng/L	*537.1	LC/MS/MS
Perfluorooctanesulfonamide (FOSA)	ng/L	*537.1	LC/MS/MS
NEtFOSA	ng/L	*537.1	LC/MS/MS
NMeFOSA	ng/L	*537.1	LC/MS/MS
NMeFOSAA	ng/L	*537.1	LC/MS/MS
NEtFOSAA	ng/L	*537.1	LC/MS/MS
NMeFOSE	ng/L	*537.1	LC/MS/MS
NEtFOSE	ng/L	*537.1	LC/MS/MS
4:2 FTS	ng/L	*537.1	LC/MS/MS
6:2 FTS	ng/L	*537.1	LC/MS/MS
8:2 FTS	ng/L	*537.1	LC/MS/MS
10:2 FTS	ng/L	*537.1	LC/MS/MS
4,8-Dioxa-3H-perfluorononanoic acid (DONA)	ng/L	*537.1	LC/MS/MS
HFPO-DA (GenX)	ng/L	*537.1	LC/MS/MS
F-53B Major	ng/L	*537.1	LC/MS/MS
F-53B Minor	ng/L	*537.1	LC/MS/MS
3:3 FTCA	ng/L	*537.1	LC/MS/MS
5:3 FTCA	ng/L	*537.1	LC/MS/MS
7:3 FTCA	ng/L	*537.1	LC/MS/MS
6:2 FTCA	ng/L	*537.1	LC/MS/MS
6:2 FTUCA	ng/L	*537.1	LC/MS/MS
8:2 FTCA	ng/L	*537.1	LC/MS/MS
8:2 FTUCA	ng/L	*537.1	LC/MS/MS
10:2 FTCA	ng/L	*537.1	LC/MS/MS
10:2 FTUCA	ng/L	*537.1	LC/MS/MS
PFECHS	ng/L	*537.1	LC/MS/MS

PFPrS	ng/L	*537.1	LC/MS/MS
PFPrA	ng/L	*537.1	LC/MS/MS
NFDHA	ng/L	*537.1	LC/MS/MS
PFMBA	ng/L	*537.1	LC/MS/MS
PFMPA	ng/L	*537.1	LC/MS/MS
PFEESA	ng/L	*537.1	LC/MS/MS
PFMOAA	ng/L	*537.1	LC/MS/MS
PFECA G	ng/L	*537.1	LC/MS/MS
PFO4DA	ng/L	*537.1	LC/MS/MS
PFO3OA	ng/L	*537.1	LC/MS/MS
PFO2HxA	ng/L	*537.1	LC/MS/MS
R-EVE	ng/L	*537.1	LC/MS/MS
NVHOS	ng/L	*537.1	LC/MS/MS
Hydro-EVE Acid	ng/L	*537.1	LC/MS/MS
EVE Acid	ng/L	*537.1	LC/MS/MS
PFO5DA	ng/L	*537.1	LC/MS/MS
PMPA	ng/L	*537.1	LC/MS/MS
PEPA	ng/L	*537.1	LC/MS/MS
MTP	ng/L	*537.1	LC/MS/MS
PS Acid	ng/L	*537.1	LC/MS/MS
Hydro-PS Acid	ng/L	*537.1	LC/MS/MS
R-PSDA	ng/L	*537.1	LC/MS/MS
Hydrolyzed PSDA	ng/L	*537.1	LC/MS/MS
R-PSDCA	ng/L	*537.1	LC/MS/MS

Appendix B. Correlation coefficients (R) for 21 detected PFAS compounds across all surface samples (n = 72). *Italic* is significant at $p < 0.05$ and ***italic bold*** is significant at $p < 0.01$.

	PFBA	*PFPeA*	*PFHxA*	*PFHpA*	*PFOA*	*PFNA*	*PFBS*	*PFHxS*	*PFOS*	*PFDA*	*PFPrS*	*PFPrA*	*PFPeS*	*R-PSDA*	*PMPA*	*PFHpS*	*PSDA*	*R-EVE*	*FTS*	*PFNS*	*NVHOS*
PFBA	1.00																				
PFPeA	0.19	1.00																			
PFHxA	0.19	***0.94***	1.00																		
PFHpA	0.16	***0.80***	***0.86***	1.00																	
PFOA	0.06	***0.79***	***0.87***	***0.82***	1.00																
PFNA	0.03	***0.64***	***0.73***	***0.66***	***0.86***	1.00															
PFBS	0.17	***0.32***	***0.37***	***0.38***	*0.28*	***0.31***	1.00														
PFHxS	0.02	***0.71***	***0.81***	***0.82***	***0.89***	***0.70***	***0.38***	1.00													
PFOS	0.09	***0.57***	***0.66***	***0.55***	***0.77***	***0.97***	*0.26*	***0.60***	1.00												
PFDA	0.12	***0.49***	***0.58***	***0.42***	***0.62***	***0.87***	0.17	***0.42***	***0.94***	1.00											
PFPrS	*0.25*	-0.19	-0.20	*-0.28*	*-0.26*	-0.19	-0.05	*-0.25*	-0.14	-0.07	1.00										
PFPrA	***0.45***	0.02	-0.03	-0.10	-0.06	0.01	-0.04	-0.13	0.04	0.06	0.24	1.00									
PFPeS	0.13	***0.54***	***0.55***	***0.54***	***0.62***	***0.54***	***0.62***	***0.64***	***0.46***	*0.28*	-0.12	-0.05	1.00								
R-PSDA	0.08	0.20	0.17	0.09	0.07	-0.05	-0.07	0.15	-0.08	-0.07	0.05	-0.13	-0.03	1.00							
PMPA	0.15	***0.35***	***0.37***	*0.29*	0.14	0.09	0.15	0.14	0.04	0.08	-0.03	-0.01	0.18	-0.04	1.00						
PFHpS	0.08	***0.44***	***0.54***	***0.47***	***0.70***	***0.83***	***0.38***	***0.68***	***0.84***	***0.75***	-0.07	0.14	***0.53***	-0.09	-0.03	1.00					
PSDA	0.08	*0.24*	0.20	0.17	*0.28*	***0.48***	0.10	0.16	***0.45***	***0.37***	-0.03	***0.32***	0.23	-0.04	-0.01	***0.52***	1.00				
R-EVE	0.17	*0.25*	0.21	*0.23*	0.15	-0.04	0.03	0.13	-0.08	-0.07	-0.01	0.14	0.06	*0.27*	-0.03	-0.06	-0.03	1.00			
FTS	-0.03	-0.02	0.10	*0.25*	***0.31***	0.16	-0.01	***0.56***	0.11	-0.03	-0.03	-0.06	***0.36***	-0.04	-0.01	***0.42***	-0.01	-0.03	1.00		

PFNS	-0.01	-0.02	-0.03	-0.01	-0.02	-0.05	-0.01	-0.02	-0.04	-0.03	-0.03	-0.06	-0.05	-0.04	-0.01	-0.03	-0.01	-0.03	-0.01	1.00	
NVHOS	-0.01	0.01	0.02	0.11	0.04	0.01	0.01	0.04	0.01	-0.03	-0.03	-0.06	-0.05	-0.04	-0.01	-0.03	-0.01	-0.03	-0.01	-0.01	1.00

Appendix C. Correlation coefficients (R) for 21 detected PFAS compounds across all well samples (n = 36). *Italic* is significant at p < 0.05 and ***italic bold*** is significant at p < 0.01.

	PFBA	*PFPeA*	*PFHxA*	*PFHpA*	*PFOA*	*PFNA*	*PFBS*	*PFHxS*	*PFOS*	*PFDA*	*PFPrS*	*PFPrA*	*PFPeS*	*R-PSDA*	*PMPA*	*PFHpS*	*PSDA*	*R-EVE*	*FTS*	*PFNS*	*NVHOS*
PFBA	1.00																				
PFPeA	-0.17	1.00																			
PFHxA	-0.04	***0.53***	1.00																		
PFHpA	-0.15	***0.65***	***0.74***	1.00																	
PFOA	-0.04	***0.64***	***0.74***	***0.70***	1.00																
PFNA	0.07	-0.04	*0.42*	***0.51***	***0.67***	1.00															
PFBS	***0.84***	-0.10	-0.16	-0.17	-0.11	-0.08	1.00														
PFHxS	-0.28	0.01	0.07	0.10	-0.17	-0.11	-0.32	1.00													
PFOS	-0.25	0.11	0.19	0.23	-0.02	0.00	-0.32	***0.93***	1.00												
PFDA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.00											
PFPrS	*0.42*	-0.14	-0.06	-0.22	-0.15	-0.11	0.34	0.00	0.02	NA	1.00										
PFPrA	*0.41*	-0.05	-0.09	-0.11	-0.07	-0.08	0.40	-0.19	-0.20	NA	-0.07	1.00									
PFPeS	***0.57***	-0.24	-0.27	*-0.38*	-0.26	-0.18	0.58	0.07	0.01	NA	0.25	0.24	1.00								
R-PSDA	-0.10	-0.12	-0.14	-0.19	-0.13	-0.09	-0.03	0.18	0.17	NA	*0.42*	-0.20	0.15	1.00							
PMPA	-0.19	***0.70***	***0.78***	***0.63***	***0.55***	-0.04	-0.12	0.01	0.10	NA	-0.16	-0.03	-0.23	-0.11	1.00						
PFHpS	-0.17	-0.05	-0.08	-0.08	-0.06	-0.04	-0.22	***0.43***	***0.46***	NA	-0.14	-0.08	-0.07	-0.03	0.00	1.00					
PSDA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.00				
R-EVE	0.12	-0.04	-0.06	-0.06	-0.04	-0.03	0.24	-0.10	-0.11	NA	***0.56***	-0.08	0.05	0.31	-0.04	-0.04	NA	1.00			
FTS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.00		
PFNS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.00	
NVHOS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.00

Appendix D. Monthly stacked column PFAS concentration plots for all surface and well sites.

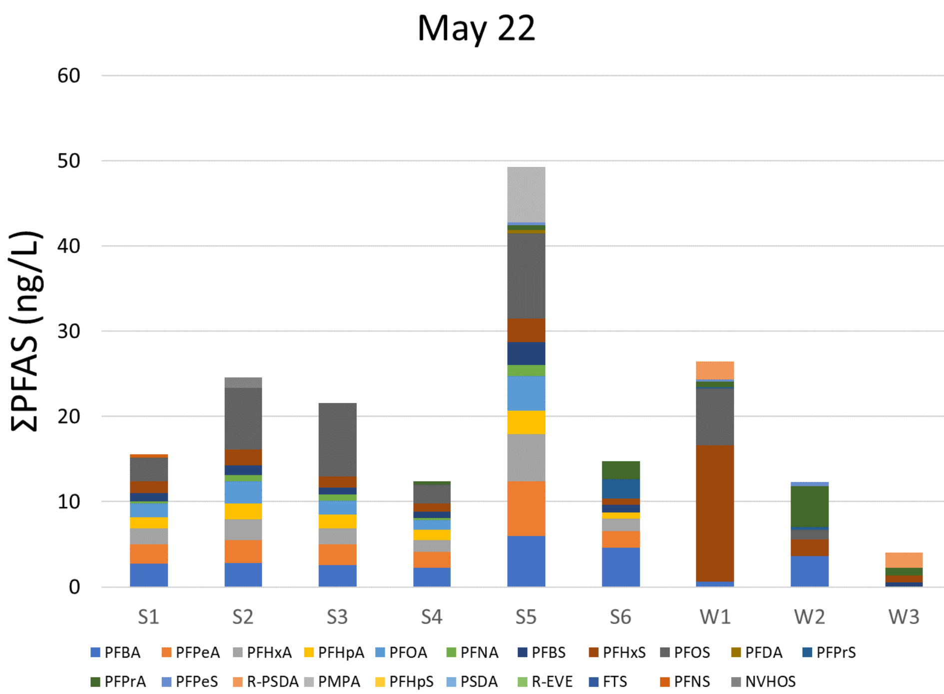

Figure 11. May 2022 stacked column PFAS concentration plots for all surface and well sites.

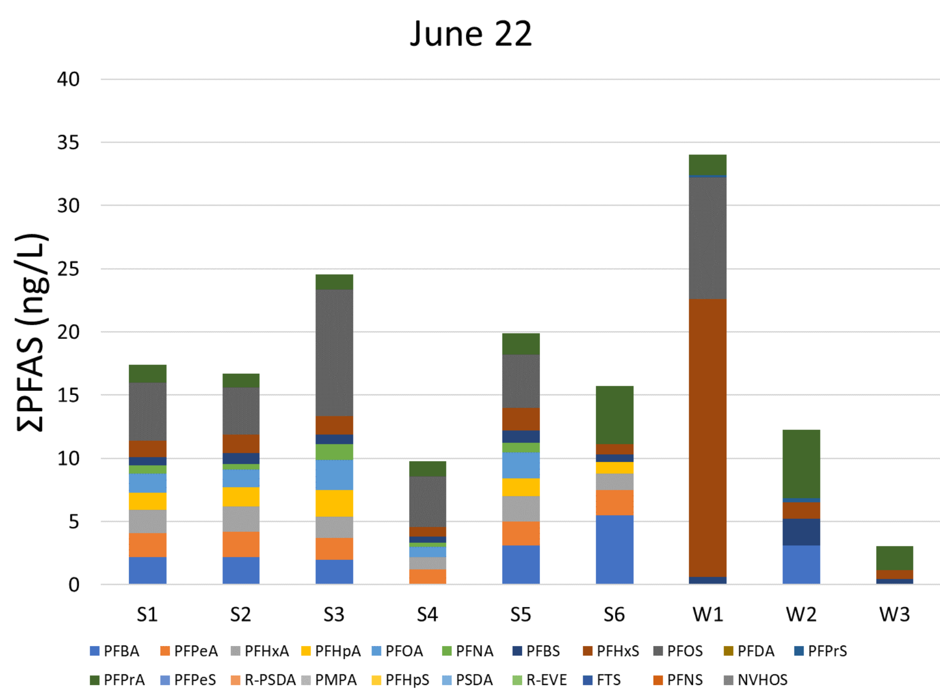

Figure 12. June 2022 stacked column PFAS concentration plots for all surface and well sites.

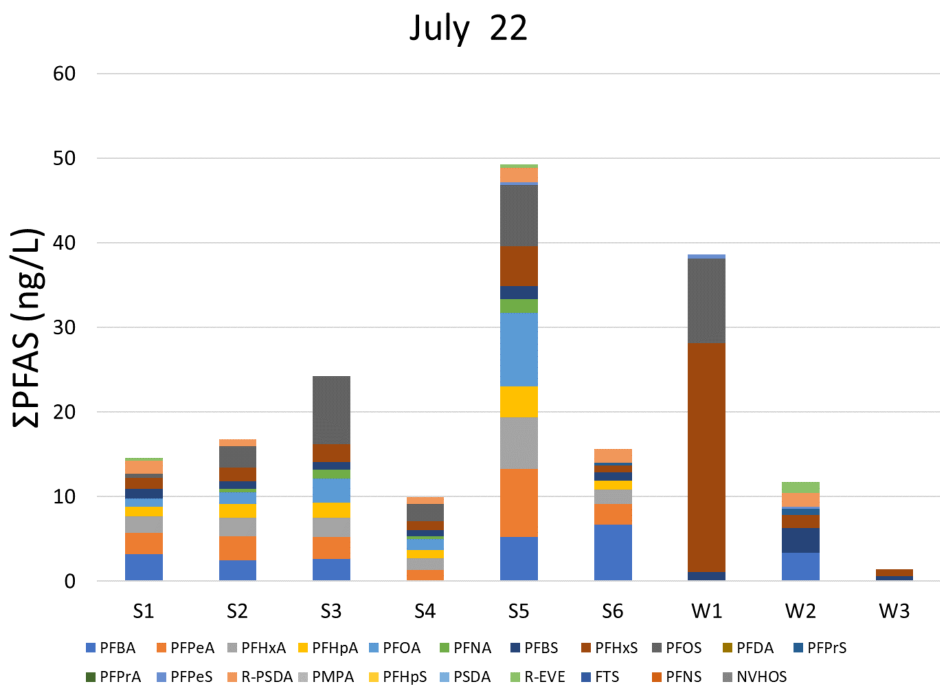

Figure 13. July 2022 stacked column PFAS concentration plots for all surface and well sites.

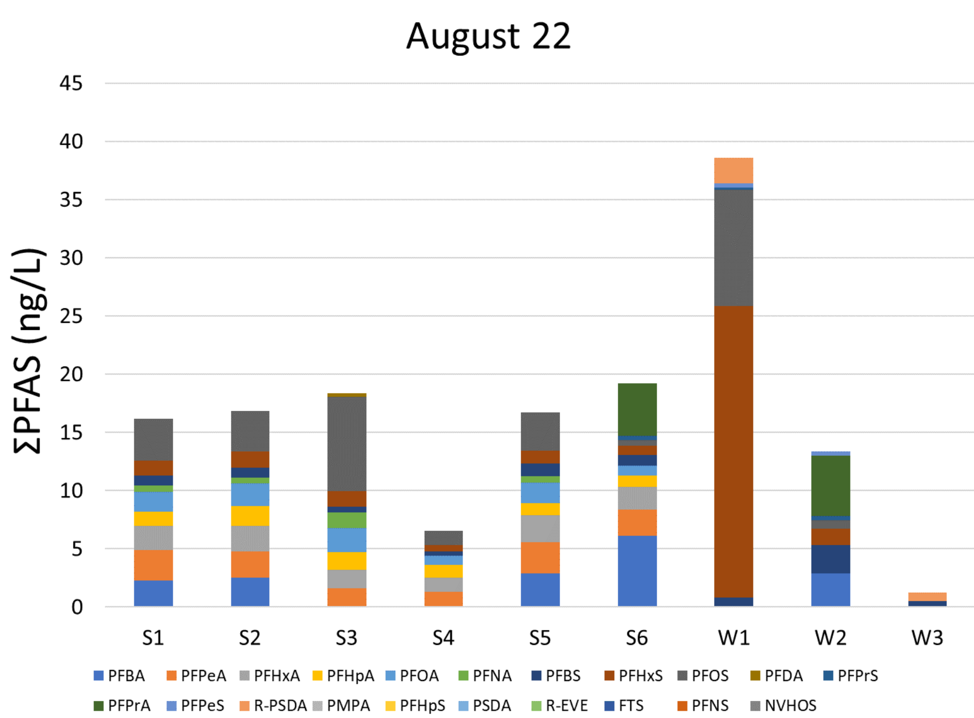

Figure 14. August 2022 stacked column PFAS concentration plots for all surface and well sites.

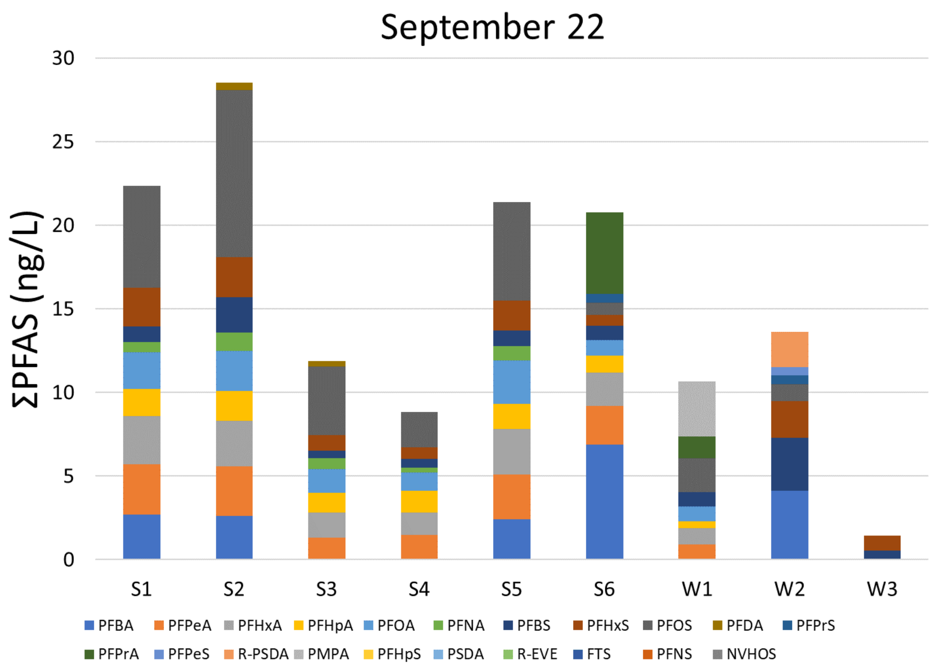

Figure 15. September 2022 stacked column PFAS concentration plots for all surface and well sites.

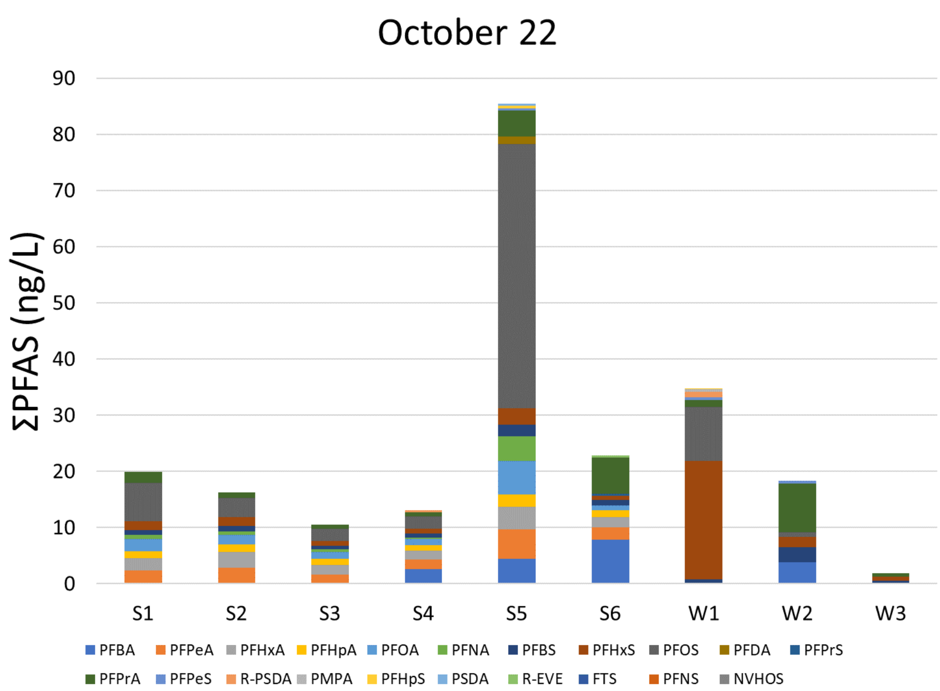

Figure 16. October 2022 stacked column PFAS concentration plots for all surface and well sites.

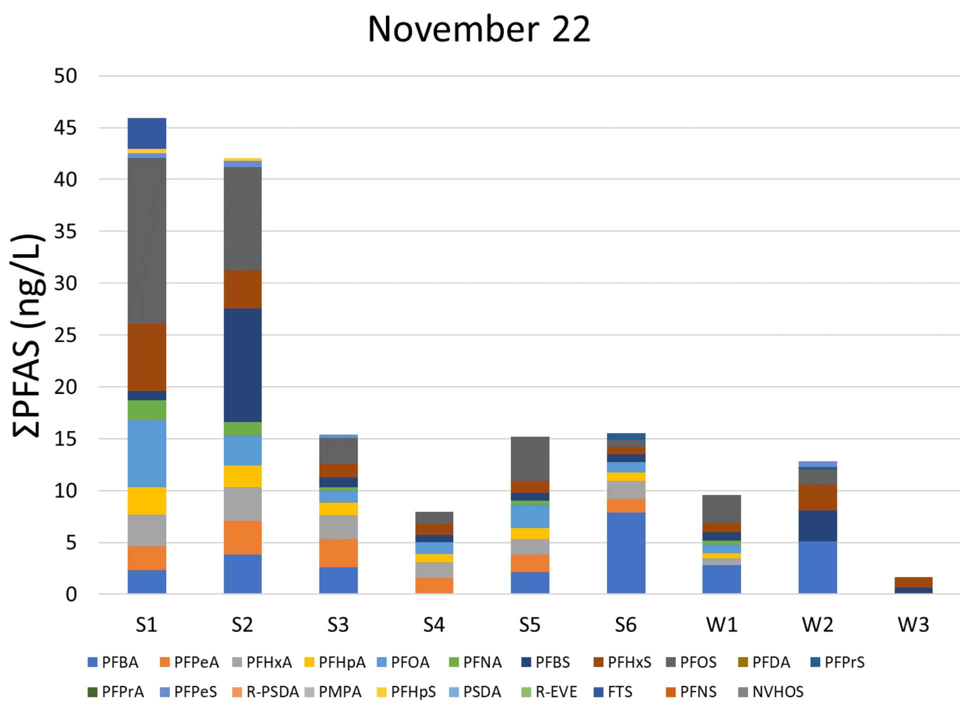

Figure 17. November 2022 stacked column PFAS concentration plots for all surface and well sites.

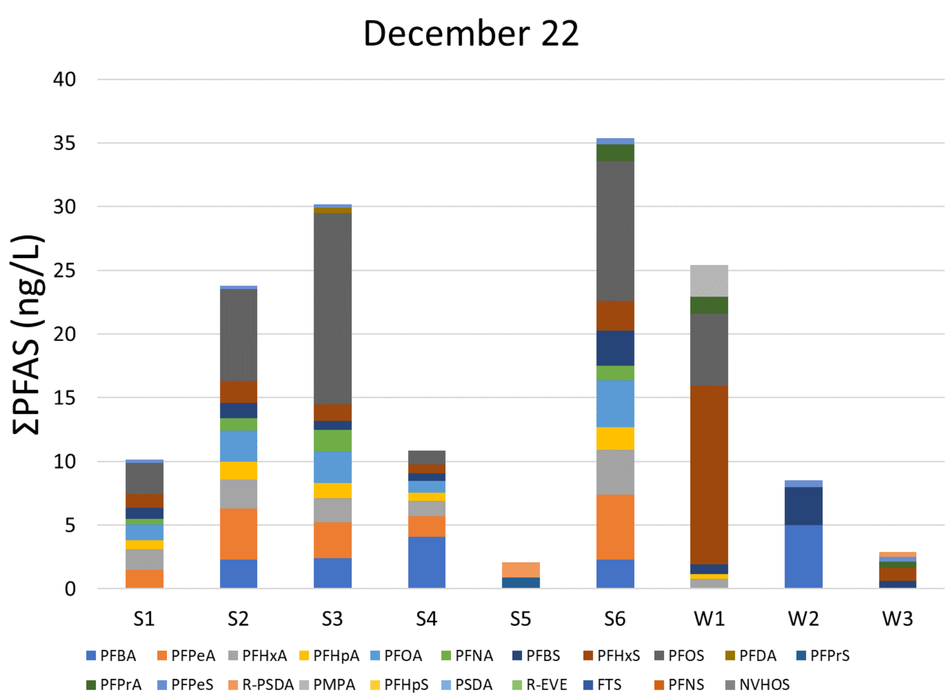

Figure 18. December 2022 stacked column PFAS concentration plots for all surface and well sites.

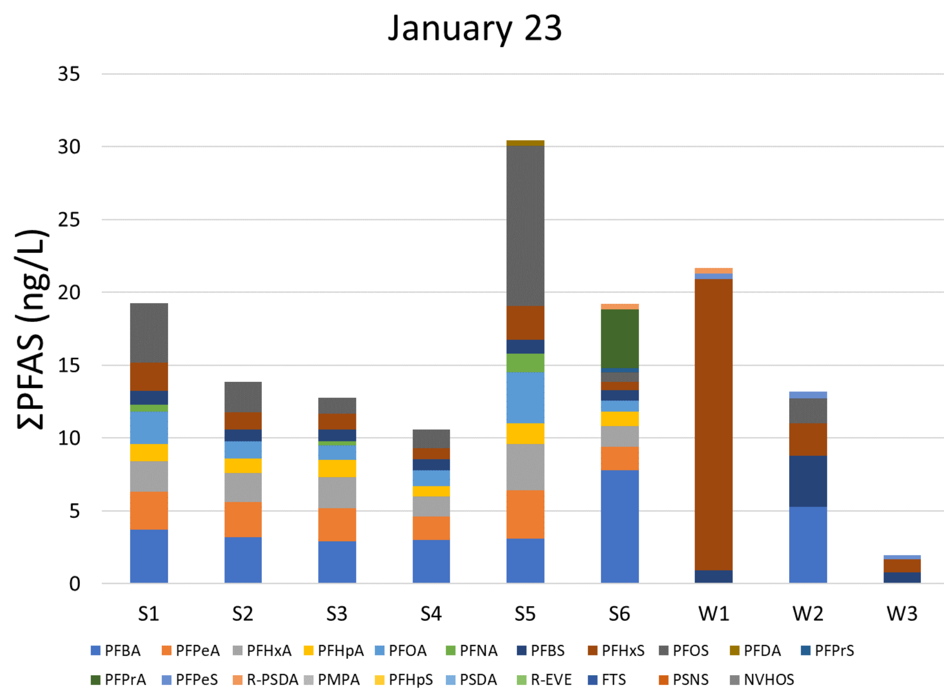

Figure 19. January 2023 stacked column PFAS concentration plots for all surface and well sites.

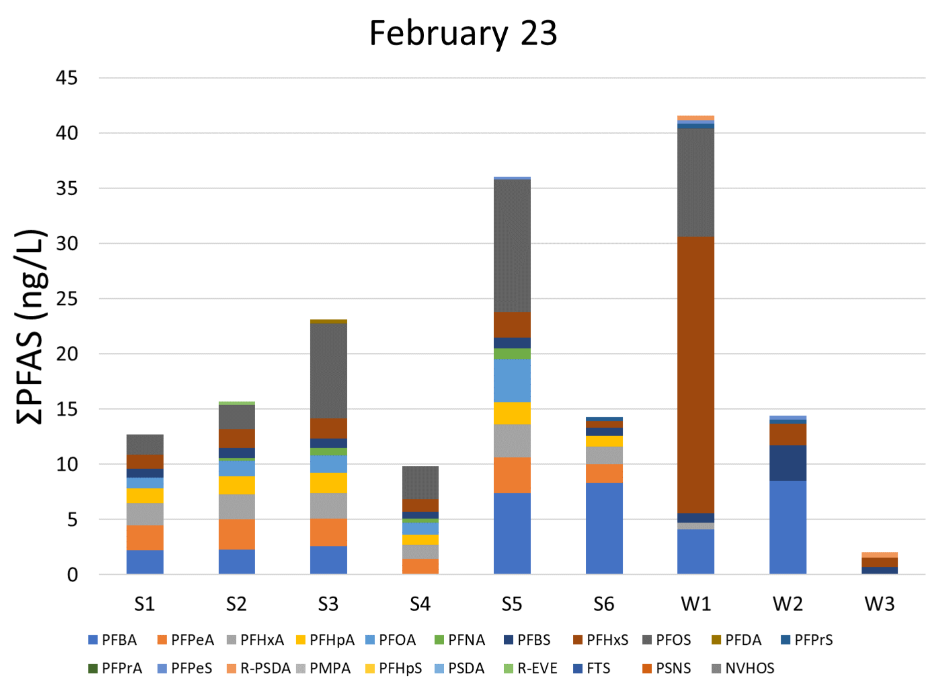

Figure 20. February 20232 stacked column PFAS concentration plots for all surface and well sites.

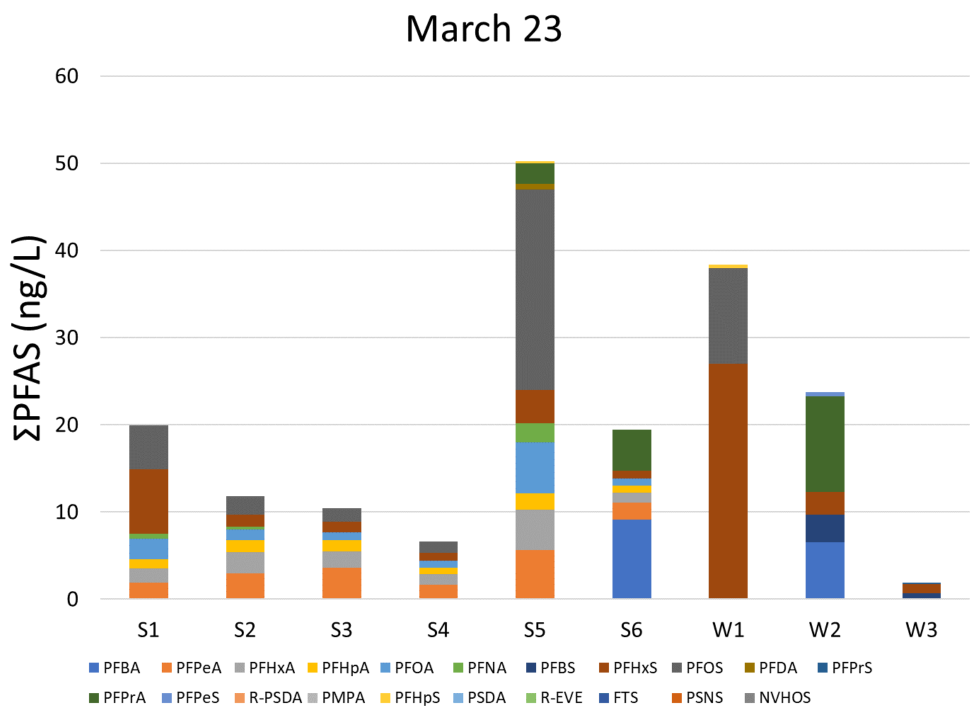

Figure 21. March 2023 stacked column PFAS concentration plots for all surface and well sites.

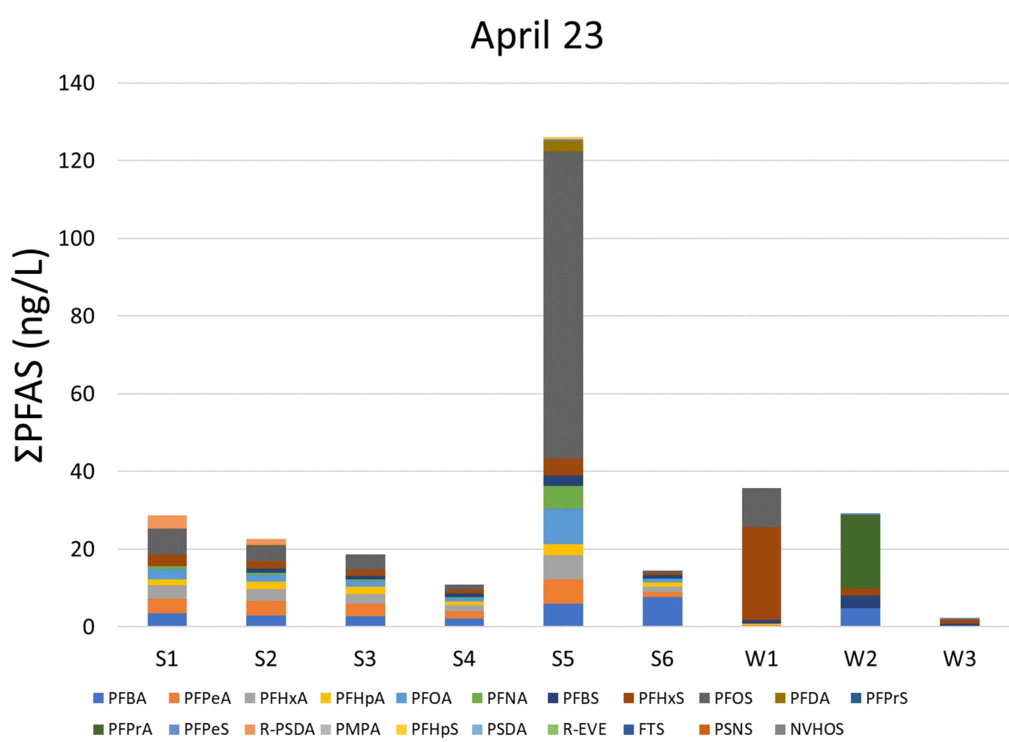

Figure 22. April 2023 stacked column PFAS concentration plots for all surface and well sites.

Appendix E. Table of monthly detected PFAS compounds at all surface and well sites from May 2022 to April 2022. Concentration units are ng/L.

May-22

Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	2.7	2.3	1.9	1.3	1.6	0.27	0.9	1.4	2.8	0	0	0	0	0	0	0	0	0	0	0.42	0	15.59
S2	2.8	2.7	2.4	1.9	2.6	0.74	1.1	1.9	7.2	0	0	0	0	0	0	0	0	0	0	0	1.2	24.54
S3	2.6	2.4	1.9	1.6	1.6	0.75	0.78	1.3	8.6	0	0	0	0	0	0	0	0	0	0	0	0	21.53
S4	2.2	1.9	1.4	1.2	1.1	0.29	0.72	0.99	2.2	0	0	0.36	0	0	0	0	0	0	0	0	0	12.36
S5	6	6.4	5.5	2.8	4	1.3	2.7	2.8	10	0.37	0	0.59	0.27	0	6.5	0	0	0	0	0	0	49.23
S6	4.6	1.9	1.5	0.74	0	0	0.91	0.68	0	0	2.3	2.1	0	0	0	0	0	0	0	0	0	14.73
W1	0.65	0	0	0	0	0	0	16	6.6	0	0.22	0.58	0.27	2.1	0	0	0	0	0	0	0	26.42
W2	3.6	0	0	0	0	0	0	2	1.1	0	0.32	4.8	0.46	0	0	0	0	0	0	0	0	12.28
W3	0	0	0	0	0	0	0.54	0.79	0	0	0	0.87	0	1.8	0	0	0	0	0	0	0	4
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Jun-22

Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	2.2	1.9	1.8	1.4	1.5	0.64	0.64	1.3	4.6	0	0	1.4	0	0	0	0	0	0	0	0	0	17.38
S2	2.2	2	2	1.5	1.4	0.46	0.84	1.5	3.7	0	0	1.1	0	0	0	0	0	0	0	0	0	16.7
S3	2	1.7	1.7	2.1	2.4	1.2	0.77	1.5	10	0	0	1.2	0	0	0	0	0	0	0	0	0	24.57
S4	0	1.2	0.99	0	0.79	0.37	0.47	0.74	4	0	0	1.2	0	0	0	0	0	0	0	0	0	9.76
S5	3.1	1.9	2	1.4	2.1	0.72	1	1.8	4.2	0	0	1.7	0	0	0	0	0	0	0	0	0	19.92
S6	5.5	2	1.3	0.93	0	0	0.58	0.82	0	0	0	4.6	0	0	0	0	0	0	0	0	0	15.73
W1	0	0	0	0	0	0	0.62	22	9.6	0	0.21	1.6	0	0	0	0	0	0	0	0	0	34.03
W2	3.1	0	0	0	0	0	2.1	1.3	0	0	0.36	5.4	0	0	0	0	0	0	0	0	0	12.26
W3	0	0	0	0	0	0	0.45	0.69	0	0	0	1.9	0	0	0	0	0	0	0	0	0	3.04
Blank	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	5.5	0	0	7

Jul-22

Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	3.2	2.5	2	1.1	1	0	1.1	1.3	0.53	0	0	0	0	1.5	0	0	0	0.34	0	0	0	14.57
S2	2.5	2.8	2.2	1.6	1.4	0.38	0.95	1.6	2.5	0	0	0	0	0.87	0	0	0	0	0	0	0	16.8
S3	2.6	2.6	2.3	1.8	2.8	1.1	0.92	2.1	8	0	0	0	0	0	0	0	0	0	0	0	0	24.22
S4	0	1.3	1.4	1	1.3	0.33	0.69	1.1	2	0	0	0	0	0.86	0	0	0	0	0	0	0	9.98
S5	5.2	8.1	6.1	3.6	8.7	1.6	1.6	4.7	7.2	0	0	0	0.37	1.7	0	0	0	0.36	0	0	0	49.23
S6	6.7	2.4	1.7	1.1	0	0	0.99	0.77	0	0	0.36	0	0	1.6	0	0	0	0	0	0	0	15.62
W1	0	0	0	0	0	0	1.1	27	10	0	0	0	0.51	0	0	0	0	0	0	0	0	38.61
W2	3.4	0	0	0	0	0	2.9	1.5	0	0	0.73	0	0.29	1.6	0	0	0	1.3	0	0	0	11.72
W3	0	0	0	0	0	0	0.58	0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	1.41
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Aug-22

Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	2.3	2.6	2.1	1.2	1.7	0.52	0.87	1.3	3.6	0	0	0	0	0	0	0	0	0	0	0	0	16.19
S2	2.5	2.3	2.2	1.7	1.9	0.51	0.83	1.4	3.5	0	0	0	0	0	0	0	0	0	0	0	0	16.84
S3	0	1.6	1.6	1.5	2.1	1.3	0.54	1.3	8.1	0.34	0	0	0	0	0	0	0	0	0	0	0	18.38
S4	0	1.3	1.2	1.1	0.81	0	0.34	0.57	1.2	0	0	0	0	0	0	0	0	0	0	0	0	6.52
S5	2.9	2.7	2.3	1	1.8	0.52	1.1	1.1	3.3	0	0	0	0	0	0	0	0	0	0	0	0	16.72
S6	6.1	2.3	1.9	1	0.84	0	0.92	0.77	0.53	0	0.33	4.5	0	0	0	0	0	0	0	0	0	19.19
W1	0	0	0	0	0	0	0.83	25	10	0	0.22	0	0.36	2.2	0	0	0	0	0	0	0	38.61
W2	2.9	0	0	0	0	0	2.4	1.4	0.77	0	0.33	5.2	0.39	0	0	0	0	0	0	0	0	13.39
W3	0	0	0	0	0	0	0.51	0	0	0	0	0	0	0.71	0	0	0	0	0	0	0	1.22
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sep-22

Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	2.7	3	2.9	1.6	2.2	0.61	0.95	2.3	6.1	0	0	0	0	0	0	0	0	0	0	0	0	22.36
S2	2.6	3	2.7	1.8	2.4	1.1	2.1	2.4	10	0.43	0	0	0	0	0	0	0	0	0	0	0	28.53
S3	0	1.3	1.5	1.2	1.4	0.66	0.45	0.95	4.1	0.32	0	0	0	0	0	0	0	0	0	0	0	11.88
S4	0	1.5	1.3	1.3	1.1	0.31	0.5	0.71	2.1	0	0	0	0	0	0	0	0	0	0	0	0	8.82
S5	2.4	2.7	2.7	1.5	2.6	0.87	0.92	1.8	5.9	0	0	0	0	0	0	0	0	0	0	0	0	21.39
S6	6.9	2.3	2	1	0.94	0	0.85	0.66	0.72	0	0.52	4.9	0	0	0	0	0	0	0	0	0	20.79
W1	0	0.9	0.97	0.43	0.9	0	0.85	0	2	0	0	1.3	0	0	3.3	0	0	0	0	0	0	10.65
W2	4.1	0	0	0	0	0	3.2	2.2	0.99	0	0.53	0	0.5	2.1	0	0	0	0	0	0	0	13.62
W3	0	0	0	0	0	0	0.54	0.89	0	0	0	0	0	0	0	0	0	0	0	0	0	1.43
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Oct-22

Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	0	2.4	2.2	1.2	2.2	0.75	0.86	1.5	6.9	0	0	1.9	0	0	0	0	0	0	0	0	0	19.91
S2	0	2.8	2.8	1.4	1.7	0.58	0.95	1.7	3.4	0	0	0.9	0	0	0	0	0	0	0	0	0	16.23
S3	0	1.6	1.8	1	1.3	0.39	0.64	0.93	2.1	0	0	0.73	0	0	0	0	0	0	0	0	0	10.49
S4	2.6	1.7	1.6	0.93	1.1	0.29	0.71	0.9	2.2	0	0	0.72	0	0.35	0	0	0	0	0	0	0	13.1
S5	4.5	5.2	4	2.2	6	4.3	2.1	3	47	1.3	0	4.7	0.33	0	0	0.49	0.35	0	0	0	0	85.47
S6	7.9	2.1	1.9	1.2	0.87	0	1	0.68	0	0	0.31	6.5	0	0	0	0	0	0.34	0	0	0	22.8
W1	0	0	0	0	0	0	0.84	21	9.7	0	0	1.2	0.51	0.86	0.51	0.18	0	0	0	0	0	34.8
W2	3.8	0	0	0	0	0	2.7	1.8	0.9	0	0	8.7	0.38	0	0	0	0	0	0	0	0	18.28
W3	0	0	0	0	0	0	0.6	0.73	0	0	0	0.61	0	0	0	0	0	0	0	0	0	1.94
Blank	2.9	8.6	5	1.5	4.5	0.6	19	0.71	0.63	0.65	0	1.4	0	0	0	0	0	0	0	0	0	45.49

Nov-23																						
Sample #	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	2.3	2.3	3.1	2.6	6.5	1.9	0.87	6.5	16	0	0	0	0.48	0	0	0.4	0	0	3	0	0	45.95
S2	3.8	3.3	3.2	2.1	2.9	1.3	11	3.6	10	0	0	0	0.57	0	0	0.27	0	0	0	0	0	42.04
S3	2.6	2.7	2.3	1.2	1.2	0.29	0.96	1.4	2.4	0	0	0	0.34	0	0	0	0	0	0	0	0	15.39
S4	0	1.6	1.5	0.76	1.2	0	0.67	1.1	1.1	0	0	0	0	0	0	0	0	0	0	0	0	7.93
S5	2.1	1.7	1.5	1.1	2.2	0.46	0.7	1.2	4.2	0	0	0	0	0	0	0	0	0	0	0	0	15.16
S6	7.9	1.3	1.7	0.87	0.97	0	0.75	0.69	0.76	0	0.59	0	0	0	0	0	0	0	0	0	0	15.53
W1	2.8	0	0.69	0.46	0.84	0.37	0.82	0.91	2.7	0	0	0	0	0	0	0	0	0	0	0	0	9.59
W2	5.1	0	0	0	0	0	3	2.5	1.4	0	0.3	0	0.5	0	0	0	0	0	0	0	0	12.8
W3	0	0	0	0	0	0	0.64	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1.64
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

22-Dec	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PFNS	NVHOS	ΣPFAS
S1	0	1.5	1.6	0.74	1.2	0.44	0.88	1.1	2.4	0	0	0	0.27	0	0	0	0	0	0	0	0	10.13
S2	2.3	4	2.3	1.4	2.4	1	1.2	1.7	7.2	0	0	0	0.28	0	0	0	0	0	0	0	0	23.78
S3	2.4	2.8	1.9	1.2	2.5	1.7	0.69	1.3	15	0.41	0	0	0.27	0	0	0	0	0	0	0	0	30.17
S4	4.1	1.6	1.2	0.63	0.94	0	0.62	0.69	1.1	0	0	0	0	0	0	0	0	0	0	0	0	10.88
S5	0	0	0	0	0	0	0	0	0	0	0.89	0	0	1.2	0	0	0	0	0	0	0	2.09
S6	2.3	5.1	3.5	1.8	3.7	1.1	2.8	2.3	11	0	0	1.3	0.48	0	0	0	0	0	0	0	0	35.38
W1	0	0	0.78	0.39	0	0	0.75	14	5.7	0	0	1.3	0	0	2.5	0	0	0	0	0	0	25.42
W2	5	0	0	0	0	0	3	0	0	0	0	0	0.52	0	0	0	0	0	0	0	0	8.52
W3	0	0	0	0	0	0	0.63	1	0	0	0	0.52	0.38	0.34	0	0	0	0	0	0	0	2.87
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

23-Jan	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PSNS	NVHOS	ΣPFAS
S1	3.7	2.6	2.1	1.2	2.2	0.49	0.97	1.9	4.1	0	0	0	0	0	0	0	0	0	0	0	0	19.26
S2	3.2	2.4	2	0.98	1.2	0	0.79	1.2	2.1	0	0	0	0	0	0	0	0	0	0	0	0	13.87
S3	2.9	2.3	2.1	1.2	1	0.3	0.78	1.1	1.1	0	0	0	0	0	0	0	0	0	0	0	0	12.78
S4	3	1.6	1.4	0.68	1.1	0	0.77	0.75	1.3	0	0	0	0	0	0	0	0	0	0	0	0	10.6
S5	3.1	3.3	3.2	1.4	3.5	1.3	0.95	2.3	11	0.37	0	0	0	0	0	0	0	0	0	0	0	30.42
S6	7.8	1.6	1.4	1	0.8	0	0.67	0.6	0.65	0	0.29	4	0	0.41	0	0	0	0	0	0	0	19.22
W1	0	0	0	0	0	0	0.92	20	0	0	0	0	0.36	0.39	0	0	0	0	0	0	0	21.67
W2	5.3	0	0	0	0	0	3.5	2.2	1.7	0	0	0	0.47	0	0	0	0	0	0	0	0	13.17
W3	0	0	0	0	0	0	0.79	0.88	0	0	0	0	0.3	0	0	0	0	0	0	0	0	1.97
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

23-Feb	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PSNS	NVHOS	ΣPFAS
S1	2.2	2.3	2	1.3	1	0	0.79	1.3	1.8	0	0	0	0	0	0	0	0	0	0	0	0	12.69
S2	2.3	2.7	2.3	1.6	1-Jan	0.29	0.87	1.7	2.2	0	0	0	0	0	0	0	0	0.35	0	0	0	15.71
S3	2.6	2.5	2.3	1.8	1.6	0.7	0.86	1.8	8.6	0.34	0	0	0	0	0	0	0	0	0	0	0	23.1
S4	0	1.4	1.3	0.9	1.1	0.41	0.61	1.1	3	0	0	0	0	0	0	0	0	0	0	0	0	9.82
S5	7.4	3.2	3	2	3.9	1	0.96	2.3	12	0	0	0	0.28	0	0	0	0	0	0	0	0	36.04
S6	8.3	1.7	1.6	0.96	0	0	0.75	0.6	0	0	0.35	0	0	0	0	0	0	0	0	0	0	14.26
W1	4.1	0	0.63	0	0	0	0.87	25	9.8	0	0.42	0	0.31	0.42	0	0	0	0	0	0	0	41.55
W2	8.5	0	0	0	0	0	3.2	2	0	0	0.32	0	0.41	0	0	0	0	0	0	0	0	14.43
W3	0	0	0	0	0	0	0.67	0.87	0	0	0	0	0	0.48	0	0	0	0	0	0	0	2.02
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

23-Mar	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PSNS	NVHOS	ΣPFAS

S1	0	1.9	1.6	1.1	2.3	0.63	0	7-Jan	5	0	0	0	0	0	0	0	0	0	0	0	0	19.93
S2	0	3	2.4	1.4	1.2	0.28	0	1.4	2.1	0	0	0	0	0	0	0	0	0	0	0	0	11.78
S3	0	3.6	1.9	1.3	0.85	0	0	1.2	1.6	0	0	0	0	0	0	0	0	0	0	0	0	10.45
S4	0	1.7	1.2	0.69	0.83	0	0	0.91	1.3	0	0	0	0	0	0	0	0	0	0	0	0	6.63
S5	0	5.6	4.7	1.8	5.9	2.2	0	3.8	23	0.67	0	2.3	0	0	0	0.3	0	0	0	0	0	50.27
S6	9.1	2	1.1	0.81	0.81	0	0	0.89	0	0	0	4.7	0	0	0	0	0	0	0	0	0	19.41
W1	0	0	0	0	0	0	0	27	11	0	0	0	0	0	0	0.38	0	0	0	0	0	38.38
W2	6.5	0	0	0	0	0	3.2	2.6	0	0	0	11	0.44	0	0	0	0	0	0	0	0	23.74
W3	0	0	0	0	0	0	0.71	1	0	0	0.22	0	0	0	0	0	0	0	0	0	0	1.93
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

23-Apr	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFOS	PFDA	PFPrS	PFPrA	PFPeS	R-PSDA	PMPA	PFHpS	PSDA	R-EVE	FTS	PSNS	NVHOS	ΣPFAS
S1	3.5	3.8	3.4	1.5	2.7	0.71	0	3.1	6.5	0	0	0	0	3.5	0	0	0	0	0	0	0	28.71
S2	3	3.7	3.1	1.8	1.8	0.52	1.1	1.9	4	0.28	0	0	0	1.5	0	0	0	0	0	0	0	22.7
S3	2.8	3.1	2.5	1.9	1.5	0.45	0.98	1.4	4	0	0	0	0	0	0	0	0	0	0	0	0	18.63
S4	2.2	1.9	1.5	0.92	0.97	0.24	0.86	0.97	1.4	0	0	0	0	0	0	0	0	0	0	0	0	10.96
S5	6	6.3	6.2	2.9	9	5.8	2.7	4.4	79	2.9	0	0	0.31	0	0	0.54	0	0	0	0	0	126.05
S6	7.6	1.4	1.4	1	1	0	0.9	0.66	0.55	0	0	0	0	0	0	0	0	0	0	0	0	14.51
W1	0	0.42	0	0.46	0	0	0.85	24	10	0	0	0	0	0	0	0	0	0	0	0	0	35.73
W2	4.9	0	0	0	0	0	3.1	1.9	0	0	0	19	0.44	0	0	0	0	0	0	0	0	29.34
W3	0	0	0	0	0	0	0.79	1.1	0	0	0	0	0.38	0	0	0	0	0	0	0	0	2.27
Blank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0