



Reconnaissance Plan for Per and Polyfluoroalkyl Substances (PFAS) in Utah

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Acronyms/Abbreviations

µg	Microgram
AFFF	Aqueous Fire Fighting Foam
AOF/EOF	Adsorbable/Extractable Organic Fluorine
AOF-CIC	Adsorbable Organic Fluorine – Combustion Ion Chromatography
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIC	Combustion Ion Chromatography
CWA	Clean Water Act
DDW	Division of Drinking Water
DEQ	Department of Environmental Quality
DERR	Division of Environmental Response and Remediation
DI	Deionized water
DOD	Department of Defense
DWQ	Division of Water Quality
EPA	Environmental Protection Agency
ETFE	Ethylene Tetrafluoroethylene
F	Fluoride
FEP	Fluorinated Ethylene Propylene
FTA	Fire Training Areas
g	Gram
HAFB	Hill Air Force Base
HDPE	High-density Polyethylene
IC	Ion Chromatography
IRIS	Integrated Risk Information System
ISO	International Organization for Standardization
ITRC	Interstate Technology and Regulation Council
Kg	Kilogram
L	Liter
LC-MS/MS	Liquid Chromatography Tandem-Mass Spectrometry
LDPE	Low-Density Polyethylene
LHA	Lifetime Health Advisory
mL	Milliliter

NAICS	North American Industry Classification System
ng	Nanogram
PA	Preliminary Assessment
PFAAs	Perfluoroalkyl acids, as carboxylates
PFAS	Per- and Polyfluoroalkyl Substances
PFBS	Perfluorobutane Sulfonate
PFCAs	Perfluoroalkyl Carboxylates
PFHpA	Perfluoroheptanoic acid
PFHxS	Perfluorohexanesulfonic acid
PFNA	Perfluorononanoic Acid
PFOA	Perfluorooctanoic Acid
PFOS	Perfluorooctane sulfonic acid
pH	Potential Hydrogen
POTW	Publically Owned Treatment Works
PP	Polypropylene
ppb	Parts per Billion
PPE	Personal Protective Equipment
PPE	Polypropylene containers
ppt	Parts per Trillion
PTFE	Teflon, Polytetrafluoroethylene
PVDF	Polyvinylidene Fluoride
QA	Quality Assurance
QC	Quality Control
QSM	Quality Systems Manual
RCRA	Resource Conservation and Recovery Act
RLs	Reporting Limits
RPD	Relative Percent Difference
SAP	Sampling Analysis Plan
SOP	Standard Operating Procedures
SDWA	Safe Drinking Water Act
SI	Site Inspection
SPE	Solid-Phase Extraction
Teflon tape	PipeThread Compounds and Tape
TSCA	Toxic Substances Control Act
U.S.	United States of America
USAF	United State Air Force
UCMR	Unregulated Contaminant Monitoring Rule
UCMR3	Third Unregulated Contaminant Monitoring Rule
UTANG	Utah Air National Guard
WMRC	Division of Waste Management and Radiation Control
WQS	Water Quality Standards
WRRF	Water Resources Recovery Facility
WWTP	Wastewater Treatment Plant

Introduction

Per- and polyfluoroalkyl substances (PFAS) are a group of manmade, fluorinated chemicals that include long-chain PFAS such as PFOA and PFOS and short-chain PFAS compounds such as PFBA and PFBS, collectively known as GenX. PFAS have been manufactured and used in a variety of industries around the world, including in the United States, since the 1940s. More than 6,000 PFAS compounds are known to exist, although not all are in current use or production (EPA).

PFAS compounds have become essential in many industries due to their unique properties. They are chemically stable, reduce surface tension to a much lower state than other surfactants, repel water and oil, possess friction-reducing properties, and can function in environments where other products would degrade. These properties which have given rise to a variety of industrial and commercial products that are resistant to oil, grease, water, soil, and stain. These products are used in firefighting foams, metal plating and coating formulations, polyurethane production, inks, varnishes, and lubricants (ITRC, 2017). Additionally, they are considered vital to the aviation, mining and gas, photographic imaging, semiconductor, automotive, construction, and electronics industries (EPA,2016). PFAS are found in many consumer products like cookware, food packaging, and stain repellants. Some of the main sources of PFAS are PFAS manufacturing and processing facilities, facilities that use PFAS in the production of other products, and airports and military installations that use firefighting foams.

Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) were manufactured the longest in the U.S. and are the most widespread PFAS chemicals in the environment. Growing concerns about the long-term impacts to human health and the environment from PFOS and PFOA led to a phase-out of these two chemicals between 2002 and 2015. New PFAS compounds emerged to take their place: GenX compounds for PFOA and perfluorobutane sulfonic acid (PFBS) for PFOS. While PFOA and PFOS are no longer manufactured in the U.S., they are still produced in other countries and could continue to contribute to human and environmental exposure in America. Many complex PFAS have the potential to break down into less complex perfluoroalkyl acids (PFAAs), a subgroup of PFAS that includes PFOA and PFOS. This breakdown is compounded by the fact that the production of certain PFAS, such as fluoropolymers, requires the use of PFAAs in their manufacture. Their use increases total PFAA contamination and exposure through industrial discharge from the production of Teflon® and impurities in PFAS-containing products (Reade, Quinn, & Schreiber, 2019).

The qualities that make PFAS an essential component in many products — its chemical stability and ability to function well in harsh environments— also lead to its persistence in the environment and bioaccumulation in the human body. Although the phase-out of PFOA and PFOS in manufacturing processes led to a decrease in PFAS in blood serum levels in the U.S. population, their persistence in the environment makes it very likely that they will continue to be a source of exposure well into the future. There is growing concern that short-chain substitutes pose equally troubling environmental and human health risks (Brendal, Fetter, Staude, Vierke, & Biegl-Engler, 2018). Alternative methods for detecting PFAS in blood serum show an increasing trend of unidentified organofluorine in blood serum samples, suggesting human exposure to new and unidentified PFAS (Yeung & Mabury, 2015).

There is growing evidence that exposure to PFAS can lead to adverse human health effects (Pelch, Reade, Wolffe, & Kwiatkowski, 2019). These health effects include impacts to the liver, immune system, fetal development and pregnancy (preeclampsia), endocrine system, reproductive system, and cardiovascular system, in addition to an increased risk for testicular and kidney cancer. PFOA and PFOS have been the subject of more study than other PFAS chemicals, but research is expanding to include other PFAS, specifically GenX compounds. A 2018 EPA draft toxicity assessment confirmed that GenX chemicals are associated with liver and pancreatic cancers, and PFBS is associated with thyroid and kidney effects (EPA, 2018) (EPA, 2018). Recent studies commissioned by the FDA indicate that 6:2 FTOH, a common short-chain PFAS compound, has similar health effects as older long-chain PFAS (Kabadi, et al., 2020) (Rice, Aungst, Cooper, Bandale, & Kabadi, 2020).

PFAS can be released into the air, soil, and water, including sources of drinking water. Potential pathways of significant human PFAS exposure from these releases include:

- Drinking water from public water and private water systems. Contamination is typically localized and associated with a release from a specific facility such as a PFAS manufacturer or processor, landfill, wastewater treatment plant, or a facility using PFAS-containing firefighting foams.
- Consumption of plants and meat from animals, including fish, that are grown or caught from areas where PFAS has contaminated surface water, groundwater, sediments, or soils
- Employment in a workplace that produces or uses PFAS, including chemical production facilities or industries that utilize PFAS in their processes (e.g., chromium electroplating, electronics manufacturing, or oil recovery). Workers may be exposed to PFAS by inhalation, dermal contact, or ingestion, with inhalation being the most common pathway.
- Accidental ingestion of contaminated soil or dust

(USEPA 2018a), (ATSDR 2018b), (Fromme, Tittlemeier, Volkel, Wilhelm, & Twardella, 2009), (Ghisi, Vameralli, & Manzetti, 2019). 2018, (McGlodrick & Murphy, 2016), (Stahl, et al., 2014), (Franko, Frasch, Meade, & Barbero, 2012)

Concerns regarding PFAS and their possible health impacts increased after these chemicals were discovered in drinking water and the blood serum of most people in the U.S. Researchers have made significant progress recent years in the development of PFAS analytical methods, evaluation of treatment and remediation techniques for PFAS, understanding of the potential exposure from various environmental media, and evaluation of the human health impacts of GenX chemicals. However, characterization efforts continue to be hampered by the analytical challenges associated with PFAS and the limited toxicity data available for only a small number of PFAS. The available data demonstrate that PFAS exposures are a human health hazard, but scientists are still working to understand and address PFAS toxicity and develop human health toxicity assessments for both long-and short-chain PFAS. Recommended toxicity values range from 70 nanograms per liter (ng/L) to seven ng/L to as low as one ng/L (EPA, 2019), (ATSDR, 2020), (Grandjean & Budtz-Jorgensen, 2013). Data are generally lacking to further characterize the hazard and provide reliable estimates of the negative impacts to human health.

Currently, a limited number of PFAS are analyzed by the U. S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act (SDWA) and only two of those — PFOA and PFOS — are subject to Lifetime Health Advisory (LHA) health-based drinking water levels. PFAS are not currently listed as hazardous substances under the Federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), nor as hazardous wastes under the Federal Resource Conservation and Recovery Act (RCRA). They are also not currently regulated under the Toxic Substances Control Act (TSCA). Finally, no PFAS are listed as a toxic or priority pollutant under the Federal Clean Water Act (CWA).

On February 20, 2020, EPA published an update to its 2019 PFAS Action Plan that contained proposals to address PFAS under the agency's statutory authority. These include:

- A proposal to regulate PFOA and PFOS under SDWA. If EPA finalizes a positive regulatory determination, the agency would start the process to establish a national primary drinking water regulation for PFOA and PFOS.
- A commitment to monitor for PFAS in the next Unregulated Contaminant Monitoring Rule cycle (UCMR5)
- Efforts to determine whether there are enough available data and research to support development of CWA water quality criteria for PFAS
- Advancement of the regulatory process for designating PFOA and PFOS as hazardous substances under CERCLA
- A proposal to add certain PFAS to the list of chemicals that companies are required to report as part of the Toxics Release Inventory (TRI)
- A requirement that facilities track and collect information on PFAS chemicals during 2020
- A proposal for a Significant New Use Rule (SNUR) that strengthens regulations on imported products containing PFAS as a surface coating. When finalized, this rule would ensure that uses phased out in products in the U.S. cannot be imported.

As the most recent EPA update shows, PFAS science is rapidly evolving, and the strategy outlined in this document represents the current understanding of the Utah Department of Environmental Quality (DEQ) of the sources of PFAS and applicable analytical approaches. As the science advances and more information becomes available, the agency's approach will be modified as appropriate.

DEQ created a workgroup to develop a monitoring reconnaissance plan for PFAS since little is known regarding the use of PFAS in Utah. The workgroup is comprised of representatives from the Utah DEQ Divisions of Drinking Water (DDW), Water Quality (DWQ), Waste Management and Radiation Control (WMRC), Environmental Response and Remediation (DERR), and the Utah Bureau of Epidemiology. Its primary goal is development of an ongoing monitoring and reporting strategy to determine if PFAS contamination is present and/or in concentrations of concern in Utah's drinking water, groundwater, surface waters, or land. The initial efforts are focused on evaluating potential sources of human exposure. The results of these investigations will be used to determine if additional investigations or actions are warranted. Decisions for any additional actions will be made according to the regulatory authorities of each DEQ division.

PFAS in Utah

With the exception of the drinking water data discussed below, little data are available to characterize the probable occurrence or use of PFAS in Utah. DEQ has not identified any PFAS manufacturers in Utah, but the number of businesses using PFAS in Utah remains unknown. Based on data compiled from other states, possible industrial sectors that use PFAS may include:

- Plastic manufacturers
- Semi-conductor manufacturers
- Aerospace manufacturers
- Metal-finishing companies
- Fabric-coating businesses
- Spring and wire manufacturers

Releases from industrial sites that use PFAS and locations where aqueous fire-fighting foam (AFFF) has been repeatedly applied have the greatest potential for PFAS releases to the environment.

PFAS Data for Utah Drinking Water

In May 2012, EPA required large and very large community water systems that served populations of 10,000 residents or greater to test for 60 unregulated contaminants (30 contaminants, 28 chemicals, and two viruses) between 2013 and 2015 (Table 1). This included requirements for testing for PFOA and PFOS under the Third Unregulated Contaminant Monitoring Rule (UCMR3). In Utah, 61 water systems were required to sample, which included 1,680 drinking water sources. The UCMR3 sampling effort covered drinking water systems for 86% of the population, or approximately 2.5 million residents. PFOA and PFOS were not detected in any of these systems above the 70 nanogram per liter (ng/L) threshold identified by EPA.

Table 1. UCMR3 (Six Perfluorinated Compounds)

Contaminant	CAS Registry Number ¹	Minimum Reporting Level	Sampling Points ²	Analytical Methods
Perfluorooctanesulfonic acid (PFOS)	1763-23-1	4.0 ng/L	EPTDS	EPA 537 Rev 1.1
Perfluorooctanoic acid (PFOA)	335-67-1	2.0 ng/L	EPTDS	EPA 537 Rev 1.1
Perfluorononanoic acid (PFNA)	375-95-1	2.0 ng/L	EPTDS	EPA 537 Rev 1.1
Perfluorohexanesulfonic acid (PFHxS)	355-46-4	3.0 ng/L	EPTDS	EPA 537 Rev 1.1
Perfluoroheptanoic acid (PFHpA)	375-85-9	1.0 ng/L	EPTDS	EPA 537 Rev 1.1
Perfluorobutanesulfonic acid (PFBS)	375-73-5	9.0 ng/L	EPTDS	EPA 537 Rev 1.1

Potential Health Effects of PFAS Exposures

Studies show nearly all people in the United States have PFAS in their blood, regardless of their age (CDC, 2015). The most common PFAS compounds found in blood are PFOA and PFOS. Both chemicals are no longer manufactured in the United States but can still be found in products manufactured in other countries. Blood concentrations of PFAS have decreased since the production and use of PFOS and PFOA has ended in the U.S., but as was mentioned earlier, alternative methods for detecting PFAS in blood serum indicate increasing levels of unidentified organofluorine which may suggest exposure to new and unidentified PFAS (Yeung & Mabury, 2015). Additional data show that the PFAS alternatives hexafluoropropylene oxide dimer (HFPO-DA), hexafluoropropylene trimer acids (HFPO-TA), and 6:2 chlorinated polyfluorinated ether sulfonic acid (6:2 Cl-PFESA) have become the dominant global perfluorinated pollutants, and while there are a few toxicity assessments of these novel fluorinated alternatives, they exhibited comparable or even more serious potential toxicity than legacy PFAS, indicating that these fluorinated alternatives are also harmful to the environment. (Wang, Chang, Wang, Wang, & Li, 2019)

Contaminated drinking water, food packaged in material that contains PFAS, indoor dust, and hand-to-mouth transfer from treated carpets are the primary exposure routes for the general population (CDC, 2015). Consumer products such as nonstick cookware, stain-resistant carpeting, and water-repellant clothing can expose individuals to PFAS. Fish caught from contaminated water may also be an exposure route for the general population, and wild game in areas with PFAS contamination has been found to have high levels of PFAS in their meat (Michigan Department of Environment). People living near facilities that used to manufacture PFOS and PFOA or whose drinking water was contaminated with PFOS or PFOA have higher exposures. Research has suggested that exposure to PFOA and PFOS from consumer products is usually low, especially when compared to exposures from contaminated drinking water (CDC, 2015).

Researchers have found links between PFAS and potential adverse effects to human health. (Sunderland, et al., 2018). Most of these studies are based on mice and rat responses to exposure, but some of the findings are supported by health effects observed in human epidemiological studies (EPA, 2016). These effects are observed at relatively low concentrations and include higher cholesterol levels, changes in liver function, reduced immune response, pregnancy-induced hypertension/preeclampsia, and increased risk of thyroid disease. Evidence also suggests the increased possibility of kidney and testicular cancer at higher PFOS and PFOA exposures.

Currently, there are no federal regulatory levels set for PFAS, although some states have established their own guidance and screening levels (Figure 1). The EPA Lifetime Health Advisory (LHA) for PFOA and PFOS in drinking water is 70 nanograms per liter (ng/L) (EPA, 2016). PFOS and PFOA are more toxic than any other PFAS compound that EPA has evaluated for drinking water, but additional data are needed to fully evaluate the long-term toxicity of newer PFAS compounds. The low concentrations at which health effects occur, along with the potential for a number of different health impacts, has increased concerns around PFAS. The seriousness of the health effects — cancer, developmental delays, altered immunological responsiveness, the low concentrations at which effects occur, and their persistence in

the environment — increases the urgency to identify and reduce potential sources of exposures to the general population.

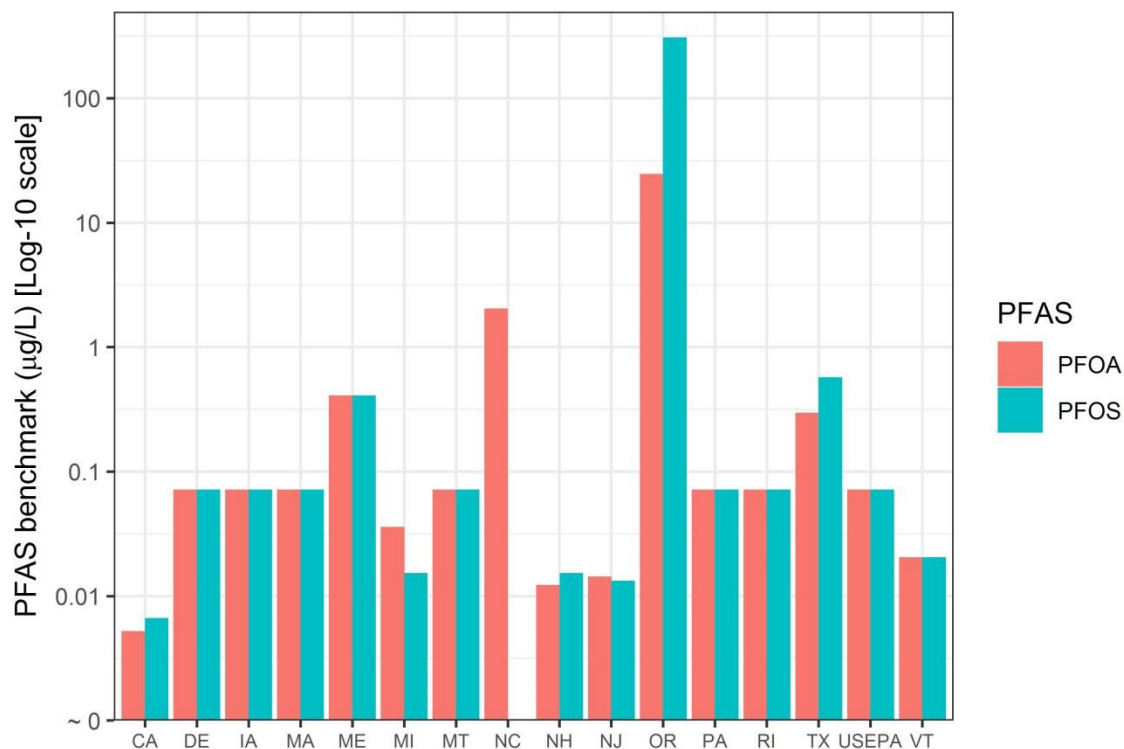


Figure 1. Variability in PFOA and PFOS Comparison Values for Safe Drinking Water based on Table 4-1 of (ITRC(f), 2019)

PFAS Sources in Utah and the Potential for Public Exposures

DEQ has identified potential sources of PFAS in Utah and linked these to potential exposure pathways to the public. These sources have been ranked as high, medium, and low to facilitate prioritization of initial sampling efforts (see Figure 2). The most likely sources of PFAS in Utah are listed below.

Aqueous Film-Forming Foams: Military Installations, Airports, and Refineries

AFFFs have been used for several decades by the U.S. military, civilian airports, and other facilities to extinguish liquid fuel fires (ITRC, 2018). Fire-training Areas (FTA) are known to have PFAS releases, but many other sites are also likely affected by AFFF from past emergency response incidents and the discharge of AFFF-containing fire suppression systems within large aircraft hangars and buildings. AFFFs may also be used to extinguish fires involving trucks transporting fuel. Accidental releases of AFFF from storage tanks, railcars, and piping during delivery or transfer impact additional sites. Once released to the environment, AFFF can contaminate soils, surface water, and groundwater.

Hill Air Force Base (HAFB)

The United States Air Force (USAF) began using AFFF firefighting agents containing PFAS in 1970 for extinguishing petroleum fires. Although the USAF has been working to remove PFAS-containing AFFFs from its inventory, the impacts to the environment from the use of these firefighting agents remains mostly unknown. In response to emerging health and environmental concerns regarding PFAS, Hill Air Force Base initiated a Preliminary Assessment (PA) of known or suspected areas of AFFF discharges.

As part of the PA, HAFB identified source areas for potential release of AFFF. These areas included fire training areas and fire stations, buildings with AFFF in the fire suppression system, crash sites and fuel spills, and stormwater retention ponds located within the base boundaries. Based on the information available, there may be potential sources warranting further investigation for each of these potential source areas. Work to further evaluate the extent of PFAS in the environment from activities at HAFB is ongoing and currently focused on private drinking water well adjacent to the facility.

Utah National Guard (UTANG)

The Utah National Guard has also conducted sampling at three suspected AFFF release areas at the Utah Air National Guard Base (UTANG) in Salt Lake County, Utah. The three AFFF areas inspected include three separate fire-training areas used between the late 1940s and 1978. Surface and subsurface soils samples indicated no concentrations exceeding screening criteria. However, all of the groundwater samples results indicated concentrations for PFOA and PFOS above the project screening criteria (risk based values/regional screening level). An expanded site inspection (SI) has been recommended to determine whether groundwater and surface water is migrating off the base and/or presenting a possible health threat through contaminated drinking water (USACE, 2018).

Tooele Army Depot

Sampling for PFAS has also been conducted at drinking water systems for two Army facilities located in Utah (Tooele Army Depot and Dugway Proving Ground) as well as Camp Williams, a National Guard training center site. The results from these facilities have indicated there is not a drinking water impact. However, not all groundwater sources have been sampled.

Industrial Sites

Industrial PFAS sources include manufacturing facilities where PFAS-containing products are synthesized and made into products or chemical feed stocks, or where PFAS are used as processing aids in fluoro-polymer production. Secondary manufacturing facilities may use these products or feed stocks as part of industrial processes such as coating application to finished products. Facilities that may be sources of PFAS releases to the environment include textile and leather processors, paper mills, metal finishers, wire manufacturers, plating facilities, aviation manufacturers, and facilities that use surfactants, resins, molds, plastics, and semiconductors. Industrial facilities may release PFAS to the environment via wastewater discharges, on- and off-site disposal of wastes, accidental releases such as leaks and spills, and stack emissions.

The U.S. Census Bureau maintains a database of U.S. businesses classified by the North American Industry Classification System (NAICS). Utah maintains the Utah-specific portion as the FirmFind

database. The NAICS Codes for businesses that manufacture products known to contain PFAS were identified and these codes searched in FirmFind. Businesses in Utah that manufactured products known to contain PFAS were assigned the highest priority for further investigation. Businesses that have the potential to use PFAS in their processes were judged to be a medium priority as potential PFAS sources, and those that have a lower potential to use PFAS or are unlikely to use PFAS in appreciable quantities were judged as the lowest priority. No businesses in Utah manufacture PFAS.

Over 600 businesses were identified that potentially use PFAS. This list (Table 2), while anticipated to be incomplete regarding potential PFAS sources, likely overestimates the number of businesses that are potential sources of PFAS. Based on these factors, initial efforts will focus on the highest priority businesses, of which there are 74 total.

Table 2. Industries Potentially Using PFAS in Utah from FirmFind

NAICS Code	Description	Relative Priority	Number of Businesses
332813	Electroplating, plating, polishing, anodizing, and coloring	Highest	24
313320	Fabric coating mills	Highest	1
325199	Plasticizers (i.e., basic synthetic chemicals), manufacturing	Highest	5
325211	Plastics and synthetic resins regenerating, precipitating, and coagulating	Highest	9
325613	Finishing agents, textile and leather, manufacturing	Highest	2
333242	Micro-lithography equipment, semiconductor, manufacturing	Highest	3
334413	Wafers (semiconductor devices) manufacturing	Highest	24
322220	Bags (except plastics only) made by laminating or coating combinations of purchased plastics, foil, and paper	Highest	6
314110	Doormats, all materials (except entirely of rubber or plastics), manufacturing, rugs and carpets made from textile materials	Medium	1
315280	Coats, waterproof (e.g., plastics, rubberized fabric, similar materials), rubberizing fabric, and manufacturing coats	Medium	10
315990	Bibs and aprons, waterproof (e.g., plastics, rubber, similar materials), rubberizing fabric, and manufacturing bibs and aprons	Medium	19
316210	Footwear, men's leather or vinyl upper with rubber or plastics soles, manufacturing	Medium	3
325510	Plastic wood fillers, manufacturing	Medium	0
326111	Frozen food bags, plastics film, single wall or multiwall, manufacturing	Medium	3
326112	Packaging film, plastics, single-web or multi-web, manufacturing	Medium	2

NAICS Code	Description	Relative Priority	Number of Businesses
326113	Sheet, plastics, un-laminated (except packaging), manufacturing	Medium	2
326121	Profile shapes (e.g., rod, tube), non-rigid plastics, manufacturing	Medium	5
326122	Fittings and unions, rigid plastics pipe, manufacturing	Medium	11
326140	Jugs, vacuum, polystyrene foam plastics, manufacturing	Medium	8
326150	Insulation and cushioning, foam plastics (except polystyrene), manufacturing, chests or coolers, urethane or other plastics foam (except polystyrene), manufacturing	Medium	12
326160	Bottles, plastics, manufacturing	Medium	3
326191	Shower stalls, plastics or fiberglass, manufacturing	Medium	10
326199	Handles (e.g., brush, tool, umbrella), plastics, manufacturing	Medium	82
332812	Coating of metal and metal products with plastics for the trade	Medium	34
336612	Boats, inflatable plastics (except toy-type), manufacturing	Medium	10
424610	Foam, plastics, resins and shapes, merchant wholesalers	Medium	41
333994	Furnaces and ovens, semiconductor wafer, manufacturing	Medium	0
336411	Aircraft manufacturing	Medium	10
336412	Aircraft engine and engine parts manufacturing	Medium	4
336413	Other aircraft parts and auxiliary equipment manufacturing	Medium	38
336414	Guided missile and space vehicle manufacturing	Medium	6
336415	Guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing	Medium	8
336419	Other guided missile and space vehicle parts and auxiliary equipment manufacturing	Medium	4
325220	Artificial and synthetic fibers and filaments manufacturing	Medium	1
326299	All other rubber product manufacturing	Medium	2
314910	Bags, plastics, made from purchased woven plastics	Lowest	24
325991	Reformulating plastics resins from recycled plastics products	Lowest	3
326220	Vacuum cleaner belts, rubber or plastics, manufacturing	Lowest	5
333511	Molds for plastics and rubber-working machinery,	Lowest	20

NAICS Code	Description	Relative Priority	Number of Businesses
	manufacturing		
337125	Dining room chairs (including upholstered), plastics manufacturing	Lowest	3
337215	Furniture parts, finished plastics, manufacturing	Lowest	14
424990	Plastics foam products (except disposable and packaging) merchant wholesalers	Lowest	152

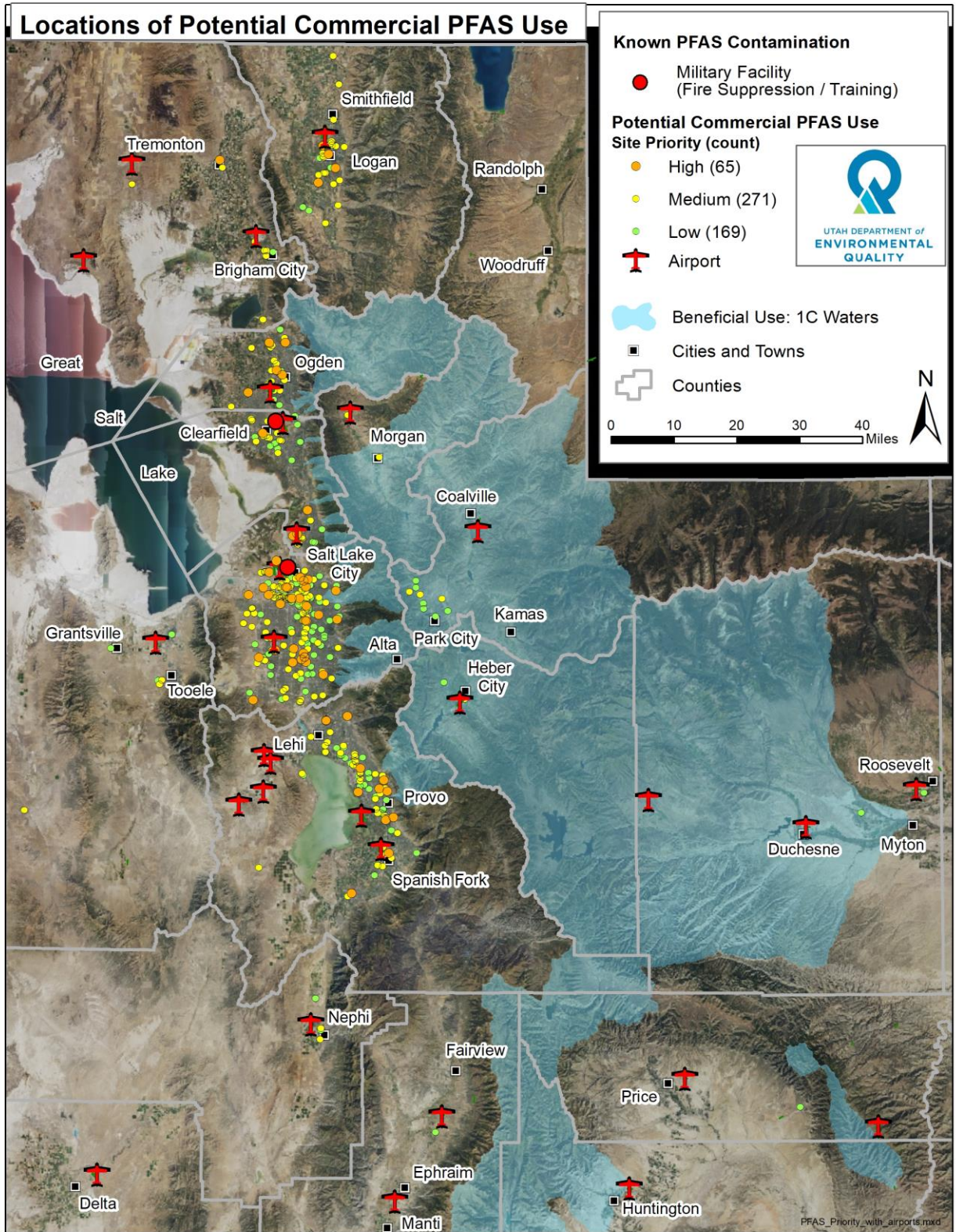


Figure 2. Locations of Potential PFAS Use in Utah

Landfills: Solid and Hazardous Waste Disposal

Landfills can be sources of PFAS because they are the ultimate repositories of not only of PFAS-contaminated industrial waste, sewage sludge, and waste from site mitigation, but also PFAS-bearing consumer goods treated with stain-resistant coatings. Consumer products landfilled since the 1950s are potential sources of PFAS to the environment. Industrial waste can be a significant source of PFAS in landfills, particularly those that accept waste from industries using PFAS in their manufacturing processes. In addition, many landfills accept sewage sludge from wastewater treatment facilities that may contain PFAS. Waste disposal regulations define solid wastes and the subset of these wastes that may be hazardous wastes. Specific requirements for disposal facilities are based on the type of waste. PFAS are not specifically regulated as hazardous wastes and could be mixed with wastes that are regulated as solid wastes, resulting in their disposal in solid waste landfills.

Solid Waste Landfills

Solid waste landfills are permitted to accept nonhazardous wastes, some hazardous household waste, and very small quantity generator (VSQG) hazardous waste. Liquid wastes are not allowed in the landfill unless they pass the [Paint Filter Liquid Test \(SW846-9095B\)](#) verifying that no liquids greater than five gallons are disposed into the landfill. These facilities must meet the siting requirements of [R315-302-1](#) that include requirements for avoiding drinking water sources. These landfills are required to be lined if they are new or have expanded in size from their original footprint since 1992. Some landfills constructed before 1992 are not lined. Prior to 1990, there was little to no regulation governing the disposal of non-hazardous waste in solid waste landfills. However, most of these landfills monitor the groundwater to identify potential releases.

Landfills that were operating prior to the early 1990s likely have PFAS because of their widespread use in consumer products. Wastes from certain PFAS industries have the potential for higher concentrations.

Industrial Landfills

Industrial landfills are permitted to accept industrial wastes. Similar to the solid waste landfills, they have siting requirements. These landfills are required to be lined and monitor groundwater to identify potential releases. Liquid wastes are not allowed in the landfill unless they pass the [Paint Filter Liquid Test \(SW846-9095B\)](#) verifying that no liquids greater than five gallons are disposed into the landfill.

These landfills could have PFAS-contaminated wastes. However, these landfills also have requirements that make any releases of wastes to the environment, including PFAS, unlikely. Based on the currently available information, no additional investigations of PFAS are recommended for industrial landfills. Industrial landfills serve on the facility permitted and cannot accept waste from offsite. This limits the types of waste being accepted.

Hazardous Waste Landfills

Hazardous waste landfills are constructed in accordance with [R315-264](#) to ensure a construction quality assurance program is in place. Hazardous waste landfills are required to be lined and usually have leachate collection systems. Liquid wastes are not allowed in the landfill unless they pass the [Paint Filter](#)

[Liquid Test \(SW846-9095B\)](#) verifying that no liquids greater than five gallons are disposed into the landfill. These landfills also monitor leachate and groundwater for a variety of other compounds to identify potential releases.

These landfills could already be managing PFAS-contaminated wastes at their sites. However, these landfills have very stringent requirements that make any release of contaminants into the environment manageable through leachate collection system monitoring. Leachates from the landfill cells may also be used as dust suppression, but these activities should not result in a release to the environment.

Municipal Wastewater: Publically Owned Treatment Works (POTWs) and Industrial Wastewater Treatment Plants

Publically owned treatment works (POTWs) and industrial waste water treatment plants (WWTPs) can introduce PFAS into the environment from point-source discharges of effluent, leakage, unintended releases from surface impoundments, air emissions, or disposal of biosolids and other byproducts generated during the treatment process. PFAS may be concentrated in solid waste such as sewage sludge during the treatment process and may contaminate groundwater, surface water, or both. PFAS may also be introduced to the environment through the land application of biosolids as a beneficial soil amendment, potentially allowing PFAS to enter surface water through runoff or infiltrate into groundwater.

POTW and WWTP Liquid Wastes

Most businesses in Utah discharge their liquid wastes to publically owned treatment works (POTWs). A small percentage of businesses have a permit that allows them to discharge their liquid wastes, after treatment, to Utah's surface waters. Four industrial facilities are associated with industrial processes that potentially use PFAS in manufacturing. However, none of these facilities discharge to waters that are used for drinking water (Class 1C), but all four discharge to Class 4 agricultural use waters. If the liquid wastes from a commercial facility cannot be discharged to a POTW because of the presence of regulated pollutants, the waste is sent to an industrial landfill, deep-well injected, or sent to an incinerator, depending on the specific waste and regulatory requirements.

Because of their widespread use in consumer products, all POTWs are expected to receive some PFAS. If PFAS are present, they could ultimately be released to the environment because conventional treatment processes used by POTWs and WWTPs are generally ineffective for PFAS. The treatment processes can also transform the original PFAS to a different PFAS, such as PFOS (Eriksson, Haglund, & Karrman, 2017). Industrial processes that use significant amounts of PFAS may contain elevated concentrations of PFAS in the effluent. Absent information on which Utah industries use PFAS and the quantities ultimately discharged to a POTW, additional data are needed to assess if PFAS releases are occurring. The one WWTP in Utah where PFAS may be used in industrial processes is unlikely to affect drinking water because it discharges to Blue Creek, which is not a drinking water source or in a groundwater protection area. The creek ultimately discharges to Bear River Bay, Great Salt Lake.

Lined landfills may have a leachate collection system that collects the liquid at the bottom of the landfill. If not used onsite for dust control, the leachate may be piped or trucked to a WWTP. Based on a study

conducted in Michigan, the contribution of PFAS from landfill leachate is unlikely to significantly add to the amount of PFAS discharged from a POTW (MWRA, 2019). The study demonstrated that POTWs that accept landfill leachate had higher concentrations of PFOA and PFOS in the influent than the POTWs that did not. However, when the volume of leachate is considered, the contribution of PFAS from leachate to the POTW is relatively small compared to all other PFAS sources to the POTW. (Note: the Michigan study uses the term “WWTP” to refer to both public and private wastewater treatment facilities). Some conclusions of the study:

- a. Leachate provides a relatively minor contribution to the overall PFOA and PFOS concentration/mass in most WWTP influent because of the relatively low leachate discharge volumes.
- b. Non-leachate sources of PFOA and PFOS significantly contribute to WWTP influent and at higher volumes. It is noteworthy that the WWTP influent that has no landfill leachate contribution shows a similar concentration range for PFOA and PFOS as WWTP influent that has leachate contribution.
- c. Although reduction of landfill leachate concentrations of PFOA and PFOS to the WWTP influent could be beneficial to meeting Water Quality Services (WQS) in the WWTP effluent, the impact may be minor in most cases since leachate typically contributes a relatively small volume to the overall WWTP influent.
- d. Available data show that PFOA levels in WWTP influent are well below Michigan’s most conservative surface water criteria (420 ng/L) at all WWTPs examined, and that PFOS levels in the Water Resources Recovery Facility (WRRF) influent are below Michigan’s most conservative surface water criteria (11 ng/L) at approximately two-thirds of the WWTPs examined.

Biosolids: POTW Solids

Solid wastes collected or generated during the treatment process at a POTW are disposed in landfills or sometimes used as soil amendments (biosolids). These soil amendments, also known as land application of sewage sludge, are regulated by Utah and federal regulations. The land application of biosolids is based on:

- Pollutant concentrations
- Potential for pathogens
- Control measures to prevent transmission of pathogens to other organisms such as rats or mosquitos.

PFAS have been found in biosolids and in the land on which they were applied (Lindstrom, 2011) (Venkatesana & Halden, 2013). If PFAS are present in biosolids, they could be released to the environment and potentially to groundwater. In Alabama, biosolids contaminated by a PFAS manufacturing facility and later applied as a soil amendment entered the groundwater and resulted in concentrations of PFOA and PFOS of 110 ng/L, which is above the LHA level of 70ng/L (EPA, Perfluorochemical (PFC) Contamination Near Decatur, AL Fact Sheet, 2013). In Maine, PFAS chemicals were found to be present at unsafe levels in milk produced from a dairy farm that had historically applied biosolids to its fields. As of March 2019, all sewage sludge in Maine must be tested for PFAS and meet the concentrations shown in **Error! Reference source not found..**

Table 3. Maine PFAS Requirements for Biosolids (Maine DEP, 2019)

PFAS	PFOA	PFOS	PFBS
Screening Level	0.0025 mg/kg	0.0052 mg/kg	1.9 mg/kg

Potential Human Exposures

PFAS must be released to the environment through a complete exposure pathway to pose an exposure risk to people. Studies show that the majority of the U.S. population is exposed to PFAS primarily from consumer products, with the most significant exposure pathway appearing to be from the ingestion of food and drink. (Poothong, Papadopoulou, Padilla-Sanchez, Thomsen, & Haug, 2020). People living near PFAS manufacturing facilities or manufacturing facilities that use large quantities of PFAS, as well as sites where AAAF was repeatedly applied, have elevated exposures. These elevated exposures are most commonly attributed to contaminated drinking water (CDC, 2015).

DWQ prioritized locations for additional investigation by mapping the locations of the businesses listed in Table 2 (see Figure 2 **Error! Reference source not found.**). Because PFAS must actually be released to the environment to contaminate the drinking water sources, the waste management practices of these facilities were also considered. If PFAS are discharged to surface waters or groundwater, people could be exposed if:

- Contaminated water is used as a drinking water source.
- Contaminated water is used for irrigating crops for human consumption.
- Contaminated water is used for watering livestock or irrigating livestock forage and the livestock used to feed people.
- People consume fish or other aquatic-dependent wildlife from exposed to contaminated water.
- Contaminated biosolids from a POTW are applied to crops for human consumption.
- Contaminated biosolids from a POTW are used on livestock forage and the livestock used to feed people.

Drinking Water

Utah’s drinking water sources have several layers of protection against contamination. Both surface and groundwater source areas are protected in accordance with drinking water Source Protection Plans. The routine testing required for source waters, while not specific for PFAS, will detect other contaminants that indicate contamination. Utah’s surface waters used as drinking water sources are also assigned a beneficial use of Class 1 (drinking water) and monitored for contamination not specific to PFAS.

As was previously discussed in Section 1.2, PFAS samples for PFOA, PFOS, and PFBF collected from Utah’s large and very large drinking water systems during UMCR3 (2013-2015) were either non- detect or detected at concentrations less than the minimum reporting level (MRL). The MRL is the smallest measured concentration of a substance that can be measured by the analytical method used — in this

case, EPA Method 537. (It should be noted that non-detect does not necessarily imply not present). The majority of Utah's remaining drinking water systems remain untested.

DEQ reviewed Utah's permits for discharges to groundwater, and none of the permitted businesses were expected to use PFAS. Groundwater used for drinking water is protected under Source Protection Plans, and these areas were compared to the locations of businesses potentially using significant quantities of PFAS (Figure 2). To help ensure that Utah's drinking waters remain uncontaminated, DEQ compared the locations of businesses that potentially use PFAS with drinking water source protection areas for overlap. The results suggest a low potential for past or future contamination.

Any investigation of PFAS in drinking water is limited by the available analytical methods and toxicity information. Two validated analytical methods are currently available for a limited number of specific PFAS (see Section 3.0). Toxicity data are more limited than analytical methods, and EPA has published chronic reference doses (i.e., virtually safe dose over a lifetime) for two PFAS: PFOS and PFOA. A reference dose, along with estimates of exposure (e.g., how much drinking water is ingested per day), are used to determine if adverse health impacts are unlikely or possible. These reference doses from the EPA Office of Water haven't undergone the rigorous review required to be included in the EPA [Integrated Risk Information System \(IRIS\)](#). Absent any reference dose, it will be difficult to interpret Utah's drinking water sampling results.

Other states have developed reference doses or similar determinations of safe doses. However, the observed high variability between state values illustrates the lack of high-quality toxicity studies on which to base a reference dose. Even if sufficient data from human or animal toxicity studies are available, deriving reference doses is resource intensive. The currently available toxicity data are not consistent with each other. Additionally, specific expertise not available within DEQ or DOH may be necessary to interpret observed effects on a specific organ system or in extrapolating animal results to humans. DEQ does not anticipate independently deriving reference doses because of these challenges.

The available reference doses for PFOA and PFOS indicate that these PFAS are potentially toxic at very small doses. Therefore, any reliable detection of PFAS is cause for concern. These detections should be addressed with controls to reduce exposures to the extent practical. These actions may include administrative controls such as notifications to drinking water providers and consumers. Engineering controls may be appropriate if the source of PFAS can be eliminated or reduced. In extreme cases, alternative sources of drinking water may need to be provided.

Farm Products

Eight-two percent of Utah's diverted waters are used for agriculture (Utah OLRGC, 2012). Utah's surface waters used for irrigation are designated Class 4. A substantial portion of Utah's irrigation waters come from groundwater in addition to surface waters. PFAS have been shown to be transported from soil or water into crops (EPA, Drinking Water Health Advisory Perfluorooctane Sulfonate (PFOS), 2016) (Ghisi, Vameralli, & Manzetti, 2019). Dairy cows that eat forage grown using PFAS-contaminated water or drink contaminated stock water can accumulate PFAS in their milk, which can then pass to humans through their consumption of contaminated milk (Laca A.-L. , 2019).

The sheer number of agricultural points of diversion poses a challenge to assessing the likelihood of PFAS contamination in agricultural products. Using satellite photos, DEQ identified the locations of Utah businesses that potentially use PFAS. Facilities located within one mile of a farm or ranch, or surface water with Class 4 (agricultural) use, are the highest priority for further investigation.

As was mentioned earlier, contaminated biosolids were the suspected source of PFAS that contaminated dairy products in Maine (Laca A.-L. , 2019). The allowable uses of biosolids are based on the concentrations of certain contaminants, but these contaminant concentrations don't include PFAS, with the exception of Maine. Locations where biosolids are used may vary over time. Therefore, biosolids should be analyzed for PFAS from the POTWs that have a permit to provide biosolids for application on agricultural lands.

All POTWs are expected to have PFAS from consumer products. The PFAS concentrations observed in Utah's biosolids could be compared to literature values and POTWs in Utah. POTWs with significant sources of PFAS should have significantly higher PFAS concentrations than POTWs whose only sources are consumer products. Concurrently, or as a separate phase, testing of solids could be extended to all POTWs to identify potential PFAS releases to the environment.

Fish

Fish have been shown to accumulate PFAS from contaminated water (D'Hollander, W.; de Voogt, P.; De Coen, W.; Bervoets, L., 2010). Fish are a better indicator of PFAS contamination than water sampling alone because PFAS tend to bioaccumulate in fish and the concentrations in fish better represent longer-term PFAS concentrations in water than grab samples. Nine states currently have fish consumption advisories for PFAS: Alabama, Alaska, Connecticut, Indiana, Michigan, Minnesota, New Jersey, New York, and Wisconsin. No EPA-approved analytical methods are available for fish tissue. Some states have developed analytical methods that DEQ will need to review to determine if they are sufficiently reliable for application in Utah. DEQ will also identify commercial laboratories that can analyze fish tissues for PFAS.

Waterfowl

The wetlands near the Great Salt Lake in Utah support both private and public waterfowl hunting. In 2019, Utah reported almost 14,000 active adult duck hunters (USFWS, 2019). Although no U.S. data were found that specifically identify PFAS bioaccumulation in waterfowl, Michigan is currently developing a waterfowl sampling program. The Australian EPA has issued waterfowl consumption advisories for PFAS (Sharp, 2019). No EPA approved methods are available for duck tissue, and the limitations previously described for fish tissue and other solids apply for assessing waterfowl for human consumption.

Analytical Methods and Procedures

PFAS Lab Methods

Analytical methods for detection, quantitation, and identification of PFAS from environmental media continue to evolve and improve. Currently, multi-laboratory validated methods have only been

published for drinking water samples. The most recent method developed, [EPA Method 533](#), focuses on short-chain PFAS with carbon-chain lengths of four to 12. Method 533 complements [EPA Method 537.1](#) and can test for 11 additional PFAS. EPA 537.1 (Ver. 1.0, 2018) (EPA), includes 18 PFAS analytes, six of which were analyzed during EPA's Third Unregulated Contaminant Monitoring Rule (UCMR3). Both analytical approaches are based on solid-phase extraction (SPE) extraction and analysis by liquid chromatography tandem-mass spectrometry (LC-MS/MS) and multiple-reaction monitoring of mass-specific parent-to-product ion transitions for all targeted analytes. Addition of ¹³C-isotopically labeled surrogates and internal standards are used to monitor analyte recovery during sample preparation.

An expanded set of performance-based methods are in development for non-drinking water matrices (e.g., surface waters, wastewater, sludge and soils) by the American Society for Testing and Materials (ASTM), International Organization for Standardization (ISO), and others that rely on a similar LC-MS/MS approach. These methods involve distinct quality control (QC) procedures and allow more method modifications to improve performance. In particular, isotope dilution of target analytes when available during sample preparation is used to account for matrix-interference effects. To date, these methods have not yet been validated by EPA for use under Clean Water Act (CWA) or Safe Drinking Water Act (SDWA) programs. Available options for quantitative measurement of waters and other media are summarized in Section 3.1 and 3.2, respectively.

In addition to these quantitative methods, some semi-quantitative methods are in development that may provide a more inclusive assessment of PFAS occurrence at contaminated sites. One semi-quantitative approach (TOP Assay) uses persulfate digestion to transform a wide range of PFAS compounds to PFCAs (perfluoroalkyl carboxylates), where the hydrophilic (water-loving) functional group is converted to a carboxylate forms and then analyzed via LC-MS/MS. In principal, this method can provide a conservative measure of total PFAS concentration in a sample by converting the wide range of PFAS constituents into a smaller set of PFCAs prior to analysis. A second semi-quantitative approach (AOF-CIC) uses activated carbon to adsorb organofluorine compounds followed by combustion, where fluoride ions are trapped in deionized water and then analyzed by ion chromatography. While not specific to PFAS, this approach could be used for screening high-level contamination across a site. Commercial availability of these methods is limited. Available information on semi-quantitative PFAS measurements is summarized below.

For initial project-scoping purposes, information about analysis of PFAS from water and solid samples was requested from a subset of laboratories previously provided by EPA during the UCMR3 process. The following labs provided information on analytical methods, method and reporting limits, and analysis costs:

- 1) ALS, Kelso, Washington
- 2) BSK Associates, Fresno, California
- 3) Accurate Labs, Stillwater, Oklahoma
- 4) Anatek Labs, Moscow, Idaho
- 5) Eurofins-Eaton Analytical, Scottsdale, Arizona
- 6) Test America Inc., Sacramento, California

7) Utah Public Health Lab (UPHL), Salt Lake City, Utah

DEQ will select the lab(s) that demonstrate appropriate quality assurance (QA) elements, including proficiency testing and matrix-specific QC results, to ensure that results are comparable over time and across laboratories.

Target Analytes

A key challenge in developing a baseline survey of PFAS in Utah is identifying which PFAS compounds to evaluate. More than 6,000 distinct PFAS compounds have been produced or released to the global environment, but identification and quantitation of specific compounds at ultra-trace concentrations (e.g., ng/L) require specialized and expensive instrumentation and are limited by the availability of specific analytical standards (Wang, Dewitt, Higgins, & Cousins, 2017) (McDonough & Higgins, 2018).

EPA established drinking water health advisory levels for two PFAS compounds— PFOA and PFOS —at 70ng/L, separately or in combined concentrations. EPA’s UCMR3 survey of public water systems included six PFAS compounds. EPA Method 537 (Ver. 1.1, 2009) includes 14 compounds, EPA 537.1 (Ver. 1.0, 2018) includes 18 compounds and 7 surrogate/internal standards, and EPA Method 533 includes [25 PFAS compounds](#), 11 of which are not covered by 537.1. Other state programs (e.g., North Dakota and Michigan) have used in-house methods of commercial labs to analyze 24 to 32 PFAS compounds from surface water, groundwater, or biota (fish). Finally, ASTM and ISO are developing performance-based methods that rely heavily on measurement of ¹³C isotopically-labeled standards for non-drinking water matrices. The number of analytes potentially available from these methods is only restricted by the ability to meet method-specific QC requirements.

Of the labs that provided information to DEQ, the number of potential analytes ranged from two to 30 for methods based on EPA 537/537.1, while one laboratory-specific method reported up to 39 analytes. Reporting limits range from 1.0 to 90.0ng/L. It is not known how environmental sample matrices other than drinking water affect the actual precision and accuracy of measured PFAS concentrations, and what compound-specific reporting limits are relevant to characterize potentially contaminated sites in Utah. Special care is required during data evaluation of external (field collection) and internal (laboratory) QC samples to understand potential limitations for interpreting analytical results.

Overview of Quantitative Methods for Drinking Water

Drinking Water and Groundwater

Currently, the only EPA-approved methods for analysis of PFAS from drinking water are EPA Methods 537.1 and 533. Sample collection protocols established in EPA 537.1 and EPA 533 include appropriate bottle types, collection procedures, QC sample requirements, shipment and storage, and sample holding times.

Sample bottles should be 250 milliliter (mL) polypropylene (PP) bottle with PP screw cap (NOT a Teflon®-lined cap), provided by the laboratory. For finished drinking water samples, bottles should also contain Trizma (pH 7, 5 g/galiter(g/L)) buffer to remove free chlorine, if applicable.

All labs that provided analysis information to DWQ appeared capable of determining PFAS concentrations from finished drinking water based on EPA drinking water methods 537 (2009), 537.1 (2018) and 533 (2019). It is likely that groundwater used as drinking water sources could also be analyzed using these methods so long as matrix interferences are minimal and all appropriate sample collection and handling procedures are followed. Analyses from other state-level PFAS projects, in addition to laboratory specific information provided to DEQ, indicate that some commercial labs have provided results for other, non-drinking water matrices based on in-house modifications to EPA 537. Some modifications are permitted in EPA method 537/537.1, so long as method-specific QC requirements are maintained.

The number of available analytes for method EPA 537 range from six to 14, 18 for EPA 537.1, and 25 for EPA 533. For the six PFAS analytes surveyed under UCMR3 (PFBS, PFHxS, PFHpA, PFOA, PFOS, and PFNA), reporting limits (RLs) from available laboratories range from 1.0 to 90ng/L, with analyte-specific limits from most labs less than 20ng/L. Over 64% of RLs from available labs were at or below 2.0ng/L. RLs for PFOA and PFOS, assumed to be the most common PFAS constituents, are routinely < 20ng/L.

Using the 70ng/L EPA national health advisory level for comparison, any of the available labs would provide sufficient sensitivity for PFOA and PFOS. Interestingly, five of 18 states have PFAS screening or guidance levels lower than EPA's health advisory level (ITRC). If a heightened level of sensitivity is required, a smaller set of labs would meet the required RLs.

Surface Water and Wastewaters

For environmental samples with more complicated matrices, such as surface waters (streams, lakes, wetlands) and wastewater (influent and effluent), the higher concentrations of suspended solids, dissolved organic compounds, or dissolved inorganic solutes (salts) compared to relatively pure finished drinking water may interfere with otherwise accurate analytical procedures and result in poor sensitivity or biased results. These matrix effects can be examined through analysis of particular QC samples (Delaney, M.F., 2017) (Krynitsky, A.J., et al.). For instance, EPA Method 537.1 does not contain steps to alleviate matrix interference from surface water or solid samples, and currently there are no EPA methods for the preparation and analysis of other sample media (ITRC, 2018).

Methods for non-drinking water samples are becoming available from consensus standards organizations (ASTM and ISO) and gradually being adopted by some commercial laboratories. ASTM methods include [D7979 \(Water\)](#) and [D7968](#) (Soils Section Overview of Quantitative Methods for Solids). ASTM D7979-17 involves direct injection of a sample, thereby requiring little sample preparation, but is probably more appropriate for liquids with higher PFAS concentrations (See Table 4, PFAS method comparison). ISO methods 25101 and 21675 were both developed for determination of PFAS in waters; the latter method includes a greater number of analytes and higher sensitivity. Two EPA SW-846 methods are currently in development for direct injection ([Draft Method 8237](#)) and SPE LC-MS/MS with isotope dilution ([Draft Method 8238](#)) approaches to PFAS analysis, but details have not yet been released. These methods allow matrix-specific sample preparation modifications in addition to specialized analytical techniques such as isotope dilution, addition of surrogate compounds, and confirmatory monitoring of additional parent-product ion ratios. Since these modifications are neither

standardized nor validated by multiple laboratories, alternative analytical methods may provide results with widely varying precision and accuracy. Project-level data quality can be improved by evaluation of QC sample results against a list of QC checks for PFAS analysis prepared in Department of Defense (DOD) Quality Systems Manual (QSM) for Environmental Laboratories (DOD). Particular concerns when analyzing non-drinking water samples for PFAS may include:

- Excessive sample (or similar organic compounds) sorbed to SPE cartridge, resulting in low-bias of analytical results, identified by low percent recovery of isotopically labeled surrogates and internal standards
- Poorly resolved chromatography from complex mixtures of co-eluted organics, particularly from wastewater influent and effluent, biosolids, or soils that contain high concentrations of humic substances. This may result in poor precision when monitoring analyte-specific parent-product ion transition area ratios.

The data quality standards in DOD QSM Table B-15 are performance based. Moreover, isotope-dilution is strongly preferred for quantitation of all PFAS compounds where isotopically labeled analogs are commercially available. This requirement helps account for interferences caused by complex sample matrices and bias introduced by sample preparation and instrument-operation issues. Additional key analytical advances are likely to occur via improved chromatographic separation and selective retardation of contaminant peaks, equipment improvements (e.g., PEEK tubing for solvents), and additional columns (e.g., trap column) that allow for better MS resolution.

Except for some fluorotelomers and N-derivatives, PFAS reporting limits are routinely less than 2.0 to 5.0ng/L from all three laboratories. Key issues to consider for analysis of surface and wastewater samples include collecting additional samples for matrix spike and tracking spike recovery compared to lab control spike samples to evaluate the significance of potential matrix effects.

Table 4. PFAS Method Comparison

Method	EPA 533	EPA 537	EPA 537.1 (2018)	ASTM D7979 (water)	ASTM D7968 (soil)	ISO CD 21675 *
Validation	Multi-lab	Single lab	Multi-lab	Two labs (Region 5 & ASTM)	Single Lab	<i>In Review</i>
Extraction	SPE: 250 mL -> 1 mL	SPE: 250 mL -> 1 mL	SPE: 250 mL -> 1 mL	Dilute 1:1 w/ MeOH (5 mL), filter, direct injection	Extract 2 g w/ 10 mL (1:1 MeOH)	SPE: 1000 to 50 mL
Holding Time	Extract in 28 d; analyze in 28 d; Temp < 6 °C	Extract in 14 d; analyze in 28 d; [DW 5 g/L Trisma]; Temp < 6 °C	Extract in 14 d; analyze in 28 d; Temp < 6 °C	28 d; T < 6 °C	28 d; T < 6 °C	4 wk; T ~ 5 ± 3 °C
Matrix [design]	Drinking Water	Drinking Water	Drinking Water	Water and sludge (< 0.2% solids)	Soil	Water (< 0.2% solids)
Matrices Tested	Groundwater, surface water, drinking water	Cincinnati tap, groundwater, surface, UCMR samples	Groundwater, surface water, tap water	Chicago River water, POTW influent/effluent, 2 POTW w/ overflows	Ottawa sand, Frederick sand, Annapolis clay, Vicksburg silt / clay	Drinking water, river water, seawater, wastewater
Analytes	25 + 16 IDAs + 3 IS	14 + 3 surr. & 3 IS	18 + 4 surr. & 3 IS	21 + 9 surr.	21 + 9 surr.	30 + 31 IS
Quantitation Range	Under Review	5 - 15 ng/L (at 250:1)	5 - 15 ng/L (at 250:1), so long as conc. within ± 30%	5 - 8000 ng/L	25 - 20,000 ng/kg	> 0.002 ng/L
Quantitation Type	Isotope Dilution	Internal Stds	Internal Stds	External Stds, (Isotope Dilution allowed)	ES, (Isotope Dilution allowed)	Isotope Dilution
Calibration	≥ 5 pts	≥ 5 pts	≥ 5 pts over 20-fold range	5 - 9 pts	5 - 9 pts	≥ 5 pts
Force origin	Y	Y	Y	no	no	no
Goodness of Fit	RSE ≤ 30%	RSE ≤ 30%	RSE ≤ 30%	RSE ≤ 30%	RSE ≤ 30%	ISO 8466-1
Peak Asymmetry	Not req.	0.8 - 1.5	0.8 - 1.5	not req.	not req.	not req.
Confirmation Ion	Not req.	not req.	not req.	Yes, if avail.	Yes, if avail.	Yes, if avail.
Batch size	≤ 20 samp	≤ 20 samp	≤ 20 samp	≤ 30 samp	≤ 30 samp	≤ 20 samp
Max. Blank	≤ 1/3 MRL	≤ 1/3 MRL	≤ 1/3 MRL	≤ ½ RLCS	< ½ RLCS	≤ 1/10 ML
Internal Standards (IS)	Not req. (70-130%)	< 50% area drift	< 50% area drift	not req. (70-130%)	not req. (70-130%)	70-125%
Surrogate Recovery	70-130%	70-130%	70-130%	70-130%	70-130%	70-125%
MS/MSD Recovery	70-130%	70-130%	70-130%	70-130%	70-130%	70-125%
RPD	≤ 30%	≤ 30%	≤ 30%	≤ 30%	≤ 30%	no criteria

Refs: (1) Eurofins_Eaton Talk at NELAC National Environmental Monitoring Conference (NEMC), 2018 [url: http://nemc.us/meeting/2018/techprog.php#tpm1_5]
(2) EPA Method 537.1 Information for EPA 537.1 derived from method procedures document from National Exposure Research Laboratory, ORD. (see footnote-
Error! Bookmark not defined. in text above).
IS: Internal Standards; ES: External Standards; ID: Isotope Dilution approach; surr.: surrogate compounds
* Full method in review, to be released in 2019.
Details on SW846-based methods (8237, 8237) not yet available

Overview of Quantitative Methods for Solids

Soils, sediments and other solids are collected to characterize the nature and three-dimensional extent of the plume when a site is determined to be contaminated by PFAS. However, sampling and analysis of wastewater treatment plant sludge, i.e., biosolids, could also be used to inform larger, synoptic-scale surveys of potential PFAS contamination. Currently, specialized treatment processes appear to be required to achieve more than minimal reduction of PFAS in municipal waste streams. Most commonly, shorter-chain PFAS compounds have higher relative solubility and pass through treatment plants in aqueous phase, while longer-chain PFAS compounds are readily sorbed to wastewater solids. Some longer-chain PFAS compounds (C8 and higher) would accumulate in WWTP biosolids and may provide information about which wastewater plants have PFAS inputs to their system.

Information for analysis of solids from commercial labs is sparse, and procedures for quantitative analysis of PFAS from soils remain in development. DEQ received information from two laboratories about in-house modifications to EPA 537 or lab-specific methods for soils. The general idea of PFAS soil analysis is available from method ASTM D7968-17 and based on solvent extraction, filtration, and LC-MS/MS analysis. Isotopically-labeled surrogates are added to raw samples prior to extraction, where multiple parent-product ion mass transitions are monitored for compound identification, and quantitation is performed by external calibration. As written, ASTM D7968-17 is described as a “quick extraction” and not intended for exhaustive recover of all PFAS compounds. Further modifications to the method are allowed, including use of isotope dilution for PFAS quantitation and more intensive soil-PFAS extractions. Close adherence to the QC checks identified in DOD Quality Systems Manual, Table B-15, may result in higher sensitivity and quantification of additional PFAS compounds. Comparing these screening levels, RLs for PFAS in soils should be sufficient. Closer coordination with prospective laboratories is needed to ensure that sample collection, transport, and preparation activities are followed to support the required sensitivity and specificity.

Overview of Semi-quantitative Techniques

A single targeted method is unlikely to quantify all PFAS present in a sample because of the large number of PFAS compounds and their varied structural characteristics (ITRC, 2018). For releases that are not well understood or comprised of multiple sources, alternative ways of measuring PFAS in a more comprehensive but less targeted fashion may be desirable.

The literature is showing progress in two semi-quantitative approaches to obtain a more inclusive or integrated quantitation of total PFAS concentration from a sample. The total oxidizable precursor assay (TOP assay) involves conversion of various PFAS compounds in a sample to PFAAs (perfluoroalkyl acids, as carboxylates), which are then identified and quantified by LC-MS/MS. The amount of PFAAs generated by the assay may be a conservative estimate of total PFAS compounds, while the change in PFAA distribution before and after the oxidation treatment can represent compounds that may be transformed to PFAAs via biotic or abiotic processes.

The second semi-quantitative approach, adsorbable/extractable organic fluorine (AOF/EOF) quantified by combustion ion chromatography (CIC), involves concentration of organic compounds from samples

on carbon-based sorbent. This material is then combusted at high temperature and the gas stream passed through de-ionized (DI) water to collect inorganic fluoride (F) ions released by combustion. Finally, the DI solution is analyzed by ion chromatography (IC) for fluoride. This method has been demonstrated on blood and other aqueous samples. The key here is the specificity of the extraction step, as other organofluorine compounds may be included in the sample. This method is not known to be commercially available at the present time. However, if available at lower cost than LC-MS/MS, this approach could be used as a quick screening tool. Questions remain as to how much of the total organofluorine compounds are PFAS, particularly since detection limits are on the order of 0.77 µg F/L (reported in (Willach, Brauch, & Lange, 2016) – equivalent to 13 µg PFOS/L. These limits may be two to three orders of magnitude too high for screening purposes.

Currently, TOP assay is the more widely used and commercially available semi-quantitative technique. DEQ received very little information regarding the TOP assay from one laboratory (Eurofins/Eaton-Analytical). The lab suggested that TOP analysis would be on the order of twice the per-sample cost as LC-MS/MS since analyses are run before and after the oxidation step, making it unsuitable as a potential screening tool. Additional information may be obtainable if this approach is considered fruitful. No commercial information on AOF-CIC was reported to DEQ.

Overview of PFAS Sampling Precautions

Because of the ubiquity and low ambient concentrations (ng /L) of PFAS in the environment, special precautions are required for field sampling procedures and materials to avoid sample cross-contamination and reduce the chance of false positive detections. These precautions and procedures will be defined in individual Sampling and Analysis Plans (SAPs) and Standard Operating Procedures (SOPs)(See Section 4).

Background PFAS Contamination

To minimize background PFAS contamination to samples, sampling crews should review all materials and sampling protocols to avoid contamination or possible adsorption issues. Care should be taken to ensure there is no PFAS transfer from sampler gear or PPE (personal protective equipment) to field-samples. Materials that could contaminate samples and introduce high-bias include:

- Teflon® (polytetrafluoroethylene (PTFE)
- Waterproof coatings containing PFAS
- Fluorinated ethylene propylene (FEP)
- Ethylene tetrafluoroethylene (ETFE)
- Low-density polyethylene (LDPE)
- Polyvinylidene fluoride (PVDF)
- Pipe thread compounds and tape (Teflon® tape)

Additional information on allowed / prohibited materials is available from [Michigan DEQ General PFAS Sampling Guidance](#) (Michigan DEQ, 2018).

The materials listed above should also be avoided for reuseable tools or containers, and sampling crews should ensure all reuseable equipment is fully and consistently decontaminated. Two decontamination

methods are described in Michigan DEQ Sampling Guidance; others may also be available. Allowable solutions include Alconox, Liquinox or Citranox, and triple-rinse with PFAS-free deionized water. PFAS-free deionized/rinse water should be obtained from the laboratory.

QC checks include the collection of field blanks and equipment blanks as appropriate, depending on the sample matrix being collected and collection protocols. The type of sampling program can influence the frequency of field and equipment blanks. Intensive site investigations may include one or more sets of blanks per day at a single site. In contrast, broad-scale surveys may include a field blank for every sampling trip and equipment blanks for every ten field samples collected. Matrix-specific sampling needs may include:

- Drinking water (finished) : allowed bottles, no transfer containers, no PTFE lids
- Surface water : allowed bottles, transfer containers / tools if necessary
- Groundwater : allowed bottles, transfer tubing (pumps) or bailer, no PTFE
- Soil/biosolids : bulk containers, homogenization equipment (stainless steel mixing bowl, spatula), rinse/decon water, no PTFE

Sample Representativeness

Ensuring that a collected sample is representative is critical. For drinking water and surface water samples, the entire sample should be used for analysis via solid-phase extraction. Groundwater samples from wells may also be collected by usual protocols but care must be taken to eliminate cross-contamination from pump-tubing or similar materials. Solid samples or other mixed-media should be well-homogenized in the field if composite samples are collected, and homogenization containers should be stainless steel or polypropylene. Since solids are typically extracted with solvent prior to further SPE preparation in the lab, analysts should also homogenize the submitted sample well before sub-sampling.

In addition to the above techniques, collection of sufficient field replicates should satisfy QC checks for representativeness where sample-specific RPDs are less than across-site differences, if appropriate.

Sample Matrix Effects

While less an issue with drinking water or groundwater samples, some surface waters and soils/biosolids are likely to have substantial matrix effects on laboratory instrument performance. Use of isotope dilution for analyte quantitation and addition of labeled surrogate compounds help identify strong reductions in extraction efficiency. This is particularly true when surrogate and internal standard compounds are added to the sample prior to extraction or cleanup steps. Additional QC checks involve routine collection of extra field samples for use as matrix spikes at a frequency greater than specific in most methods. Recovery of matrix spike samples is compared to recovery from lab control spikes (lab method blank spiked before analysis) to identify instrument performance vs. matrix interference. Lastly, particularly for projects where clean and PFAS-contaminated sites are surveyed, it may be useful to develop low- and high-spike concentration solutions in order to understand the magnitude of potential matrix effects across the sample universe. For example, if a five-standard calibration curve is used, levels two and four could be used as spike concentrations.

Special Considerations for PFAS Sampling

- Communicate with the laboratory before and after sampling to identify any known, highly contaminated samples to avoid unnecessary lab equipment contamination and ensure proper sample containers are used and sufficient sample volumes are collected.
- Use PFAS-free water for field blanks, equipment blanks, equipment rinsing, and decontamination procedures. The lab should provide documented verification that the supplied water is PFAS-free.
- Explicitly define “PFAS-free” so unacceptable bias is not introduced into the sampling process:
 - Blank concentrations below detection limit
 - Blank concentrations < ½ quantitation limit
- Specify bottle type. For instance, Method EPA 537 requires 250-mL polypropylene containers (PPE) and caps for drinking water sampling. Check with the laboratory regarding method- and matrix-specific requirements. Sample containers are typically composed of PPE or HDPE bottles with unlined plastic caps. Note also that samples of finished drinking water should include Trizma preservative or equivalent (per the method) to scavenge free chlorine.

Additional sampling guidance documents are available from Michigan DEQs PFAS website:

https://www.michigan.gov/pfasresponse/0,9038,7-365-86510_87154-469832--,00.html

Laboratory Data Evaluation

Preliminary steps to evaluate the quality of data for its intended use involve reviewing all factors that may affect data precision, accuracy, representativeness, comparableness, completeness, and sensitivity.

The following data-quality criteria should be met.

- Data are precise. Sufficient agreement exists between results from the same or very similar sample location.
- Data are accurate. Results are sufficiently close to expected/true values.
- Data are representative. Results sufficiently characterize the site.
- Data are comparable. Samples are collected and analyzed using similar procedures and techniques.
- Data are complete. All required samples are collected, all collected samples are analyzed, and all requested analytes are reported.
- Data are sensitive. Analytical method and field-collection procedures provide for reporting/detection limits below appropriate regulatory action levels.

Recommendations

DEQ examined potential exposure pathways to evaluate how people in Utah might come into contact with or be exposed to PFAS. The PFAS workgroup investigated possible sources of PFAS, their probable fate and transport in the environment if released, potential exposure areas, potential exposure routes,

and potentially exposed populations. All five elements of an exposure pathway must be present for the pathway to be considered “complete” ([ATSDR](#)).

The following recommendations are based on the workgroup’s evaluations of the most likely avenues for PFAS to contaminate Utah’s drinking water, groundwater, surface waters, or other sources of human exposure. While consumer products and atmospheric emissions are also sources of human exposure, DEQ is focusing on water and land contamination from PFAS.

The science of PFAS compounds continues to evolve rapidly. These recommendations will be re-evaluated as new information becomes available. The recommendations and resulting sampling priorities will also be re-evaluated as more Utah-specific data become available.

The DEQ PFAS Workgroup used the potential for human exposure to prioritize its investigation and sampling for PFAS in Utah, as follows.

Priority 1: Drinking Water

In the U.S., elevated human exposures of PFAS are most often associated with contaminated drinking water linked to local manufacturers of PFAS or industrial sites where large volumes of PFAS were used and released to the environment. While DEQ did not identify any PFAS manufacturers in Utah, more information is needed to determine what industries use, or have used, significant amounts of PFAS that were released to the environment. These releases include the use of aqueous film-forming foams (AFFFs) at military installations, airports, and refineries. These releases will be evaluated further to determine if they have or could impact drinking water. An accompanying Sampling and Analysis Plan - Statewide PFAS Monitoring Phase I: Drinking Water Systems (DWQ, 2020) provides specific detail on site selection, laboratory analysis, and sampling methods.

Priority 2: Agriculture/Food

The predominant route of PFAS exposure to the general public, apart from those living near a source of PFAS or working in an industry that manufactures/uses PFAS, is through the ingestion of PFAS in food (Gebink, Berger, & IT, 2014). Releases to surface water and groundwater, as well as the land application of biosolids, can result in potential human exposure from agricultural products, wild game, or fish. Industries that use PFAS may discharge to a POTW, which may contaminate liquid effluent/solids and subsequently impact crops or domestic/wild sources of meat. DEQ did not identify any industries associated with high levels of PFAS that have direct discharge permits to Utah’s surface or groundwater. Businesses that may use PFAS in their processes or products were identified, and, with one exception, these facilities are located in urban areas serviced by POTWs, limiting the impact to agricultural lands.

Priority 3: Environmental Exposures

Any remaining potential PFAS sites should be further evaluated to characterize releases to the environment. Less data are available to evaluate the potential environmental impacts of PFAS on ecological receptors such as aquatic life and wildlife. However, the persistence and tendency of some

PFAS to accumulate in organisms supports a heightened level of concern if these exposures are occurring.

PFAS Monitoring Strategy

Little data are currently available for PFAS in Utah, which necessitated some assumptions for implementing the investigations. A phased approach is recommended so data from previous phases and new data from other sources will inform later phases. The phases were initially prioritized based on:

1. The likelihood of complete potential exposure pathways
2. The potential magnitude of the exposures
3. The expected number of people potentially exposed

New information may warrant re-prioritizing the sequence of the phases or adding additional phases to address potential exposure pathways that are currently unknown. Each phase includes:

- Preparation of an individual monitoring plan
- Development of detailed Sampling and Analysis Plans (SAPs) that include data quality objectives (DQOs), laboratory and methods review, funding mechanisms, standard operating procedures (SOPs), and results analysis
- Stakeholder outreach and communication plans specific to the media sampled

Funding for this project is anticipated to come from existing resources. Since these resources are limited, phasing the investigations will support identified priorities for sampling and analysis. As additional funding becomes available, DEQ can implement additional phases.

While this document represents initial efforts to communicate to the public and potentially affected public, DEQ will develop more detailed communication strategies for each phase of the sampling and monitoring to ensure stakeholder involvement.

Phase 1

The first phase of the PFAS monitoring strategy will focus on drinking water sources potentially impacted by the use of AFFFs at military facilities such as Hill Air Force Base and industries that may have used PFAS in their manufacturing processes. Please reference the Sampling and Analysis Plan (DEQ 2020) for specific details on proposed methods, sampling locations, and other study objectives.

In addition to sampling individual source wells of public water systems, Phase 1 will include sampling a selection of private wells in impacted areas. Since PFAS are not currently regulated by the EPA through SDWA, this effort will require significant outreach to water providers, local health departments (LHDs), and homeowners with private wells to obtain access to their wells. DEQ will work closely with the Utah Department of Health, LHDs, and water providers to interpret results of monitoring data and refine existing communication plans to relay the information to the public and well owners. Depending on the results, DEQ will help homeowners and water providers determine a course of action for evaluating health risks, treatment options, and alternative sources of drinking water.

Phase 2

This phase of the strategy will focus on evaluating concentrations of PFAS in fish and waterfowl tissue to determine the risk from human consumption. The intention of this monitoring is to compile data for consumption advisories, similar to DEQ’s existing program for tissue consumption advisories for mercury and selenium. Evaluating the presence of PFAS in wildlife, where present, will also inform future monitoring of potential sources. Areas of focus will be high-use fisheries and waterfowl hunting areas known areas of PFAS contamination based on ongoing evaluation of industrial uses and AFFF releases and informed by subsequent sampling and analysis. DEQ will work closely with the Department of Natural Resources to prioritize sampling sites, coordinate specimen collection, and develop advisories and communication plans for notifying the public regarding the risk from consumption of contaminated tissue.

Phase 3

The third phase of this strategy will focus on the presence of PFAS in surface waters and contributions of PFAS from industrial, pretreatment, and wastewater sources. Since the primary goal is to assess impacts to human health, the monitoring design will focus on waterbodies classified for agricultural uses such as livestock watering and irrigation. During SAP development, specific risk factors will be evaluated to target sampling locations that could identify the potential human health and agricultural impacts of PFAS contamination. Additionally, DEQ will sample biosolids used for agricultural production to determine the fate of PFAS after treatment and composting. This will require coordination with wastewater facilities and biosolids programs to understand the distribution and potential pathways from these biosolids to agricultural products, as well as working with LHDs to notify the public where risks might occur.

Future Phases

Additional phases will complete characterizations for any remaining potential human exposures identified in previous phases.

Timeline

The following represents an estimated timeline for current and future efforts for evaluating PFAS in Utah. This schedule may change depending on results of initial phases and the need for follow-up monitoring to evaluate sources and impacts to drinking water systems,

Component of PFAS Monitoring	2020			2021				2022			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Drinking Water System Monitoring											
Call for Data and Information											
Outreach to PWS and LHDs											
Well Sampling											
Fish and Waterfowl Monitoring											
Surface, Wastewater, Biosolids Monitoring											

Communication Plan

The DEQ PFAS workgroup has developed a preliminary communication plan that formed the basis of current web resources that inform the public about PFAS and provide updates on the DEQ PFAS program <https://deq.utah.gov/pollutants/per-and-polyfluoroakyl-substances-pfas>. Each phase of the strategy will require the development of outreach materials and information to communicate with the public and impacted drinking water providers to ensure data and potential risk are clearly communicated. DEQ will coordinate closely with the Department of Health and Local Health Departments to develop communication plans and outreach materials.

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