HEALTH CONSULTATION

Florida State Fire College

Per- and Polyfluoroalkyl Substances (PFAS)

Report 3

Off-site private, residential well investigation of per- and polyfluoroalkyl substances (PFAS) in groundwater

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FOREWORD

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EXECUTIVE SUMMARY

In September 2018, the Florida Department of Environmental Protection (FDEP) notified the Florida Department of Health (FDOH) that per- and polyfluoroalkyl substances (PFAS) had been found in well water at the Florida State Fire College (FSFC) in Marion County. FDOH has tested private well water within one mile of the FSFC and completed three health consultation reports to evaluate possible health risk from PFAS exposures on and near the FSFC. Reports 1 and 2 evaluate PFAS exposures at the FSFC and the adjacent Lhoist Mine Site, respectively. This evaluation (Report 3) focuses on exposures to PFAS in drinking water from residential wells within one mile of the FSFC.

PFAS are a large group of manufactured chemicals used in various industrial and consumer products since the 1940s. Because of their widespread use, PFAS have been found everywhere in the environment (e.g., water, soil, dust, wildlife) all around the world. Most people are exposed to low PFAS levels in their daily lives and have PFAS in their blood. Increasing scientific information indicates that exposure to elevated levels of PFAS could cause adverse health effects in humans.

Most studies to date have focused on two main PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS, also known as perfluorooctane sulfonic acid). Limited information is available for other PFAS, such as perfluorononanoic acid (PFNA) and perfluorohexane sulfonate (PFHxS, also known as perfluorohexane sulfonic acid). This evaluation is based on these four PFAS

Current knowledge from human studies suggests that exposure to elevated levels of PFAS may cause increased cholesterol levels, changes in liver enzymes, decreased vaccine response in children (immune effect), small decreases in birth weight (developmental effect) and increased risk of high blood pressure or pre-eclampsia in pregnant women. PFAS exposure has also been associated with other health effects such as changes in thyroid and reproductive hormones, infertility and childhood obesity, but study results are limited and inconsistent. More information is needed to determine if PFAS can cause cancers in humans. Limited evidence from human studies have associated PFOA exposure with kidney, testicular and prostate cancers, and animal studies have also shown kidney and testicular cancers in animals exposed to PFOA. Animal studies suggest that PFOS can cause liver cancer.

PFAS has been found in groundwater near areas that used PFAS-based firefighting foams known as aqueous film forming foam (AFFF). Groundwater contamination is a concern when used to supply drinking water and other household uses. Therefore, in 2018, FDEP began investigations of fire training facilities in Florida.

In early August 2018, FDEP contacted the FSFC in Ocala and confirmed that AFFF had been used for training at the site. The facility has an on-site water supply well, which is used for drinking and other household purposes. In early September 2018, FDEP collected a water sample from this well for PFAS analysis. The water contained a combined concentration of PFOA and PFOS of 250 nanograms per liter (ng/L). This level

exceeds the United States Environmental Protection Agency (EPA) 2016 lifetime health advisory level (HAL[1]) of 70 ng/L for combined PFOA and PFOS.

Residents who live near the FSFC have expressed concern that drinking water from their private wells could pose a potential health risk. Therefore, FDOH conducted this health assessment for the residential population within a one-mile radius of the FSFC. FDOH evaluated possible health threats from exposure to PFOS, PFOA, PFHxS and PFNA in contaminated well water. FDOH used national health guidelines developed by the Agency for Toxic Substances and Disease Registry (ATSDR) for the assessment.

On March 12, 2021, FDOH released this and two additional health consultation reports related to the FSFC for public comment. The comment period ended on May 14, 2021. FDOH received a total of four comments from two community members during the public comment period. Appendix E provides responses to the four comments.

FDOH used data collected during 2018/2019 and health guidelines released by the federal Agency for Toxic Substances and Disease Registry (ATSDR) in 2021. We evaluated potential health risk from exposure to PFOA, PFOS, PFNA and PFHxS in drinking water, individually. **FDOH summarized five main conclusions**:

- **Conclusion 1.** Drinking unfiltered water from wells with PFOS levels at and above 59 ng/L and PFHxS levels at and above 630 ng/L in 2018/2019 could pose increased immune, developmental and/or thyroid health risk for some residents
- **Conclusion 2.** Residents of all age (exposure) groups are not likely to be at increased risk of liver effects, if they drank water or formula made from wells evaluated in this assessment for two weeks or longer during 2018/2019.
- **Conclusion 3:** Residents of all age groups who showered at their residences with water containing 2018/2019 levels of PFOA and PFOS daily for two weeks or longer are not likely to experience an increased risk of developing harmful non-cancer health effects due to PFAS exposure via showering. Though, even when exposure via showering alone is not expected to contribute to an increased risk of developing harmful non-cancer health effects, it could have contributed to an overall PFAS exposure.
- **Conclusion 4.** Some health risk evaluations are limited.
- **Conclusion 5.** The combined health risk from exposure to multiple PFAS, from multiple sources (e.g., drinking water, food packaging) and routes of exposure (e.g., ingestion, skin contact) is expected to be higher than that of any individual PFAS but cannot be determined at this time.

[1] HAL – Health Advisory Level. In 2016, the U.S. Environmental Protection Agency (EPA) developed a lifetime health advisory level for combined PFOA and PFOS of 70 nanograms per liter (ng/L). The HAL is a non-regulatory guidance level to help inform state agencies and public health officials about drinking water contaminants. The EPA considers levels below HAL safe over a lifetime of exposure. Levels above HAL do not necessarily mean health effects will occur.

Conclusion 1

PFAS drinking water exposures within a one-mile radius of the Florida State Fire College during 2018/2019 could pose increased immune, developmental and/or thyroid health risk for some residents.

Drinking unfiltered water from wells with PFOS levels at and above 59 ng/L and PFHxS levels of 603 ng/L and above in 2018/2019 could pose increased health risk for some residents.

- Health risk varies with PFAS level and age at time of exposure.
- Immune, developmental and thyroid effects are the main health effects of concern.
- Infants and small children are generally at most risk.
- Past exposures before 2018 cannot be determined.
- Future exposures can be reduced with a well-maintained filter.
- Future exposures from wells without a filter cannot be determined but are possible.
- Cancer risk cannot be determined at this time (Conclusion 4).
- The combined health risk of exposure to multiple PFAS, from multiple sources and via multiple routes of exposure is expected to be higher than that of any individual PFAS but cannot be determined at this time (Conclusion 5).

The table below outlines the potential health risk for residents drinking well water or formula made from well water with specific PFAS concentrations for two weeks or longer in 2018/2019:

Residents at possible risk	Health Effects		
	Immune	Developmental	Thyroid
	PFOS (ng/L)		*PFHxS (ng/L)*
Birth to less than 1 year	59 and above	750 and above	630 and above
1 to less than 2 years	89 and above	1,000 and above	1,200 and above
2 to less than 11 years	190 and above	1,900 and above	**N/A *****
All age groups including pregnant and breastfeeding woman	230 and above	2,300 and above	**N/A *****

N/A * [Not Available]** *PFHxS =1,200 ng/L was the maximum level sampled in residential well water within one-mile radius of the Florida State Fire College in 2018/2019.*

In general, any levels of PFAS such as PFOA, PFOS and PFHxS could contribute to an overall PFAS exposure and possible adverse health effects (See Conclusion 5). A combined effect of all PFAS is expected to be higher than the effect of the individual one on its own.

The most likely ***immune effect*** from PFOS exposure in humans is reduced antibody response to vaccines. Immunocompromised individuals may be particularly sensitive to PFAS exposure. PFOA and PFHxS exposures have been associated with similar immune responses in humans and may increase risk of immune effects compared to PFOS

exposure alone. Infants and children up to 11 years are generally at highest risk because they drink more fluid per body weight compared to older children and adults. *Drinking water exposure evaluations include drinking well water and formula made from well water. A mother who drinks the water can also transfer PFAS to an unborn fetus or nursing infant. ATSDR recommends based on current science that the known benefits of breastfeeding outweigh the risk for infants exposed to PFAS in breast milk.*

Prenatal and childhood PFOS exposure may cause changes in fetal and childhood growth (***developmental effect***). Both animal and human studies have associated small reductions in birth weight with PFOS and PFOA exposure. Temporary decreases in body weight and small delays in development have also been observed in animals exposed to PFOA, PFOS and PFNA. Some human studies indicate that prenatal exposure to PFOA, PFOS, PFNA and PFHxS might lead to childhood obesity, however studies are very limited.

Current knowledge of the possible health effects of PFHxS exposure in humans is very limited. ***Thyroid cell damage*** is the most sensitive effect observed in animal studies to date. Animal studies have also shown changes in thyroid hormone levels in animals exposed to PFOA and PFOS. Some human studies indicate that PFOA, PFOS, PFHxS and PFNA exposure may increase risk of thyroid disease or changes in thyroid hormones. However, study results are inconsistent, and some studies found no associations between PFAS exposure and changes to thyroid. The combined effect of PFOA, PFOS, PFHxS and PFNA is likely higher than the effect of PFHxS on its own.

In addition to immune, developmental, thyroid and liver effects, human studies have associated PFAS exposure with ***changes to serum cholesterol and increased risk of high blood pressure or pre-eclampsia in pregnant women***. Results vary with PFAS compound and study. Cancer risk cannot be determined at this time (Conclusion 5).

Basis for Conclusion 1

Estimated PFOS drinking water exposures could increase risk of immune and developmental effects for some or all age groups, because the estimated exposures are close to or exceed the exposure level of concern for immune and developmental health effects.

- **Immune effects due to PFOS exposure.**

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **59 ng/L** and above are close to levels predicted to cause immune health effects in residential children from birth to less than 1 year.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **89 ng/L** and above are close to levels predicted to cause immune health effects in residential children from 1 to less than 2 years.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **190 ng/L** and above are close to levels predicted to cause immune health effects in residential children from 2 to less than 11 years.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **230 ng/L** and above are close to levels predicted to cause immune health effects in all age groups including pregnant and breastfeeding woman.

- **Developmental effects due to PFOS exposure.**

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **750 ng/L** and above are close to levels predicted to cause developmental health effects in residential children from birth to less than 1 year.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **1,000 ng/L** and above are close to levels predicted to cause developmental health effects in residential children from 1 to less than 2 years.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **1,900 ng/L** and above are close to levels predicted to cause developmental health effects in residential children from 2 to less than 11 years.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFOS levels in water of **2,300 ng/L** and above are close to levels predicted to cause developmental health effects in all age groups including pregnant and breastfeeding woman.

- **Thyroid effects due to PFHxS exposure.**

Based on predictions made from animal studies, the estimated exposures associated with drinking PFHxS levels in water of **630 ng/L** and above are close to levels predicted to cause thyroid health effects in residential children from birth to less than 1 year.

Based on predictions made from animal studies, the estimated exposures associated with drinking PFHxS levels in water of **1,200 ng/L** and above are close to levels predicted to cause thyroid health effects in residential children from 1 to less than 2 years.

Next Steps

- ✓ FDOH recommends that residents avoid consumption of PFAS-contaminated private well water and find an alternative water source for cooking, brushing teeth, making baby formular, etc. until a more permanent solution for clean water has been found and approved by FDEP, e.g., hook up to municipal water supply or installation of a granulated activated carbon (GAC) filter. A GAC filter can prevent exposure to PFAS-contaminated well water. If such filter is installed, FDOH recommends periodic monitoring of the GAC filter (via well water and indoor tap water samples) to ensure continued functionality of the GAC filter and to prevent exposure to PFAS-contaminated water on-site.
- ✓ FDOH recommends that filters are well-maintained and tested regularly to confirm that the filter reduces PFAS to below detection limits or health advisories at the time of testing. Wells usually have several filters installed in sequence. Samples should be taken before the filter, roughly in the middle and from an inside faucet.

The middle of the filter will show contamination breakthrough before it breaks through the last filter and serve as an early indicator that the filter needs replacement.

- ✓ FDOH recommends that visiting children are kept under supervision to prevent exposure to PFAS-contaminated water. PFAS exposure has been associated with developmental effects such as reduced birth weight, childhood obesity and small developmental delays.
- ✓ FDOH continues to monitor the well water for interested well owners with PFOA and PFOS above 35 ng/L and those with a filter installed on the well by FDEP.

Conclusion 2

Residents of all age and exposure groups are not likely to be at increased risk of liver effects, if they drank water or formula made from wells evaluated in this assessment for two weeks or longer during 2018/2019.

Drinking unfiltered water from wells with PFOA levels at and below 54 ng/L, PFOS levels at and below 2,300 ng/L and PFHxS levels at and below 1,200 ng/L are not likely to pose an increased liver health risk for all residents.

Basis for Conclusion 2

The estimated PFOA, PFOS and PFHxS doses are well below the doses of concern for liver effects.

Next Steps

- ✓ FDOH recommends that well owners with concerns about PFAS have their well water tested annually and if PFAS are detected, avoid using the water for consumption, connect to a municipal water supply or have a filter installed that is certified to reduce PFAS levels in the well water.

Conclusion 3

Residents of all age groups who showered at their residences with water containing 2018/2019 levels of PFOA and PFOS daily for two weeks or longer are not likely to experience an increased risk of developing harmful non-cancer health effects due to PFAS exposure via showering. Though, even when exposure via showering alone is not expected to contribute to an increased risk of developing harmful non-cancer health effects, it could have contributed to an overall PFAS exposure.

Basis for Conclusion 3

Estimated daily exposure doses for PFOA and PFOS via showering are less than their respective MRLs. Therefore, residents who showered at private residential properties with 2018/2019 levels of PFOA and PFOS are not likely to experience non-cancer illnesses from PFOA and PFOS exposure via showering alone.

Next Steps

- ✓ FDOH does not consider it a risk to shower at the private residential properties within a one-mile radius of the FSFC. Though, based on ATSDR's recommendations for PFAS, FDOH suggests that an alternative water source be used for cooking, brushing teeth and drinking until a more permanent solution for clean water has been found and approved by FDEP, e.g., hook up to municipal water supply or installation of a GAC filter. A GAC filter can prevent exposure to PFAS-contaminated well water. If such filter is installed FDOH recommends periodic monitoring of the GAC filter (via well water and indoor tap water samples) to ensure continued functionality of the GAC filter and to prevent exposure to PFAS-contaminated water on-site.
- ✓ FDOH recommends that well owners with concerns about PFAS have their well water tested annually and if PFAS are detected, avoid using the water for consumption, connect to a municipal water supply or have a filter installed that is certified to reduce PFAS levels in the well water.

Conclusion 4

Some health risk evaluations are limited, such as evaluation of:

- exposures before 2018/2019,
- exposures in the future,
- exposure to PFNA and PFHxS via showering,
- exposure to PFAS via irrigation,
- exposure to PFAS for residential visitors and trespassers,
- exposure to PFAS via breastfeeding,
- increased cancer risk.

Basis for Conclusion 4

- ➢ **Past exposure.**

Exposure ***before 2018/2019*** cannot be evaluated, because no data exist for PFAS in residential well water before this time. Without data, FDOH is not able to evaluate the likelihood of harmful health effects to former residents who may have been exposed to PFAS in private well water via drinking before 2018/2019.

➢ Future exposure.

Future exposure to PFAS via drinking well water at private residences is unlikely when an alternative, permanent drinking water source is supplied. PFAS exposures can be reduced with a well-maintained filter. Filter performance must be checked periodically to ensure filter cartridges are replaced as needed.

➢ PFNA and PFHxS exposure via showering.

PFNA and PFHxS currently cannot be evaluated using the ***Shower Model***. However, showering is generally considered a minor pathway for PFAS due to their poor absorption over the skin and minimal vaporization into the air (inhalation).

➢ PFAS exposure via irrigation.

Residents may have been exposed to PFAS-contaminated water when used ***for irrigation*** purposes. However, because specific parameters such as frequency and duration of irrigation as well as potential exposure are uncertain, it was not possible to perform a meaningful assessment. In general, neither breathing in vapors nor skin contact with PFAS contaminated irrigation water are likely to cause health problems. Therefore, watering a lawn with non-edible plants and grass poses a low risk. No data are currently available for Florida to evaluate possible risks when consuming garden fruits and vegetables watered with PFAS contaminated water.

➢ PFAS exposure to residential visitors and trespassers.

Residents may have ***visitors*** who spend short periods of time at the residential properties. Visitors may have been exposed to PFAS in the private well water. However, because receptor-specific parameters such as frequency and duration of exposure are uncertain, it was not possible to perform a meaningful assessment.

It is unknown if people ***trespass*** at residential properties located within a one-mile radius of the FSFC. Potential trespassers are unlikely to access drinking water at private residences, but there could be exposure to PFAS-contaminated water when used for irrigation purposes. Without data, FDOH was unable to evaluate the likelihood of harmful health effects to trespassers, who may get exposed to PFAS via irrigation water at the residential properties of concern.

➢ PFAS exposure via breast feeding.

Possible health effects associated with PFAS exposure via breastfeeding cannot be evaluated due to current limitations in toxicological data. It is known that PFAS can be transferred to infants via breastfeeding [ATSDR 2018]. Based on current knowledge, ATSDR recommends that the health and nutritional benefits of breastfeeding outweigh the risks associated with PFAS in breast milk.

➢ PFAS and cancer risk.

Cancer risk cannot be evaluated because on the ability of PFAS to cause cancers in humans is very limited:

- Human epidemiological studies provide suggestive evidence that PFOA may cause kidney, testicular and prostate cancer in humans. Animal studies also indicate that PFOA can cause kidney and testicular cancers, as well as some other cancers, but it is unknown if PFOA causes cancer in humans in the same way that it does in animals. Limited evidence from animal studies indicates that PFOS may cause liver cancer in animals but there is too little evidence to say for sure.
- The EPA considers there is suggestive evidence that PFOA and PFOS may cause cancer and is currently re-evaluating PFAS toxicity and cancer potential. The International Agency for Research on Cancer (IARC) has classified PFOA as possibly carcinogenic to humans (i.e., possibly able to cause cancer in humans). ATSDR recommends that current scientific information is too uncertain to conduct a meaningful evaluation of cancer risk for PFAS.
- FDOH considers it is possible that PFOA, PFOS and other PFAS, alone or in combination, may be able to cause cancers in humans. But current evidence is not sufficient to say for certain, nor to estimate possible risk. Thus, FDOH concludes that cancer risk is uncertain.

Next Steps

- ✓ FDOH recommends that residents avoid consumption of PFAS-contaminated private well water and find an alternative water source for cooking, brushing teeth, making baby formular, etc. until a more permanent solution for clean water has been found and approved by FDEP, e.g., hook up to municipal water supply or installation of a granulated activated carbon (GAC) filter.
- ✓ A GAC filter can prevent exposure to PFAS-contaminated well water. If such filter is installed, FDOH recommends periodic monitoring of the GAC filter (via well water and indoor tap water samples) to ensure continued functionality of the GAC filter and to prevent exposure to PFAS-contaminated water on-site.
- ✓ FDOH recommends that visiting children are kept under supervision to prevent exposure to PFAS-contaminated water. PFAS exposure has been associated with developmental effects such as reduced birth weight, childhood obesity and small developmental delays
- ✓ FDOH continues to follow the latest science and recommendations by ATSDR and EPA.
- ✓ FDOH can re-evaluate cancer risk based on availability of new scientific data and recommendation.

Conclusion 5

The combined health risk from exposure to multiple PFAS, from multiple sources (e.g., drinking water, food packaging) and routes of exposure (e.g., ingestion, skin contact) is expected to be higher than that of any individual PFAS but cannot be determined at this time.

Basis for Conclusion 5

FDOH is currently not able to evaluate the combined risk of all PFAS exposure (including multiple PFAS, multiple PFAS sources and multiple routes of exposure), because current information is limited.

- Current information on the combined effects of PFAS mixtures is very limited and poorly understood. Though, for some other chemical classes, it is known that compounds with similar toxic action can contribute to a combined increased effect. In other words, the mixture of compounds could increase the potential risk of developing non-cancer health effects compared to the effect of each individual compound. If PFOA, PFAS, PFNA and PFHxS have similar toxic actions, is possible that the combined risk of health effects from exposure to all PFAS in the water and other sources is higher than the risk from either PFOA, PFOS, PFNA or PFHxS exposure alone.
- People are exposed to many other PFAS in addition to those evaluated here. For some wells, PFOA, PFOS, PFNA, PFHxS and other PFAS may not pose a health risk on their own, but they all contribute to overall PFAS exposure. People, who use contaminated water, are exposed to PFAS via all household use. Although showering and irrigation water may be minor exposure pathways for PFAS, they too contribute to overall exposure. In addition, people are exposed to PFAS in their daily lives through various common consumer products (e.g., food packaging, cosmetics), furniture, carpets, clothing, indoor air and many other sources.
- The unborn fetus can be exposed to PFAS via the mother, and nursing infants can be exposed to PFAS via breastmilk and formula made with contaminated water. ATSDR recommends based on current science that the known benefits of breastfeeding outweigh the risk for infants exposed to PFAS in breast milk.

Next Steps

- ✓ FDOH continues to follow the latest science and recommendations by ATSDR and EPA.

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Limitations of Findings

All health assessments, to varying degree, require the use of assumptions, judgments and incomplete data, which introduce some uncertainties to final risk estimates. Some specific sources of uncertainty in this health consultation include exposure parameter estimates, use of modeled exposure doses, and current toxicological knowledge.

FDOH health risk assessors do not know exactly how much water each individual drinks on a daily basis. Furthermore, toxicological knowledge for PFAS is limited and the science is evolving. The tools used to predict increased non-cancer health risk for this health consultation report are based on data from epidemiological and animal studies, which lead to uncertainty in risk estimates. Suggestive evidence has linked PFOA to three types of cancers: kidney, prostate and testicular cancer. However, ATSDR recommends that current scientific information is too uncertain to conduct a meaningful evaluation of cancer risk for PFAS. Therefore, cancer risk is concluded to be 'uncertain' at this time. Risk is estimated separately for each single PFAS compound.

Because of the uncertainties, health risk assessors may have overestimated or underestimated health risk. This health consultation does not represent an absolute estimate of risk to persons exposed to PFAS in drinking water.

FDOH's health assessment process is conducted to protect human health. Therefore, assumptions and judgments in the assessment of the site's impact on public health erred on the side of caution and may have overestimated public health risk.

This health consultation used ATSDR's health guidelines, which can result in estimated risk at drinking water levels below EPA's 2016 HAL. All guidelines made to assess public health are precautionary. It is important to note that findings of risk do not mean that health effects are certain to happen.

This health consultation provides specific public health recommendations based on toxicological literature, site-specific levels of environmental contaminants, evaluation of possible exposure pathways, duration of exposure and characteristics of the exposed population.

Contaminant exposure does not always lead to harmful effects. The risk of harmful effects to a human depends on the type and amount of contaminant the human is exposed to, how exposure occurs, how well the contaminant is absorbed, how frequent and for how long exposure occurs, as well as on individual genetics and lifestyles.

For More Information

If you have concerns about your health or the health of your children, contact your health care provider. For further health evaluation information about the Florida State Fire College Residential Well Evaluation Report, contact FDOH at phtoxicology@flhealth.gov or call toll free at 877-798-2772.

ACRONYMS AND ABBREVIATIONS

ATSDR	Agency for Toxic Substances and Disease Registry
AFFF	Aqueous film-forming foam
cm^2	Square centimeter
CV	Comparison value
EF	Exposure factor
EMEG	Environmental media evaluation guideline
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FSFC	Florida State Fire College
GAC	Granulated activated carbon
HAL	Health advisory level
HED	Human equivalent doses
Int.	Intermediate
Kg	Kilogram
L	Liter
m^3	Cubic meter
mg	Milligram
min	Minute
MRL	Minimal risk level
ng	Nanogram
PFAS	Per- and polyfluoroalkyl substances
PFHxS	Perfluorohexane sulfonate/perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate/perfluorooctane sulfonic acid

1. STATEMENT OF ISSUES

In 2018, the Site Investigation Section of the Florida Department of Environmental Protection (FDEP) began environmental assessments of fire training facilities throughout Florida, including the Florida State Fire College (FSFC) located in Ocala, Marion County. FDEP investigated potential contamination with per- and polyfluoroalkyl substances (PFAS) associated with firefighting foams known as aqueous film-forming foams (AFFF). Findings of PFAS in well water at the FSFC expanded FDEP's investigation off-site to ensure that the full extent of groundwater contamination was addressed. The off-site investigation includes well sampling at the Lhoist Mine Site, as well as private well sampling within a one-mile radius of the FSFC (this report). FDEP collaborates with the Florida Department of Health (FDOH) and local County Health Department in Marion County on the ongoing investigation.

PFAS are a large group of manufactured chemicals, which have been used in a wide range of industrial and consumer products since the 1940s [ITRC 2020a]. PFAS are utilized for their ability to make products resistant to heat, water, oil and grease. Examples of consumer products that contain PFAS include some nonstick cookware, electrical wire insulation, stain-resistant carpets and fabrics, waterproof clothing, food packaging, cosmetics and other personal care products. PFAS do not break down easily after use and disposal but can persist for a long time in the environment, where they can enter waterways and human food chains [ATSDR 2018; EPA 2017].

Today, PFAS are ubiquitous contaminants found in air, soil, water, plants, animals, food and indoor dust [Ahrens 2011; Scher et al. 2018; Scheringer et al. 2014, Sunderland et al. 2019]. People can be exposed to PFAS by ingesting, breathing in or touching PFAS-contaminated air, soil, water, plants, animals, food and indoor dust. Most of the U.S. population have measurable levels of PFAS in their blood [ATSDR 2019a]. The main source of PFAS exposure in humans is through ingestion of PFAS-contaminated water and food [ATSDR 2019a].

In recent years, an increasing number of studies have linked PFAS groundwater contamination to locations that produced, used, stored or disposed of AFFF [Backe et al. 2013; Hatton et al. 2018; Moody and Field 1999]. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS; also known as perfluorooctane sulfonic acid) have been prevalent components of AFFF [EPA 2017]. Increasing scientific information indicates that exposure to elevated levels of PFOA and PFOS can cause adverse health effects in humans [ATSDR 2018; EPA 2017]. Limited but increasing information is also becoming available for additional PFAS such as perfluorononanoic acid (PFNA) and perfluorohexane sulfonate (PFHxS, also known as perfluorohexane sulfonic acid).

This health consultation is the third of three reports conducted by FDOH to evaluate the potential health implications of PFAS contamination originating from the FSFC:

> **Report 1.** On-site investigation of per- and polyfluoroalkyl substances (PFAS) in groundwater water and surface soil.
>
> **Report 2.** Off-site investigation of PFAS in groundwater at the Lhoist Mine Site.

Report 3. Off-Site Private, Residential Well Investigation of per- and polyfluoroalkyl substances (PFAS) in groundwater.

In this third report, FDOH health risk assessors evaluated possible health implications of PFAS contamination in residential wells within a one-mile radius of the FSFC.

FDOH health risk assessors reviewed the following items specifically for the residential evaluation:

- available residential well data for PFAS during 2018/2019.
- possible ways that people could get exposed to PFAS (exposure pathways[2]) before, during and after 2018/2019.
- the possibility of increased non-cancer health risks associated with PFAS exposure.

This assessment considered four PFAS chemicals for which ATSDR has developed health guidelines [ATSDR 2021]: PFOA, PFOS, PFNA and PFHxS.

Note: Data limitations and gaps in current knowledge of PFAS toxicology contributed to uncertainty in evaluating possible health threats. Precautionary assumptions and judgment were used to derive conclusions that may overestimate risk but are protective of public health. A cancer risk evaluation is not possible for PFAS because current knowledge is insufficient.

2. BACKGROUND

2.1 Site Description

The FSFC is located in Ocala in Marion County, Florida (Figure 1). The FSFC is surrounded by the Florida Department of Correction facilities to the west and south, Lhoist North America, Inc., to the northeast, east and southeast, as well as private residences to the north and northwest. FDOH sampled water from 95 residential wells within a one-mile radius of the FSFC (Figure 1).

2.2 Site History

In early August 2018, FDEP confirmed that PFAS-based firefighting foam had been stored and used at the FSFC. FDEP tested water from the FSFC supply well. The combined concentration of PFOA and PFOS exceeded the 2016 EPA lifetime Health Advisory Level (HAL[1]) of 70 nanogram per liter (ng/L). PFAS can be moved away from its point of release with groundwater flow. Therefore, FDEP conducted additional investigations, including off-site well water testing.

Since 2018, FDOH has been testing private wells within a one-mile radius of the FSFC, in collaboration with FDEP and the Florida Department of Health in Marion County. In

[2] An exposure pathway (or route) describes the way people can be exposed to a chemical (e.g., ingestion of water), including the path a chemical moves from where it was released to the point of human contact (e.g., disposal → groundwater → water tap). FDOH considered the possible pathways at residences within a one-mile radius of the FSFC before, during and after 2018/2019.

June 2019, FDEP installed monitoring wells in the area. FDEP has offered bottled water and installation of granulated activated carbon (GAC) filters for all wells with combined PFOA and PFOS above EPA's 2016 HAL. Well testing is ongoing.

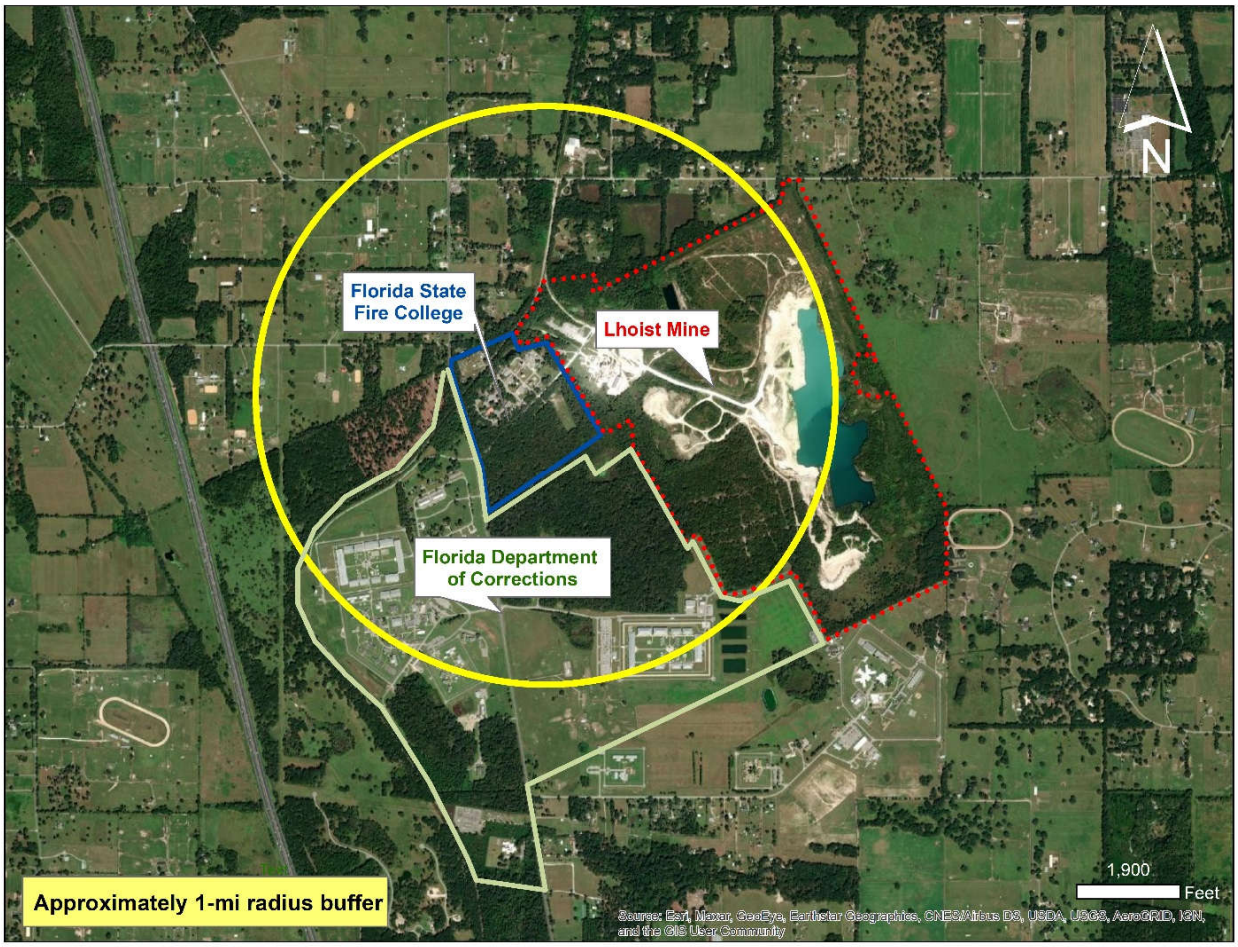

Figure 1: Florida State Fire College with the investigated one-mile radius highlighted in yellow.

3. DISCUSSION

3.1. Evaluation Process

Human health risk assessments are conducted for contaminated sites to evaluate and characterize the risk posed to human health by the contaminant(s) detected at the site. Assessments are completed via four main steps:

- hazard identification (and initial planning)
- exposure assessment
    - evaluation of possible exposure pathways
    - evaluation of available environmental data
- health risk evaluation
- risk characterization and communication

For this health consultation, FDEP was responsible for the initial hazard identification including planning, collection and first evaluations of environmental data at the FSFC (chemical concentrations in well water and soil). FDOH completed the exposure assessment (A), the health risk evaluation (B) and the risk characterization (C), which are described briefly in the following (further detailed in Appendix A):

A. Exposure Assessment

- Exposure Pathway Analysis (Section 3.2)
- Environmental Data Screening (Section 3.3)

The exposure assessment evaluates if and how the population can come in contact with the contaminant(s). If exposure is possible, the relevant environmental data (chemical concentrations in exposure elements such as water, soil and air) are compared with ATSDR's screening levels known as **comparison values or CVs**[3]. If a chemical concentration for a site exceeds the chemical's CV, the chemical is of potential concern and must be evaluated further to assess possible health risk.

B. Health Risk Evaluation

- Non-Cancer and Cancer Health Risk Evaluation (3.4)

The likelihood of health effect caused by the chemical of concern depends on how exposure occurs (ingestion, incidental swallowing, breathing in, skin contact), the amount of chemical present, how often exposure takes place (frequency) and how long a person is in contact with the chemical (duration). Many of these factors are determined by human behavior and current health condition, which vary with genetics and population type (e.g., child or adult, worker or resident). Therefore, the health risk assessor identifies site-specific population scenarios, for which relevant daily **exposure doses**[4] can be estimated. The estimated daily doses are compared with federal **health guidelines**[5] to determine if site-related doses are of potential concern. This health consultation used ATSDR's **minimal risk levels (MRL)[6] for PFOA, PFOS, PFNA and PFHxS**. If an estimated dose is higher

[3] Comparison values (CV) are estimates of chemical concentrations in the environment (water, soil, air, etc.) that a person can be exposed to without considerable health risk. Screening levels are health-based and set far below levels known to cause harmful effects. If a chemical concentration at a site is higher than its CV, the chemical is of potential concern and needs further evaluation.

[4] An **exposure dose** is the amount of chemical taken up by a person per body weight per day (milligram chemical/kilogram body weight/day). Chemicals can be taken up via ingestion, breathing and over the skin.

[5] A **health guideline** is an estimate of the daily chemical exposure dose that a person can be exposed to without considerable increased health risk. Health guidelines are set far below levels known to cause harmful effects. If an estimated dose for a site is higher than the guideline, health risk is possible and must be further evaluated. ATSDR's health guideline is called the minimal risk level (MRL). An exposure dose above MRL does not mean health effects will occur but triggers in-depth evaluation of health risk.

[6] **MRLs** are developed to protect the most sensitive populations. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without considerable risk of adverse non-cancer health effects over a specified route and duration of exposure. To derive an MRL, the lowest chemical daily dose observed to cause the most sensitive health effect (for example a developmental effect) is identified. Then this chemical dose is lowered by applying one or more numbers called uncertainty factors. This way the MRL is set far below any daily dose known to cause the most sensitive effect known.

than the MRL, the possible health implications are evaluated further and communicated for each possible pathway. The potential for increased cancer risk cannot be evaluated for PFAS because current knowledge is insufficient.

C. Risk Characterization and Communication

- Conclusions (Section 4)
- Recommendations (Section 5)
- Public Health Action Plan (Section 6)

Conclusions and recommendations are made based on the findings of Step A and B. A public health action plan is developed and communicated to the community. FDOH can make recommendations but has no regulatory jurisdiction.

3.2 Exposure Pathway Analysis

Chemical contamination is a concern for human health if people can get exposed to (come in contact with) the chemical. Without human contact, the chemical cannot enter the body and cause harmful effects. If exposure is possible, several aspects determine the actual risk of harm. These aspects are evaluated in the health risk evaluation (Section 3.4).

The exposure pathway analysis evaluates if, what, where, how and for whom exposure is possible. The analysis considers five elements:

- a **source** of chemical contamination
- an **exposed environmental element**
- an **exposure point** where chemical contact can happen
- an **exposure route** by which the chemical can enter the body
- an **exposed population**

Once all possible pathways have been identified, the health risk assessor evaluates the likelihood for each pathway to occur. The pathways are classified as completed, potential or eliminated. A **completed pathway** is a pathway, where all five elements can be verified and for which all data exist to conduct a health risk assessment. A **potential pathway** is a likely pathway for which one or more elements are uncertain. Completed and potential pathways are further evaluated in the health risk evaluation (Section 3.4). An **eliminated pathway** is a pathway for which one or more elements are missing and is usually not further evaluated.

FDOH considered three timeframes of exposure to evaluate possible health risk for residents with PFAS in their well water:

- Pre 2018/2019 (before PFAS testing)
- 2018/2019 (start of PFAS testing and mitigation[7])
- Future

[7] Mitigation is the reduction of something harmful. Installation of a water filter or providing an alternative water source are examples of PFAS mitigation methods.

3.2.1 Pathway Identification for Residential Wells

FDOH identified all pathways by which people at private residences within a one-mile radius of the FSFC could have been, could be or could become exposed to PFAS contamination:

	Element	Residential Well Pathway
✓	the **source** of chemical contamination	historical use and storage of AFFF
✓	the **environmental element** to hold or transport the chemical(s)	groundwater (feeding into private wells)
✓	the **exposure point**, where people can come in contact with the chemical(s)	water taps and showers (via private well)
✓	the **exposure route** through which the chemical(s) can enter the body	ingestion (including incidental swallowing), skin contact, inhalation (breathing in)
✓	the **exposed population**	residential children, adolescents, adults, as well as visitors and trespassers

PFAS contamination in residential well water within a one-mile radius of the FSFC most likely originates from previous use and storage of PFAS-based firefighting foam at the FSFC [***source***]. PFAS-based foam spilled or leaked onto the ground at the FSFC and contaminated on-site soil [***element***]. Periods of rain could have contributed to moving PFAS from surface soil into deeper soil and groundwater [***elements***]. Once dissolved, PFAS can remain in water for long periods of time. At an unknown point in time, PFAS contamination from the FSFC spread to surrounding groundwater and impacted well water at nearby residential properties.

All exposure pathways considered for the residential properties with PFAS-contaminated well water within a one-mile radius of the FSFC Site are illustrated in Figure 2.

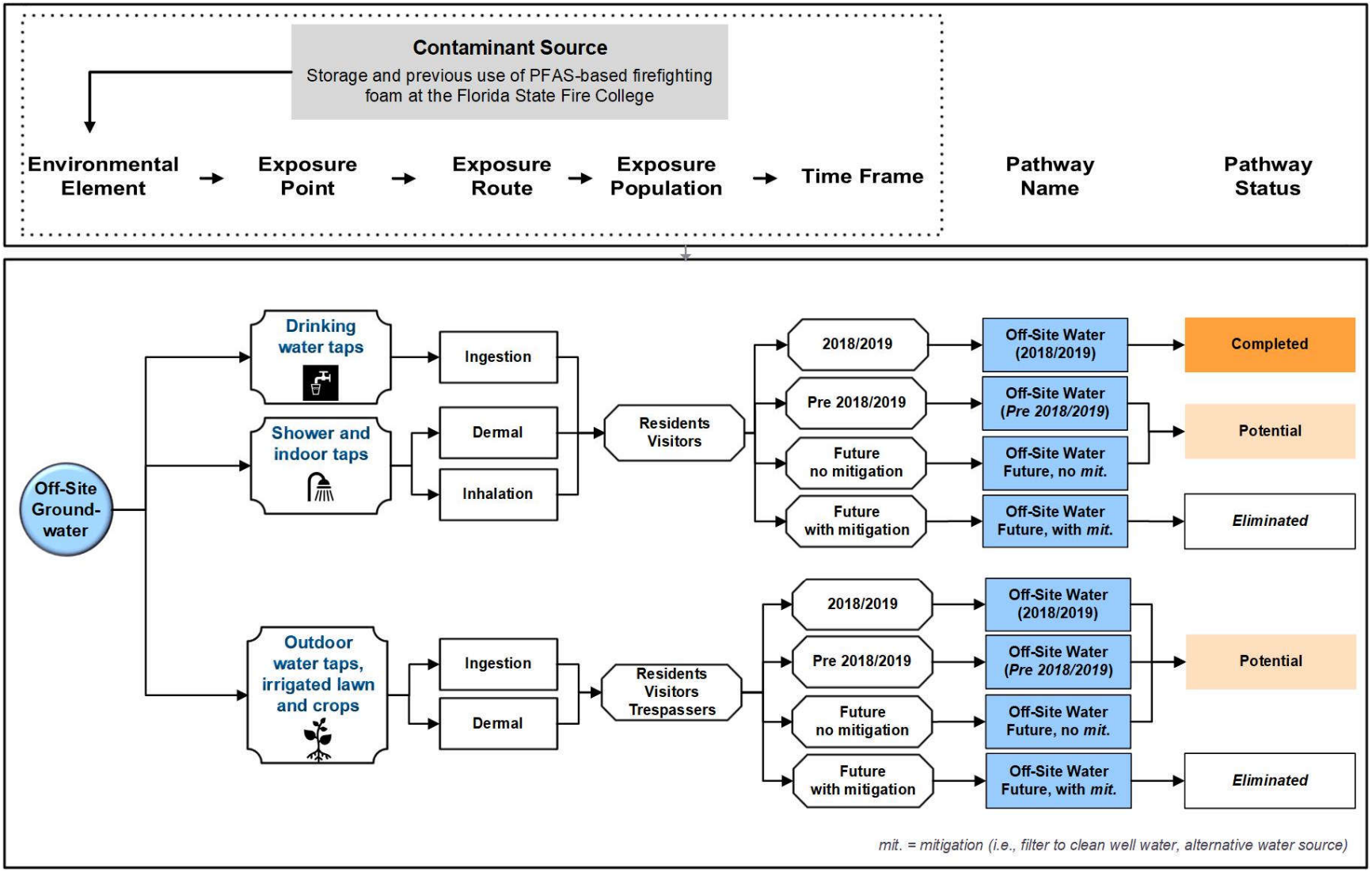

Figure 2: Overview of exposure pathways for well water at residential properties within a one-mile radius of the Florida State Fire College, Marion County.

Completed Pathways

Residential household exposure is completed (or certain) for residences that used water from wells with PFAS concentration above their respective ATSDR CV during 2018/2019.

The main residential exposure route is ingestion of PFAS-contaminated water via drinking and cooking. People can also be exposed to contaminants when showering and other household water usage by skin contact and breathing in vapors from the water. These exposures are generally considered minor pathways, because PFAS are only slowly absorbed over the skin and do not vaporize easily into the air [ATSDR 2021].

We considered drinking water, showering and other indoor household exposures completed pathways for residents of all ages, including children born or breastfed by female residents who used the water:

Population	Time frame	Exposure points	Reason pathway is completed
Residents (all ages)	2018/2019	Drinking water, shower and other indoor water taps	Exposure is certain for residents who used PFAS-contaminated well water for drinking, showering and other household purposes during 2018/2019

Potential Pathways

We considered past and future exposures potential. Both time frames lack data. Well water was not tested for PFAS before 2018/2019 and future PFAS well water concentrations cannot be predicted.

We also considered that residents could be exposed to PFAS in well water used to irrigate lawns or vegetable gardens, but data lack to evaluate such exposures. Skin exposure is considered minor and crop residue information lack to evaluate exposure via ingestion of irrigated crops.

In addition to residents and visitors, we considered potential trespassers:

Population	Time frame	Exposure points	Reason pathway is potential
Residents	Pre 2018/2019	Drinking water, shower and other indoor water taps	Exposure is possible but uncertain because well water was not tested before 2018/2019
Residents	Future no mitigation[7]	Drinking water, shower and other indoor water taps	Exposure is possible without mitigation[7] but future PFAS levels are uncertain
Residents	All time frames	Irrigation water, irrigated lawns and crops	Exposure is possible but information lacks for exposures via irrigation water and crops

Continued:

Population	Time frame	Exposure points	Reason pathway is potential
Visitors	All time frames	Drinking water, shower and other indoor water taps	Exposure during visits is likely but information for visitors is limited
Visitors	All time frames	Irrigation water, irrigated lawns and crops	Exposure is possible but information lacks for visitors and exposures via irrigation water and crops
Trespassers	All time frames	Irrigation water, irrigated lawns and crops	Exposure during trespassing is possible but information lacks for trespassers and exposures via irrigation water and crops

Eliminated Pathways

FDOH eliminated following pathways and did not evaluate those further:

Population	Time frame	Exposure point	Reason pathway is eliminated
Residents, visitors, trespassers	Future with mitigation	Drinking water, showering, irrigation water, irrigated lawns and crops	Exposure is prevented or very limited by mitigation such as installing a filter or changing to an uncontaminated water source

3.3 Environmental Data Assessment

FDOH evaluated PFAS concentrations for each residential well within a one-mile radius of the FSFC to find out if any wells contained PFAS levels of potential concern. PFAS well water concentrations were compared with ATSDR's comparison values (CVs)[3] for drinking water. This evaluation used ATSDR's environmental media evaluation guide (EMEG) for childhood intermediate exposure of 15 to 364 days via ingestion of drinking water. PFAS with concentrations greater than their CV were identified as chemicals of potential concern (see Section 3.3.2). A concentration above the CV is not necessarily a health threat, but it indicates the need for further evaluation of risk (Section 3.4). Health risk is not expected for wells with all PFAS below the CV, because CVs represent estimates of concentrations that are considered safe for consumption.

Note: PFAS are a large group of many compounds. Many PFAS were detected in the samples. This assessment evaluates four PFAS (PFOA, PFOS, PFNA and PFHxS) for which ATSDR has developed health guidelines [ATSDR 2021]. FDOH evaluates these PFAS separately due to limitations of current knowledge regarding mixtures. FDOH acknowledges that the combined risk of all PFAS is likely higher than what might be expected from any single PFAS.

3.3.1. Environmental Data Screening

During 2018 and 2019, the FDOH Well Surveillance Program collected water samples from 95 residential wells located within a one-mile radius of the FSFC. Well testing is ongoing. Sixteen (16) of the wells contained one or more PFAS in the water at concentrations that exceeded their respective CV (Table 1, Appendix B-1 and B-2).

Table 1: PFOA, PFOS, PFNA and PFHxS concentration in water of 95 residential wells within a one-mile radius of the Florida State Fire College compared to their ATSDR's respective CV.

	Concentration range (ng/L)	ATSDR CV (ng/L)	Above CV?	Number of wells above CV
PFOA	0.89 - 54	21	**yes**	5
PFOS	0.36 - 2,300	14	**yes**	16
PFNA	0.36 - 6.8	21	no	0
PFHxS	0.39 - 1,200	140	**yes**	11

ATSDR = Agency for Toxic Substances and Disease Registry; CV = comparison value. The CV used is ATSDR's environmental media evaluation guide (EMEG) for childhood intermediate exposure of 15 to 364 days via ingestion of drinking water. PFHxS = perfluorohexane sulfonate; PFNA = perfluorononanoic acid; PFOA = perfluorooctanoic acid; PFOS = perfluorooctane sulfonate.

3.3.2. Chemicals of Potential Concern

PFOA, PFOS and PFHxS are chemicals of potential concern for some specific wells in which they exceed their CVs (Table 1, Appendix B-1 and B-2).

ATSDR recommends evaluating all detected PFAS when just one of these exceed its respective CV. Therefore, PFOA, PFOS, PFHxS as well as PFNA were further evaluated to assess drinking water exposure and the potential associated health risk.

3.4. Health Risk Evaluation

PFAS is a family of more than 9,000 compounds [ITRC 2020a], but the information needed to evaluate possible health threats is only available for few of these [ITRC 2020b]. Scientists are still learning about the health effects of PFAS in humans. Epidemiological studies have associated elevated blood levels of some PFAS compunds with different health outcomes in humans [ATSDR 2021]. Differences in study conditions make it difficult to interpret epidemiological study results.

Current PFAS health guidelines rely on animal studies that exposed animals to high doses of PFAS compounds in controlled settings [ATSDR 2021]. The applied studies have demonstrated a range of health effects in animals exposed to PFAS. Humans may not respond in the same way as the test animals and high-quality data only exist for few PFAS compounds. The health guidelines used in this evaluation were developed based on immune, developmental, thyroid and liver responses observed in rodent studies.

Suggested non-cancer health effects include increased cholesterol levels, changes in liver enzymes, decreased vaccine response in children (immune effect) and developmental effects [reviewed in ATSDR 2021]. PFAS exposure has also been associated with other health effects such as changes in thyroid and reproductive hormones, as well as infertility, but study results are limited and inconsistent [reviewed in ATSDR 2021].

PFAS can be transferred from mother to fetus and child via placenta and breast milk [reviewed in ATSDR 2021]. Epidemiological studies indicate that PFAS exposure may lead to reduced birth weight, small delays in puberty and reduced vaccine response in children [ATSDR 2021]. Some studies have associated prenatal PFAS exposure with childhood obesity [Braun 2017], but study results vary, and some studies found no associations.

Pregnant women exposed to PFAS could be more susceptible to pre-eclampsia (hypertension during pregnancy), though findings are inconsistent [Borghese et al. 2020; Savitz et al. 2012; Stein et al. 2009; Wikström et al. 2019]. Studies that investigated changes in thyroid hormone have also shown mixed results [ATSDR 2021].

More detailed information about PFAS in general and about the possible health effects of exposure to PFOA, PFOS, PFNA and PFHxS can be found in Appendix D.

3.4.1. Health Risk Evaluation—Basics (PFAS)

The first step to evaluate health risk is to estimate daily exposure doses[4] for the identified exposure pathways and chemicals of potential concern (see Appendix A for detailed description of dose estimation). A daily exposure dose is the amount of a chemical a person is exposed to in their ambient environment in a day. Site-specific exposure doses are calculated using site-specific input parameters (*e.g.*, chemical concentrations for a specific well) and population-specific input parameters (*e.g.*, age and age-specific intake rates and body weight.

The estimated site-specific exposure doses are compared with ATSDR's minimal risk levels (MRLs)[6]. An MRL is an estimated safe dose, which is considered unlikely to cause adverse ***non-cancer health effects*** in humans for a given exposure scenario. In other words, non-cancer health effects are considered unlikely if an estimated exposure dose is lower than the MRL. Non-cancer health effects do not necessarily happen because an estimated exposure dose exceeds the MRL, but doses above MRL are more carefully evaluated to assess and communicate the possibility of an increased health risk. Further information on the possible non-cancer effects caused by PFOA, PFOS, PFNA and PFHxS exposure is presented Appendix D.

The possibility of ***increased cancer risk*** due to PFAS exposure cannot be evaluated at this time. Human epidemiological and animal studies provide suggestive evidence that PFAS exposure can cause cancer, but further research is needed to establish cause and effect. At this time, data are too limited to evaluate cancer risk and determine a causal link between PFOS exposure and human cancers. Epidemiological studies have suggested links between PFOA exposure and elevated rates of kidney, prostate and

testicular cancers [ATSDR 2021]. Animal studies have also observed increased rates in kidney, testicular and other cancers in animals exposed to PFOA (Appendix D). For PFOS, results from animal studies provide suggestive evidence that exposure may cause liver cancer (Appendix D). FDOH considers it possible that PFOA, PFOS and other PFAS, alone or in combination, may be able to cause cancers in humans, but further research and toxicological information is needed.

It is important to note that, in general, one in every three Americans is expected to be diagnosed with cancer at least once in their lifetime.

3.4.2. PFAS Health Risk Evaluation for Private, Residential Wells within a One-Mile Radius of the FSFC

Note: *This evaluation is based on individual levels of four PFAS. People are exposed to multiple PFAS at any one time and to many other PFAS in addition to those evaluated here. People, who use contaminated water, are exposed to PFAS via all household use (e.g., showering, cooking). In addition, people are exposed to PFAS in their daily lives through various common consumer products (e.g., food packaging, cosmetics), furniture, carpets, clothing, indoor air and many other sources. The combined health risk from all exposures is expected to be higher than that of any individual PFAS but cannot be determined at this time*

FDOH evaluated data for 95 private wells within a one-mile radius of the FSFC and identified 16 residential wells with PFAS levels of potential concern (Section 3.3.1).

This assessment is specific for these residential wells and focuses on exposure to PFAS via drinking water as well as showering and household taps during 2018/2019. PFAS exposure via ***irrigation*** water is possible but was not evaluated. Skin contact and inhalation of PFAS from irrigation water and wet lawns are considered minor pathways. Data are too limited to evaluate possible exposure via ingestion of irrigated crops. ***Visitors*** are possibly exposed to PFAS in the well water during visits at the evaluated residences. Visitors' exposure duration and frequency are however not known well enough to conduct a meaningful exposure assessment. It is recommended that visitors follow the same general recommendations made for residents. Information about possible ***trespassing*** is also too limited to perform a meaningful assessment.

Health risk assessors estimated daily doses for exposure during 2018/2019 (Appendix C). Doses were estimated for residents exposed to PFAS in private well water located within a one-mile radius of the FSFC. Doses were estimated for specific age groups from birth to adulthood (21 years and older), as well as for pregnant and breastfeeding women.

Residents were assumed to be exposed to PFAS by drinking well water seven days a week, 50 weeks per year and for up to 33 years (Appendix B-3). Inhalation and dermal exposure via showering and other non-consumption household uses were evaluated for PFOA and PFOS using a software model (Shower Model) developed by ATSDR. Showering input parameters are presented in Appendix B-4. The Shower Model is not currently used to evaluate exposure to PFNA and PFHxS. Inhalation and skin exposure are generally considered minor pathways for PFAS due to their poor absorption over the

skin and minimal vaporization into the air. The main exposure pathway for PFAS via well water is ingestion via drinking and cooking.

Detailed information regarding the calculation process is provided in Appendix A. Detailed results including estimated exposure doses and risk can be found in Appendix C-1 to C-18.

PFOS is the main PFAS contaminant for all wells tested. Health risk depends on the concentration of each PFAS found in the well, as well as age and other specific factors. Our conclusions vary from well to well. Wells with similar findings are grouped together for the discussion in the following sections.

Residents

Exposure to PFAS via drinking private well water

FDOH health assessors evaluated the estimated exposure doses for ***PFOA, PFOS, PFNA and PFHxS*** for residents drinking water in more detail by comparing them with the respective MRL[6] (Appendix A, Appendix C).

Estimated daily doses[4], MRLs and non-cancer risk for exposure to ***PFOA, PFOS, PFNA and PFHxS*** are presented in Appendix C:

> Residents who drank private well water at their residences with 2018/2019 levels of PFOA, PFOS and PFHxS could be at increased risk of harmful, non-cancer health effects. This includes children, adolescents and adults, including those who plan to become pregnant, as well as pregnant and breastfeeding women. ***PFNA*** levels in the private well water during 2018/2019 likely do not pose a risk of non-cancer health effects via drinking but may contribute to overall PFAS exposure for residents.

PFOS is the main chemical of concern at private residential properties within a one-mile radius of the FSFC where PFAS levels exceeding ATSDR health-based Comparison Values (CVs)[3] were discovered in the well water. ATSDR's environmental media evaluation guides for childhood intermediate exposure were used as they are the most protective values.

The estimated exposure doses (Appendix C) for well water with ***PFOS*** concentration of 16 ng/L and above exceeds the MRL for following exposure groups:

PFOS Concentration ng/L	Exposure Group
16 and above	Birth to less than 1 year
36 and above	1 to less than 2 years
59 and above	2 less than 11 years
89 and above	All age groups including pregnant and breastfeeding woman

The estimated exposure doses for ***PFOA*** in well water with a maximum PFOA concentration of 54 ng/L exceed the MRL for infants and children less than two years old.

The estimated exposure doses (Appendix C) for well water with ***PFHxS*** concentration of 150 ng/L and above exceeds the MRL for following exposure groups:

PFHxS Concentration ng/L	Exposure Group
150 and above	Birth to less than 1 year
400 and above	1 to less than 6 years
480 and above	6 to less than 11 years and breastfeeding woman
630 and above	All age groups including pregnant and breastfeeding woman

The estimated exposure doses for ***PFNA*** were below the MRL for all age groups.

➔ *Potential Health Outcomes*

FDOH health assessors compared the estimated exposure doses for PFOA, PFOS and PFHxS for residents' drinking water above the respective MRLs to human exposure doses of concern for immune, developmental, liver and thyroid effects predicted from animal studies (Appendix A, Appendix C).

- **Immune effects could be of concern due to PFOS exposure.**

  Residents of specific exposure groups[8] including pregnant and breastfeeding women could be at increased risk of immune effects, if they drank water or formula with PFOS concentration of 59 ng/L or above for two weeks or longer during 2018/2019:

PFOS Concentration ng/L	Exposure Group
59 and above	Birth to less than 1 year
89 and above	1 to less than 2 years
190 and above	2 to less than 11 years
230 and above	All age groups including pregnant and breastfeeding woman

  Immuno-compromised individuals from all age groups may be particularly sensitive to the potential immune effects of PFOS exposure. The most likely immune effect from PFOS exposure in humans is reduced antibody response to vaccines. PFOA and PFHxS exposures have been associated with similar immune responses in humans and may increase risk of immune effects compared to PFOS exposure alone.

  Infants and children less than 11 years are generally at highest risk because they drink more fluid per body weight compared to older children and adults:

  - Fluid includes both drinking water and formula made from the water.

[8] **Exposure groups:** Exposure is evaluated by age groups (birth to less than 1 year, 1 to less than 2 years, 2 to less than 11 years, 11 to less than 16 years, 16 to less than 21 years, 21 years and older (adult). Exposure evaluation also includes assessment of breastfeeding and pregnant woman.

- **Developmental effects could be of concern due to PFOS exposure.**

Residents of specific exposure groups including pregnant and breastfeeding women could be at increased risk of developmental effects, if they drank water or formula with PFOS concentration of 750 ng/L or greater for two weeks or longer during 2018/2019. The estimated PFOS doses are lower than the dose found to cause health effects in animal studies, but close to the dose of concern for developmental effects:

PFOS Concentration ng/L	Exposure Group
750 and above	Birth to less than 1 year
1,000 and above	1 to less than 2 years
1,900 and above	2 to less than 11 years and adults, including breastfeeding woman
2,300 and above	All age groups including pregnant and breastfeeding woman

Pregnant and breastfeeding women could be at increased risk of developmental effects in their current and future infants and children:

- Prenatal and childhood PFOS exposure may cause changes in fetal and childhood growth.
- Both animal and human studies have associated small reductions in birth weight with PFOS and PFOA exposure. Temporary decreases in body weight and small delays in development have also been observed in animals exposed to PFOA, PFOS and PFNA. Some human studies indicate that prenatal exposure to PFOA, PFOS, PFNA and PFHxS might lead to childhood obesity, however studies are very limited.
- Only PFOS is close to the levels of concern for developmental effects for this well. However, the combined effect of all PFAS is expected to be higher than the effect of PFOS on its own.

NOTE: PFAS can be transferred from mother to fetus and from breast milk or contaminated formula to nursing infant. It is important for women who plan to become pregnant, or are pregnant or nursing, to reduce exposure to PFAS as much as possible. A woman's decision to breastfeed is an individual choice, often made in consultation with her healthcare provider. ATSDR recommends that, based on current science, the known benefits of breastfeeding outweigh the risk for infants exposed to PFAS in breast milk.

- **Thyroid effects could be a concern due to PFHxS exposure**

Residents of specific exposure groups including pregnant and breastfeeding women could be at increased risk of thyroid effects, if they drank water or formula with PFHxS concentration of 630 ng/L or greater for two weeks or longer during 2018/2019.The estimated PFHxS doses are lower but close to the dose of concern for thyroid effects:

PFHxS Concentration ng/L	Exposure Group
630 and above	Birth to less than 1 year
1,200 and above	1 to less than 2 years

Current knowledge of the possible health effects of PFHxS exposure in humans is very limited. Thyroid cell damage is the most sensitive effect observed in animal studies to date. Animal studies have also shown changes in thyroid hormone levels in animals exposed to PFOA and PFOS. Some human studies indicate that PFOA, PFOS, PFHxS and PFNA exposure may increase risk of thyroid disease or changes in thyroid hormones. However, study results are inconsistent, and some studies found no associations between PFAS exposure and changes to thyroid. Only PFHxS levels are close to the levels of concern for thyroid effects for this well. However, the combined effect of PFOA, PFOS, PFHxS and PFNA may be higher than the effect of PFHxS on its own.

- **Liver effects due to PFAS exposure are not likely to be of concern.**

  Residents of all age and exposure groups are not likely to be at increased risk of liver effects, if they drank water or formula made from wells evaluated in this assessment for two weeks or longer during 2018/2019. The estimated PFOA, PFOS and PFHxS doses are well below the doses of concern for liver effects.

- **Past exposures before 2018 and future exposures cannot be evaluated.**

  Data for private well water does not exist before 2018/2019. Therefore, FDOH is not able to evaluate the likelihood of harmful health effects to residents who may have been exposed to PFAS in their private well water before 2018/2019.
  Future PFAS levels in the well water cannot be predicted. Most of the wells evaluated in this assessment had a filter installed between 2018 and 2021 to reduce PFAS levels. Exposures are expected to be limited if filters are maintained.

Exposure to PFAS via showering using private well water

FDOH health assessors further evaluated the estimated exposure doses for ***PFOA and PFOS*** for residents via showering by comparing them with human exposure doses predicted from animal studies (Appendix A, Appendix B-4, Appendix C-17 and C-18).

Estimated daily doses (for inhalation and dermal contact), minimal risk levels (MRLs) and non-cancer risk for exposure to ***PFOA and PFOS*** are presented in Appendix C.

Estimated daily exposure doses for ***PFOA*** and ***PFOS*** via showering are less than their respective MRLs.

➔ ***Potential Health Outcome***

Health effects due to PFAS exposure via showering are not likely to be of concern. Estimated daily exposure doses for ***PFOA*** and ***PFOS*** via showering are less than their respective MRLs. Therefore, residents who showered at private residential properties with 2018/2019 levels of PFOA and PFOS are not likely to experience non-cancer illnesses from PFOA and PFOS exposure via showering alone.

PFNA and ***PFHxS*** currently cannot be evaluated using the Shower Model. However, showering is generally considered a minor pathway for PFAS due to their poor absorption over the skin and minimal vaporization into the air (inhalation).

FDOH health risk assessors acknowledge that residents could have been exposed to additional PFOA and PFOS as well as low levels of other PFAS compounds via other sources such as drinking water, furniture and consumer products. By contributing to total PFAS exposure, showering exposure may increase the total risk of non-cancer health effects for residents. Due to the limited understanding of PFAS mixture effects, the actual combined risk cannot be evaluated at this time. Drinking water exposure is likely the dominant pathway for PFAS exposure for residents near the FSFC, with PFOS being the main contaminant of concern.

- **Past exposures before 2018 and future exposures cannot be evaluated**

  Data for private well water does not exist before 2018/2019. Therefore, FDOH was not able to evaluate the likelihood of harmful health effects to former residents who may have been exposed to PFAS at residential properties via showering before 2018/2019.

  Future PFAS levels in the well water cannot be predicted. Most wells evaluated in this assessment had a filter installed between 2018 and 2021 to reduce PFAS levels. Exposures are expected to be limited if filters are maintained.

Exposure to PFAS via contact with irrigation water

Residents may have been exposed to PFAS-contaminated water when used for irrigation purposes. However, because specific parameters, such as frequency and duration of irrigation as well as potential exposure, are uncertain it was not possible to perform a meaningful assessment.

In general, neither breathing in vapors nor skin contact with PFAS contaminated irrigation water are likely to cause health problems. Therefore, watering a lawn with non-edible plants and grass poses a low risk.

No data are currently available for Florida to evaluate possible risks when consuming garden fruits and vegetables watered with PFAS contaminated water.

Residential Visitors

Residents may have visitors who spend short periods of time at the residential properties. Visitors may have been exposed to PFAS in the private well water. However, because receptor-specific parameters such as frequency and duration of exposure are uncertain, it was not possible to perform a meaningful assessment. Although visitors may only spend short periods of time at the residential properties, it is recommended that visitors read the conclusions made for residents who were exposed to 2018/2019 PFAS contaminated well water.

Potential Trespassers

It is unknown if people trespass at residential properties located within a one-mile radius of the FSFC. Potential trespassers are unlikely to access drinking water at private residences, but there could be exposure to PFAS-contaminated water when used for irrigation purposes. Without data, FDOH was unable to evaluate the likelihood of harmful health effects to trespassers, who may get exposed to PFAS via irrigation water at the residential properties of concern.

Breastfeeding Women

Previous health consultations for PFAS-contaminated sites have attracted questions about the risk of breastfeeding [ATSDR 2020].

Possible health effects associated with PFAS exposure via breastfeeding cannot be evaluated due to current limitations in toxicological data. It is known that PFAS can be transferred to infants via breastfeeding [ATSDR 2018]. Based on current knowledge, ATSDR recommends that the health and nutritional benefits of breastfeeding outweigh the risks associated with PFAS in breast milk.

The decision to breastfeed is an individual choice and involves many considerations. Women with concerns may find it helpful to discuss breastfeeding with their health care provider. Guidance for health care professionals regarding PFAS can be found here [ATSDR 2019b]:
https://www.atsdr.cdc.gov/pfas/resources/info-for-health-professionals.html.

4. CONCLUSIONS

Based on the available environmental data and federal guidelines for PFOA, PFOS, PFHxS, and PFNA, FDOH health risk assessors made the following conclusions for the private residential properties within a one-mile radius of the FSFC using well water:

Exposure to PFAS in unfiltered private well water via drinking

Based on the calculated results, exposure to PFAS-contaminated water at some private residential properties has the potential to cause harmful health effects. Developmental,

immune and thyroid effects are of concern for residents within one-mile of the Florida State Fire College who were exposed to unfiltered private well water:

Immune effects:

- ✓ Children (birth to less than 1 year), who drink well water daily with 2018/2019 PFOS levels of 59 ng/L and above may be at increased risk of harmful immune health effects.
- ✓ Children (1 to less than 2 years), who drink well water daily with 2018/2019 PFOS levels of 85 ng/L and above may be at increased risk of harmful immune health effects.
- ✓ Children (2 to less than 11 years) and breastfeeding woman, who drink well water daily with 2018/2019 PFOS levels of 190 ng/L and above may be at increased risk of harmful immune health effects.
- ✓ Children (11 to less than 16 years), adolescents, adults (including those who plan to become pregnant), pregnant women and breastfeeding women, who drink well water daily with 2018/2019 PFOS levels of 230 ng/L and above may be at increased risk of harmful immune health effects.

Developmental effects:

- ✓ Children (birth to less than 1 year), who drink well water daily with 2018/2019 PFOS levels of 750 ng/L and above may be at increased risk of harmful developmental health effects.
- ✓ Children (1 to less than 2 years), who drink well water daily with 2018/2019 PFOS levels of 1,000 ng/L and above may be at increased risk of harmful developmental health effects.
- ✓ Children (2 to less than 11 years), adults and breastfeeding woman who drink well water daily with 2018/2019 PFOS levels of 1,900 ng/L and above may be at increased risk of harmful developmental health effects.
- ✓ Children (11 to less than 16 years), adolescents, adults (including those who plan to become pregnant), pregnant women and breastfeeding women, who drink well water daily with 2018/2019 PFOS levels of 2,300 ng/L and above may be at increased risk of harmful developmental health effects.

Thyroid effects:

- ✓ Children (birth to less than 1 year), who drink well water daily with 2018/2019 PFHxS levels of 630 ng/L and above may be at increased risk of harmful thyroid health effects.
- ✓ Children (1 to less than 2 years), who drink well water daily with 2018/2019 PFHxS levels of 1,200 ng/L and above may be at increased risk of harmful thyroid health effects.

Liver effects:

- ✓ Residents of all exposure groups[8] are not likely to be at increased risk of liver effects, if they drink water or formula made from wells evaluated in this assessment for two weeks or longer during 2018/2019

The 2018/2019 PFNA levels in well water at private residential properties within one-mile radius of the FSFC are not expected to increase risk of harmful non-cancer health effects for residents, who drink the water daily. However, PFNA may have contributed to the overall PFAS exposure and could have increased the overall risk of developing non-cancer health effects.

Exposure to PFAS in unfiltered private well water via showering

- ✓ Residents who shower with well water at private residential properties within a one-mile radius of the FSFC with 2018/2019 levels of PFAS are not likely to be at increased risk of non-cancer health effects due to PFAS exposure via showering.

Exposure to PFAS in unfiltered private well water via irrigation

- ✓ Residents who are exposed to PFAS well water via watering the lawn with non-edible plants and grass at private residential properties within a one-mile radius of the FSFC with 2018/2019 levels of PFAS are not likely to be at increased risk of non-cancer health effects. Neither breathing in vapors nor skin contact with PFAS contaminated irrigation water are likely to cause health problems.
- ✓ Probable risks of adverse health outcomes due to PFAS exposure when eating garden fruits and vegetables watered with PFAS contaminated water cannot be assessed.

Additional conclusions

- ✓ Conclusions regarding increased cancer risk due to exposure to 2018/2019 PFAS levels in residential private well water via drinking, showering and/or irrigation use are uncertain.
- ✓ Probable risks of adverse health outcomes due to PFAS exposure via drinking, showering and/or irrigation use at private residential properties within a one-mile radius of the Florida State Fire College before 2018/2019 cannot be assessed.
- ✓ PFAS exposure via drinking, showering and/or irrigation use at private residential properties within a one-mile radius of the Florida State Fire College in the future is unlikely when an alternative water source is used.

- ✓ The risk of health effects to ***residential visitors*** and ***trespassers*** at private residential properties within a one-mile radius of the Florida State Fire College cannot be evaluated.
- ✓ While some individual PFAS levels and exposure routes are not expected to cause non-cancer health effects, they could contribute to the overall PFAS exposure at the site. The combined risk from multiple exposures may be higher than the risk from one exposure alone.

5. RECOMMENDATIONS

1. Residents of all ages, including those who plan to become pregnant, as well as pregnant and breastfeeding women, should avoid consumption of private, unfiltered well water that exceeds ATSDR's health-based comparison values for PFAS at residential properties within one-mile radius of the FSFC. Based on ATSDR's recommendations for PFAS, FDOH suggests that a long-term, alternative water source should be used, such as a Granulated Activate Carbon (GAC) filter or municipal water.
2. If a GAC filter is installed, periodic monitoring of the filtered well water and maintenance of the filter is recommended to ensure the function of the filter and to prevent exposure to PFAS-contaminated well water.
3. Visitors and trespassers, who were/are/will be present at the residential properties of concern should follow the recommendations made for long-term exposure greater than 1 year. It is unknown when health guidelines for short-term exposure may become available.
4. Visiting children should be kept under supervision to prevent exposure to contaminated water.
5. A decision to breastfeed is an individual decision, which involves many considerations. Women with concerns may find it helpful to discuss breastfeeding with their health care provider.

6. PUBLIC HEALTH ACTION PLAN

Actions Completed	
October 2018	- FDOH commenced private well sampling.
November 2018	- Notification of private well water results. - FDEP installed a water filter at one private residence.
February 2019	- FDEP installed further water filters at private residences.
June 2019	- FDEP sent notification letters to 49 properties in the potential groundwater plume area. - FDOH held an open house at the FSFC, for community members including private property owners and residents.
April 2021	- Mailing of one-page summary factsheets to FSFC, LHoist and residents within a one-mile radius of the FSFC informing about the conducted human health risk assessment and findings.
April/May 2021	- FDOH released three Health Consultation reports for public comment. The reports evaluate possible health impacts to the public at the FSFC, the Lhoist Mine Site and Residential Wells within one-mile radius of the FSFC.
June 2021	- Public comments received.
2021	- FDOHs communicated with ATSDR regarding residential health risk evaluation.
2021	- FDOH finalized FSFC PFAS Health Risk Evaluation reports 1 to 3.
Ongoing Actions	
	- FDEP continues to provide an alternative drinking water supply. - DOH continues to perform private well sampling and conduct outreach to homeowners encouraging their participation.
Actions Planned	
TBA	- Analytical results will determine the most appropriate course of action regarding possible future assessment and outreach.

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Appendix A. Explanation of the Human Health Risk Evaluation (Calculation) Process

1. Screening Process

To evaluate environmental data (e.g., PFAS levels in groundwater and soil), FDOH uses comparison values/**screening levels**[1] to determine which chemicals need further health evaluation. In accordance with ATSDR recommendations, FDOH always uses the lowest available CV for screening because this results in the most protective assessment. ATSDR's CVs are based on daily exposure doses set far below those known to cause health effects (further detailed in Section 2 of this Appendix). Then the doses are converted to environmental concentrations (*e.g.,* PFAS in water or soil), which represent estimated safe levels that a person can be exposed in their environment without risk of health effects. ATSDR develops CVs for both non-cancer health effects and cancer. For PFAS, the lowest CVs available are ATSDR's CVs for non-cancer health effects. We used the following CVs for PFAS in this report:

Environmental Media Evaluation Guides (EMEGs) — ATSDR estimates EMEGs for specific media (*e.g.*, water and soil), as well as for specific durations of exposure. Acute exposure is defined as 14 days or less, intermediate exposure is defined as 15-364 days, and when exposure is longer than 1 year it is considered chronic. FDOH used the EMEGs developed for childhood intermediate exposure (Appendix B, Tables B-1 to B-3), because these CVs are the most protective.

If a chemical concentration for a site is higher than the CV, the chemical is of concern and health risk must be evaluated. For example, if it is found that a chemical level in the indoor tap water is higher than its CV, and if people drink or may drink that water, a health effects assessment is warranted.

2. Estimation of Exposure Dose and Exposure Factor

The presence of chemical contamination alone does not necessarily cause harm. The likelihood of adverse health effect depends on factors such as the amount of chemical that humans come in contact with, how well it is taken up by the human body, how often (frequency) and for how long the contact with the chemical occurs (duration). Many of these factors are determined by body weight, sex, behavior, occupation, indoor and/or outdoor exposure, residential exposure, and so on. As human health risk cannot be assessed only from chemical concentrations, exposure doses are estimated for **site- and population/receptor-specific scenarios**.

[1] **Screening levels** are estimated 'safe' chemical concentrations in the environment (chemical amounts in water, soil, air, etc.). Screening levels are health-based and set far below levels known to cause harmful effects. The value of a screening level is also called a comparison value (CV), because it is used to compare with. If a chemical concentration at a site is higher than the CV, the chemical is of concern and needs further evaluation.

An **exposure dose** is the amount of chemical taken up by a person per body weight per day (milligram chemical/kilogram body/day). The contaminant can be taken up from water, soil or air, and it can be taken up via ingestion, absorption over the skin, or via inhalation (breathing it in). Doses are calculated per body weight, because the same amount of chemical is not likely to cause the same magnitude of health effect in a large adult as it would in a small child.

To estimate doses, health risk assessors used ATSDR's Public Health Assessment Site Tool program (PHAST), which applies the following equations (Eq. B-1 and B-2):

$$\textbf{Dose} = (C \times IR \times EF \times CF) / BW$$

C = *Chemical concentration in the environmental element (e.g., milligram chemical per liter of water (mg/L))*
IR = *Ingestion Rate (e.g., liter of water consumed per day (L/day))*
EF = *Exposure Factor (no unit)*
CF = *Conversion Factor (chemical-specific) (no unit)*
BW = *Body weight (kg)*

Equation A-1: Dose calculation

$$\textbf{EF} = (EFr \times ED) / AT$$

EFr = *Exposure Frequency (days per week, or, days per year)*
ED = *Exposure Duration (days or years)*
AT = *Averaging Time (days or years)*

Equation A-2: Exposure Factor calculation

For example:

*For an adult person of **80 kg** body weight working at a facility for **5 days per week, 50 weeks per year** (assuming 2 weeks of annual leave) for **10 years**, and **ingesting 3 liters of water** a day that contains an average **contaminant concentration of 1 mg/L**, the exposure dose is estimated as follows:*

Dose = (1 mg/L x 3 L/day x EF x 1) / 80 kg = 0.026 mg/kg/day

$EF_{chronic}$ = (5 days/week x 50 weeks/year) x 10 years / 3,650 days = 0.68

The above example represents a simple scenario for exposure via drinking water. Other types of exposure involve more receptor-specific considerations. When dermal exposure doses are estimated, the assessor must also account for the skin surface area available for exposure and this varies with age. The FSFC and population/receptor-specific human health cancer and non-cancer risk evaluation input parameter and results for the dose calculations are listed in Appendix B and C, respectively.

The estimated daily doses are compared with national **health guidelines.**[2] This health consultation used ATSDR's **provisional minimal risk level (MRL) for PFOA, PFOS, PFNA and PFHxS**. To be protective of the most sensitive populations, MRLs are based on the highest dose, where no effect was observed for the most sensitive endpoint (health effect), or, by the lowest dose observed to cause that endpoint. Then several uncertainty factors are applied to lower the dose to make it as protective as possible. An example of an uncertainty factor is a number to account for human variability because some people are more sensitive to certain effects than others.

- **Estimation of non-cancer risk:**

Non-cancer health effects refer to all health effects, such as immune and developmental effects, except cancer. The risk of non-cancer health effect is assessed by screening (comparison) of the estimated dose with the respective health guideline[2], in this case the provisional MRL. This comparison is done by dividing the estimated dose by the MRL resulting in an **'Hazard Quotient'** (HQ):

$$\mathbf{HQ = D / MRL}$$

HQ = Hazard Quotient
D = Exposure Dose (mg/kg/day),
MRL = Minimal Risk Level (mg/kg/day)

Equation A-3: Hazard Quotient calculation

An estimated exposure dose lower than the MRL derives a hazard quotient (HQ) of less than 1, meaning a non-cancer health risk is unlikely. An estimated exposure dose equal to or higher than the MRL derives an HQ equal to or higher than 1, meaning non-cancer health risk is possible. The higher the HQ, the higher the possibility of non-cancer health risk.

If an estimated dose is higher than the health guideline, the possible health implications are evaluated in more detail for the population of concern and communicated.

The health risk assessor may compare estimated doses directly with doses known to cause effect to evaluate what types of effects may be of most concern. The health risk assessor also uses professional judgement in the evaluation. When estimated doses are close to the guideline value, the health risk assessor may use extra precaution if the population in question could be considered more sensitive than the average population (*e.g.*, an elderly population may be particularly susceptible to immune effects).

The evaluation for the residential wells within a one-mile radius of the FSFC included in-depth assessment of some estimated doses for PFOS, because they exceeded the

[2] **Health guidelines** are estimated 'safe' chemical daily exposure doses in humans (chemical amount ingested or otherwise taken in per body weight per day). Health guidelines are set far below levels known to cause harmful effects, and they are used to compare with doses estimated for a site. If an estimated dose is higher than the guideline, health risk is possible and needs further evaluation. ATSDR's health guideline is called the minimal risk level (MRL).

provisional MRL. Health risk assessors compared the estimated PFOS doses with 'human equivalent doses' (HED) predicted from animal studies. This evaluation used HED derived for PFOS for developmental and immune effects by ATSDR [ATSDR 2018[3], 2020[4]]. Developmental and immune effects were selected for the evaluation as these are the most sensitive endpoints found for PFOS to date.

Predicted human equivalent doses (HED) for PFOS
based on lowest observed adverse effect levels (LOAEL) found in animal studies

Effect type	LOAEL, HED	Study Reference
Developmental effect	0.0021 mg/kg/day	Luebker et al. 2005
Immune effect	0.00041 mg/kg/day	Dong et al. 2011
Immune effect	0.000031 mg/kg/day	Guruge et al. 2009

HEDs were derived from the study references by ATSDR [ATSDR 2018[3], 2020[4]].

- **Estimation of increased cancer risk:**

Cancer risk is referred to as 'increased' cancer risk because there is always some risk of cancer. One in every three Americans is expected to be diagnosed with cancer in their lifetime. Increased cancer risk is calculated using a chemical-specific standard called a 'cancer slope factor' (CSF). CSFs only exist for chemicals known to cause cancer. The International Agency for Research on Cancer (IARC) has classified PFOA as possibly carcinogenic to humans [IARC 2017[5]] PFOS is not classified as a human carcinogen [ATSDR 2018[3]; EPA 2017[6]]. For chemicals for which cancer-association data lack, the derivation of a CSF is impossible. Thus, a CSF is available for PFOA but not for PFOS, PFNA and PFHxS. To assess the possibility of increased cancer-risk, the estimated dose is multiplied by the chemical-specific CSF:

$$\text{Increased cancer risk} = D \times CSF$$

D = Exposure Dose (mg/kg/day),
CSF = Cancer Slope Factor $(mg/kg/day)^{-1}$

Equation A-4: Cancer risk calculation

Because of uncertainties involved in estimating cancer risk, ATSDR employs a weight-of-evidence approach in evaluating relevant data [ATSDR 2018[3]]. Therefore, the increased risk for cancer is described in words (qualitatively) rather than giving a numerical risk

[3][ATSDR] Agency for Toxic Substances and Disease Registry. 2018. Toxicological profile for Perfluoroalkyls. (Draft for Public Comment). Atlanta, GA [updated 2019 September 26, accessed 2019. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=1117&tid=237.

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[6][EPA] United States Environmental Protection Agency. 2017. Technical Fact Sheet - Perfluorooctane Sulfonate (PFOS and Perfluorooctanoic acid (PFOA). (EPA 505-F-17-001). Washington DC [updated 2017 November; accessed 2020 May]. Available from: https://www.epa.gov/sites/production/files/2017-12/documents/ffrrofactsheet_contaminants_pfos_pfoa_11-20-17_508_0.pdf.

estimate only. Numerical risk estimates must be considered in the context of the variables and assumptions involved in calculating those estimates and in the broader context of biomedical opinion, host factors, and actual exposure conditions.

The risk of increased cancer can generally be communicated as following:

1 in 10 (10^{-1})	"very high" increased cancer risk
1 in 100 (10^{-2})	"high" increased cancer risk
1 in 1,000 (10^{-3})	"moderate" increased cancer risk
1 in 10,000 (10^{-4})	"low" increased cancer risk
1 in 100,000 (10^{-5})	"very low" increased cancer risk
1 in 1,000,000 (10^{-6})	"extremely low" increased cancer risk

FDOH considers increased cancer risk of one-in-a-million extremely low (10^{-6}, 1E-06 in the results tables, Appendix C), because it indicates that in a population of one million 'exposed' people, only one additional occurrence of cancer is expected compared to an 'unexposed' (normal) population.

Note: Current information on the ability of PFAS to cause cancers in humans is very limited.

Human epidemiological and animal studies provide suggestive evidence that PFAS exposure can cause cancer but further research is needed to establish cause and effect. The International Agency for Research on Cancer has classified ***PFOA*** as possibly carcinogenic to humans [IARC 2017**Error! Bookmark not defined.**]. Epidemiological studies have suggested links between PFOA exposure and elevated rates of kidney, prostate and testicular cancers [ATSDR 2021]. Animal studies have also observed increased rates in kidney, testicular and other cancers in animals exposed to PFOA. For PFOS, results from animal studies provide suggestive evidence that exposure may cause liver cancer. A causal link between PFOS exposure and human cancers is lacking. Other PFAS than PFOA may have the potential to cause cancer, but further research and toxicological information is needed. At this time, ***PFOS, PFNA and PFHxS*** are not classified as human carcinogens. However, information is very limited

APPENDIX B. HUMAN HEALTH NON-CANCER RISK EVALUATION INPUT PARAMETERS

Table B-1. Overview of PFAS concentrations in private wells within 1-mile of the Florida State Fire College during 2018 - 2019.

Contaminant	Source of Screening Level	Comparison Value		Concentration Range (ng/L)	Number of Wells above CV*
		Child* (ng/L)	Adult (ng/L)		
PFOA	ATSDR Intermediate EMEG	**21**	78	0.89 - 54	**4**
PFOS		**14**	52	0.36 - 2,300	**16**
PFNA		**21**	78	0.36 - 6.8	**0**
PFHxS		**140**	520	0.39 - 6.8	**10**

*We evaluated all wells with exceedance of ATSDR's most protective comparison value: The EMEG for childhood intermediate exposure of 15 to 364 days via ingestion of drinking water.

ATSDR - Agency for Toxic Substances and Disease Registry
EMEG - Environmental Media Evaluation Guide
ng/L - Nanograms per liter
PFHxS - Perfluorohexane sulfonate
PFNA - Perfluorononanoic acid
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctane sulfonate

.

Table B-2. Overview of PFAS exceedances in 16 residential wells within a one-mile radius of the Florida State Fire College during 2018-2019. Only wells with exceedance(s) of ATSDR's screening levels are shown here.

Well ID	Water Concentration (ng/L)			
	PFOA	PFOS	PFNA	PFHxS
AAI2122	3.8[I]	21	ND	17
AAI2124	7.9	25	0.53[I]	12
AAI2272	3.3[I]	16	ND	6.2
AAR1407	4.8[I]	190	ND	250
AAR1408	24	850	1.9[I]	1,100
AAR2515	54	2,300	6.8	1,200
AAR2529	1.4[I]	59	ND	88
AAR2541	17	750	4.9	480
AAR2542	44	1,900	4.2	990
AAR2585	2.2[I]	89	ND	150
AAR2587	32	900	3.8	890
AAR2590	11	36	0.96[I]	7.4
AAR4081	35	1,000	2.5[I]	630
AAR4573	3.5[I]	230	ND	400
AAR4576	5.6	250	ND	230
AAR4591	2.3[I]	110	ND	200
ATSDR Screening Level	**Comparison Value (CV)**			
Intermediate EMEG child*	**21**	**14**	**21**	**140**
Intermediate EMEG adult	**78**	**52**	**78**	**520**

ATSDR = Agency for Toxic Substances and Disease Registry; **EMEG*** = Environmental Media Evaluation Guide; **ID** = identification number; **ND** = not detected; **PFHxS** = perfluorohexane sulfonate**; PFNA** = perfluorononanoic acid; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

ng/L = nanograms per liter; [I] = *Estimated value; the chemical was detected below the laboratory practical quantitation limit.*

** We evaluated all wells with exceedance of ATSDR's most protective comparison value: The EMEG for childhood intermediate exposure of 15 to 364 days via ingestion of drinking water.*

RECEPTOR-SPECIFIC INPUT PARAMETERS

Table B-3. Residential exposure input parameters and exposure factors used to evaluate the possible risk to human health by ingesting drinking water contaminated with PFAS above the ATSDR recommended screening level.

Exposure Group	Body Weight (kg)	Age-Specific Exposure Duration (years)	Default Intake Rate* (L/day)
Birth to < 1 year	7.8	1	1.11
1 to < 2 years	11.4	1	0.893
2 to < 6 years	17.4	4	0.977
6 to < 11 years	31.8	5	1.40
11 to < 16 years	56.8	5	1.98
16 to < 21 years	71.6	5	2.44
Adult	80	33	3.09
Pregnant Women	73	NA	2.59
Lactating Women	73	NA	3.59

Duration	Days	Weeks	Years	Non-Cancer Exposure Factor	**EF cancer** = EF non-cancer x Age-Specific Exposure Duration (years)/78 years
Acute				1	
Intermediate	7	50		1	
Chronic	7	50	33	0.96	

Acute = exposure duration of 1 to 14 days; **chronic** = exposure duration of 365 days or longer; **EF** = exposure factor; **intermediate** = exposure duration of 15 to 364 days; **NA** = not applicable.

kg = kilogram; **L/day** = liters per day; **ng/L** = nanograms per liter**; <** = less than.

* We used reasonable national maximum exposure estimates for drinking water intake. Some people drink less water and would be less exposed to PFAS in the water.

Table B-4. Residential exposure input parameters for ATSDR Showering and Household Water-use Exposure Model.

Exposure Group	Body Weight (kg)	Skin Area (cm^2)		Breathing Rate (L/min)		Average Daily Exposure (min/day)			
		Hand Surface Area	Total Skin Surface Area	Shower	Main House	Bathroom Stay		Main House	Away from House
						Shower	Tub		
Birth to < 1 year	7.8	211	3,992	7.60	3.75	0	25	815	600
1 to < 2 years	11.4	300	5,300	12.00	5.56				
2 to < 6 years	17.4	348	7,225	11.25	6.81				
6 to < 11 years	31.8	510	10,800	11.00	8.33	13	0	827	
11 to < 16 years	56.8	720	15,900	13.00	10.56				
16 to < 21 years	71.6	830	18,400	12.00	11.32				
Adult	80	980	19,650	12.34	10.53	13	(50)**	827	
Pregnant Women	73	890	18,160	15.47	15.47				
Lactating Women	73	890	18,160	15.47	15.47				

cm^2 = square centimeter; **kg** = kilogram; **L/min** = liters per minute; **min/day** = minutes per day**; <** = less than.

* We used ATSDR's Shower Model Version 2.0.0 to estimate exposures.
**Parent helping small children with two evening baths. This parent will have 777 minutes in the main house (827 minus 50 minutes)

APPENDIX C. HUMAN HEALTH NON-CANCER RISK EVALUATION OUTPUT RESULTS

PFAS EXPOSURE VIA DRINKING RESIDENTIAL WELL WATER

Table C-1. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAI2122]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 3.8E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 2.1E-05 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC = 1.7E-05 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	5.2E-07	< 1	2.9E-06	1.5	NA	NA	2.3E-06	< 1
1 to < 2 years	2.9E-07	< 1	1.6E-06	< 1	NA	NA	1.3E-06	< 1
2 to < 6 years	2.0E-07	< 1	1.1E-06	< 1	NA	NA	9.2E-07	< 1
6 to < 11 years	1.6E-07	< 1	8.9E-07	< 1	NA	NA	7.2E-07	< 1
11 to < 16 years	1.3E-07	< 1	7.0E-07	< 1	NA	NA	5.7E-07	< 1
16 to < 21 years	1.2E-07	< 1	6.9E-07	< 1	NA	NA	5.6E-07	< 1
Adult	1.4E-07	< 1	7.8E-07	< 1	NA	NA	6.3E-07	< 1
Pregnant Women	1.3E-07	< 1	7.1E-07	< 1	NA	NA	5.8E-07	< 1
Breastfeeding Women	1.8E-07	< 1	9.9E-07	< 1	NA	NA	8.0E-07	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-2. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAI2124]

	PFOA[I]		PFOS		PFNA[I]		PFHxS	
	EPC = 7.9E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 2.5E-05 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 5.3E-07 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.2E-05 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	1.1E-06	< 1	3.4E-06	1.7	7.3E-08	< 1	1.6E-06	< 1
1 to < 2 years	5.9E-07	< 1	1.9E-06	1.0	4.0E-08	< 1	9.0E-07	< 1
2 to < 6 years	4.3E-07	< 1	1.3E-06	< 1	2.9E-08	< 1	6.5E-07	< 1
6 to < 11 years	3.3E-07	< 1	1.1E-06	< 1	2.2E-08	< 1	5.1E-07	< 1
11 to < 16 years	2.6E-07	< 1	8.3E-07	< 1	1.8E-08	< 1	4.0E-07	< 1
16 to < 21 years	2.6E-07	< 1	8.2E-07	< 1	1.7E-08	< 1	3.9E-07	< 1
Adult	2.9E-07	< 1	9.3E-07	< 1	2.0E-08	< 1	4.4E-07	< 1
Pregnant Women	2.7E-07	< 1	8.5E-07	< 1	1.8E-08	< 1	4.1E-07	< 1
Breastfeeding Women	3.7E-07	< 1	1.2E-06	< 1	2.5E-08	< 1	5.7E-07	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-3. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAI2172]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 3.3E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.6E-05 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC = 6.2E-06 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	4.5E-07	< 1	2.2E-06	1.1	NA	NA	8.5E-07	< 1
1 to < 2 years	2.5E-07	< 1	1.2E-06	< 1	NA	NA	4.7E-07	< 1
2 to < 6 years	1.8E-07	< 1	8.6E-07	< 1	NA	NA	3.3E-07	< 1
6 to < 11 years	1.4E-07	< 1	6.8E-07	< 1	NA	NA	2.6E-07	< 1
11 to < 16 years	1.1E-07	< 1	5.3E-07	< 1	NA	NA	2.1E-07	< 1
16 to < 21 years	1.1E-07	< 1	5.2E-07	< 1	NA	NA	2.0E-07	< 1
Adult	1.2E-07	< 1	5.9E-07	< 1	NA	NA	2.3E-07	< 1
Pregnant Women	1.1E-07	< 1	5.4E-07	< 1	NA	NA	2.1E-07	< 1
Breastfeeding Women	1.6E-07	< 1	7.5E-07	< 1	NA	NA	2.9E-07	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-4. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR1407]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 4.8E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.9E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC = 2.5E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	6.6E-07	< 1	1.9E-05	13	NA	NA	3.4E-05	1.7
1 to < 2 years	3.6E-07	< 1	1.1E-05	7.0	NA	NA	1.9E-05	< 1
2 to < 6 years	2.6E-07	< 1	7.5E-06	5.0	NA	NA	1.3E-05	< 1
6 to < 11 years	2.0E-07	< 1	5.9E-06	4.0	NA	NA	1.1E-05	< 1
11 to < 16 years	1.6E-07	< 1	4.7E-06	3.2	NA	NA	8.3E-06	< 1
16 to < 21 years	1.6E-07	< 1	4.6E-06	3.1	NA	NA	8.2E-06	< 1
Adult	1.8E-07	< 1	5.2E-06	3.5	NA	NA	9.3E-06	< 1
Pregnant Women	1.6E-07	< 1	4.8E-06	3.3	NA	NA	8.5E-06	< 1
Breastfeeding Women	2.3E-07	< 1	6.6E-06	4.5	NA	NA	1.2E-05	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-5. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR1408]

	PFOA		PFOS		PFNA[I]		PFHxS	
	EPC = 2.4E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 8.5E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 1.9E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.1E-03 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	3.3E-06	< 1	0.00012	60	2.6E-07	< 1	0.00015	7.5
1 to < 2 years	1.8E-06	< 1	6.4E-05	32	1.4E-07	< 1	8.3E-05	4.1
2 to < 6 years	1.3E-06	< 1	4.6E-05	23	1.0E-07	< 1	5.9E-05	3.0
6 to < 11 years	1.0E-06	< 1	3.6E-05	18	8.0E-08	< 1	4.7E-05	2.3
11 to < 16 years	8.0E-07	< 1	2.8E-05	14	6.3E-08	< 1	3.7E-05	1.8
16 to < 21 years	7.9E-07	< 1	2.8E-05	14	6.2E-08	< 1	3.6E-05	1.8
Adult	8.9E-07	< 1	3.2E-05	16	7.0E-08	< 1	4.1E-05	2.0
Pregnant Women	8.2E-07	< 1	2.9E-05	14	6.5E-08	< 1	3.7E-05	1.9
Breastfeeding Women	1.1E-06	< 1	4.0E-05	20	9.0E-08	< 1	5.2E-05	2.6

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-6. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2515]

	PFOA		PFOS		PFNA		PFHxS	
	EPC = 5.4E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 2.3E-03 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 6.8E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.2E-03 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	7.4E-06	2.5	0.00031	155	9.3E-07	< 1	1.6E-04	8.2
1 to < 2 years	4.1E-06	1.4	0.00017	85	5.1E-07	< 1	9.0E-05	4.5
2 to < 6 years	2.9E-06	< 1	0.00012	60	3.7E-07	< 1	6.5E-05	3.2
6 to < 11 years	2.3E-06	< 1	9.7E-05	49	2.9E-07	< 1	5.1E-05	2.5
11 to < 16 years	1.8E-06	< 1	7.7E-05	39	2.3E-07	< 1	4.0E-05	2.0
16 to < 21 years	1.8E-06	< 1	7.5E-05	38	2.2E-07	< 1	3.9E-05	2.0
Adult	2.0E-06	< 1	8.5E-05	43	2.5E-07	< 1	4.4E-05	2.2
Pregnant Women	1.8E-06	< 1	7.8E-05	39	2.3E-07	< 1	4.1E-05	2.0
Breastfeeding Women	2.5E-06	< 1	0.00011	55	3.2E-07	< 1	5.7E-05	2.8

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; **I** = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-7. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2529]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 1.4E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 5.9E-05 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC = 8.8E-05 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	1.9E-07	< 1	8.1E-06	4.1	NA	NA	1.2E-05	< 1
1 to < 2 years	1.1E-07	< 1	4.4E-06	2.2	NA	NA	6.6E-06	< 1
2 to < 6 years	7.5E-08	< 1	3.2E-06	1.6	NA	NA	4.7E-06	< 1
6 to < 11 years	5.9E-08	< 1	2.5E-06	1.3	NA	NA	3.7E-06	< 1
11 to < 16 years	4.7E-08	< 1	2.0E-06	1.0	NA	NA	2.9E-06	< 1
16 to < 21 years	4.6E-08	< 1	1.9E-06	1.0	NA	NA	2.9E-06	< 1
Adult	5.2E-08	< 1	2.2E-06	1.1	NA	NA	3.3E-06	< 1
Pregnant Women	4.8E-08	< 1	2.0E-06	1.0	NA	NA	3.0E-06	< 1
Breastfeeding Women	6.6E-08	< 1	2.8E-06	1.4	NA	NA	4.1E-06	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-8. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2541]

	PFOA		PFOS		PFNA		PFHxS	
	EPC = 1.7E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 7.5E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 4.9E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 4.8E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	2.3E-06	< 1	0.00010	50	6.7E-07	< 1	6.6E-05	3.3
1 to < 2 years	1.3E-06	< 1	5.6E-05	28	3.7E-07	< 1	3.6E-05	1.8
2 to < 6 years	9.2E-07	< 1	4.0E-05	20	2.6E-07	< 1	2.6E-05	1.3
6 to < 11 years	7.2E-07	< 1	3.2E-05	16	2.1E-07	< 1	2.0E-05	1.0
11 to < 16 years	5.7E-07	< 1	2.5E-05	13	1.6E-07	< 1	1.6E-05	< 1
16 to < 21 years	5.6E-07	< 1	2.5E-05	13	1.6E-07	< 1	1.6E-05	< 1
Adult	6.3E-07	< 1	2.8E-05	14	1.8E-07	< 1	1.8E-05	< 1
Pregnant Women	5.8E-07	< 1	2.6E-05	13	1.7E-07	< 1	1.6E-05	< 1
Breastfeeding Women	8.0E-07	< 1	3.5E-05	18	2.3E-07	< 1	2.3E-05	1.1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-9. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2542]

	PFOA		PFOS		PFNA		PFHxS	
	EPC = 4.4E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.9E-03 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 4.2E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 9.9E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	6.0E-06	2.0	0.00026	130	5.7E-07	< 1	0.00014	6.8
1 to < 2 years	3.3E-06	1.1	0.00014	70	3.2E-07	< 1	7.4E-05	3.7
2 to < 6 years	2.4E-06	< 1	0.00010	50	2.3E-07	< 1	5.3E-05	2.7
6 to < 11 years	1.9E-06	< 1	8.0E-05	40	1.8E-07	< 1	4.2E-05	2.1
11 to < 16 years	1.5E-06	< 1	6.3E-05	32	1.4E-07	< 1	3.3E-05	1.7
16 to < 21 years	1.4E-06	< 1	6.2E-05	31	1.4E-07	< 1	3.2E-05	1.6
Adult	1.6E-06	< 1	7.0E-05	35	1.6E-07	< 1	3.7E-05	1.8
Pregnant Women	1.5E-06	< 1	6.5E-05	33	1.4E-07	< 1	3.4E-05	1.7
Breastfeeding Women	2.1E-06	< 1	9.0E-05	45	2.0E-07	< 1	4.7E-05	2.3

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-10. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2585]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 2.2E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 8.9E-05 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC = 1.5E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	3.0E-07	< 1	1.2E-05	6.0	NA	NA	2.1E-05	1.0
1 to < 2 years	1.7E-07	< 1	6.7E-06	3.4	NA	NA	1.1E-05	< 1
2 to < 6 years	1.2E-07	< 1	4.8E-06	2.4	NA	NA	8.1E-06	< 1
6 to < 11 years	9.3E-08	< 1	3.8E-06	1.9	NA	NA	6.4E-06	< 1
11 to < 16 years	7.3E-08	< 1	3.0E-06	1.5	NA	NA	5.0E-06	< 1
16 to < 21 years	7.2E-08	< 1	2.9E-06	1.5	NA	NA	4.9E-06	< 1
Adult	8.2E-08	< 1	3.3E-06	1.7	NA	NA	5.6E-06	< 1
Pregnant Women	7.5E-08	< 1	3.0E-06	1.5	NA	NA	5.1E-06	< 1
Breastfeeding Women	1.0E-07	< 1	4.2E-06	2.1	NA	NA	7.1E-06	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-11. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2587]

	PFOA		PFOS		PFNA		PFHxS	
	EPC = 3.2E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 9.0E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 3.8E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC 8.9E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	4.4E-06	1.5	0.00012	60	5.2E-07	< 1	1.2E-04	6.1
1 to < 2 years	2.4E-06	< 1	6.8E-05	34	2.9E-07	< 1	6.7E-05	3.3
2 to < 6 years	1.7E-06	< 1	4.8E-05	24	2.0E-07	< 1	4.8E-05	2.4
6 to < 11 years	1.4E-06	< 1	3.8E-05	19	1.6E-07	< 1	3.8E-05	1.9
11 to < 16 years	1.1E-06	< 1	3.0E-05	15	1.3E-07	< 1	3.0E-05	1.5
16 to < 21 years	1.0E-06	< 1	2.9E-05	15	1.2E-07	< 1	2.9E-05	1.5
Adult	1.2E-06	< 1	3.3E-05	17	1.4E-07	< 1	3.3E-05	1.6
Pregnant Women	1.1E-06	< 1	3.1E-05	16	1.3E-07	< 1	3.0E-05	1.5
Breastfeeding Women	1.5E-06	< 1	4.2E-05	21	1.8E-07	< 1	4.2E-05	2.1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-12. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR2590]

	PFOA		**PFOS**		**PFNA[I]**		**PFHxS**	
	EPC = 1.1E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 3.6E-05 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 9.6E-07 mg/L MRL = 3.0E-06 mg/kg/day		EPC 7.4E-06 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	1.5E-06	< 1	4.9E-06	2.5	1.3E-07	< 1	1.0E-06	< 1
1 to < 2 years	8.3E-07	< 1	2.7E-06	1.4	7.2E-08	< 1	5.6E-07	< 1
2 to < 6 years	5.9E-07	< 1	1.9E-06	1.0	5.2E-08	< 1	4.0E-07	< 1
6 to < 11 years	4.7E-07	< 1	1.5E-06	< 1	4.1E-08	< 1	3.1E-07	< 1
11 to < 16 years	3.7E-07	< 1	1.2E-06	< 1	3.2E-08	< 1	2.5E-07	< 1
16 to < 21 years	3.6E-07	< 1	1.2E-06	< 1	3.1E-08	< 1	2.4E-07	< 1
Adult	4.1E-07	< 1	1.3E-06	< 1	3.6E-08	< 1	2.7E-07	< 1
Pregnant Women	3.7E-07	< 1	1.2E-06	< 1	3.3E-08	< 1	2.5E-07	< 1
Breastfeeding Women	5.2E-07	< 1	1.7E-06	< 1	4.5E-08	< 1	3.5E-07	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-13. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR4081]

	PFOA		**PFOS**		**PFNA[I]**		**PFHxS**	
	EPC = 3.5E-05 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.0E-03 mg/L MRL = 2.0E-06 mg/kg/day		EPC = 2.5E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC 6.3E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	4.8E-06	1.6	0.00014	70	3.4E-07	< 1	8.6E-05	4.3
1 to < 2 years	2.6E-06	< 1	7.5E-05	38	1.9E-07	< 1	4.7E-05	2.4
2 to < 6 years	1.9E-06	< 1	5.4E-05	27	1.3E-07	< 1	3.4E-05	1.7
6 to < 11 years	1.5E-06	< 1	4.2E-05	21	1.1E-07	< 1	2.7E-05	1.3
11 to < 16 years	1.2E-06	< 1	3.3E-05	17	8.3E-08	< 1	2.1E-05	1.1
16 to < 21 years	1.1E-06	< 1	3.3E-05	17	8.2E-08	< 1	2.1E-05	1.0
Adult	1.3E-06	< 1	3.7E-05	19	9.3E-08	< 1	2.3E-05	1.2
Pregnant Women	1.2E-06	< 1	3.4E-05	17	8.5E-08	< 1	2.1E-05	1.1
Breastfeeding Women	1.6E-06	< 1	4.7E-05	24	1.2E-07	< 1	3.0E-05	1.5

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; **[I]** = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-14. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR4573]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 3.5E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 2.3E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC 4.0E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	4.8E-07	< 1	3.1E-05	16	NA	NA	5.5E-05	2.7
1 to < 2 years	2.6E-07	< 1	1.7E-05	8.5	NA	NA	3.0E-05	1.5
2 to < 6 years	1.9E-07	< 1	1.2E-05	6.0	NA	NA	2.2E-05	1.1
6 to < 11 years	1.5E-07	< 1	9.7E-06	4.9	NA	NA	1.7E-05	< 1
11 to < 16 years	1.2E-07	< 1	7.7E-06	3.9	NA	NA	1.3E-05	< 1
16 to < 21 years	1.1E-07	< 1	7.5E-06	3.8	NA	NA	1.3E-05	< 1
Adult	1.3E-07	< 1	8.5E-06	4.3	NA	NA	1.5E-05	< 1
Pregnant Women	1.2E-07	< 1	7.8E-06	3.9	NA	NA	1.4E-05	< 1
Breastfeeding Women	1.6E-07	< 1	1.1E-05	5.5	NA	NA	1.9E-05	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-15. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR4576]

	PFOA		PFOS		PFNA		PFHxS	
	EPC = 5.6E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 2.5E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC 2.3E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	7.7E-07	< 1	3.4E-05	17	NA	NA	3.1E-05	1.6
1 to < 2 years	4.2E-07	< 1	1.9E-05	9.5	NA	NA	1.7E-05	< 1
2 to < 6 years	3.0E-07	< 1	1.3E-05	6.5	NA	NA	1.2E-05	< 1
6 to < 11 years	2.4E-07	< 1	1.1E-05	5.5	NA	NA	9.7E-06	< 1
11 to < 16 years	1.9E-07	< 1	8.3E-06	4.2	NA	NA	7.7E-06	< 1
16 to < 21 years	1.8E-07	< 1	8.2E-06	4.1	NA	NA	7.5E-06	< 1
Adult	2.1E-07	< 1	9.3E-06	4.7	NA	NA	8.5E-06	< 1
Pregnant Women	1.9E-07	< 1	8.5E-06	4.3	NA	NA	7.8E-06	< 1
Breastfeeding Women	2.6E-07	< 1	1.2E-05	6.0	NA	NA	1.1E-05	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-16. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFAS in drinking water during 2018-2019. [Well ID AAR4591]

	PFOA[I]		**PFOS**		**PFNA**		**PFHxS**	
	EPC = 2.3E-06 mg/L MRL = 3.0E-06 mg/kg/day		EPC = 1.1E-04 mg/L MRL = 2.0E-06 mg/kg/day		EPC = Not detected MRL = 3.0E-06 mg/kg/day		EPC 2.0E-04 mg/L MRL = 2.0E-05 mg/kg/day	
Exposure Group	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**	**Dose (mg/kg/day)**	**Hazard Quotient**
Birth to < 1 year	3.1E-07	< 1	1.5E-05	7.5	NA	NA	2.7E-05	1.4
1 to < 2 years	1.7E-07	< 1	8.3E-06	4.2	NA	NA	1.5E-05	< 1
2 to < 6 years	1.2E-07	< 1	5.9E-06	3.0	NA	NA	1.1E-05	< 1
6 to < 11 years	9.7E-08	< 1	4.7E-06	2.4	NA	NA	8.5E-06	< 1
11 to < 16 years	7.7E-08	< 1	3.7E-06	1.9	NA	NA	6.7E-06	< 1
16 to < 21 years	7.5E-08	< 1	3.6E-06	1.8	NA	NA	6.5E-06	< 1
Adult	8.5E-08	< 1	4.1E-06	2.1	NA	NA	7.4E-06	< 1
Pregnant Women	7.8E-08	< 1	3.7E-06	1.9	NA	NA	6.8E-06	< 1
Breastfeeding Women	1.1E-07	< 1	5.2E-06	2.6	NA	NA	9.4E-06	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFAS** = per- and polyfluoroalkyl substances; **PFNA** = perfluorononanoic acid; **PFHxS** = perfluorohexane sulfonate; **PFOA** = perfluorooctanoic acid; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **<** = less than; [I] = The reported EPC is between the laboratory method detection limit and the laboratory practical quantitation limit.

Possible increased risk of health effects needs further evaluation. (Hazard quotient at or above 1, means the estimated dose is higher than the MRL. Doses higher than MRL are evaluated further).

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

PFAS EXPOSURE VIA SHOWER AND HOUSEHOLD TAPS

Table C-17. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFOA via showering, bathing and household taps in general. This example is for the highest PFOA well water concentration (54 ng/L at Well AAR2515) measured within one-mile of the Florida State Fire College during 2018-2019.

	PFOA					
	Well water concentration = 5.4E-05 mg/L MRL = 3.0E-06 mg/kg/day					
Exposure Group	**EPC (mg/m^3)**		**Dose (mg/kg/day)**			**Hazard Quotient**
	Shower/bathroom	**Main house**	**Inhalation**	**Dermal**	**Combined**	
Birth to < 1 year	2.2E-10	6.4E-12	8.0E-12	1.9E-08	1.9E-08	< 1
1 to < 2 years			8.5E-12	1.7E-08	1.7E-08	< 1
2 to < 6 years			5.6E-12	1.5E-08	1.5E-08	< 1
6 to < 11 years	1.3E-09	8.0E-12	7.4E-12	8.1E-09	8.1E-09	< 1
11 to < 16 years			5.0E-12	6.6E-09	6.6E-09	< 1
16 to < 21 years			3.7E-12	6.1E-09	6.1E-09	< 1
Adult	1.3E-09	1.7E-11	4.5E-12	5.8E-09	5.9E-09	< 1
Pregnant Women			6.3E-12	5.9E-09	6.0E-09	< 1
Breastfeeding Women			6.3E-12	5.9E-09	6.0E-09	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFOA** = perfluorooctanoic acid.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **mg/m^3** = milligrams per cubic meter; **<** = less than.

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

Table C-18. Estimated doses and hazard quotients to evaluate risk of non-cancer health effects for residents exposed to PFOS via showering, bathing and household taps in general. This example is for the highest PFOS well water concentration (2,300 ng/L at Well AAR2515) measured within one-mile of the Florida State Fire College during 2018-2019.

	PFOS					
	Well water concentration = 2.3E-03 mg/L MRL = 2.0E-06 mg/kg/day					
Exposure Group	**EPC (mg/m^3)**		**Dose (mg/kg/day)**			**Hazard Quotient**
	Shower/bathroom	**Main house**	**Inhalation**	**Dermal**	**Combined**	
Birth to < 1 year	8.2E-10	2.3E-11	3.0E-11	1.3E-06	1.3E-06	< 1
1 to < 2 years			3.2E-11	1.2E-06	1.2E-06	< 1
2 to < 6 years			2.1E-11	1.2E-06	1.2E-06	< 1
6 to < 11 years	4.8E-09	2.9E-11	2.7E-11	6.0E-07	6.0E-07	< 1
11 to < 16 years			1.8E-11	4.9E-07	4.9E-07	< 1
16 to < 21 years			1.3E-11	4.5E-07	4.5E-07	< 1
Adult	4.8E-09	6.4E-11	1.6E-11	4.4E-07	4.4E-07	< 1
Pregnant Women			2.3E-11	4.4E-07	4.4E-07	< 1
Breastfeeding Women			2.3E-11	4.4E-07	4.4E-07	< 1

ATSDR = Agency for Toxic Substances and Disease Registry; **chronic** = exposure duration of 365 days or longer; **EPC** = exposure point concentration (maximum found during 2018-2019); **MRL** = minimal risk level [we used ATSDR's MRL for intermediate exposure (15 to 364 days). This MRL is also considered protective of exposures of one year or longer]; **PFOS** = perfluorooctane sulfonate.

mg/kg/day = milligrams per kilogram per day; **mg/L** = milligrams per liter; **mg/m^3** = milligrams per cubic meter; **<** = less than.

Note: A **hazard quotient less than 1** means the estimated dose is lower than the MRL. Doses below MRL are not expected to lead to increased risk of non-cancer health effects and are not evaluated further.

APPENDIX D. CHEMICAL SPECIFIC TOXICITY INFORMATION

The toxicology of PFAS is not fully understood. Available toxicological information is based on epidemiological and animal studies. ***Epidemiological studies*** have investigated populations across three levels of exposure from background to high. Most Americans are exposed to very low levels of PFAS, and this is called background. Mid-level exposure is exposure to residents near facilities that use or produce PFAS, and high-level exposure refers to occupational exposure for workers at such facilities.

Epidemiological studies look at disease trends (differences) in observations across such different exposure populations but are not 'controlled' experiments. This means that many important, sometimes unknown variables cannot be accounted for, such as pre-existing conditions and other factors that may affect a person's susceptibility to disease. These types of studies produce data with high uncertainty (data that are not certain to be accurate).

The results of epidemiological studies for PFAS to date have been inconclusive, and most studies have focused on PFOA and PFOS with less data available for PFNA, PFHxS and other PFAS. However, data suggest a number of possible ***non-cancer health effects*** associated with PFOA, PFOS, PFNA and/or PFHxS exposure [ATSDR 2021[1]]. Possible effects include increased cholesterol levels, changes in liver enzymes, decreased vaccine response in children (immune effect) and developmental effects [reviewed in ATSDR 2021[1]].

PFAS can be transferred from mother to fetus and child via placenta and breast milk [reviewed in ATSDR 2021[1]]. Epidemiological studies indicate that PFAS exposure may lead to reduced birth weight, small delays in puberty and reduced vaccine response in children [ATSDR 2021[1]]. Some studies have associated prenatal PFAS exposure with childhood obesity [Braun 2017[2]], but study results vary, and some studies found no associations.

Pregnant women exposed to PFAS could be more susceptible to pre-eclampsia (hypertension during pregnancy), though findings are inconsistent [Borghese et al. 2020[3]; Savitz et al. 2012[4]; Stein et al. 2009[5]; Wikström et al. 2019[6]]. Studies that investigated changes in thyroid hormone have also shown mixed results [ATSDR 2021[1]].

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[1] [ATSDR] Agency for Toxic Substances and Disease Registry. 2021. Toxicological Profile for Perfluoroalkyls. Atlanta, GA [updated 2020 March; accessed 2021]. Available from: atsdr.cdc.gov/toxprofiles/tp200.pdf

[2] Braun JM. 2017. Early-Life Exposure to EDCs: Role in Childhood Obesity and Neurodevelopment. Nat Rev Endocrinol 13(3): 161-173.

[3] Borghese MM, Walker M, Helewa ME, Fraser WD and Arbuckle TE. 2020. Association of Perfluoroalkyl Substances with Gestational Hypertension and Preeclampsia in the MIREC Study. Environ Int 141: 105789.

[4] Savitz DA, Stein CR, Bartell SM, Elston B, Gong J, Shin H-M and Wellenius GA. 2012. Perfluorooctanoic Acid Exposure and Pregnancy Outcome in a Highly Exposed Community. Epidemiology 23(3): 386-392.

[5] Stein CR, Savitz DA and Dougan M. 2009. Serum Levels of Perfluorooctanoic Acid and Perfluorooctane Sulfonate and Pregnancy Outcome. Am J Epidemiol 170(7): 837-846.

[6] Wikström S, Lindh CH, Shu H and Bornehag C-G. 2019. Early Pregnancy Serum Levels of Perfluoroalkyl Substances and Risk of Preeclampsia in Swedish Women. Sci Rep 9(1): 9179.

PFAS exposure has also been associated with other health effects such as changes in thyroid and reproductive hormones, as well as infertility, but study results are limited and inconsistent [reviewed in ATSDR 2021[1]].

The following table outlines the possible effects of PFAS exposure as indicated by epidemiological studies to date.

Organ/system	Associated health effect	PFOA	PFOS	PFNA	PFHxS
Cardiovascular	Preeclampsia	x	x	x†	x‡
Liver	Liver damage (increase in serum enzymes, decrease in bilirubin)	x	x		x
Blood	Increased serum lipids (mainly total cholesterol and low-density lipoprotein cholesterol)	x	x	x	
Immune	Decreased antibody response to vaccines	x	x		x
Developmental	Small decreases in birth weight	x	x		
Carcinogenicity	Kidney, prostate, testicular cancer	x			

Adapted from ATSDR's draft toxicological profile for PFAS[1]. †[Wikström et al. 2019][6], ‡[Borghese et al. 2020][3].

Controlled animal studies can better demonstrate cause and effect than uncontrolled epidemiological studies. Animal studies cannot replace human studies. However, by studying the same endpoints (effects) observed in epidemiological studies under controlled conditions (known chemical doses, duration, etc.), animal studies can be used to support epidemiological findings.

To date, animal studies investigating PFAS have been conducted mostly with rodents but also with non-human primates (monkeys). Overall, these studies have identified liver, immune and reproductive systems, as well as development as the primary targets of toxicity for PFOA. For PFOS, animal studies have identified liver, nervous and immune systems, as well as development as sensitive targets of toxicity. Animal studies have also observed developmental effects for PFNA exposure, and liver and immune effects for PFHxS.

ATSDR used these animal studies to develop ***minimal risk levels (MRLs)*** for PFOA, PFOS, PFNA and PFHxS [ATSDR 2021[1]]. These MRLs were used as health guidelines for this health assessment. MRLs are developed to protect the most sensitive populations. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without considerable risk of adverse non-cancer health effects over a specified route and duration of exposure. To derive an MRL, the lowest chemical daily dose observed to cause the most sensitive health effect (for example a developmental effect) is identified. Then this chemical dose is lowered by applying one or more numbers called uncertainty factors. This way the MRL is set far below any daily dose known to cause the most sensitive effect known.

ATSDR found developmental effects data to be the most sensitive and robust for PFOA, PFOS and PFNA, while immune effects were found to be the most sensitive endpoint for PFHxS. Animal data also indicate that immune effects may be a more sensitive endpoint for PFOS. However, developmental effects data were used to estimate minimal risk levels for three of the four PFAS (PFOA, PFOS and PFNA). It is important to consider that the fetus and baby can be exposed to PFAS in the womb and through lactation. Furthermore, PFAS exposure to adults can cause effects in their offspring.

Developmental effects observed in animals exposed to ***PFOA*** include prenatal loss, decreased pup survival and birth weight, delayed development (e.g., eye opening, mammary gland development, skeletal changes), and increased motor activity [ATSDR 2021[1]]. (Effects to mammary gland development did not cause effects in the offspring). The MRL for PFOA is based on the lowest dose observed to cause developmental effects in mice. The observed endpoints were altered motor activity and skeletal changes in offspring of exposed mice [Koskela et al. 2016[7]; Onishchenko et al. 2011[8]].

PFOS-associated developmental effects observed in rodent studies include lowered pup survival, lowered birth and body weight, lowered motor activity, and developmental delays [ATSDR 2021[1]]. The most sensitive endpoints observed were decreased body weight and delayed eye opening in offspring of rats, that were exposed from before mating through gestation and lactation [Luebker et al. 2005[9]]. The MRL for PFOS is based on the highest dose, for which these sensitive effects were not observed in the rats. As noted, animal data indicate that PFOS may cause immune effects (lowered immune response) at doses ten times lower than those causing developmental effects. Thus, the immune system may be a very sensitive target for PFOS exposure. The studies, which tested potential for immune effects however used a species for which it is difficult to translate animal doses to representative human doses [ATSDR 2021[1]].

More limited data are available for PFNA and PFHxS. The MRL for ***PFNA*** is based on developmental endpoints in mice (decreased body weight and delayed development) [Das et al. 2015[10]]. The dose used to estimate MRL is the highest dose tested without observable effects. Developmental toxicity has not been investigated for ***PFHxS***, which appears to target the immune system. The endpoint used for MRL estimation is thyroid follicular cell damage in a rat species [Butenhoff et al. 2009[11]]. The dose used to estimate MRL is the highest dose tested without observable effects.

The findings in animal studies support data from human epidemiological studies, which have also found associations between PFOA and PFOS exposure and small decreases

[7] Koskela et al. 2016. Effects of developmental exposure to perfluorooctanoic acid (PFOA) on long bone morphology and bone cell differentiation. Toxicol Appl Pharmacol 301:14-21.
[8]Onishchenko et al. 2011. Prenatal exposure to PFOS or PFOA alters motor function in mice in a sex-related manner. Neurotox Res 19:452-461.
[9] Luebker DJ, Case MT, York RG, Moore JA, Hansen KJ, Butenhoff JL. 2005. Two-generation reproduction and cross-foster studies of perfluorooctanesulfonate (PFOS) in rats. Toxicology 215(1–2):129–48.
[10] Das KP, Grey BE, Rosen MB, et al. 2015. Developmental toxicity of perfluorononanoic acid in mice. Reprod Toxicol 51:133–44.
[11] Butenhoff JL, Chang S, Ehresman DJ, York RG. 2009. Evaluation of potential reproductive and developmental toxicity of potassium perfluorohexanesulfonate in Sprague Dawley rats. Reprod Toxicol 27(3–4):331–41.

in birth weight [ATSDR, 2021[1]]. Further, PFOA, PFOS, PFNA and PFHxS exposure have also been linked to reduced antibody response to vaccines in human epidemiological studies [ATSDR, 2021[1]] .

Cancer potential: Human epidemiological and animal studies provide suggestive evidence that PFAS exposure can cause cancer but further research is needed to establish cause and effect. The International Agency for Research on Cancer has classified ***PFOA*** as possibly carcinogenic to humans [IARC 2017[12]]. Epidemiological studies have suggested links between PFOA exposure and elevated rates of kidney, prostate and testicular cancers [ATSDR 2021]. Animal studies have also observed increased rates in kidney, testicular and other cancers in animals exposed to PFOA. For PFOS, results from animal studies provide suggestive evidence that exposure may cause liver cancer. A causal link between PFOS exposure and human cancers is lacking. Other PFAS than PFOA may have the potential to cause cancer, but further research and toxicological information is needed. At this time, ***PFOS, PFNA and PFHxS*** are not classified as human carcinogens. However, information is very limited.

[12][IARC] International Agency for Research on Cancer 2017. IARC Monographs on the identification of carcinogenic hazards to humans. Volume 110. Lyon France [updated 2020 March; accessed 2020 May]. Available from: https://monographs.iarc.fr/list-of-classifications/.

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS (per- and poly-fluoroalkyl substances) are a group of man-made chemicals found in air, soil, ground and surface water, and in people around the world. Studies about health effects of PFAS exposure in humans and animals have not reached clear conclusions. However, results do suggest that certain PFAS may be related to specific health problems, so researchers continue to study them.

The purpose of this factsheet is to provide an overview of frequently asked questions regarding PFAS in the environment and their possible health effects, as well as regulatory guidance and biomonitoring information. ***Note:** Questions discussed in this factsheet mainly focus on perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) as these are the most common and well-studied PFAS.*

General Facts

What are PFAS?

PFAS do not occur naturally in the environment. They are manufactured chemicals and have been used in:

- Surface protection of non-stick cookware.
- Stain resistant carpets and fabrics.
- Waterproof mattresses and clothing.
- Grease-resistant food packaging.
- Some firefighting materials.
- Photo imaging, metal plating, printers, and copy machines.

The most common and well-studied PFAS are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Information needed for investigating PFAS such as toxicity values, screening levels and lifetime health advisory levels (HAL) as provided by the U.S. Environmental Protection Agency (EPA) are only available for these two compounds.

Why are PFAS a concern?

PFAS are widespread and global. Once released, they are very persistent in the environment and the human body. They can be found in:

- Air
- Soil
- Water (ground and surface water)
- Blood
- Urine
- Breast milk
- Umbilical cord blood

How can I be exposed to PFAS?

The main way you can be exposed to PFAS is by swallowing them when you:

- Drink contaminated water.
- Eat fish caught from waters contaminated with PFAS.
- Eat food packed in PFAS-containing material (e.g., popcorn bags).
- Transfer them hand to mouth from surfaces treated with PFAS, such as carpets.

If you work with PFAS you can also be exposed to them by breathing them in or through skin contact. The uptake of PFAS through skin contact is slow and not considered significant.

For infants and toddlers, hand-to-mouth is considered the most significant source of exposure.

How long do PFAS remain in the body?

On average, PFAS can remain in the body between two and nine years.

How can PFAS potentially affect health?

- Effects on health from exposure to low levels of PFAS are not well known. Studies in humans and animals are inconclusive but suggest that certain PFAS may cause health effects.

- Non-cancer effects appear more common and include:
  - Increased cholesterol levels
  - Impacts on human hormones
  - Impacts on human immune system
  - Fetal and infant developmental effects

Can PFAS cause cancer?

- The U.S. Environmental Protection Agency (EPA) has determined there is **some** evidence that PFAS can cause cancer.

- The International Agency for Research on Cancer has classified PFOA as **possibly** cancer causing, although, there is currently no consistent scientific evidence that PFOS and PFOA cause cancer in humans.

- Some animal studies have suggested a higher risk of certain cancers, such as prostate, kidney, or testicular cancer. Humans and animals often react differently to chemicals (including PFAS) and not all the effects seen in animal tests may occur in humans.

- Some increases in kidney, prostate, and testicular cancers have been seen in individuals exposed to higher PFAS levels, mostly in occupational exposures. Most of these exposures were in people who worked in, or lived near, PFAS manufacturing facilities.

How certain are the studies that showed health risks?

- Correlations between exposure to PFAS and health effects have been inconsistent.

- More research is needed to fully understand any health effects in humans.

- Animals (mostly rats and mice) exposed to much higher levels than most people showed several health problems, such as liver damage, developmental and reproductive effects, and changes in hormone levels.

- Some human studies have found increases in prostate, kidney, and testicular cancers in workers exposed to PFAS and people living near facilities producing PFAS. However, other studies did not report a link between cancer and PFAS.

- Studies should be interpreted carefully, since the effects were not consistent across studies, there were contradictory findings among studies, and exposure levels were much higher than seen in the general population.

PFAS Regulation and Advisories

What levels of PFAS in water are considered harmful?

- The EPA has developed a lifetime drinking water health advisory level (HAL) for PFOA and/ or PFOS of 70 ng/L. The level is equal to the amount of a shot glass (1.5 oz) in approximately 150 million gallons of water. Drinking water at or below this standard for a lifetime is not expected to harm your health.

- If testing shows that your drinking water contains PFOA and/ or PFOS above the EPA HAL, use other water sources for drinking, preparing food, cooking, brushing teeth, and other uses when you might swallow water. Because the HAL is based upon long-term exposure, a short-term increase above the HAL should not increase risk significantly.

Biomonitoring and Blood Testing

Can a test determine whether I have been exposed to PFAS?

PFAS can be measured in blood, serum, and urine. However, doctors do not conduct this test to make a diagnosis or decide on treatment.

When is testing of PFAS useful and what can the results tell me?

- Testing for PFAS can be useful when they are part of a scientific investigation or a health study to determine how often and at what levels the chemical is found in the population. One such study is the National Health and Nutrition Examination Survey.

- Blood tests can be helpful when researching health effects from PFAS among persons who have been exposed to very high concentrations of the chemical, such as workers in industries where PFAS was used.

- Results of biomonitoring can compare the PFAS results from individuals tested with national averages established through these types of studies.

What can the results from blood testing for PFAS NOT tell me?

Most people in the United States (U.S.) will have measurable amounts of PFAS in their blood. We do not know how this impacts our health. These blood tests ***will not***:

- Provide information to pinpoint whether PFAS caused a particular health problem or to decide on treatment.

- Predict or rule-out the development of future health problems related to a PFAS exposure.

- Identify how or where the PFAS exposure occurred.

What is currently known about PFAS blood levels in U.S. population?

- The National Report on Human Exposure to Environmental Chemicals Report has reported that serum levels of PFAS appear to be higher in the U.S. than in some other countries.

- For the average American the PFAS level is 2,100 and 6,300 ng/L per liter of blood, respectively. The level is equal to the amount of 30 to 90 shot glasses (1.5 oz), respectively, in approximately 150 million gallons of water. These levels have been shown to be higher if a person's drinking

water source is contaminated with PFAS or if a person is exposed at a workplace that produces the PFAS product. More information can be found at: https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf or at: https://www.pehsu.net/.

Individual Concerns

If my drinking water is above the PFAS HAL, should my pets drink it?

No. Pets should be given the same drinking water you drink. As with humans, if the drinking water contains PFAS contaminant levels above the EPA HAL, use alternative water sources.

I drank water that exceeded the HAL for PFAS while I was pregnant and lactating. What impact could it have on my child?

- We do not have data to assess past risks to you and your family.
- Exposure to PFAS from drinking water with concentrations above the HAL may affect children's developmental health, including impaired growth, learning, and behavior.
- Studies in humans and animals are inconclusive and further, intense research is needed to know for sure about possible health effects related to duration and frequency of exposure.

We have tried to get pregnant for a long time without success. Could it be due to drinking water levels above the HAL for PFAS?

Infertility can be caused by many factors, both natural and chemical. At this time, we don't know if exposure to PFAS in drinking water above the HAL can affect infertility.

If PFAS have been found in my soil and water, should I be concerned?

While garden fruits and vegetables should be considered when evaluating the risk to exposure of PFAS, no data are currently available for Florida to evaluate possible risks. However, the Florida Department of Health would consider evaluation when data become available.

Can I water my lawn with water containing PFAS?

- Watering a lawn with non-edible plants and grass poses little risk.
- PFAS (PFOA and PFOS) are not absorbed effectively through the skin, nor is inhalation of vapors from water with PFAS likely to cause health problems.
- Remember that some well water specifically used for lawn maintenance only is usually not to be used for drinking purposes. For this chemical, drinking is a main route of exposure.

Can I use reuse water for watering my home produce?

No. Reuse water should never be used for home-grown produce due to the concern for human microbial pathogens. Reuse water should also not be used for drinking.

Can I swim in my pool if it is contaminated with PFAS?

Skin contact with and breathing PFAS (PFOA and PFOS) are minor concerns because these exposures are either uncommon or very low. You can drain and replace pool water with clean water from a different source. However, if you are careful to avoid swallowing pool water which is always a good practice, the risk of exposure to PFAS from swimming should be very low.

References:

Agency for Toxic Substances and Disease Registry (ATSDR) (2018). Toxicological Profile for Perfluoroalkyls. Draft for Public Comments. https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf

Agency for Toxic Substances and Disease Registry (ATSDR) (2019). Per- and Polyfluoroalkyl Substances and Your Health. https://www.atsdr.cdc.gov/pfas/index.html

Agency for Toxic Substances and Disease Registry (ATSDR) (2019). Clinician Information and Guidance: PFAS. https://www.atsdr.cdc.gov/pfas/docs/ATSDR_PFAS_ClinicalGuidance_12202019.pdf

PEHSU - Pedriatric Environmental Health Speciality Unit (2020). Per- and Polyfluoroalkyl Substances (PFAS) Resources. https://www.pehsu.net/PFAS_Resources.html

EPA - United States Environmental Protection Agency (2016). Fact Sheet: Pfoa & PFOS Drinking Water Health Advisories. https://www.epa.gov/sites/production/files/2016-06/documents/drinkingwaterhealthadvisories_pfoa_pfos_updated_5.31.16.pdf

United States Environental Protection Agency (2019). Drinking Water Health Advisories for PFOA and PFOS. https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos

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If you have questions or comments about this factsheet, we encourage you to contact us.

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Bureau of Environmental Health, Public Health Toxicology
Florida Department Health
4052 Bald Cypress Way, Bin # A-08
Tallahassee, FL 32399
phtoxicology@flhealth.gov

Or call us at: Toll free at 877-798-2772

APPENDIX G. PUBLIC COMMENT RESPONSE.

Comment 1: "I sold this property in June 2020, so I have no interest in this report. Stop mailing this to my old address."

Response:
Acknowledged. When notified, the Florida Department of Health (Department) makes efforts to remove former property owners from the Department's mailing list and to send the information to the new property owner. We will remove you from the mailing list.

Comment 2: "Reports need to be written easier for the typical resident to understand"

Response:
The Department values your feedback. The structure of the reports follows standards set by the federal Agency for Toxic Substances and Disease Registry (ATSDR). With that said, a senior health educator with the Hazardous Waste Site Health Risk Assessment program in collaboration with the Office of Communications will review future reports to ensure it fulfill the needs of the public.

Comment 3: "Reports should include the steps that are being taken to make it right with local."

Response:
The Florida Department of Health works closely with the Florida Department of Environmental Protection to assist with communication to the community on activities being done to protect public health.

Comment 4: "Who pays for all of the bottled water and the filtration systems? It surely shouldn't be put on the shoulders of the local residents."

Response:
Residents with levels of per- and polyfluoroalkyl substances in their private, potable well water above the respective Health Advisory Level of 70 nanogram/Liter are eligible to receive a filter and/or bottled water paid for by the Water Supply Restoration Program with the Florida Department of Environmental Protection. For more information, please contact the program by phone at 1-833-337-9773 or by email at Water_SupplyRestoration@floridadep.gov or visit their website at FloridaDEP.gov/Wra/Water-Supply-Restoration.