Report
2022
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PFAS SURVEY REPORT
SUMMER 2022 (U.S.)

Prepared for:

WATERKEEPER® ALLIANCE

Report
2022
532

PFAS SURVEY REPORT SUMMER 2022 (U.S.)

Powered by:
DEXSORB® Technology

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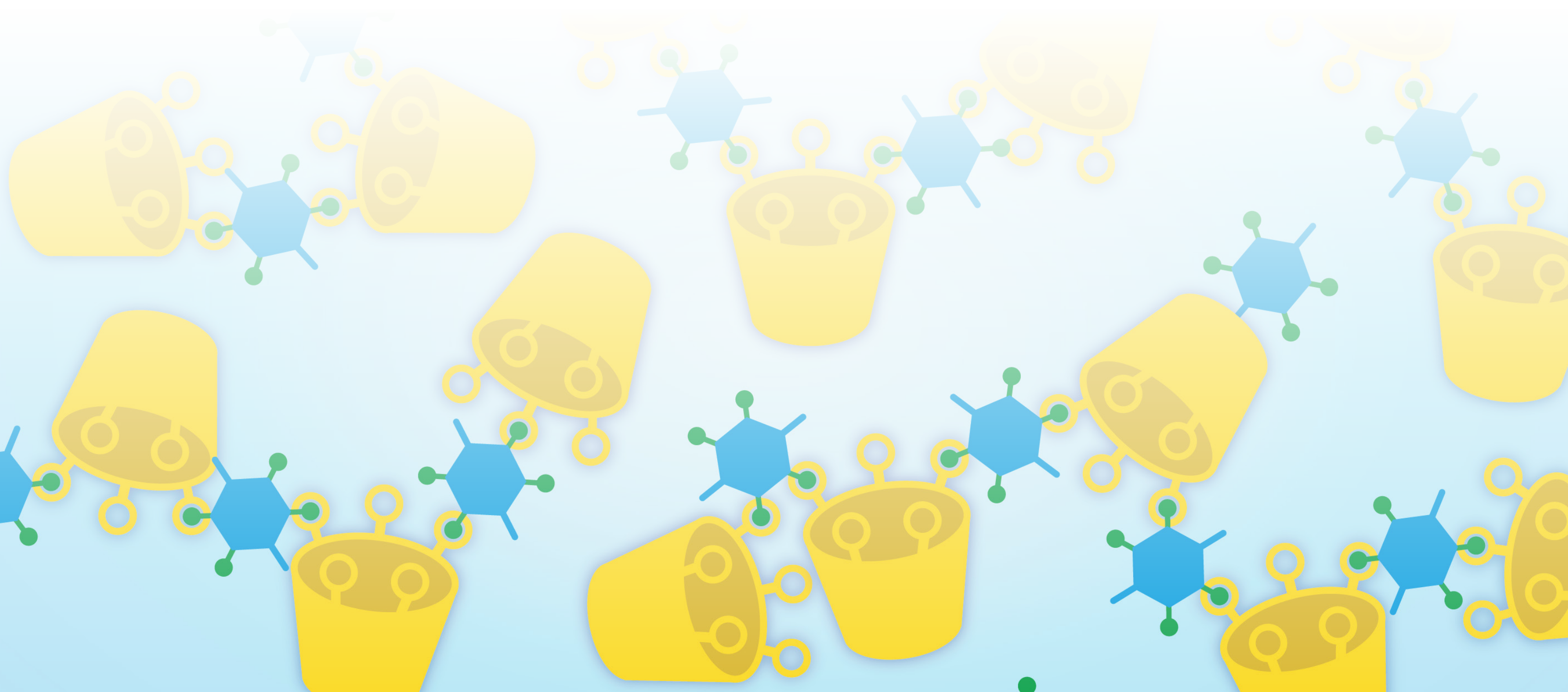

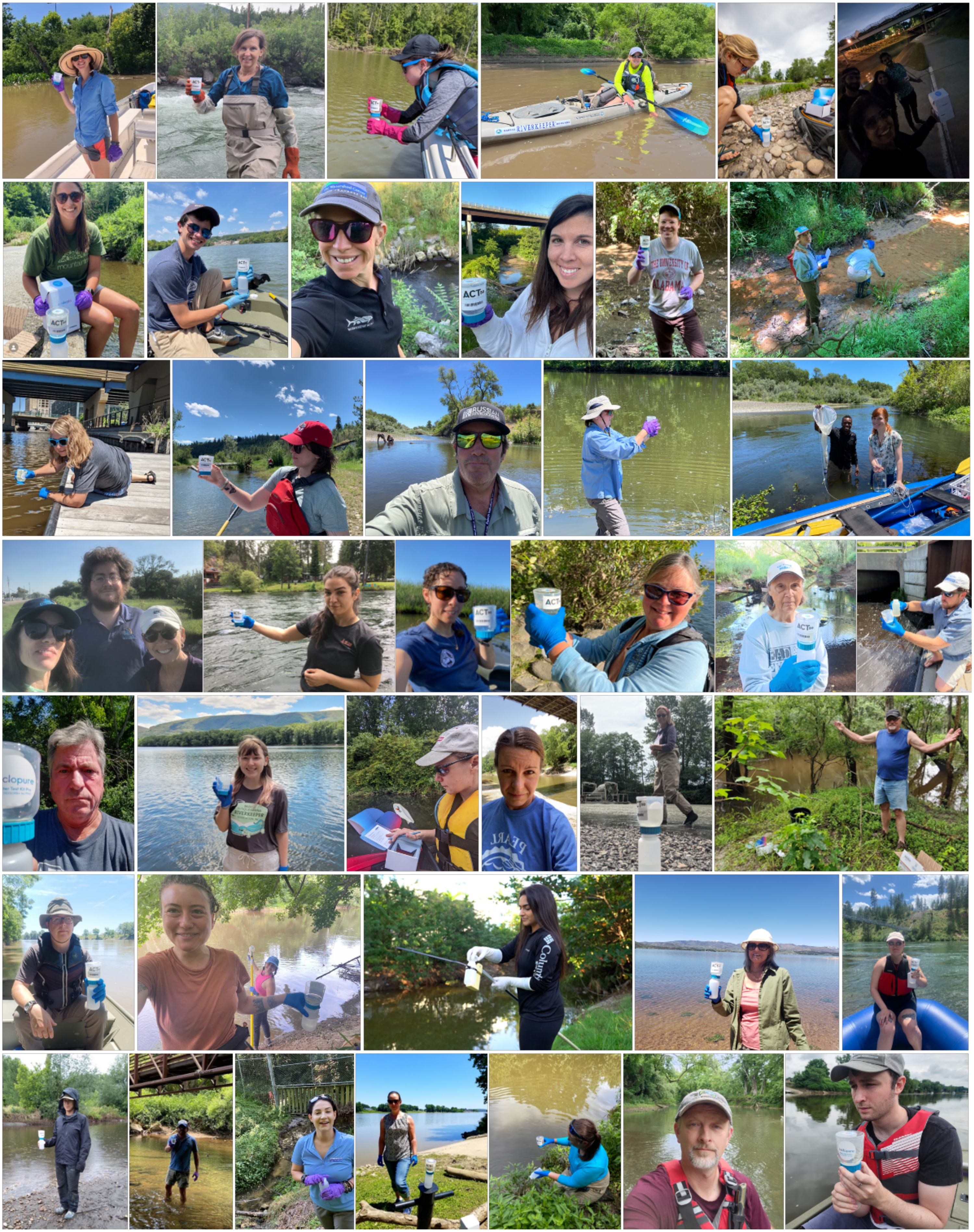
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PFAS 11 Abbreviations

PFOA - Perfluorooctanoic acid

PFOS - Perfluorooctane sulfonic acid

PFBS - Perfluorobutane sulfonic acid

GenX (HFPO-DA) - Hexafluoropropylene oxide dimer acid

PFHxA - Perfluorohexanoic acid

PFHxS - Perfluorohexane sulfonic acid

PFNA - Perfluorononanoic acid

PFDA - Perfluorodecanoic acid

PFHpA - Perfluoroheptanoic acid

PFPeA - Perfluoropentanoic acid

PFBA - Perfluorobutanoic acid

1. Introduction

"Forever Chemicals": A Water Problem. Per- and polyfluoroalkyl substances (PFAS) are a family of man-made chemicals used extensively in industry and consumer products since the 1950s.[1] Due to high chemical and thermal stability, water- and oil-repellency, and surfactant properties, PFAS have been used in industries such as aerospace, automotive, electronics, and semiconductors. They have been used to make nonstick cookware, water-repellant clothing, stain resistant fabrics, firefighting foams, and food contact materials.[2]

With high chemical and thermal stability from their fluorinated carbon chains, PFAS are extremely persistent and can remain in the environment for decades. This has given rise to the name "forever chemicals." These chemicals are highly mobile in soils and waters due to surfactant properties. From widespread use in manufacturing, PFAS are found throughout the environment and US water supplies.[3]

PFAS enter the environment through four primary pathways: (i) discharges from manufacturing facilities that make or use PFAS, (ii) runoff from aqueous film-forming foams (AFFFs) used during firefighting training or response to petroleum-based fires, (iii) effluent and sludge from wastewater treatment plants, and (iv) contaminated wastewater from landfills (i.e., leachate) where PFAS-containing industrial waste or consumer products are disposed.[1,4–7]

Human exposures to PFAS occur in multiple ways, primarily through consumption of PFAS-contaminated water, but also from fish, food, food packaging, and even clothing. A recent study estimated that over 200 million people in the U.S. are receiving tap water contaminated by PFOA and PFOS at combined concentrations above 1.0 ppt (ng/L).[3]

PFAS such as PFOA and PFOS are readily adsorbed into the body and organs by noncovalent binding to plasma proteins. Studies of human tissues identify their presence in liver, lung, kidney and bone. Similar to their environmental persistence, PFOA and PFOS are not readily eliminated from the human body as evidenced by their long half-life of 2.7 years and 3.4 years, respectively. Continuous exposure and ingestion to PFAS in drinking water can increase levels in the body over time where adverse health effects can occur, including developmental effects in fetuses and infants, cancers and other diseases of the thyroid, liver and kidneys.[8,9] It is estimated that PFAS are in the blood of 97% of Americans.[10]

The EPA has recently updated interim Health Advisory Levels to 0.004 ppt (ng/L) for PFOA and 0.02 ppt (ng/L) for PFOS, meaning that negative health effects may occur if individuals ingest in excess of these levels throughout their lifetimes. As these Health Advisory concentration values are near zero, it shows the urgent public health risk associated with PFAS contamination of drinking water supplies.

Nationwide Survey. To gain insights into PFAS contamination in U.S. waterways, Waterkeeper Alliance and Cyclopure, Inc. partnered in 2022 to conduct a nationwide PFAS survey of over 100 watersheds across the country. Waterkeeper Alliance reached its regional waterkeeper affiliates, and organized an extensive participant list of 114 U.S. Waterkeeper groups. See Appendix 1. Each of these groups identified a potential point source of PFAS pollution in their watershed area, and performed two water sample collections, one upstream and one downstream, of the specified location. Water samples were collected by means of a Cyclopure PFAS water test kit (WTK) to allow for advanced and convenient point-of-site, real time sample extraction.

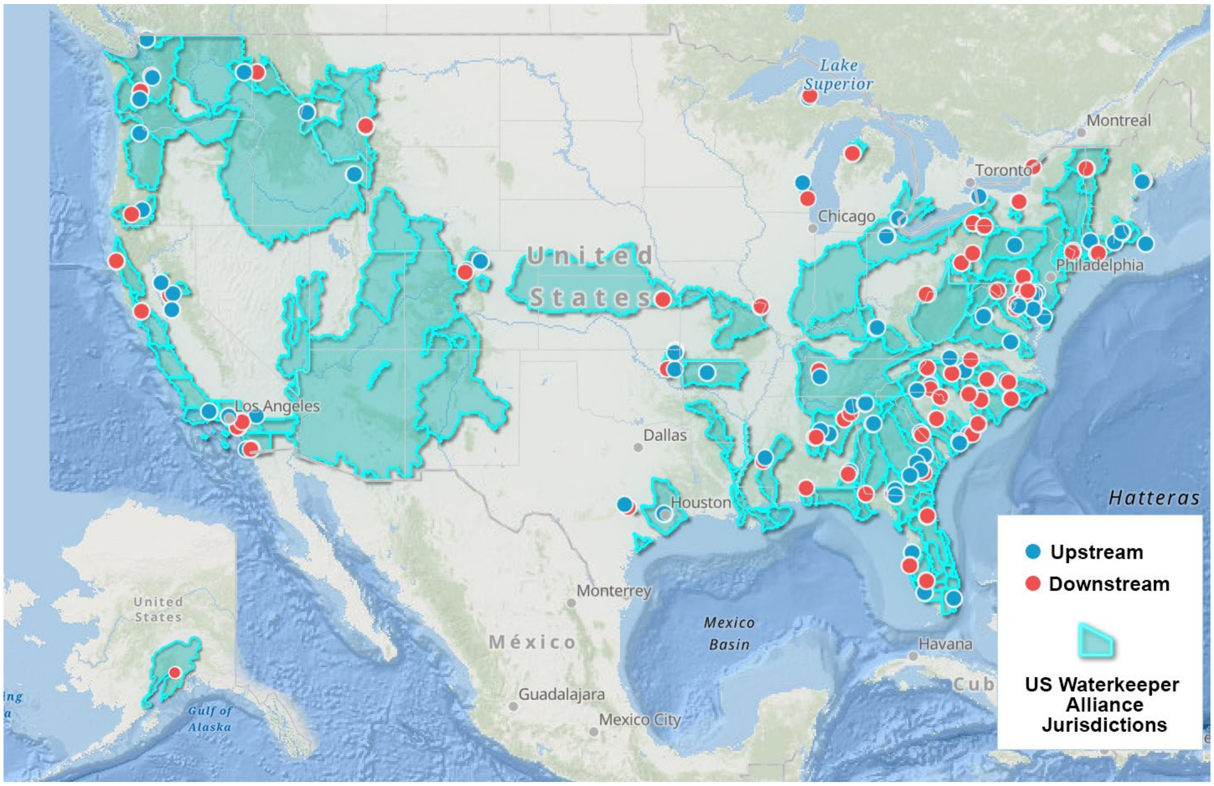


Figure 1. PFAS Survey Water Sample Collection Map.

The Waterkeeper Alliance National PFAS Monitoring Project surveyed 114 watersheds across the U.S in a first-ever study to analyze surface water samples collected during June and July 2022. **Figure 1** provides an ArcGIS map of Waterkeeper group watershed areas, along with geospatial sampling information. The primary project goal is to: **A.** characterize the presence of the 40 PFAS listed in EPA's Strategic Roadmap in 114 U.S. watersheds, **B.** analyze the detection frequency, cumulative concentration, and site concentration of individual PFAS in a nationwide survey, **C.** analyze the spatial dependence and distribution of PFAS contamination using sample location information, and **D.** perform a PFAS contamination source analysis for ten watersheds with the greatest differences in total PFAS concentration between upstream and downstream samples.

2. Material and Methods

2.1 DEXSORB® – Adsorbent with High Selectivity to PFAS

DEXSORB is a novel cyclodextrin-based adsorbent, designed for the monitoring and treatment of PFAS. The media is highly selective for PFAS and is used commercially in residential filtration products and engineered systems to treat PFAS contaminated drinking water supplies and wastewater effluent.[11–13] The rapid kinetics, high capacity and selective PFAS adsorption of DEXSORB uniquely enable point-of-site sample extractions.

Independent research and cross-lab validation studies have proven DEXSORB to be broadly applicable for advanced analysis of PFAS. Superior features include: (i) rapid extraction of diverse PFAS, (ii) simple elution with quantitative PFAS recovery, (iii) consistent performance in various water matrices, and (iv) low cost. These features derive from host-guest complexations occurring in the 0.78 nm cyclodextrin cavities. The sub-nanometer interior makes the hydrophobic cups ideally suited to PFAS adsorption through size-inclusion, and resistant to fouling by larger organic matter and smaller inorganics ions through size-exclusion.

DEXSORB is compatible with analytical applications like solid-phase extraction (SPE) and passive sampling. With no requirement of complex conditioning, DEXSORB can be simply applied in forms of WTK, SPE cartridges, and passive samplers to extract PFAS in diverse matrices from drinking water to wastewater. The media is commercially applied in passive samplers for PFAS monitoring in groundwater in the U.S. and Europe, and is being validated by the University of Rhode Island under an EPA Superfund Grant.

2.2 PFAS Water Test Kit

Cyclopure developed the PFAS WTK using DEXSORB under a grant from the National Institute of Environmental Health Sciences (NIEHS) to provide a convenient, affordable and accurate way to detect PFAS compounds. The WTK enables real-time PFAS extractions from grab samples at the point of testing. Extractions occur during sampling as PFAS are adsorbed onto a DEXSORB-loaded filtration disc at the bottom of a 250-mL collection cup. PFAS are locked securely into the cyclodextrin media for transport to the Cyclopure analytical laboratory for recovery and analysis. No shipment of water is necessary. Sampling by this method tests water sources in real-time under actual conditions, preserving sample extractions in on-site state and ensuring highly consistent PFAS analysis.

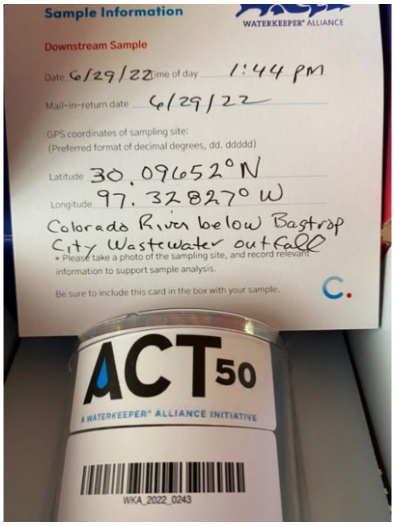
To date, Cyclopure has tested and reported on over 2,000 water samples in 42 States across the U.S. The PFAS WTK is actively used by households, municipalities, environmental organizations and research institutions. NIEHS has listed the kit as a SBIR STTR Sensor Technology for the 21st Century.[14]

2.3 Site Selection and Sampling Method

The Waterkeeper Alliance National PFAS Monitoring Project surveyed 114 watersheds across the U.S. A total of 114 Waterkeeper groups collected 228 surface water samples using Cyclopure's PFAS WTK. For each watershed of interest, a potential point source of PFAS pollution was identified, and two surface water samples were collected upstream and downstream of the identified potential source. Potential point sources of PFAS pollution included landfill sites, airfields, industrial sites, and wastewater treatment plants.[15]

Figure 2. PFAS WTK collection cup and DEXSORB Disc.

Major elements of Cyclopure WTK include a 250-mL collection cup and a DEXSORB extraction disc (see **Figure 2**). Testers were instructed to fill collection cups with 250 mL of water sample taken from local surface waters. Each tester was provided with gloves to wear during sampling and advised to sample clear water to avoid sediments. After filling, the WTK filters sample through the open bottom of the cup, passing through the DEXSORB extraction disc. Sample filtration averages 20-30 minutes, depending on water turbidity. After filtration, all PFAS in the water sample are adsorbed by and secured in the DEXSORB filter disc.


Sample Information

WATERKEEPER® ALLIANCE

Downstream Sample

Date 6/29/22 Time of day 1:44 pm

Mail-in-return date 6/29/22

GPS coordinates of sampling site:
(Preferred format of decimal degrees, dd. ddddd)

Latitude 30.09652° N
Longitude 97.32827° W

Colorado River below Bastrop City Wastewater outfall

* Please take a photo of the sampling site, and record relevant information to support sample analysis.

Be sure to include this card in the box with your sample.

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2.4 Analytical Methods and Validation

Fully-drained WTKs were then placed back in the original packaging and returned for in-lab recovery and analysis at the Cyclopure analytical laboratory.

Cyclopure analytical chemists use methanol amended with ammonia acetate as eluent to recover PFAS compounds by standard SPE procedures from the DEXSORB disc. Eluted PFAS samples were subsequently analyzed on a HPLC-MS/MS (QExactive hybrid quadrupole orbitrap, ThermoFisher) for target analysis of 40 compounds listed under EPA Methods 533, 537, and 1633 (draft).

Analytical procedures used isotope dilution for PFAS measurement and quantification. The analysis of water samples has been validated to the requirements of EPA Methods 533, 537 and 1633 (draft), and follow instrument procedures for internal standardization and calibration. The limit of quantification (LOQ) for all 40 PFAS tested under Cyclopure analytical methods are 1.0 ppt (ng/L), other than GenX (HFPO-DA) and 3:3 FTCA which is 2.0 ppt (ng/L). Reporting limits have been validated to the accuracy criteria of EPA methods, including Minimum Reporting Limit (MRL) confirmation.

3. Results and Discussion

The Waterkeeper Alliance National PFAS Monitoring Project surveyed 114 watersheds across the U.S. A total of 114 Waterkeeper groups collected 228 surface water samples using Cyclopure PFAS WTK. For each watershed of interest, a potential point source of PFAS pollution was identified, and two surface water samples were collected, one upstream and one downstream, of a potential identified pollution source. Each of the 40 PFAS compounds, included in the EPA PFAS strategic roadmap, was measured by means of HPLC-MS/MS at Cyclopure analytical laboratory. This project established a unique and comprehensive PFAS contamination database of watersheds across the U.S., which attests to the need for further regulatory activities and provides enriched PFAS distribution data for source analysis and identification.

3.1 Individual PFAS Detections

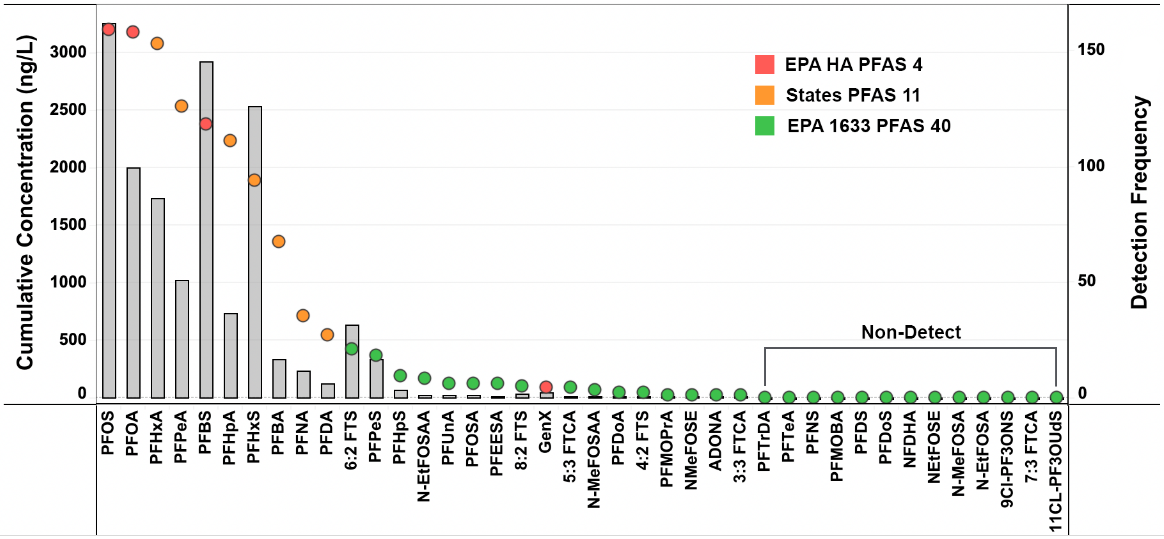
In this section, we discuss PFAS findings by (i) detection frequency, (ii) cumulative concentrations, and (iii) site concentration across the 114 watersheds sampled during this study. PFAS discussions are organized around categorization of PFAS into three groups: EPA PFAS 4; States PFAS 11, and EPA 1633 PFAS 40. The 40 target PFAS were selected for their regulatory relevance and public interest.

EPA PFAS 4. This group is composed of PFOA, PFOS, PFBS, and GenX (HFPO-DA) that are the subject of EPA's recent health advisory update of June 16, 2022.

States PFAS 11. In addition to the EPA PFAS 4, this group references 7 PFAS covered by current state regulatory limits, specifically PFHxA, PFHxS, PFNA, PFDA, PFHpA, PFPeA, and PFBA. In 2020, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) established Maximum Contaminant Levels (MCL) for seven PFAS: PFOA, PFOS, PFHxA, PFNA, PFBS, PFHxS, and GenX (HFPO-DA). Also in 2020, Massachusetts Department of Environmental Protection published a cumulative MCL of 20 ppt for a group of six PFAS: PFOA, PFOS, PFHpA, PFNA, PFDA, and PFHxS.

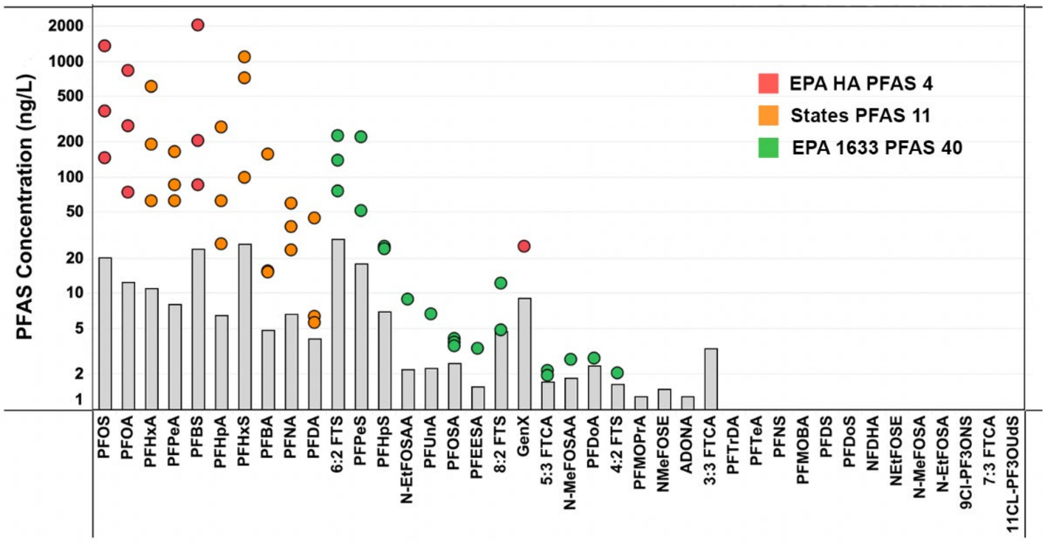
EPA 1633 PFAS 40. In addition to the States PFAS 11, this group covers 29 additional PFAS analytes that are referenced in EPA's June 2022 Draft Method 1633, which includes all PFAS specified in EPA Methods 533 and 537.

Figure 3 summarizes the detection frequency (circles) and cumulative concentration (ng/L; bars) of PFAS measured in surface water samples using Cyclopure's PFAS WTK. Within the EPA 1633



PFAS 40 group, approximately 68% of these PFAS (27 out of 40) were detected at least once across the sampled watersheds; 10 of the PFAS compounds measured had greater than 10% detection frequency.

Figure 4 illustrates the distribution of PFAS concentrations by compound. The gray bar represents the average concentration of each PFAS for all detections. Circles show the three highest concentrations for each PFAS.



EPA PFAS 4. We found that PFOA and PFOS were the most frequently detected PFAS across the 114 sampled watersheds in the U.S. See Appendix 2 for the complete dataset.

- **PFOA** was detected in 158 out of 228 sampling sites (a 69% detection frequency), with measured concentrations ranging from 1.0 to 847.0 ppt (ng/L). PFOA, with seven fluorinated carbons and a carboxylic acid head group, has been used in a variety of consumer products and in the production of fluoropolymers.
- **PFOS** was detected in 159 sampling sites (a 70% detection frequency), with measured concentrations ranging from 1.0 to 1,364.7 ppt (ng/L). With eight fluorinated carbons and a sulfonic acid head group, PFOS is stable under high temperature and used extensively in AFFFs – a fire suppressant widely applied at firefighting training sites and airports. In addition, PFOS is used in stain-resistant fabrics, food packaging, textiles, and metal plating.

The widespread distribution of PFOA and PFOS in U.S. watersheds can be attributed to (i) extensive historical use, (ii) high persistence in the environment, and (iii) the pervasive disposition of PFAS-containing residential and industrial waste in landfills across the country.

Within the EPA PFAS 4 group, PFBS and GenX (HFPO-DA) were detected at lower frequency relative to PFOA and PFOS. PFBS was detected in 118 out of 228 sampling sites (a 52% detection frequency), while GenX (HFPO-DA) was detected in 4 samples from three watersheds.

- **PFBS**, as a short-chain sulfonic acid with four fluorinated carbons, shares similar physicochemical properties, application uses, and toxicological effects with PFOS. Because of its shorter chain length and smaller molecular size, the half-life of PFBS in the body is significantly shorter than for PFOS (weeks versus years). Accordingly, the EPA health advisory level of 2,000 ppt (ng/L) for PFBS is over 100,000 times higher than PFOA (0.004 ppt; ng/L) and PFOS (0.02 ppt; ng/L).

- **GenX** (HFPO-DA) was developed to replace the use of PFOA in the manufacture of high-performance fluoropolymers. Recent studies have associated exposure to GenX (HFPO-DA) with health effects in the liver, kidney, immune system, and cancer. Though the toxicity of GenX (HFPO-DA) is estimated to be lower than that of PFOA, EPA's health advisory level of 10 ppt (ng/L) for GenX (HFPO-DA) reflects a high degree of concern among regulators and policy makers regarding GenX (HFPO-DA) contamination. In this project, GenX (HFPO-DA) was detected in the Congaree River (South Carolina), Cape Fear River (North Carolina), and Tar Creek (Oklahoma). The highest concentration (25.8 ppt; ng/L) was measured in the Cape Fear River downstream sample, which is consistent with other monitoring observations conducted by North Carolina Department of Environmental Quality (NCDEQ), Environmental Working Group (EWG), and local organizations in this region.

State PFAS 11. In addition to the EPA PFAS 4, the other seven PFAS in this group were also among the most frequently detected compounds (>10% detection frequency). Detections for this group were: PFHxA (153 sites; 67%), PFPeA (126 sites; 55%), PFHpA (111 sites; 49%), PFHxS (94 sites; 41%), PFBA (67 sites; 29%), PFNA (35 sites; 15%), and PFDA (27 site; 12%). Among these compounds, six are carboxylic acids (PFBA, PFPeA, PFHxA, PFHpA, PFNA and PFDA) having the same head group as PFOA in chain lengths varying from 3 to 9 fluorinated carbons; and one is a sulfonic acid (PFHxS) having the same head group as PFOS with a chain length of 6 fluorinated carbons.

This group of PFAS is subject to the highest level of regulatory attention among EPA and state regulators. As provided in the PFAS Strategic Roadmap, EPA is currently developing toxicity assessments for PFBA, PFHxA, PFHxS, PFNA and PFDA. The resulting toxicity assessments will then be applied to determine health advisory levels for each of these five PFAS.

EPA 1633 PFAS 40. Excluding the 11 PFAS discussed above, the other 29 PFAS in the EPA 1633 PFAS 40 group, except for FBSA, were detected with limited frequency and low concentrations; 13 of which were non-detect for all sampling sites. FBSA, a sulfonamide with a linear chain of 4 fluorinated carbons, was present at 31 sites, a detection frequency of 14%. See Appendix 3 for additional statistical analysis of PFAS spatial occurrence and concentration patterns.

Summary. From the sampling of 228 upstream and downstream sites in 114 watersheds, we found that (i) PFOA and PFOS are the most frequently detected compounds, with PFOS measured at the highest cumulative concentration of 3,255.9 ppt (ng/L), (ii) among the EPA PFAS 4 group, PFBS was detected with the second highest cumulative concentration of 2,914.2 ppt (ng/L), (iii) GenX (HFPO-DA) was only detected in South Carolina, North Carolina and Oklahoma, with the highest concentration found in the sample collected from Cape Fear River in North Carolina. These results and observations show high consistency with other regional monitoring projects, and provide support for the need of further regulation that targets PFAS contamination.

3.2 Geospatial Distribution of PFAS Contamination

This section provides analysis of geospatial distribution of PFAS contamination across the 114 watersheds. **Figure 5** illustrates the total concentration of EPA 40 PFAS group detections at upstream and downstream sites for each watershed. To organize analysis, we divided sampling areas into four regions: Midwest, Northeast, South, and West. Watersheds in the Northeast and South regions presented higher PFAS concentrations. However, this observation does not necessarily translate to more severe PFAS contamination in these two regions compared to the Midwest and West, as 70% of total samples taken were collected in the Northeast (34 sites) and the South (126 sites).

Midwest. This region had the fewest water samples collected (16 sampling sites) from a total of 5 states. Among these states, the most elevated PFAS concentrations were measured at sites in Missouri and Ohio. The highest total PFAS concentration was found in the downstream sample collected by Missouri Confluence Waterkeeper from Coldwater Creek, which flows into the Missouri River. In this sample, total PFAS concentration was measured at 380.0 ppt (ng/L), with PFOS being the highest at 125.5 ppt (ng/L). Other EPA 4 PFAS compounds PFOA and PFBS were also detected in this sample at 17.0 ppt (ng/L) and 11.6 ppt (ng/L), respectively.

Northeast. In this region, water samples were collected at 34 sampling sites from a total of 8 states. Sites in Pennsylvania, Rhode Island and New York had the most elevated PFAS concentrations. The highest total PFAS concentration was found in the downstream sample collected by Lower Susquehanna Riverkeeper from Kreutz Creek in PA. The PFAS concentration of 6,192.0 ppt (ng/L) at this site was the highest measured across all 228 sampling sites, with PFBS being the

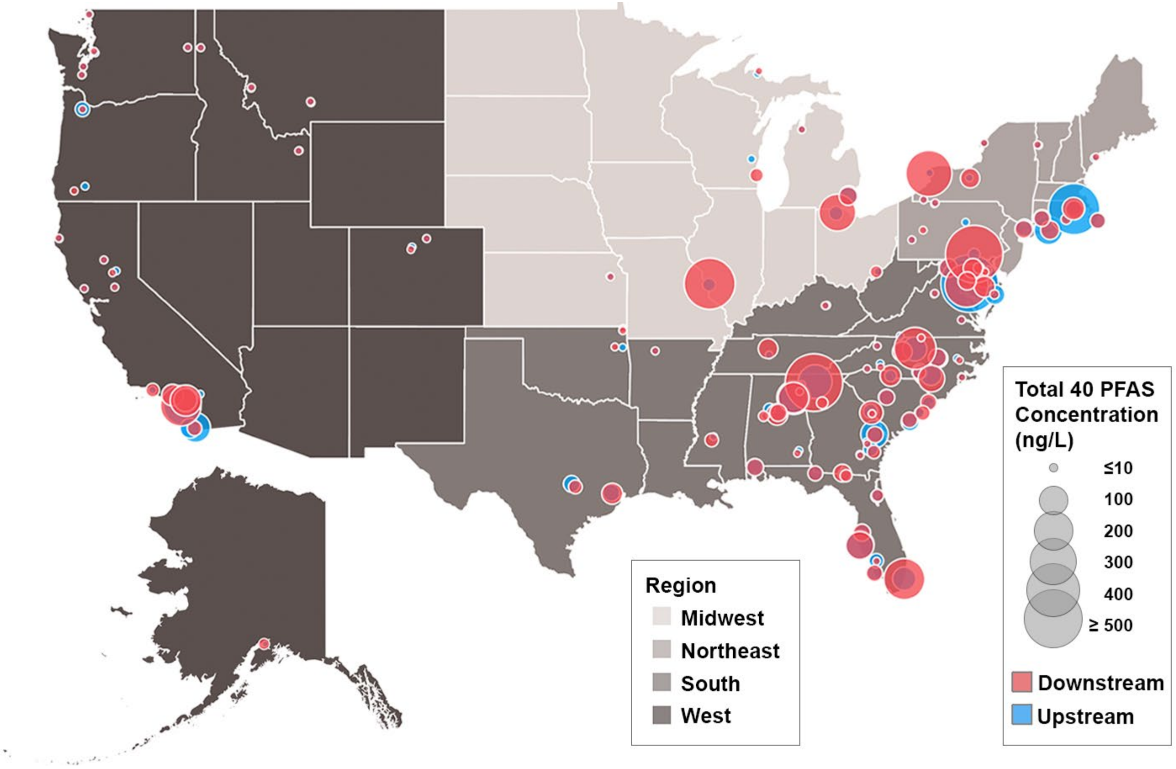


Figure 5. Total PFAS concentrations (EPA PFAS 40) in each watershed for Upstream site (blue circles) and for Downstream site (red circles). Circle sizes correlate to measured PFAS concentrations at a sampling location. See legend. The base map is colored by four U.S. regions.

highest at 2,083.3 ppt (ng/L). Other EPA 4 PFAS compounds PFOA and PFOS were also detected in this sample at 847.0 ppt (ng/L) and 374.3 ppt (ng/L), respectively.

South. This region had the most water samples collected (126 sampling sites) from a total of 14 states. Sites in Maryland, Georgia, Florida, West Virginia, and North Carolina had the most elevated PFAS concentrations. The highest total PFAS concentration was found in the upstream sample collected by Potomac Riverkeeper from Piscataway Creek in MD. In this sample, total PFAS was measured at 3,050.0 ppt (ng/L), with PFOS being the highest at 1,364.7 ppt (ng/L). Other EPA 4 PFAS compounds PFOA and PFBS were also detected in this sample at 282.8 ppt (ng/L) and 48.2 ppt (ng/L), respectively.

West. In this region, water samples were collected at 50 sampling sites from a total of 7 states. High PFAS concentrations were detected in Southern California (e.g., Orange County, San Diego and Los Angeles). The highest total PFAS concentration was found in the downstream sample collected by Orange County Coastkeeper from San Diego Creek in CA. In this sample, total PFAS was measured at 222.0 ppt (ng/L), with PFOA being the highest at 61.5 ppt (ng/L). In addition to PFOA, PFOS and PFBS were also detected in this sample at 34.4 ppt (ng/L) and 12.7 ppt (ng/L), respectively.

Table 1. Waterkeeper groups with highest PFAS concentration measurements in each region.

Region	Waterkeeper Organization Name	Regional Rank	State	Upstream Downstream	Total 40 PFAS Concentration (ng/L or ppt)
Midwest	Missouri Confluence Waterkeeper	Top 1	Missouri	Downstream	380
Midwest	Lake Erie Waterkeeper	Top 2	Ohio	Downstream	177
Northeast	Lower Susquehanna Riverkeeper	Top 1	Pennsylvania	Downstream	6192
Northeast	Narragansett Baykeeper	Top 2	Rhode Island	Upstream	385
South	Potomac Riverkeeper	Top 1	Maryland	Upstream	3050
South	Upper Coosa Riverkeeper	Top 2	Georgia	Downstream	558
West	Orange County Coastkeeper	Top 1	California	Downstream	222
West	Orange County Coastkeeper	Top 2	California	Upstream	181

Co-Presence of PFAS. Reviewing data from the eight sampling sites in **Table 1** (the "Regional 8 Sites"), we observed that samples from these sites presented consistent collections of PFAS, regardless of region. PFOA, PFOS and PFBS were detected and measured in the sample for each Regional 8 Site. For six of the Regional 8 Sites, the highest PFAS concentration came from the group of EPA PFAS 4. These data show that legacy PFAS like PFOA, PFOS and PFBS are still the most prevalent PFAS across the U.S. Although PFOA and PFOS were phased out years ago by EPA, these chemicals are still pervasive in U.S. watersheds due to high environmental persistence and their ongoing presence in landfill accumulations.

This geospatial analysis affirms the need for further PFAS regulatory activity, and provides a high-quality dataset to assist ongoing PFAS remediation.

3.3 Source Analysis and Identification

This section provides a PFAS contamination source analysis of samples taken from 10 Case Study Watersheds. The 10 Case Study Watersheds were selected for the greatest difference between total upstream and downstream PFAS concentrations. See **Figure 6** for total PFAS concentrations for each 10 Case Study Watershed. This analysis was conducted to identify potential point sources for PFAS contamination using the watershed and geological information provided by each Waterkeeper group. We classified the 10 Case Study Watersheds based on four primary contamination sources: Landfills, Airports, Industry, and Wastewater Treatment Plants (WWTPs).

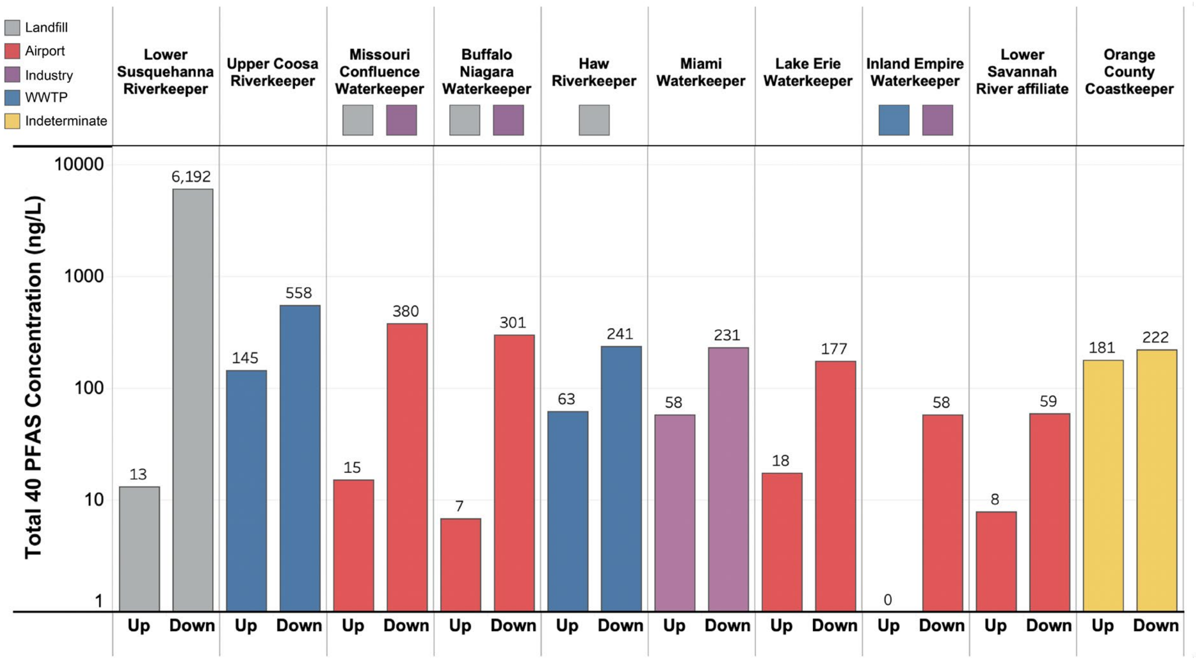


Figure 6. 10 Case Study Watersheds. PFAS point contamination sources: Landfill in grey, Airport in red, Industry in purple, WWTP in blue and Indeterminate in yellow. Bar colors indicate the primary suspect sources for each watershed. Colored boxes depicted above the bar, indicate secondary suspect sources. Up denotes Upstream, and Down denotes Downstream.

Landfills. Municipal solid waste (MSW) landfills are a significant contamination source of PFAS. As discussed above, PFAS have been applied in a wide variety of residential and industrial products. Most of these products end up as MSW at landfill sites, where they undergo various physical, chemical, and microbial decomposition and degradation processes. When rainwater percolates through the wastes, pollutants accumulate in the water-based solution, known as landfill leachate. PFAS in landfill leachate can contaminate adjacent soil and water systems. Additionally, PFAS-containing landfill leachate is often transferred to WWTPs for further processing.

The watershed with the highest total PFAS concentration change between upstream and downstream was sampled by Lower Susquehanna Riverkeeper at Kreutz Creek in PA. For this location, a landfill site was identified as the major potential point source for PFAS contamination. Only half a mile apart, the upstream and downstream samples had total PFAS detections of 13.4 ppt (ng/L) and 6,191.9 ppt (ng/L), respectively. In the downstream sample, 20 PFAS were detected with dominant species concentrations of 2,083.3 ppt (ng/L) for PFBS, 1,093.3 ppt (ng/L) for PFHxS, 847.0 ppt (ng/L) for PFOA, 607.1 ppt (ng/L) for PFHxA, 374.3 ppt (ng/L) for PFOS and

272.8 ppt (ng/L) for PFHpA. In the sampling locations for Missouri Confluence Waterkeeper, Buffalo Niagara Waterkeeper and Haw Riverkeeper, landfills were also identified as a potential PFAS contamination source.

Airports. Firefighting training and emergency fire suppression are common activities at U.S. airports, both for military and civilian operations. AFFF is a synthetic mixture containing a variety of PFAS, such as PFOS. Due to its thermal stability, it is highly effective for suppression of combustion during firefighting activities. The use of AFFF for incidents and exercises has led to direct emissions of PFAS into the environment and contamination of adjacent surface water and groundwater.

Among the 10 Case Study Watersheds, we identified five locations which have at least one airport as the potential primary or secondary PFAS contamination source. The identified airports include (i) St. Louis Lambert International Airport (Missouri Confluence Waterkeeper), (ii) Niagara Falls International Airport (Buffalo Niagara Waterkeeper), (iii) Eugene F. Kranz Toledo Express Airport (Lake Erie Waterkeeper), (iv) SBD International Airport and Flabob Airport (Inland Empire Waterkeeper), and (v) Augusta Regional Airport (Lower Savannah River affiliate). For Missouri Confluence Waterkeeper (Coldwater Creek) and Buffalo Niagara Waterkeeper (Cayuga Creek), the sampled creeks flow directly through the airport, and show larger total PFAS concentration differences between upstream and downstream sites than sampling locations associated with Lake Erie, Inland Empire, and Lower Savannah River.

Industry. With desirable physicochemical properties, PFAS are produced in substantial volume to meet the requirements of industrial (e.g., textiles, pesticides, leather, medical devices, semiconductors, and metal plating) and consumer applications (e.g., food packaging, personal care products, non-stick cookware, water-repellant clothing and stain resistant fabrics). Lesser known items using PFAS, include ammunition, climbing ropes, guitar strings, and artificial turf. The discharge of solid and liquid waste generated during these industrial activities is a source of PFAS contamination of soil and water systems. In this regard, EPA has proposed the use of NPDES permits to restrict PFAS discharges to water bodies.

Industrial activity has been identified as the potential primary or secondary source of PFAS contamination for four of the 10 Case Study Watersheds: Miami Waterkeeper, Missouri Confluence Waterkeeper, Buffalo Niagara Waterkeeper, and Inland Empire Waterkeeper.

- For Miami Waterkeeper, the Eastview Commerce Center between upstream and downstream sampling sites, contains numerous industrial activities, including furniture manufacturing.
- For Missouri Confluence Waterkeeper, two categories of industry were identified: (i) consumer products manufacturers, such as plastic fabrication, janitorial supplies, home improvement products, and packaging materials; and (ii) aerospace industry and high precision machining.
- For Buffalo Niagara Waterkeeper, manufacturers related to aerospace and sensor industry were identified.
- For Inland Empire Waterkeeper, numerous industries are located between upstream and downstream sampling sites over a distance of 50 miles, including artificial turf, plumbing supplies, battery testers, and control panels.

WWTPs. As noted above, landfill leachate and industrial liquid waste can be major sources for PFAS contamination. Moreover, they are often sent to WWTPs for further treatment. Studies have shown that PFAS are present in every stage of the WWTP treatment process (i.e., raw wastewater, treated wastewater and sewage sludge, and suspended solids).

Among the 10 Case Study Watersheds, we identified three that have WWTP as a potential primary or secondary source of PFAS contamination, including Upper Coosa Riverkeeper (Dalton Utilities Wastewater Treatment Facilities), Haw Riverkeeper (TZ Osborne WWTP), and Inland Empire Waterkeeper (Western Riverside County Regional Wastewater Authority, Riverside WWTP, Colton WWTP, San Bernardino Water Reclamation, and Redlands Wastewater Treatment).

Indeterminate PFAS Source. For *Orange County Coastkeeper*, the upstream and downstream sites are located in a highly populated residential area. Due to divergent community activities, definitive potential point sources of PFAS contamination were not identifiable.

4. Implications For Future Regulation

This nationwide PFAS survey provides valuable insights into (i) the most pervasive PFAS species found at 228 distinct surface water sampling sites, (ii) a geographic distribution of PFAS contamination for 114 watersheds across 36 states and Washington D.C., and (iii) the identification of potential PFAS contamination sources. All these observations and insights reinforce the scope of PFAS contamination and the need for focused and effective regulation.

4.1 EPA PFAS 4

This study highlights that PFOA, PFOS, and PFBS are the PFAS of greatest concern due to their (i) pervasive occurrence across U.S. watersheds, and (ii) predominant concentrations in all samples with positive detections. As discussed in Section 3.1, PFOA and PFOS are the most frequently detected compounds, and were found in ~70% of water samples. PFOS and PFBS were measured with the highest cumulative concentration for all sites at 3,255.9 ppt and 2,914.2 ppt, respectively. As shown in the geospatial analysis of Section 3.2, PFOA, PFOS and PFBS were detected together at each of the most contaminated sites found in the Midwest, Northeast, South, and West regions.

These data show that PFOA, PFOS, and PFBS continue to be the most prevalent PFAS found in U.S. surface waters, and warrant the primary focus of regulatory activities.

4.2 States PFAS 11

As noted in Section 3, multiple other PFAS (in addition to the EPA PFAS 4) were detected and measured with high frequency in the National PFAS Monitoring Project, including PFHxA (153 sites; 67%), PFPeA (126 sites; 55%), PFHpA (111 sites; 49%), and PFHxS(94 sites; 41%). These findings reinforce the high level of regulatory attention given the States PFAS 11 by EPA and state regulators.

4.3 Landfill Sites as PFAS Source Points

From case study analyses in Section 3.3, we identified landfills as an important source of PFAS contamination in U.S. watersheds. Significant increases in PFAS concentrations of downstream water samples were observed in four of the 10 Case Study Watersheds, where landfill sites were identified as the potential primary or secondary source of PFAS contamination.

The identification of landfills as a potential source of PFAS contamination in these watersheds is consistent with previous studies, and supports the EPA proposal to classify PFOA, PFOS, PFBS and GenX (HPDO-DA) as Hazardous Constituents under subtitle C of the Resource Conservation Recovery Act (RCRA) and restrict the disposal of PFAS-containing waste at MSW landfills.

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Appendix 1 - Waterkeeper Participants

Table A1. Waterkeeper participant information (No.1 - 56).

No.	Barcode	Upstream_Downstream	Waterkeeper Organization Name	Waterkeeper Name
1	WKA_2022_0001	Upstream	Narragansett Baykeeper	Mike Jarbeau
2	WKA_2022_0002	Downstream	Narragansett Baykeeper	Mike Jarbeau
3	WKA_2022_0003	Upstream	Upper Missouri Waterkeeper	Quincey Johnson
4	WKA_2022_0004	Downstream	Upper Missouri Waterkeeper	Quincey Johnson
5	WKA_2022_0005	Upstream	Humboldt Baykeeper	Jennifer Kalt
6	WKA_2022_0006	Downstream	Humboldt Baykeeper	Jennifer Kalt
7	WKA_2022_0007	Upstream	Gunpowder Riverkeeper	Theaux Le Gardeur
8	WKA_2022_0008	Downstream	Gunpowder Riverkeeper	Theaux Le Gardeur
9	WKA_2022_0009	Upstream	Choptank Riverkeeper	Matt Pluta
10	WKA_2022_0010	Downstream	Choptank Riverkeeper	Matt Pluta
11	WKA_2022_0011	Upstream	Grand Riverkeeper	Martin Lively
12	WKA_2022_0012	Downstream	Grand Riverkeeper	Martin Lively
13	WKA_2022_0013	Upstream	West Virginia Headwaters Waterkeeper	Angie Rosser
14	WKA_2022_0014	Downstream	West Virginia Headwaters Waterkeeper	Angie Rosser
15	WKA_2022_0017	Downstream	Santa Barbara Channelkeeper	Benjamin Pitterle
16	WKA_2022_0018	Upstream	Santa Barbara Channelkeeper	Benjamin Pitterle
17	WKA_2022_0023	Upstream	Waterkeepers Florida	John Quarterman
18	WKA_2022_0024	Downstream	Waterkeepers Florida	John Quarterman
19	WKA_2022_0025	Upstream	Shore Rivers	Elle Bassett
20	WKA_2022_0026	Downstream	Shore Rivers	Elle Bassett
21	WKA_2022_0027	Upstream	Tualatin Riverkeeper	Maya Hurst-Mayr
22	WKA_2022_0028	Downstream	Tualatin Riverkeeper	Maya Hurst-Mayr
23	WKA_2022_0031	Upstream	Poudre Waterkeeper	Jennifer Sunderland
24	WKA_2022_0032	Downstream	Poudre Waterkeeper	Jennifer Sunderland
25	WKA_2022_0033	Upstream	Green Riverkeeper	Gray Jernigan
26	WKA_2022_0034	Downstream	Green Riverkeeper	Gray Jernigan
27	WKA_2022_0035	Upstream	Twin Harbors Waterkeeper	Lee First
28	WKA_2022_0036	Downstream	Twin Harbors Waterkeeper	Lee First
29	WKA_2022_0037	Upstream	Chattahoochee Riverkeeper	Jessica Sterling
30	WKA_2022_0038	Downstream	Chattahoochee Riverkeeper	Jessica Sterling
31	WKA_2022_0043	Upstream	Cook Inletkeeper	Liz Mering
32	WKA_2022_0044	Downstream	Cook Inletkeeper	Liz Mering
33	WKA_2022_0045	Upstream	South, West & Rhode Riverkeeper	Evann Magee
34	WKA_2022_0046	Downstream	South, West & Rhode Riverkeeper	Evann Magee
35	WKA_2022_0047	Upstream	Upper Potomac Riverkeeper	Brent E Walls
36	WKA_2022_0048	Downstream	Upper Potomac Riverkeeper	Brent E Walls
37	WKA_2022_0049	Upstream	Arkansas Ozark Waterkeeper	Teresa Turk
38	WKA_2022_0050	Downstream	Arkansas Ozark Waterkeeper	Teresa Turk
39	WKA_2022_0051	Upstream	Snake River Waterkeeper	Ferrell Ryan
40	WKA_2022_0052	Downstream	Snake River Waterkeeper	Ferrell Ryan
41	WKA_2022_0053	Upstream	Kentucky Riverkeeper	Pat A Banks
42	WKA_2022_0054	Downstream	Kentucky Riverkeeper	Pat A Banks
43	WKA_2022_0057	Upstream	Nantucket Waterkeeper	RJ Turcotte
44	WKA_2022_0058	Downstream	Nantucket Waterkeeper	RJ Turcotte
45	WKA_2022_0059	Upstream	Yadkin Riverkeeper	Grace Fuchs
46	WKA_2022_0060	Downstream	Yadkin Riverkeeper	Grace Fuchs
47	WKA_2022_0061	Upstream	Suncoast Waterkeeper	Abbey Tyrna
48	WKA_2022_0062	Downstream	Suncoast Waterkeeper	Abbey Tyrna
49	WKA_2022_0063	Upstream	Upper Coosa Riverkeeper	Jesse Demonbreun-Chapman
50	WKA_2022_0064	Downstream	Upper Coosa Riverkeeper	Jesse Demonbreun-Chapman
51	WKA_2022_0065	Upstream	Lumber Riverkeeper	Jefferson Currie II
52	WKA_2022_0066	Downstream	Lumber Riverkeeper	Jefferson Currie II
53	WKA_2022_0067	Upstream	Middle Susquehanna Riverkeeper Association	John Zaktansky
54	WKA_2022_0068	Downstream	Middle Susquehanna Riverkeeper Association	John Zaktansky
55	WKA_2022_0069	Upstream	Kansas Riverkeeper	Dawn Buehler
56	WKA_2022_0070	Downstream	Kansas Riverkeeper	Dawn Buehler

Continued Table A1. Waterkeeper participant information (No. 57 – 110).

No.	Barcode	Upstream_Downstream	Waterkeeper Organization Name	Waterkeeper Name
57	WKA_2022_0071	Upstream	Detroit Riverkeeper	Robert Burns
58	WKA_2022_0072	Downstream	Detroit Riverkeeper	Robert Burns
59	WKA_2022_0073	Upstream	Neuse Riverkeeper	Samantha Krop
60	WKA_2022_0074	Downstream	Neuse Riverkeeper	Samantha Krop
61	WKA_2022_0077	Upstream	Rogue Riverkeeper	Frances Oyung
62	WKA_2022_0078	Downstream	Rogue Riverkeeper	Frances Oyung
63	WKA_2022_0084	Upstream	Yuba River Waterkeeper (South Yuba River Citizens League)	Kyle McNeil
64	WKA_2022_0085	Downstream	Yuba River Waterkeeper (South Yuba River Citizens League)	Kyle McNeil
65	WKA_2022_0086	Upstream	Spokane Riverkeeper	Jule Schultz
66	WKA_2022_0087	Downstream	Spokane Riverkeeper	Jule Schultz
67	WKA_2022_0088	Upstream	Waccamaw Riverkeeper	Cara Schildtknecht
68	WKA_2022_0089	Downstream	Waccamaw Riverkeeper	Cara Schildtknecht
69	WKA_2022_0090	Upstream	Chautauqua-Conewango Consortium	Jane Conroe
70	WKA_2022_0091	Downstream	Chautauqua-Conewango Consortium	Jane Conroe
71	WKA_2022_0094	Upstream	Cape Fear Riverkeeper	Kemp Burdette
72	WKA_2022_0095	Downstream	Cape Fear Riverkeeper	Kemp Burdette
73	WKA_2022_0096	Upstream	Upper Colorado River Watershed Group	Andy Miller
74	WKA_2022_0097	Downstream	Upper Colorado River Watershed Group	Andy Miller
75	WKA_2022_0098	Upstream	Hurricane Creekkeeper	John Wathen
76	WKA_2022_0099	Downstream	Hurricane Creekkeeper	John Wathen
77	WKA_2022_0100	Upstream	Little River Waterkeeper	Angie Shugart
78	WKA_2022_0101	Upstream	Tennessee Riverkeeper	David Whiteside
79	WKA_2022_0102	Downstream	Tennessee Riverkeeper	David Whiteside
80	WKA_2022_0103	Downstream	Little River Waterkeeper	Angie Shugart
81	WKA_2022_0105	Upstream	Calusa Waterkeeper	John Cassani
82	WKA_2022_0106	Downstream	Calusa Waterkeeper	John Cassani
83	WKA_2022_0107	Upstream	Tar Creekkeeper	Rebecca Jim
84	WKA_2022_0108	Downstream	Tar Creekkeeper	Rebecca Jim
85	WKA_2022_0109	Upstream	Collier County Warerkeeper	KC Schulberg
86	WKA_2022_0110	Downstream	Collier County Warerkeeper	KC Schulberg
87	WKA_2022_0111	Upstream	Black Warrior Riverkeeper	John Kinney
88	WKA_2022_0112	Downstream	Black Warrior Riverkeeper	John Kinney
89	WKA_2022_0113	Upstream	Broad Riverkeeper	David Caldwell
90	WKA_2022_0114	Downstream	Broad Riverkeeper	David Caldwell
91	WKA_2022_0115	Upstream	Coosa Riverkeeper	Justinn Overton / Lucas Allison
92	WKA_2022_0116	Downstream	Coosa Riverkeeper	Justinn Overton / Lucas Allison
93	WKA_2022_0117	Upstream	Bayou City Waterkeeper	Mashal Awais
94	WKA_2022_0118	Downstream	Bayou City Waterkeeper	Mashal Awais
95	WKA_2022_0119	Upstream	Milwaukee Riverkeeper	Katie Rademacher
96	WKA_2022_0120	Downstream	Milwaukee Riverkeeper	Katie Rademacher
97	WKA_2022_0121	Downstream	Casco Baykeeper (Friends of Casco Bay)	Ivy L. Frignoca
98	WKA_2022_0122	Upstream	Apalachicola Riverkeeper	Georgia Ackerman
99	WKA_2022_0123	Downstream	Apalachicola Riverkeeper	Georgia Ackerman
100	WKA_2022_0124	Upstream	South County Coastkeeper (Save The Bay)	David Prescott
101	WKA_2022_0125	Downstream	South County Coastkeeper (Save The Bay)	David Prescott
102	WKA_2022_0126	Upstream	Casco Baykeeper (Friends of Casco Bay)	Ivy L. Frignoca
103	WKA_2022_0127	Upstream	CA Urban Streams Alliance - The Stream Team	Timmarie Hamill
104	WKA_2022_0128	Downstream	CA Urban Streams Alliance - The Stream Team	Timmarie Hamill
105	WKA_2022_0129	Upstream	James Riverkeeper	Erin Reilly
106	WKA_2022_0130	Downstream	James Riverkeeper	Erin Reilly
107	WKA_2022_0131	Upstream	White Oak Waterkeeper (Coastal Carolina Riverwatch)	Rebecca Drohan
108	WKA_2022_0132	Downstream	White Oak Waterkeeper (Coastal Carolina Riverwatch)	Rebecca Drohan
109	WKA_2022_0133	Upstream	Peconic Baykeeper	Peter Topping
110	WKA_2022_0134	Downstream	Peconic Baykeeper	Peter Topping

Continued Table A1. Waterkeeper participant information (No. 111 – 167).

No.	Barcode	Upstream_Downstream	Waterkeeper Organization Name	Waterkeeper Name
111	WKA_2022_0135	Upstream	Mobile Baykeeper	Cade Kistler
112	WKA_2022_0136	Downstream	Mobile Baykeeper	Cade Kistler
113	WKA_2022_0137	Upstream	Tampa Bay Waterkeeper	Justin Tramble
114	WKA_2022_0138	Upstream	Potomac Riverkeeper	Phillip Musegaas
115	WKA_2022_0139	Downstream	Potomac Riverkeeper	Phillip Musegaas
116	WKA_2022_0140	Downstream	Tampa Bay Waterkeeper	Justin Tramble
117	WKA_2022_0141	Upstream	San Diego Coastkeeper	Marie Diaz
118	WKA_2022_0142	Downstream	San Diego Coastkeeper	Marie Diaz
119	WKA_2022_0143	Upstream	Charleston Waterkeeper	Andrew Wunderley
120	WKA_2022_0144	Downstream	Charleston Waterkeeper	Andrew Wunderley
121	WKA_2022_0145	Upstream	Puget Soundkeeper Alliance	Blair Englebrecht
122	WKA_2022_0146	Upstream	Inland Empire Waterkeeper	Raymond Hiemstra
123	WKA_2022_0147	Downstream	Inland Empire Waterkeeper	Raymond Hiemstra
124	WKA_2022_0148	Upstream	Pamlico-Tar Riverkeeper	Jill Howell
125	WKA_2022_0149	Downstream	Pamlico-Tar Riverkeeper	Jill Howell
126	WKA_2022_0150	Downstream	Puget Soundkeeper Alliance	Blair Englebrecht
127	WKA_2022_0151	Upstream	Long Island Soundkeeper	Emma Deloughry
128	WKA_2022_0152	Downstream	Long Island Soundkeeper	Emma Deloughry
129	WKA_2022_0153	Upstream	Cahaba Riverkeeper	David Butler
130	WKA_2022_0154	Downstream	Cahaba Riverkeeper	David Butler
131	WKA_2022_0155	Downstream	Shenandoah Riverkeeper	Alan Lehman
132	WKA_2022_0160	Upstream	Grand Traverse Baykeeper	Heather Smith
133	WKA_2022_0161	Downstream	Grand Traverse Baykeeper	Heather Smith
134	WKA_2022_0162	Upstream	Shenandoah Riverkeeper	Alan Lehman
135	WKA_2022_0165	Downstream	Watauga Riverkeeper	Andy Hill
136	WKA_2022_0166	Upstream	Watauga Riverkeeper	Andy Hill
137	WKA_2022_0167	Upstream	Chester Riverkeeper at ShoreRivers	Annie Richards
138	WKA_2022_0168	Upstream	Catawba Riverkeeper	Brandon Jones
139	WKA_2022_0169	Downstream	Catawba Riverkeeper	Brandon Jones
140	WKA_2022_0170	Upstream	Satilla Riverkeeper	Chris Bertrand
141	WKA_2022_0171	Downstream	Satilla Riverkeeper	Chris Bertrand
142	WKA_2022_0172	Upstream	Upper Allegheny River Project	Pamela Digel
143	WKA_2022_0173	Downstream	Upper Allegheny River Project	Pamela Digel
144	WKA_2022_0174	Upstream	Altamaha Riverkeeper	Maggie Van Cantfort
145	WKA_2022_0175	Downstream	Altamaha Riverkeeper	Maggie Van Cantfort
146	WKA_2022_0176	Upstream	Upper St. Lawrence Riverkeeper	Lauren Eggleston
147	WKA_2022_0177	Downstream	Upper St. Lawrence Riverkeeper	Lauren Eggleston
148	WKA_2022_0178	Upstream	Los Angeles Waterkeeper	Maggie Gardner
149	WKA_2022_0179	Downstream	Los Angeles Waterkeeper	Maggie Gardner
150	WKA_2022_0180	Upstream	Lake Champlain Lakekeeper	Julie Silverman
151	WKA_2022_0181	Downstream	Lake Champlain Lakekeeper	Julie Silverman
152	WKA_2022_0182	Upstream	Congaree Riverkeeper	Bill Stangler
153	WKA_2022_0183	Downstream	Congaree Riverkeeper	Bill Stangler
154	WKA_2022_0184	Upstream	North Sound Baykeeper	Kirsten McDade
155	WKA_2022_0185	Downstream	North Sound Baykeeper	Kirsten McDade
156	WKA_2022_0186	Upstream	Assateague Coastkeeper	Gabrielle Ross
157	WKA_2022_0187	Downstream	Assateague Coastkeeper	Gabrielle Ross
158	WKA_2022_0188	Upstream	Anacostia Riverkeeper	Suzy Kelly/Christine Burns
159	WKA_2022_0189	Downstream	Anacostia Riverkeeper	Suzy Kelly/Christine Burns
160	WKA_2022_0190	Upstream	Yellow Dog Riverkeeper (Yellow Dog Watershed Preserve)	Sarah Heuer
161	WKA_2022_0191	Downstream	Yellow Dog Riverkeeper (Yellow Dog Watershed Preserve)	Sarah Heuer
162	WKA_2022_0192	Upstream	Seneca Lake Guardian, a Waterkeeper Alliance Affiliate	Joseph Campbell
163	WKA_2022_0193	Downstream	Seneca Lake Guardian, a Waterkeeper Alliance Affiliate	Joseph Campbell
164	WKA_2022_0194	Upstream	Choctawhatchee Riverkeeper	Michael Mullen
165	WKA_2022_0195	Downstream	Choctawhatchee Riverkeeper	Michael Mullen
166	WKA_2022_0196	Upstream	Narragansett Bay Riverkeeper	Kate McPherson
167	WKA_2022_0197	Downstream	Narragansett Bay Riverkeeper	Kate McPherson

Continued Table A1. Waterkeeper participant information (No. 168 – 210).

No.	Barcode	Upstream_Downstream	Waterkeeper Organization Name	Waterkeeper Name
168	WKA_2022_0200	Upstream	Haw Riverkeeper	Emily Sutton
169	WKA_2022_0201	Downstream	Haw Riverkeeper	Emily Sutton
170	WKA_2022_0202	Upstream	Lower Susquehanna Riverkeeper	Ted Evgeniadis
171	WKA_2022_0203	Downstream	Lower Susquehanna Riverkeeper	Ted Evgeniadis
172	WKA_2022_0204	Downstream	Chester Riverkeeper at ShoreRivers	Annie Richards
173	WKA_2022_0205	Upstream	Sassafras Riverkeeper (ShoreRivers)	Zack Kelleher
174	WKA_2022_0206	Downstream	Sassafras Riverkeeper (ShoreRivers)	Zack Kelleher
175	WKA_2022_0207	Upstream	Missouri Confluence Waterkeeper	Rachel Bartels
176	WKA_2022_0208	Downstream	Missouri Confluence Waterkeeper	Rachel Bartels
177	WKA_2022_0210	Downstream	St. Johns Riverkeeper	Lisa Rinaman
178	WKA_2022_0211	Upstream	St. Johns Riverkeeper	Lisa Rinaman
179	WKA_2022_0212	Downstream	Miami Waterkeeper	Aliza Karim
180	WKA_2022_0213	Upstream	Miami Waterkeeper	Aliza Karim
181	WKA_2022_0218	Upstream	Baltimore Harbor Waterkeeper	Cody Matteson
182	WKA_2022_0219	Downstream	Baltimore Harbor Waterkeeper	Cody Matteson
183	WKA_2022_0222	Upstream	Three Rivers Waterkeeper	Heather Hulton VanTassel
184	WKA_2022_0223	Downstream	Three Rivers Waterkeeper	Heather Hulton VanTassel
185	WKA_2022_0224	Upstream	Russian Riverkeeper	Ariel Majorana/Birkin Newell
186	WKA_2022_0225	Downstream	Russian Riverkeeper	Ariel Majorana/Birkin Newell
187	WKA_2022_0226	Upstream	Lake Coeur d'Alene Waterkeeper	Shelley Austin
188	WKA_2022_0227	Downstream	Lake Coeur d'Alene Waterkeeper	Shelley Austin
189	WKA_2022_0228	Upstream	Deschutes Estuary Restoration Team, a Puget Soundkeeper Affiliate	Jae Harris-Townsend
190	WKA_2022_0229	Downstream	Deschutes Estuary Restoration Team, a Puget Soundkeeper Affiliate	Jae Harris-Townsend
191	WKA_2022_0230	Upstream	Lower Savannah River affiliate (Savannah Riverkeeper)	Tonya Bonitatibus
192	WKA_2022_0231	Downstream	Lower Savannah River affiliate (Savannah Riverkeeper)	Tonya Bonitatibus
193	WKA_2022_0232	Upstream	Pearl Riverkeeper	Abby Braman
194	WKA_2022_0233	Downstream	Pearl Riverkeeper	Abby Braman
195	WKA_2022_0234	Upstream	Ogeechee Riverkeeeper	Damon Mullis
196	WKA_2022_0235	Downstream	Ogeechee Riverkeeeper	Damon Mullis
197	WKA_2022_0238	Upstream	Hackensack Riverkeeper	Hugh Carola
198	WKA_2022_0239	Downstream	Hackensack Riverkeeper	Hugh Carola
199	WKA_2022_0240	Upstream	Lower Savannah River affiliate (Savannah Riverkeeper)	Tonya Bonitatibus
200	WKA_2022_0241	Downstream	Lower Savannah River affiliate (Savannah Riverkeeper)	Tonya Bonitatibus
201	WKA_2022_0242	Upstream	Environmental Stewardship	Steve Box
202	WKA_2022_0243	Downstream	Environmental Stewardship	Steve Box
203	WKA_2022_0246	Upstream	Severn Riverkeeper	Sara Caldes
204	WKA_2022_0247	Downstream	Severn Riverkeeper	Sara Caldes
205	WKA_2022_0248	Upstream	Lake Erie Waterkeeper	John Keener
206	WKA_2022_0249	Downstream	Lake Erie Waterkeeper	John Keener
207	WKA_2022_0250	Upstream	Altamaha Riverkeeper	Maggie Van Cantfort
208	WKA_2022_0251	Downstream	Altamaha Riverkeeper	Maggie Van Cantfort
209	WKA_2022_0252	Upstream	Spring Creek Coalition	Beth Rooney / Sandy Whitekiller
210	WKA_2022_0253	Downstream	Spring Creek Coalition	Beth Rooney / Sandy Whitekiller

Continued Table A1. Waterkeeper participant information (No. 211 – 228).

No.	Barcode	Upstream_Downstream	Waterkeeper Organization Name	Waterkeeper Name
211	WKA_2022_0256	Upstream	Waterkeepers Florida	John Quarterman
212	WKA_2022_0257	Downstream	Waterkeepers Florida	John Quarterman
213	WKA_2022_0258	Upstream	Bitterroot River Protection Association	Michael Howell
214	WKA_2022_0259	Downstream	Bitterroot River Protection Association	Michael Howell
215	WKA_2022_0260	Upstream	Inland Empire Waterkeeper	Raymond Hiemstra
216	WKA_2022_0261	Downstream	Inland Empire Waterkeeper	Raymond Hiemstra
217	WKA_2022_0262	Upstream	Orange County Coastkeeper	Raymond Hiemstra
218	WKA_2022_0263	Downstream	Orange County Coastkeeper	Raymond Hiemstra
219	WKA_2022_0264	Upstream	Coosa Riverkeeper	David Butler
220	WKA_2022_0265	Downstream	Coosa Riverkeeper	David Butler
221	WKA_2022_0266	Upstream	Black-Sampit Riverkeeper	Erin Donmoyer
222	WKA_2022_0267	Downstream	Black-Sampit Riverkeeper	Erin Donmoyer
223	WKA_2022_0268	Upstream	California Coast Keeper Alliance	Sean Bothwell
224	WKA_2022_0269	Downstream	California Coast Keeper Alliance	Sean Bothwell
225	WKA_2022_0270	Upstream	Dan RiverKeeper	Steven Pullian
226	WKA_2022_0271	Downstream	Dan RiverKeeper	Steven Pullian
227	WTK_PFAS_1280	Downstream	Buffalo Niagara Waterkeeper	Elizabeth Cute
228	WTK_PFAS_1282	Upstream	Buffalo Niagara Waterkeeper	Elizabeth Cute

Appendix 2 - PFAS Test Results

Table A2. EPA PFAS 4 concentrations and total concentrations for EPA 1633 PFAS 40. (No. 1 – 58)

No.	Barcode	PFOA (ng/L)	PFOS (ng/L)	PFBS (ng/L)	GenX (ng/L)	Total EPA HA PFAS 4 (ng/L)	Total EPA 1633 PFAS 40 (ng/L)
1	WKA_2022_0001	29	34.5	6.6	< 2 ng/L	70.1	384.8
2	WKA_2022_0002	7.1	4	3.7	< 2 ng/L	14.8	30.6
3	WKA_2022_0003	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
4	WKA_2022_0004	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
5	WKA_2022_0005	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
6	WKA_2022_0006	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
7	WKA_2022_0007	1.9	1.5	1.6	< 2 ng/L	5	6.6
8	WKA_2022_0008	2.3	3.1	1.7	< 2 ng/L	7.1	12.4
9	WKA_2022_0009	2.9	1.6	3.3	< 2 ng/L	7.8	17.9
10	WKA_2022_0010	5.6	2.6	5.2	< 2 ng/L	13.4	45.9
11	WKA_2022_0011	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
12	WKA_2022_0012	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
13	WKA_2022_0013	3.3	1.6	1.6	< 2 ng/L	6.5	7.9
14	WKA_2022_0014	6.8	2	1.3	< 2 ng/L	10.1	13.9
15	WKA_2022_0017	3.8	< 1 ng/L	2.4	< 2 ng/L	6.2	16.9
16	WKA_2022_0018	< 1 ng/L	1.5	2.8	< 2 ng/L	4.3	4.3
17	WKA_2022_0023	1.4	4.9	2.2	< 2 ng/L	8.5	17.7
18	WKA_2022_0024	1.2	3.8	1.8	< 2 ng/L	6.8	13.6
19	WKA_2022_0025	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
20	WKA_2022_0026	5.2	2.2	4.7	< 2 ng/L	12.1	19.9
21	WKA_2022_0027	2.7	6	1.9	< 2 ng/L	10.6	19.9
22	WKA_2022_0028	1.4	5.8	< 1 ng/L	< 2 ng/L	7.2	9.6
23	WKA_2022_0031	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
24	WKA_2022_0032	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
25	WKA_2022_0033	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
26	WKA_2022_0034	1.3	1.2	< 1 ng/L	< 2 ng/L	2.5	4.1
27	WKA_2022_0035	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
28	WKA_2022_0036	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
29	WKA_2022_0037	1.9	2	1.3	< 2 ng/L	5.2	10
30	WKA_2022_0038	2.5	2.4	1.7	< 2 ng/L	6.6	13
31	WKA_2022_0043	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
32	WKA_2022_0044	2.4	7.1	< 1 ng/L	< 2 ng/L	9.5	18.2
33	WKA_2022_0045	4.1	3	1.4	< 2 ng/L	8.5	28.3
34	WKA_2022_0046	3.5	4.9	1.1	< 2 ng/L	9.5	23.9
35	WKA_2022_0047	2.5	14.6	3.7	< 2 ng/L	20.8	35.8
36	WKA_2022_0048	2.6	11	3.3	< 2 ng/L	16.9	32.2
37	WKA_2022_0049	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
38	WKA_2022_0050	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
39	WKA_2022_0051	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
40	WKA_2022_0052	1.3	< 1 ng/L	< 1 ng/L	< 2 ng/L	1.3	2.7
41	WKA_2022_0053	< 1 ng/L	1.6	< 1 ng/L	< 2 ng/L	1.6	4.4
42	WKA_2022_0054	< 1 ng/L	1.4	< 1 ng/L	< 2 ng/L	1.4	1.4
43	WKA_2022_0057	6.5	5.1	1.1	< 2 ng/L	12.7	22.1
44	WKA_2022_0058	6.3	7.3	< 1 ng/L	< 2 ng/L	13.6	21.9
45	WKA_2022_0059	5.1	6.7	< 2 ng/L	< 4 ng/L	11.8	36.3
46	WKA_2022_0060	4	11.6	2	< 2 ng/L	17.6	39.1
47	WKA_2022_0061	7.7	14.3	13.8	< 2 ng/L	35.8	96.2
48	WKA_2022_0062	11	29.6	10.6	< 2 ng/L	51.2	90.3
49	WKA_2022_0063	8.7	9.6	87	< 2 ng/L	105.3	144.5
50	WKA_2022_0064	75.7	82	207.4	< 2 ng/L	365.1	558.2
51	WKA_2022_0065	4.6	3.4	1.3	< 2 ng/L	9.3	23.2
52	WKA_2022_0066	3.8	2.7	1.1	< 2 ng/L	7.6	15.9
53	WKA_2022_0067	1	< 1 ng/L	< 1 ng/L	< 2 ng/L	1	3
54	WKA_2022_0068	1.1	1.1	< 1 ng/L	< 2 ng/L	2.2	3.5
55	WKA_2022_0069	< 1.4 ng/L	< 1.4 ng/L	< 1.4 ng/L	< 2.8 ng/L	ND	ND
56	WKA_2022_0070	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
57	WKA_2022_0071	1	2.2	< 1 ng/L	< 2 ng/L	3.2	33.4
58	WKA_2022_0072	3.1	17.9	1.9	< 2 ng/L	22.9	32.3

Continued Table A2. EPA PFAS 4 concentrations and total concentrations for EPA 1633 PFAS 40. (No. 59 – 116)

No.	Barcode	PFOA (ng/L)	PFOS (ng/L)	PFBS (ng/L)	GenX (ng/L)	Total EPA HA PFAS 4 (ng/L)	Total EPA 1633 PFAS 40 (ng/L)
59	WKA_2022_0073	5.6	8.5	2.8	< 2 ng/L	16.9	32.8
60	WKA_2022_0074	4.6	10.3	2.6	< 2 ng/L	17.5	31.3
61	WKA_2022_0077	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	1.1
62	WKA_2022_0078	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
63	WKA_2022_0084	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
64	WKA_2022_0085	< 0.5 ng/L	< 0.5 ng/L	< 0.5 ng/L	< 1 ng/L	ND	ND
65	WKA_2022_0086	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
66	WKA_2022_0087	< 1 ng/L	1.7	< 1 ng/L	< 2 ng/L	1.7	3.3
67	WKA_2022_0088	3.6	1.7	2.4	< 2 ng/L	7.7	16.2
68	WKA_2022_0089	5.8	2.2	2.2	< 2 ng/L	10.2	24.3
69	WKA_2022_0090	1.7	1.8	< 1 ng/L	< 2 ng/L	3.5	4.7
70	WKA_2022_0091	1.7	1.7	< 1 ng/L	< 2 ng/L	3.4	4.5
71	WKA_2022_0094	5.3	13.2	3.3	< 2 ng/L	21.8	46.1
72	WKA_2022_0095	7.4	17.3	5	25.8	55.5	81.1
73	WKA_2022_0096	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
74	WKA_2022_0097	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
75	WKA_2022_0098	1.1	1.4	< 1 ng/L	< 2 ng/L	2.5	3.8
76	WKA_2022_0099	1.1	1.4	< 1 ng/L	< 2 ng/L	2.5	3.7
77	WKA_2022_0100	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
78	WKA_2022_0101	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
79	WKA_2022_0102	7.1	7.2	1.8	< 2 ng/L	16.1	38.8
80	WKA_2022_0103	1.1	1.4	2.3	< 2 ng/L	4.8	4.8
81	WKA_2022_0105	4.7	5.6	3.2	< 2 ng/L	13.5	18.9
82	WKA_2022_0106	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
83	WKA_2022_0107	< 1 ng/L	< 1 ng/L	< 1 ng/L	4.5	4.5	4.5
84	WKA_2022_0108	< 1 ng/L	1.4	< 1 ng/L	< 2 ng/L	1.4	1.4
85	WKA_2022_0109	3.5	6.2	3.2	< 2 ng/L	12.9	19
86	WKA_2022_0110	4.2	8.5	3.6	< 2 ng/L	16.3	25.4
87	WKA_2022_0111	2	3.6	1.3	< 2 ng/L	6.9	13.4
88	WKA_2022_0112	1.7	3.9	1	< 2 ng/L	6.6	11.7
89	WKA_2022_0113	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
90	WKA_2022_0114	2	1.1	< 1 ng/L	< 2 ng/L	3.1	7
91	WKA_2022_0115	16.8	27.8	48.7	< 2 ng/L	93.3	142.7
92	WKA_2022_0116	13.7	22.2	37.6	< 2 ng/L	73.5	113.9
93	WKA_2022_0117	3.2	2.7	1.4	< 2 ng/L	7.3	27
94	WKA_2022_0118	4.7	4.6	3	< 2 ng/L	12.3	44.8
95	WKA_2022_0119	1	< 1 ng/L	< 1 ng/L	< 2 ng/L	1	3.2
96	WKA_2022_0120	3	3.1	1.7	< 2 ng/L	7.8	16.7
97	WKA_2022_0121	1.8	1.8	< 1 ng/L	< 2 ng/L	3.6	5.8
98	WKA_2022_0122	6	3.8	1.1	< 2 ng/L	10.9	18.8
99	WKA_2022_0123	6.5	4.2	1.3	< 2 ng/L	12	20.5
100	WKA_2022_0124	2.4	1.5	2.2	< 2 ng/L	6.1	7.3
101	WKA_2022_0125	2.9	1.7	2.2	< 2 ng/L	6.8	11.6
102	WKA_2022_0126	1.3	1.2	< 1 ng/L	< 2 ng/L	2.5	2.5
103	WKA_2022_0127	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
104	WKA_2022_0128	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
105	WKA_2022_0129	2.2	1.5	1.3	< 2 ng/L	5	8.3
106	WKA_2022_0130	2.3	1.8	1.3	< 2 ng/L	5.4	10
107	WKA_2022_0131	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
108	WKA_2022_0132	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
109	WKA_2022_0133	3.9	12	< 1 ng/L	< 2 ng/L	15.9	95.1
110	WKA_2022_0134	3.2	6	< 1 ng/L	< 2 ng/L	9.2	34.3
111	WKA_2022_0135	4.3	6.5	8.4	< 2 ng/L	19.2	27.6
112	WKA_2022_0136	3.7	5.8	8.1	< 2 ng/L	17.6	27.1
113	WKA_2022_0137	3.6	5.7	2.9	< 2 ng/L	12.2	22.8
114	WKA_2022_0138	282.8	1364.7	48.2	< 2 ng/L	1695.7	3050.1
115	WKA_2022_0139	27.9	91.6	6.4	< 2 ng/L	125.9	257.5
116	WKA_2022_0140	3.7	10.1	4.1	< 2 ng/L	17.9	28.2

Continued Table A2. EPA PFAS 4 concentrations and total concentrations for EPA 1633 PFAS 40. (No. 117 – 176)

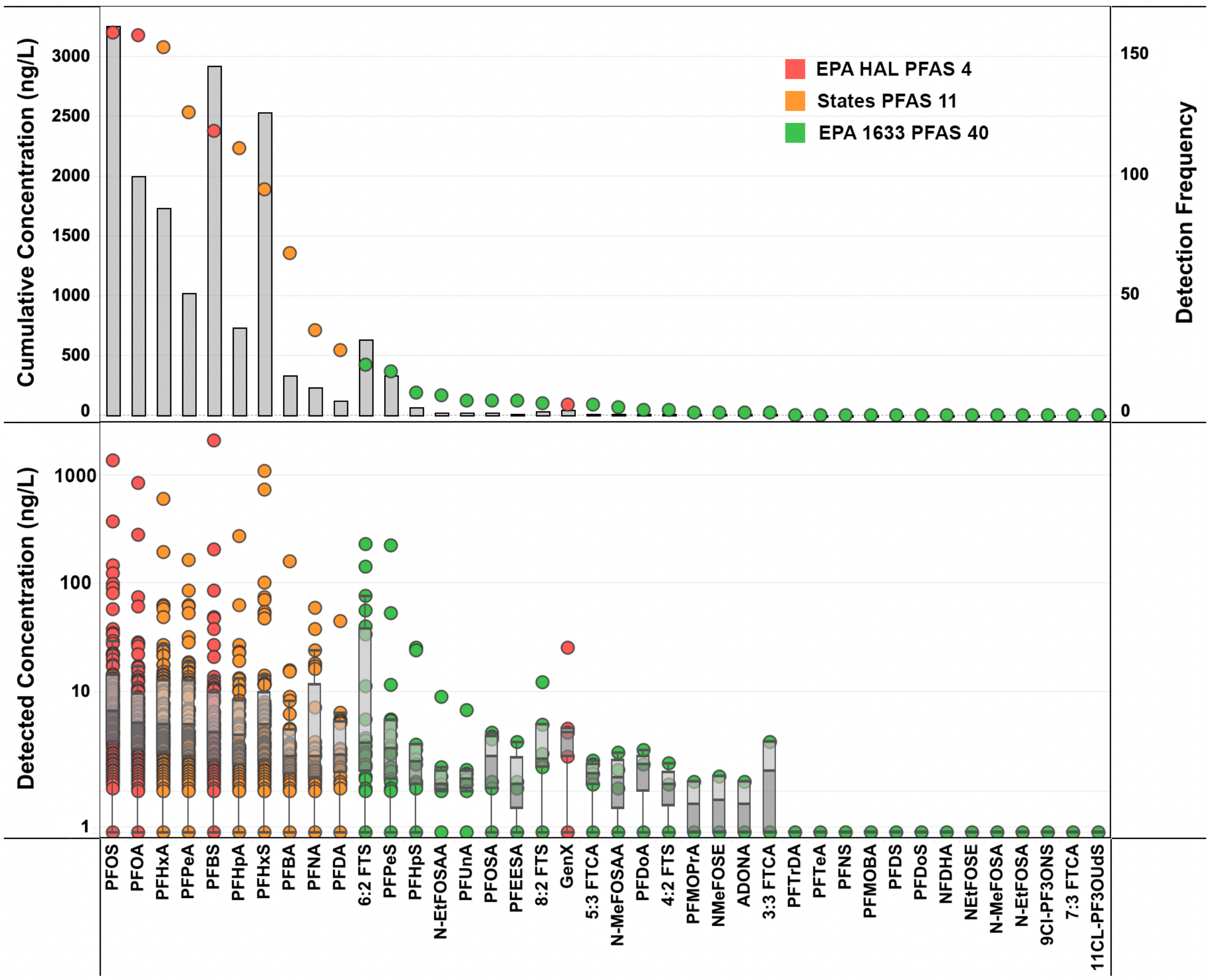
No.	Barcode	PFOA (ng/L)	PFOS (ng/L)	PFBS (ng/L)	GenX (ng/L)	Total EPA HA PFAS 4 (ng/L)	Total EPA 1633 PFAS 40 (ng/L)
117	WKA_2022_0141	16.6	22	10.4	< 2 ng/L	49	106.6
118	WKA_2022_0142	1.7	6.4	1.2	< 2 ng/L	9.3	19.7
119	WKA_2022_0143	4.3	6.5	2.5	< 2 ng/L	13.3	29.9
120	WKA_2022_0144	4.2	5.8	2.4	< 2 ng/L	12.4	22.5
121	WKA_2022_0145	< 1 ng/L	1.7	< 1 ng/L	< 2 ng/L	1.7	1.7
122	WKA_2022_0146	8.6	1.6	5.2	< 2 ng/L	15.4	39.9
123	WKA_2022_0147	26.3	20	11	< 2 ng/L	57.3	118.8
124	WKA_2022_0148	2.4	2.8	< 1 ng/L	< 2 ng/L	5.2	6.2
125	WKA_2022_0149	2.6	4.1	1.2	< 2 ng/L	7.9	9.1
126	WKA_2022_0150	< 1 ng/L	1.8	< 1 ng/L	< 2 ng/L	1.8	1.8
127	WKA_2022_0151	4.2	8.1	< 1.4 ng/L	< 2.9 ng/L	12.3	26.2
128	WKA_2022_0152	3.8	9.5	< 1.6 ng/L	< 3.3 ng/L	13.3	23.6
129	WKA_2022_0153	2.4	3.2	3.8	< 2 ng/L	9.4	18.3
130	WKA_2022_0154	3.3	4.4	5.7	< 2 ng/L	13.4	28
131	WKA_2022_0155	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	2.7
132	WKA_2022_0160	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
133	WKA_2022_0161	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
134	WKA_2022_0162	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	3.4
135	WKA_2022_0165	1.3	3.3	1.5	< 2 ng/L	6.1	9.2
136	WKA_2022_0166	1	1.3	< 1 ng/L	< 2 ng/L	2.3	2.3
137	WKA_2022_0167	1.3	2	< 1 ng/L	< 2 ng/L	3.3	4.7
138	WKA_2022_0168	2.4	2.1	< 1 ng/L	< 2 ng/L	4.5	13.2
139	WKA_2022_0169	4.8	3.6	1.4	< 2 ng/L	9.8	45.2
140	WKA_2022_0170	1.7	1.7	< 1.1 ng/L	< 2.1 ng/L	3.4	8.4
141	WKA_2022_0171	1.3	1.8	< 1 ng/L	< 2 ng/L	3.1	5.2
142	WKA_2022_0172	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	1.1
143	WKA_2022_0173	1.3	1.7	< 1 ng/L	< 2 ng/L	3	4.3
144	WKA_2022_0174	2.3	4.4	2.2	< 2 ng/L	8.9	19.8
145	WKA_2022_0175	2.2	4	2.3	< 2 ng/L	8.5	16.7
146	WKA_2022_0176	1.9	2.1	< 1 ng/L	< 2 ng/L	4	6.7
147	WKA_2022_0177	1.8	2.3	< 1 ng/L	< 2 ng/L	4.1	5.2
148	WKA_2022_0178	12.9	3.1	2.8	< 2 ng/L	18.8	37.3
149	WKA_2022_0179	12.7	4.3	3.9	< 2 ng/L	20.9	48.6
150	WKA_2022_0180	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
151	WKA_2022_0181	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
152	WKA_2022_0182	3.8	6.4	2	4.1	16.3	24
153	WKA_2022_0183	4	4.8	1.7	2.4	12.9	23.1
154	WKA_2022_0184	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
155	WKA_2022_0185	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
156	WKA_2022_0186	3.5	< 1 ng/L	< 1 ng/L	< 2 ng/L	3.5	38.9
157	WKA_2022_0187	1.8	< 1 ng/L	< 1 ng/L	< 2 ng/L	1.8	10.5
158	WKA_2022_0188	3.5	5.1	2.1	< 2 ng/L	10.7	21.1
159	WKA_2022_0189	4.6	7.7	3	< 2 ng/L	15.3	32
160	WKA_2022_0190	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
161	WKA_2022_0191	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
162	WKA_2022_0192	2	1.7	< 1 ng/L	< 2 ng/L	3.7	5
163	WKA_2022_0193	12.2	2.6	1.5	< 2 ng/L	16.3	37.4
164	WKA_2022_0194	< 1 ng/L	1.3	< 1 ng/L	< 2 ng/L	1.3	1.3
165	WKA_2022_0195	< 1 ng/L	1.1	< 1 ng/L	< 2 ng/L	1.1	1.1
166	WKA_2022_0196	4.4	4.2	1.5	< 2 ng/L	10.1	21.4
167	WKA_2022_0197	7.8	8.9	2.2	< 2 ng/L	18.9	53.7
168	WKA_2022_0200	10.4	22.6	4.3	< 2 ng/L	37.3	63.4
169	WKA_2022_0201	15.3	38	27.3	< 2 ng/L	80.6	241.4
170	WKA_2022_0202	2.7	1.8	2.3	< 2 ng/L	6.8	13.4
171	WKA_2022_0203	847	374.3	2083.3	< 2 ng/L	3304.6	6191.9
172	WKA_2022_0204	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
173	WKA_2022_0205	1.3	< 1 ng/L	< 1 ng/L	< 2 ng/L	1.3	2.4
174	WKA_2022_0206	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
175	WKA_2022_0207	1.2	4.2	2.4	< 2 ng/L	7.8	15.2
176	WKA_2022_0208	17	125.5	11.6	< 2 ng/L	154.1	379.9

Continued Table A2. EPA PFAS 4 concentrations and total concentrations for EPA 1633 PFAS 40. (No. 177 – 228)

No.	Barcode	PFOA (ng/L)	PFOS (ng/L)	PFBS (ng/L)	GenX (ng/L)	Total EPA HA PFAS 4 (ng/L)	Total EPA 1633 PFAS 40 (ng/L)
177	WKA_2022_0210	2	3.3	1.7	< 2 ng/L	7	14.1
178	WKA_2022_0211	1.9	3.3	1.8	< 2 ng/L	7	15.1
179	WKA_2022_0212	10	58.5	6.1	< 2 ng/L	74.6	231.1
180	WKA_2022_0213	5.9	21.3	4.5	< 2 ng/L	31.7	57.9
181	WKA_2022_0218	1.9	1.4	< 1 ng/L	< 2 ng/L	3.3	4.6
182	WKA_2022_0219	4.2	10.7	1.9	< 2 ng/L	16.8	38.3
183	WKA_2022_0222	< 1 ng/L	1.1	< 1 ng/L	< 2 ng/L	1.1	1.1
184	WKA_2022_0223	1.6	3.5	1.1	< 2 ng/L	6.2	6.2
185	WKA_2022_0224	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
186	WKA_2022_0225	1.5	< 1 ng/L	1	< 2 ng/L	2.5	5.9
187	WKA_2022_0226	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
188	WKA_2022_0227	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
189	WKA_2022_0228	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
190	WKA_2022_0229	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	1.2
191	WKA_2022_0230	3	7.5	< 1 ng/L	< 2 ng/L	10.5	18.6
192	WKA_2022_0231	2.7	4	1.3	< 2 ng/L	8	9.4
193	WKA_2022_0232	1.1	2.1	< 1 ng/L	< 2 ng/L	3.2	6
194	WKA_2022_0233	2.5	3.6	1.8	< 2 ng/L	7.9	16.8
195	WKA_2022_0234	3.7	6.7	2	< 2 ng/L	12.4	88.6
196	WKA_2022_0235	3.6	5.2	3	< 2 ng/L	11.8	24.9
197	WKA_2022_0238	7.8	6.7	1.9	< 2 ng/L	16.4	27.8
198	WKA_2022_0239	7.9	5.2	1.6	< 2 ng/L	14.7	29.2
199	WKA_2022_0240	2.7	1.9	1.6	< 2 ng/L	6.2	7.9
200	WKA_2022_0241	6.1	14.1	4.9	< 2 ng/L	25.1	59.3
201	WKA_2022_0242	2.7	4.2	1.9	< 2 ng/L	8.8	25.8
202	WKA_2022_0243	1.7	3	1.3	< 2 ng/L	6	17.4
203	WKA_2022_0246	2.8	1.4	1.2	< 2 ng/L	5.4	13.4
204	WKA_2022_0247	2.1	3	< 1 ng/L	< 2 ng/L	5.1	11.3
205	WKA_2022_0248	3.8	5.6	1.8	< 2 ng/L	11.2	17.8
206	WKA_2022_0249	8.4	98.3	3.3	< 2 ng/L	110	176.5
207	WKA_2022_0250	1.7	< 1 ng/L	4.5	< 2 ng/L	6.2	6.2
208	WKA_2022_0251	1.9	1.1	4.2	< 2 ng/L	7.2	7.2
209	WKA_2022_0252	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
210	WKA_2022_0253	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
211	WKA_2022_0256	1.2	2.6	< 1 ng/L	< 2 ng/L	3.8	5.9
212	WKA_2022_0257	2.2	9.1	3.2	< 2 ng/L	14.5	30
213	WKA_2022_0258	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
214	WKA_2022_0259	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
215	WKA_2022_0260	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
216	WKA_2022_0261	8.9	7.7	5.2	< 2 ng/L	21.8	57.9
217	WKA_2022_0262	22.4	13	21.2	< 2 ng/L	56.6	181.4
218	WKA_2022_0263	61.5	34.4	12.7	< 2 ng/L	108.6	222.3
219	WKA_2022_0264	2.7	3.8	3.8	< 2 ng/L	10.3	19
220	WKA_2022_0265	5.1	3.4	9.2	< 2 ng/L	17.7	47.4
221	WKA_2022_0266	2.4	3.2	1	< 2 ng/L	6.6	11.1
222	WKA_2022_0267	4.5	6.7	1.5	< 2 ng/L	12.7	20.3
223	WKA_2022_0268	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
224	WKA_2022_0269	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
225	WKA_2022_0270	< 1 ng/L	< 1 ng/L	< 1 ng/L	< 2 ng/L	ND	ND
226	WKA_2022_0271	1.9	2.2	< 1 ng/L	< 2 ng/L	4.1	5.3
227	WTK_PFAS_1280	10.3	147.7	5.2	< 2 ng/L	163.2	301.1
228	WTK_PFAS_1282	1.6	1.4	< 1 ng/L	< 2 ng/L	3	6.8

Appendix 3 - PFAS Spatial Occurrence and Concentration Patterns

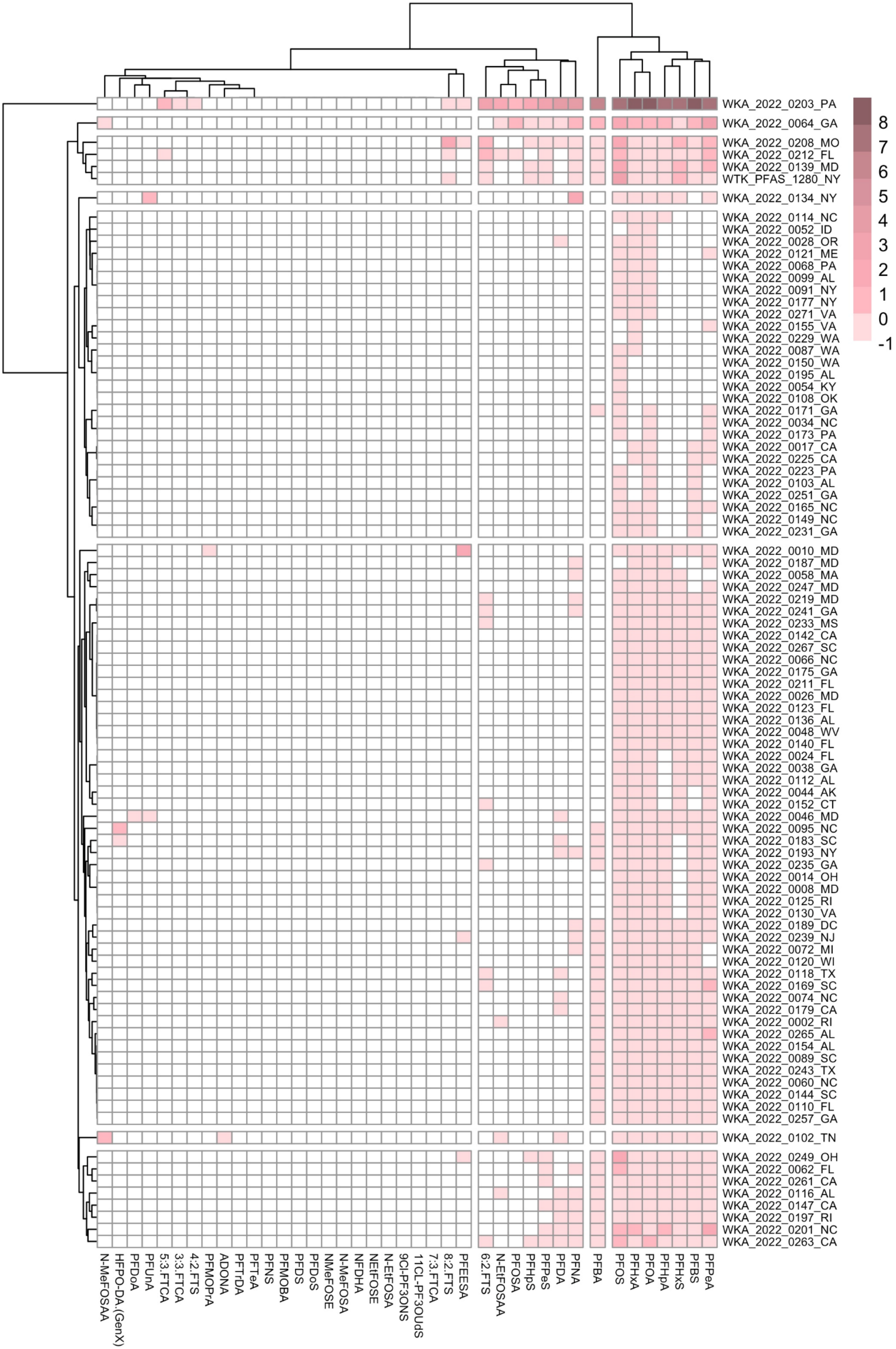
Figure A1. Top panel: Detection frequency (circles) and cumulative concentrations (ng/L; bars) of each PFAS measured in surface water samples using Cyclopure PFAS WTK. Bottom panel: Detected concentrations (ng/L; circles) of each PFAS by 228 sampling site; boxes, centerlines, and whiskers indicate the interquartile range (IQR), median, and 1.5*IQR, respectively.



Heatmap with z-score normalization is a clustering method which can provide the correlation visualization of two groups of observations. A statistic space will be created for each of the observation group and employed to calculate the distance among each pair of observations. The observations, that are statistically close to each other, will form clusters in the Heatmap. In this case, the z-score normalization was performed on each PFAS to remove the effect of varying concentrations under different sampling scenarios to investigate the geospatial normalized concentration patterns among the 40 PFAS. The mean and variance were calculated for each PFAS across the 114 Downstream samples, and the z-score was calculated based on the equation: $z = (x - \mu) / \sigma$, where x is the raw score, μ is the population mean, and σ is the population standard deviation. *The non-detect raw scores were given a z-score of -2.*

The result is visualized as **Figure A2**. With respect to PFAS, the most significant cluster was found to be the seven PFAS group of PFPeA, PFBS, PFHxS, PFHpA, PFOA, PFHxA and PFOS. This indicates the high relevance among these 7 PFAS for both spatial occurrence and concentration patterns. On the other dimension, the sampling scenarios were clustered into eight groups. PFAS contamination of the landfill leachate (WKA_20220203_PA) was found to be significantly different from all the other 113 Downstream samples, with 17 PFAS detected at elevated concentrations.

Figure A2 (Next Page). Heatmap of 40 PFAS clustered by *z-score normalized concentration profiles* in all Downstream samples. The color of each cell represents the normalized value based on concentration distribution across 114 downstream sites by each PFAS compound. The dendrogram was cut to present 8 sample (Barcode_State Code) scenario clusters and 4 PFAS clusters. 23 of the 114 Downstream samples were removed due to no detection for any of the 40 PFAS.


8
7
6
5
4
3
2
1
0
-1
WKA_2022_0203_PA
WKA_2022_0064_GA
WKA_2022_0208_MO
WKA_2022_0212_FL
WKA_2022_0139_MD
WTK_PFAS_1280_NY
WKA_2022_0134_NY
WKA_2022_0114_NC
WKA_2022_0052_ID
WKA_2022_0028_OR
WKA_2022_0121_ME
WKA_2022_0068_PA
WKA_2022_0099_AL
WKA_2022_0091_NY
WKA_2022_0177_NY
WKA_2022_0271_VA
WKA_2022_0155_VA
WKA_2022_0229_WA
WKA_2022_0087_WA
WKA_2022_0150_WA
WKA_2022_0195_AL
WKA_2022_0054_KY
WKA_2022_0108_OK
WKA_2022_0171_GA
WKA_2022_0034_NC
WKA_2022_0173_PA
WKA_2022_0017_CA
WKA_2022_0225_CA
WKA_2022_0223_PA
WKA_2022_0103_AL
WKA_2022_0251_GA
WKA_2022_0165_NC
WKA_2022_0149_NC
WKA_2022_0231_GA
WKA_2022_0010_MD
WKA_2022_0187_MD
WKA_2022_0058_MA
WKA_2022_0247_MD
WKA_2022_0219_MD
WKA_2022_0241_GA
WKA_2022_0233_MS
WKA_2022_0142_CA
WKA_2022_0267_SC
WKA_2022_0066_NC
WKA_2022_0175_GA
WKA_2022_0211_FL
WKA_2022_0026_MD
WKA_2022_0123_FL
WKA_2022_0136_AL
WKA_2022_0048_WV
WKA_2022_0140_FL
WKA_2022_0024_FL
WKA_2022_0038_GA
WKA_2022_0112_AL
WKA_2022_0044_AK
WKA_2022_0152_CT
WKA_2022_0046_MD
WKA_2022_0095_NC
WKA_2022_0183_SC
WKA_2022_0193_NY
WKA_2022_0235_GA
WKA_2022_0014_OH
WKA_2022_0008_MD
WKA_2022_0125_RI
WKA_2022_0130_VA
WKA_2022_0189_DC
WKA_2022_0239_NJ
WKA_2022_0072_MI
WKA_2022_0120_WI
WKA_2022_0118_TX
WKA_2022_0169_SC
WKA_2022_0074_NC
WKA_2022_0179_CA
WKA_2022_0002_RI
WKA_2022_0265_AL
WKA_2022_0154_AL
WKA_2022_0089_SC
WKA_2022_0243_TX
WKA_2022_0060_NC
WKA_2022_0144_SC
WKA_2022_0110_FL
WKA_2022_0257_GA
WKA_2022_0102_TN
WKA_2022_0249_OH
WKA_2022_0062_FL
WKA_2022_0261_CA
WKA_2022_0116_AL
WKA_2022_0147_CA
WKA_2022_0197_RI
WKA_2022_0201_NC
WKA_2022_0263_CA
N-MeFOSAA
HFPO-DA.(GenX)
PFDoA
PFUnA
5:3.FTCA
3:3.FTCA
4:2.FTS
PFMOPrA
ADONA
PFTrDA
PFTeA
PFNS
PFMOBA
PFDS
PFDoS
NMeFOSE
N-MeFOSA
NFDHA
NEtFOSE
N-EtFOSA
9Cl-PF3ONS
11CL-PF3OUdS
7:3.FTCA
8:2.FTS
PFEESA
6:2.FTS
N-EtFOSAA
PFOSA
PFHpS
PFPeS
PFDA
PFNA
PFBA
PFOS
PFHxA
PFOA
PFHpA
PFHxS
PFBS
PFPeA