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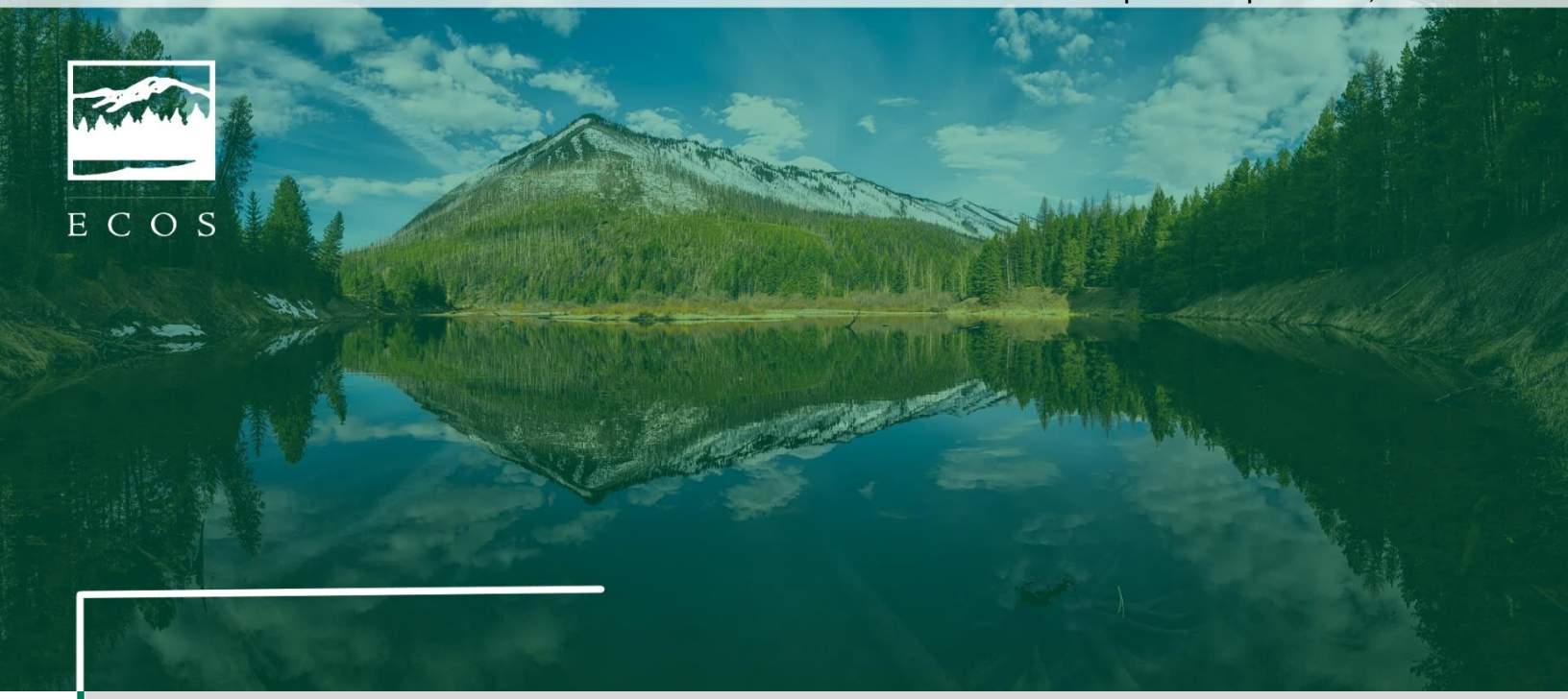

Processes & Considerations for Setting State PFAS Standards

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Supported by & in conjunction with the ECOS PFAS Caucus

Executive Summary

In recent years, federal, state, and international authorities have established various health-based regulatory values and evaluation criteria for a number of specific per- and polyfluoroalkyl substances (PFAS) in response to growing concerns with contamination. At this time, the U.S. has no federally enforceable PFAS standards, leaving individual states to navigate various avenues for addressing PFAS contamination. Some states have established legally enforceable values for certain PFAS in drinking water, groundwater, surface water, soil, or other environmental media (e.g., drinking water Maximum Contaminant Levels [MCLs]). Other states and regulatory agencies have opted for non-enforceable values such as guidance levels, screening numbers, or advisories that may apply to PFAS for which promulgated standards do not exist.

The Environmental Council of the States (ECOS) in 2019 compiled information on state PFAS standards, advisories, and guidance values (hereinafter referred to as "guidelines"[1]). Sharing data and regulatory approaches helps federal, state, and international authorities avoid unnecessary duplication of efforts, as well as understand and communicate about differences in guidelines. This paper[2] outlines ECOS' findings on state efforts and considerations for future regulatory activities on PFAS.

[1] For the purposes of this white paper, the term "guidelines" will apply to both regulatory (enforceable) standards and non-regulatory (non-enforceable) values.

[2] The white paper was initially published in February 2020. It was updated with new information and state participants in April 2021 and March 2022, and will continue to be updated annually as appropriate.

Table of Contents

List of Acronyms

ACRONYM	FULL PHRASE
ACGIH	American Conference of Governmental Industrial Hygienists
ACWA	Association of Clean Water Administrators
AFFF	Aqueous film-forming foam
APFO	Ammonium perfluorooctanoate
ASDWA	Association of State Drinking Water Administrators
ASTM	ASTM International (formerly American Society for Testing and Materials)
ATSDR	Agency for Toxic Substances and Disease Registry
BMDL	Benchmark dose (lower confidence limit)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIPFPECA	Chloroperfluoropolyether carboxylate
CSF	Cancer slope factor
CTL	Cleanup Target Level
CWA	Clean Water Act
DOD	U.S. Department of Defense
ECOS	Environmental Council of the States
EMEG	Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
ESL	Effect Screening Level
FOSA	Perfluorooctane sulfonamide
FTE	Full-time employee
FTS	Fluorotelomer sulfonate
GAC	Granular activated carbon
HBV	Health-Based Value
HED	Human equivalent dose
HFPO-DA	Hexafluoropropylene oxide dimer acid
HRL	Health Risk Limit
ISO	International Organization for Standardization
ITRC	Interstate Technology and Regulatory Council
ITSL	Interim Threshold Screening Level
kg	Kilogram
L	Liter

LHA	U.S. EPA Lifetime Health Advisory
LOAEL	Lowest Observed Adverse Effect Level
MCL	Maximum Contaminant Level
mg	Milligram
MLA	Multi-linear array (SGS Axys method)
MPART	Michigan PFAS Action Response Team
MRL	Minimal risk level
NDAA	National Defense Authorization Act
NEtFOSA	N-ethyl perfluorooctane sulfonamide
NEtFOSAA	N-Ethyl perfluorooctane sulfonamidoacetic acid
NEtFOSE	N-Ethyl perfluorooctane sulfonamidoethanol
NGO	Non-governmental organization
NOAEL	No Observed Adverse Effect Level
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulation
NRWQC	National Recommended Water Quality Criteria
PFAS	Per- and polyfluoroalkyl substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutanesulfonic acid
PFDA	Perfluorodecanoic acid
PFHpA	Perfluoroheptanoic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonic acid
PFIB	Perfluoroisobutylene
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFOSA	Perfluorooctanesulfonamide
POD	Point of Departure
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per trillion
PWS	Public water system
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose

RSC	**Relative Source Contribution**
RSL	**Regional Screening Level**
RCL	**Residual Contaminant Level**
SDWA	**Safe Drinking Water Act**
SOP	**Standard operating procedure**
SPE	**Solid phase extraction**
SPLP	**Synthetic precipitation leaching procedure**
TOF	**Total organic fluorine**
TOP	**Total oxidizable precursor**
TSCA	**Toxic Substances Control Act**
WAX	**Weak anion exchange**

Introduction

PFAS are a group of synthetic chemicals used in a wide array of consumer and industrial products since the 1940s. Several decades later, publicly available studies on certain PFAS risks indicated potential human health concerns related to these chemicals. In 2000, 3M announced a voluntary phase-out of certain legacy PFAS (e.g., perfluorooctanoic acid [PFOA], perfluorooctane sulfonate [PFOS], perfluorohexane sulfonic acid [PFHxS]). In 2006, the U.S. Environmental Protection Agency (EPA) initiated the PFOA Stewardship Program, which encouraged eight major chemical manufacturers to eliminate the use of PFOA and similar long-chain[3] PFAS in their products and in the emissions from their facilities.[4] International signatories of the United Nations' Stockholm Convention on Persistent Organic Pollutants treaty voted in 2009 and 2020 to add PFOS and PFOA, respectively, to the list of substances to be eliminated.[5] In 2020, the EPA issued a rule under the Toxic Substances Control Act (TSCA) prohibiting the manufacturing, processing, and/or importing of products containing certain PFAS without prior agency review and approval, and began the process of annually adding certain PFAS to the list of chemicals covered by the Toxics Release Inventory beginning in Reporting Year 2021. Despite these actions, U.S. manufacturers can with approval still import PFOA, PFOS, and PFHxS for use in consumer goods, and some U.S. sites are legally required to keep PFAS-containing firefighting foams on-site for emergencies.

U.S. manufacturers have developed numerous PFAS to replace long-chain PFAS such as PFOA, PFOS, and perfluorononanoic acid (PFNA). One example is hexafluoropropylene oxide dimer acid (HFPO-DA) and the HFPO-DA ammonium salt, the two chemical substances that are part of the **GenX** technology developed by Chemours (formerly DuPont), that were developed as a PFOA replacement. These replacement chemicals are part of the larger suite of more than 9,000[6] PFAS, some of which the EPA has approved for manufacture and use in the U.S. This is a problem on many fronts: PFAS do not break down or, in the case of PFAS that are precursors[7], are converted to terminal PFAS that do not break down, and are very hard to remove and/or destroy with treatment. Therefore, there is a persistent "supply" of PFAS in the environment that maintain their carbon-fluorine chemical structures and potential toxicity, in contrast to many other organic compounds. In addition, regulators currently lack routinely available analytical methods for PFAS detection and measurement across some environmental media and have little, if any, toxicological data for the majority of PFAS (especially the precursors) to define risks to human and ecological receptors.

In 2016, the EPA updated its short-term Provisional Health Advisory values for PFOA (400 parts per trillion [ppt]) and PFOS (200 ppt) to a Lifetime Health Advisory (LHA) of 70 ppt for PFOA and PFOS, individually or in combination, in finished drinking water.[8] The EPA states that this LHA was calculated "to provide Americans,

[3] Long-chain PFAS are those with carbon chain lengths of 6 or higher for sulfonic acids like PFOS and PFHxS, and carbon chain lengths of 8 or higher for carboxylic acids like PFOA and perfluorononanoic acid (PFNA). In general, perfluoroalkyl acids (sulfonic acids and carboxylates) of all chain lengths do not break down, and long-chain PFAS have been found to bioaccumulate and pose risks to human health and the environment.

[4] **Fact Sheet**, History and Use of Per- and Polyfluoroalkyl Substances (PFAS), Interstate Technology and Regulatory Council (ITRC) (2020). ITRC is a subsidiary of ECOS.

[5] For more information on international PFAS regulations, including the European Union's Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulation, see the **European Chemicals Agency website**.

[6] See U.S. EPA's Master List of PFAS Substances on its **Comptox Chemical Dashboard**

[7] Precursor, as used here, are PFAS, known or unknown, which have the potential to degrade to terminal PFAS that do not break down in the environment.

[8] In December 2019, the EPA issued **interim guidance** that recommends a screening level of 40 ppt to assess whether the levels of PFOA and/or PFOS present in groundwater at a federal cleanup site may require further investigation. The EPA will use the LHA of 70 ppt as a preliminary remediation goal for contaminated groundwater. While this may be useful to states, many states have their own guidance for PFAS in groundwater.

including the most sensitive populations, with a margin of protection from a lifetime of exposure to PFOA and PFOS from drinking water."[9] The LHA is a non-regulatory and non-legally enforceable value, and is intended to provide guidance to federal, state, and municipal governments for addressing PFOA and PFOS contamination in public water systems and private potable wells. In February 2019, the EPA released its **PFAS Action Plan** in which the agency committed to make a "regulatory determination" for PFOA and PFOS under the Safe Drinking Water Act (SDWA). The SDWA requires the EPA to make formal regulatory determinations for at least five contaminants from the most recent drinking water Contaminant Candidate List[10] within five years of the completion of the previous round of regulatory determinations. A positive determination initiates the rulemaking process to establish an enforceable **National Primary Drinking Water Regulation** (NPDWR) (i.e., MCL or Treatment Technique). In January 2021, the EPA announced that it had evaluated more than 11,000 public comments and made a final decision to regulate PFOA and PFOS. This decision was reissued by the new Administration on February 22, 2021. The agency also noted that it intends to fast track evaluation of other PFAS for future drinking water regulatory determinations if necessary data and information are available. In November 2021, the EPA requested that its Science Advisory Board review draft scientific documents that support the development of NPDWRs for PFOA and PFOS, as well as a draft document that provides a framework for risk assessment of PFAS mixtures. In the draft documents, the EPA **concludes** that "recent scientific data and new analyses … indicate that negative health effects may occur at much lower levels of exposure to PFOA and PFOS than previously understood and that PFOA is a likely carcinogen." The EPA also has initiated efforts to engage the public on environmental justice considerations for the NPDWR and to obtain input from stakeholders, including small public water systems and state, local, and tribal officials. Per the Agency's October 18, 2021 publication of the **PFAS Strategic Roadmap**, the EPA expects to propose MCLs for PFOA and PFOS in the fall of 2022, with a final rule to follow in late 2023.

In 2021, the U.S. Health and Human Services' Agency for Toxic Substances and Disease Registry (ATSDR) finalized **minimal risk levels** (MRLs) for four PFAS: PFOA, PFOS, PFHxS, and PFNA. MRLs are not regulatory values and are not intended to be used as public water or environmental cleanup standards. MRLs are screening tools to identify contaminants of concern at hazardous waste sites. If an exposure is below an MRL, it is not expected to result in adverse health effects, whereas an exposure exceeding an MRL warrants further investigation to determine if the exposure might harm human health. Additionally, MRLs are presented as dosage amounts (a measurement of exposure in units of milligrams/kilogram/day) and not in terms of concentration (the amount of a substance present in a particular media in units of parts per million [ppm], parts per billion [ppb], or ppt), analogous to Reference Doses (RfDs) developed by the EPA. The ATSDR developed Environmental Media Evaluation Guides (EMEGs) specific to children and adults to convert these dosages into concentrations about how much water a person can drink each day. Differences among the MRLs, EMEGs, RfDs, and LHAs have resulted in public confusion and emphasize the need for improved risk communication, especially in the news media, to explain that the ATSDR's MRLs and EMEGs and the EPA's RfDs and LHAs are used in different situations and are not/should not be considered "equivalent."

Historically, many states relied on the promulgated standards from federal agencies to regulate chemicals, while other states have had the authority to develop their own standards for contaminants of concern. If no federal standard exists, states may rely on toxicity values from the **EPA Tier 3 Toxicity Value Workgroup document** or similar reference documents. Noting the broad range and complexity of PFAS, the need for cross-media consideration, and the absence of promulgated federal standards, states have taken alternative routes to actively address PFAS across a wide range of programs. At least 25 states[11] have developed draft, proposed, or final health-

[9] The **EPA Drinking Water Health Advisories for PFOA and PFOS**

[10] The EPA's **Contaminant Candidate List** is a list of contaminants that are currently not subject to proposed or promulgated national primary drinking water regulations, but are known or anticipated to occur in public water systems.

[11] Several states in addition to those that completed the ECOS survey are known to have drafted, proposed, or finalized health-based regulatory and/or guidance values for PFAS in various environmental media. They are not included in the facts and figures outlined in this report.

based regulatory and/or guidance values for several PFAS in drinking water, groundwater, surface water, soil, air, and/or fish and wildlife. These guidelines may significantly differ from the EPA's LHA and from state-to-state given various legislative and scientific considerations. For example, states may have different mandates (e.g., regulations, policies) that direct them to interpret toxicity data (including considering exposures to sensitive life stages like infants or pregnant women) to develop risk assessments or require them to use the EPA's risk assessments as the basis for their guidelines. Several states have developed drinking water guidelines for PFOA and PFOS that are lower than the EPA's LHA due to considerations of more recent scientific information, more sensitive toxicological endpoints, and/or more stringent exposure parameters. Many of these states have also developed guidelines for various PFAS in addition to PFOA and PFOS. Other states have adopted the EPA's LHA for PFOA and PFOS in drinking water and/or groundwater to guide their efforts upon detection of contamination.[12]

With a growing body of science to inform standard development, an absence of a federally enforceable standard, and pressures from the public and legislative bodies to take regulatory action, it is important to know which states are setting guidelines, understand how the guidelines are developed, and be able to educate legislators on differences between state, federal, and other guidelines. This is essential so that states can make informed decisions when implementing their own regulations and/or risk communication practices.

Overview of States' PFAS Guidelines

ECOS surveyed states on their processes, rulemaking requirements, and other considerations for establishing PFAS guidelines (e.g., occurrence of specific PFAS in drinking water sources or other environmental media). ECOS and its working group of state environmental agency officials (the PFAS Caucus) examined responses from *33 states (Alabama, Alaska, Arizona, California, Colorado, Connecticut, Delaware, Florida, Hawaii, Idaho, Illinois, Indiana, Kansas, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oklahoma, Oregon, Tennessee, Texas, Vermont, Washington, Wisconsin, Wyoming).*[13] Below are findings and conclusions from the 33 states that completed the ECOS survey.

States without PFAS Guidelines

Nine states (Alabama, Arizona, Idaho, Kansas, Missouri, Nebraska, Oklahoma, Tennessee, Wyoming) indicated that they do not have state guidelines.[14]

Reasoning for Not Establishing State PFAS Guidelines:

- *Eight states (Arizona, Idaho, Indiana, Maryland, Missouri, New Mexico, North Carolina, Oklahoma)*[15,16] have restrictions that prohibit them from setting a drinking water or groundwater guideline more stringent (i.e.,

[12] The health basis for standards for other contaminants of emerging concern may be as low as those for PFAS, but the actual standards for those other contaminants are often higher because they are based on analytical limitations, while the PFAS standards can be set at the health-based levels.
[13] Individual state PFAS websites can be found in the "Overview" section on ECOS' **PFAS Risk Communication Hub**.
[14] These states may use the EPA's LHA of 70 ppt as guidance, remediation goals, action levels, or for regulatory oversight if PFAS contamination is detected. However, they will likely wait for a federal standard before enacting their own state guidelines.
[15] Indiana, Maryland, New Mexico, and North Carolina are included in this list because they have such a law governing rule-based standards in at least one environmental medium. However, they have a guideline for at least one PFAS analyte, as indicated below.
[16] North Carolina's restrictions prohibit setting more stringent standards in drinking water or groundwater. However, the statute does provide exemptions, such as if there is a serious and unforeseen threat to public health, as they pertain only to federal

more protective) than a federal standard in at least one environmental medium. This could dissuade a state from setting a PFAS standard (at any level), or from setting a PFAS standard lower than the EPA's LHA in anticipation that a federal MCL may be enacted at a similar level, forcing the state to amend its guideline(s) in a way that appears to "weaken" it.
- Many states lack the capacity or resources to effectively and individually regulate PFAS. Barriers include lack of technical expertise needed for toxicity interpretation and standard development, labs certified to test for PFAS in the state, interdependence of programs, legislative support, and funding.
- There are still limitations to available toxicity data, approved monitoring or analytical methods, and established federal criteria, all of which may contribute to scientific and regulatory uncertainty. Many states noted the need for more peer-reviewed science to make informed decisions on whether to establish guidance levels for some of the PFAS that have been found in their environmental media. States may also have many sites with known contaminants that need to be addressed and must choose to prioritize those over others impacted by emerging contaminants with less available data.

Without their own state-based guidelines, several of these states are still taking actions to inform the public, and to monitor, investigate, and remediate PFAS. Efforts include statewide sampling of Public Water Systems (PWSs) and surface water and groundwater intakes; conducting inventories of facilities that use or have used or produced PFAS; responding to drinking water and fish contamination; notifying local emergency planning committees, fire departments, airports, and industry of the human health and environmental impacts associated with using legacy aqueous film-forming foams (AFFF); sampling potentially-impacted private wells; and forming interagency task forces to coordinate the messaging for and response to PFAS contamination within the state.

States with PFAS Guidelines

25 states (Alaska, California, Colorado, Connecticut, Delaware, Florida, Hawaii, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oregon, Texas, Vermont, Washington, Wisconsin) have a guideline for at least one PFAS in at least one environmental medium.[17]

State guidelines for water and soil specified in ECOS' survey have been incorporated into the ITRC's **PFAS regulations fact sheets**. The tables define which environmental medium each standard applies, as well as whether the values are promulgated or advisory. States may have slightly different definitions of each medium. For example, most states consider drinking water standards to be finished water from the PWSs, but a state may also include groundwater used as drinking water from a private residential well or similar source. ECOS compiled responses based on how the state categorized each medium in the survey and how it defines it generally for the public. For more detailed state-specific definitions, see **state PFAS websites**.

Of the states that responded to ECOS' survey, the following have different types of guidelines:

Regulatory Standards

- Drinking Water[18]: *Eight states (Maine [interim], Massachusetts, Michigan, New Hampshire, New Jersey, New York, Vermont, Washington)*
- Groundwater: *Ten states (Alaska, Colorado, Delaware, Massachusetts, Michigan, New Hampshire, New Jersey, New Mexico, Texas, Vermont)*

rules, like a MCL under the SDWA.

[17] These include promulgated or interim rules and advisories (e.g., action and notification levels, cleanup target levels, initiation levels), and may be determined by the state or may be consistent with EPA's LHA of 70 ppt.

[18] See States with a Final or Proposed MCL (Drinking Water Only) designation below.

- Surface Water: *Three states (Michigan, Minnesota [site-specific criteria], New Mexico)*
- Soil: *Eight states (Alaska, Massachusetts, Michigan, New Hampshire, New Mexico, Texas, Vermont, Wisconsin)*
- Air: *Two states (Michigan, New Hampshire)*
- Other: *California* added PFOA and PFOS as developmental toxicants, PFOA and "PFOS and its salts and transformation and degradation precursors" as carcinogens, and PFNA and its salts as male reproductive toxicants to the Proposition 65 list of chemicals known to cause cancer or reproductive toxicity; *Washington* has regulatory standards for PFAS as halogenated organic compounds in state designated hazardous waste, for PFOA and PFOS in children's products, and regulatory requirements for PFAS in Class B firefighting foams, certain consumer products, and certain food packaging

Advisory Guidelines

- Drinking Water: *12 states (Alaska, California, Connecticut, Hawaii, Illinois, Indiana, Maryland, Minnesota, North Carolina, Oregon, Vermont, Wisconsin)*
- Groundwater: 11 *states (California, Colorado, Connecticut, Florida, Hawaii, Illinois, Maine, Minnesota, New York, North Carolina, Wisconsin)*
- Surface Water: *Five states (Colorado, Florida, Hawaii, Minnesota, Oregon [wastewater])*
- Soil: *Eight states (California, Connecticut, Florida, Hawaii, Indiana, Maine, Minnesota, New York)*
- Air: *Three states (Minnesota, New Jersey, Texas)*
- Water Interface: *One state (Alaska)*
- Fish or Wildlife Consumption Advisories[19]: *13 states (California [seafood], Connecticut [fish], Delaware [in process], Hawaii [in process], Maine [fish, beef, milk, and deer], Maryland [fish], Michigan [fish and deer], Minnesota [fish], New Hampshire [fish], New Jersey [fish], New York [fish], Washington [in process], Wisconsin [fish and deer])*

States with a Final or Proposed MCL (Drinking Water Only)

- *Massachusetts* (Enacted for six PFAS, individually and summed)
- *Michigan* (Enacted for seven PFAS, individually)
- *New Hampshire* (Enacted for four PFAS, individually)
- *New Jersey* (Enacted for PFOA, PFOS, and PFNA, individually)
- *New York* (Enacted for PFOA and PFOS, individually)
- *Vermont* (Enacted for five PFAS, individually and summed)
- *Wisconsin* (In process for 18 PFAS in two separate rule cycles. The proposed PFOA and PFOS combined standard of 20 ppt was modified (to 70 ppt), adopted by the agency board, and is undergoing legislative review. The proposed MCLs for the other 16 PFAS are still in process.)

Grouping PFAS

Recently proposed congressional legislation suggested creating a federal MCL for a sum of total PFAS, derived by adding the concentration of each PFAS detected in a sample. This total PFAS concentration depends on which analytical methods are used, as different analytical methods detect different suites of PFAS and have different reporting levels. Given that there are more than 9,000 PFAS, most of which have little known information about their toxicities, some regulators and subject-matter experts advise against grouping PFAS as an entire class, while other regulators and experts are considering all of the thousands of PFAS a class based on common properties such as environmental persistence. Additionally, some state guidelines address PFOA, PFOS, and other specific PFAS individually, while other state guidelines are based on the total concentration of PFOA and PFOS, as the EPA does in

[19] Advisories apply to fish only, unless otherwise noted.

its LHA, or on the total concentration of PFOA, PFOS, and several additional specific long-chain PFAS, based on the assumption of similar toxicological and toxicokinetic properties.

States' approaches for grouping PFAS, and the reasoning provided for grouping PFAS under each method, are as follows:

Individual PFAS

- *19 states*
    - *Alaska*: Soil and groundwater cleanup levels for PFOA, PFOS
    - *California*: Non-regulatory notification levels and response levels for PFOA, PFOS, and PFBS in drinking water; Non-regulatory environmental screening levels for PFOA, PFOS in soil, groundwater, aquatic habitat, terrestrial habitat, and leaching to groundwater
    - *Florida:* Provisional Soil Cleanup Target Levels for PFOA, PFOS; Provisional Irrigation Water Screening Levels for PFOA, PFOS; Surface Water Screening Levels for fish consumption for PFOA, PFOS[20]
    - *Hawaii:* Action levels for PFOA, PFOS, PFNA, PFBS, PFHxS, PFHpS, PFDS, PFBA, PFPeA, PFHxA, PFHpA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, PFOSA, HFPO-DA in drinking water, groundwater, surface water, soil
    - *Illinois:* Advisory levels for PFOA, PFOS, PFBS, PFHxS, PFNA, HFPO-DA in drinking water and groundwater
    - *Indiana:* Guidance Remediation Screening Levels for PFBS in drinking water, soil
    - *Maine:* Screening levels used as remedial action guidelines for PFOA, PFOS, and PFBS in soil and fish, and for PFOS in milk and beef
    - *Maryland:* Drinking water advisory level for PFHxS as a requirement for impacted water utilities to provide alternative water to customers;[21] Site-specific fish consumption advisory for PFOS
    - *Michigan*: MCLs for 7 PFAS (PFOA, PFOS, PFNA, PFHxA, PFHxS, PFBS, HFPO-DA); Surface Water Quality Standards for PFOA, PFOS, PFBS (pending); Groundwater cleanup criteria for 7 PFAS (PFOA, PFOS, PFNA, PFBS, PFHxA, PFHxS, HFPO-DA); Soil Criteria for Groundwater-Surface Water Interface protection for PFOA (in process of updating), PFOS; Consumption advisories for PFOS in fish and deer tissue; Initial Threshold Screening Levels (ITSLs) for PFOA, PFOS, 6:2 fluorotelomer sulfonate (FTS)
    - *Minnesota:* Promulgated Health Risk Limits (HRLs) for PFOA, PFOS, PFBA, PFBS, PFHxA in groundwater[22]; Health-Based Values (HBVs) for PFOS, PFBS, PFHxS in groundwater; Rule-based Intervention Limits for PFOA, PFOS, PFBA, PFBS to protect surface water and groundwater at solid waste facilities; Soil Reference Values for PFOA, PFOS, PFBS, PFBA, PFHxS; Site-Specific Criteria for PFOA, PFOS in surface water; Fish Consumption Advice for PFOS; Risk-Based Inhalation Values for PFOS, PFHxS, PFBA, PFBS (pending), PFHxA (pending) in air
    - *New Hampshire:* MCLs and Ambient Groundwater Quality Standards for PFOA, PFOS, PFHxS, PFNA; Soil contact value for PFOA, PFOS, PFHxS, PFNA for evaluating sites; Ambient air limit for APFO
    - *New Jersey:* MCLs and Ground Water Quality Standards for PFOA, PFOS, and PFNA; Interim Specific Ground Water Quality Standard for chloroperfluoropolyether carboxylates (CIPFPECAs); Fish

[20] Florida developed Provisional Groundwater and Soil Cleanup Target Levels (CTLs) in accordance with rules 62-780.150 and 62-780.650, Florida Administrative Code. The Provisional CTLs are considered enforceable as they were generated in accordance with the process established in these rules that allows for the development of CTLs.

[21] This may include acquisition of an alternative water source, improvements to the construction of the existing source, connection to another water system, or treatment of the source. If treatment is installed, the system is asked to conduct quarterly monitoring if feasible.

[22] Minnesota's Health Risk Limits and Health-Based Values for groundwater are also used as guidance values for drinking water.

Consumption Advisories for PFOS in some waterbodies; inhalation Reference Concentrations (RfCs) for PFOA, PFOS; screening inhalation RfC for HFPO-DA (GenX)
  - *New Mexico:* Groundwater and surface water standards for PFOA, PFOS, PFHxS; soil and tap water screening levels for PFOA, PFOS, PFHxS
  - *New York:* MCLs and groundwater, soil, and fish advisories for PFOA, PFOS
  - *North Carolina:* Groundwater Interim Maximum Allowable Concentration for PFOA[23]; Non-Regulatory Drinking Water Health Goal for HPFO-DA (GenX)
  - *Oregon:* Initiation levels for PFOA, PFOS, PFNA, PFHpA, PFOSA in municipal wastewater effluent
  - *Texas:* Health-Based Non-Carcinogenic Toxicity Factors and Cleanup Values for 16 PFAS (including PFOA and PFOS) in soil and groundwater; interim short- and long-term Effects Screening Levels (ESLs) for PFOA, PFOS in air permitting
  - *Washington:* Action levels for PFOA, PFOS, PFNA, PFHxS, PFBS in drinking water; Fish Consumption Advisory for PFOS (in process); Regulatory standards for PFOA, PFOS in children's products under the Children's Safe Products Act
  - *Wisconsin:* Proposed enforcement standards for 12 PFAS in drinking water and groundwater; proposed standards for PFOA, PFOS in surface water; Residual Contaminant Levels (RCLs) for PFOA, PFOS, PFBS in Soil, based upon the EPA Regional Screening Levels (RSLs) web calculator; Fish and wildlife consumption advisories for PFOS

- Reasoning:

  - Risk assessors evaluate PFAS analytes individually in the regulatory determination process. Regulations are therefore based on conclusions that human health effects, analytical limitations, and removal of drinking water contaminants vary among PFAS.
  - Regulations vary based on the presence of PFAS in a state, availability of chemical guidelines used for testing, and ability of available labs to test for and measure that analyte. States with more limited contamination potential and evaluations of health effects may be waiting to see whether the EPA develops a technical basis for grouping PFAS before summing or regulating additional analytes.
  - Toxicologists have more data on the perfluoroalkyl acids (carboxylates and sulfonates) that are a result of the terminal degradation process of PFAS precursors, and less on the PFAS precursors and other non-perfluoroalkyl acids in the same family.
  - Toxicological studies demonstrate differences in the potency and bioaccumulation (i.e., physiological half-lives) among individual PFAS.

PFOA & PFOS, Summed

- *Seven states*

  - *Alaska*: Drinking water action level for PFOA and PFOS
  - *Connecticut*: Fish tissue consumption criteria for PFOA and PFOS
  - *Delaware:* Hazardous substance screening values for PFOA and PFOS implemented through its risk-based cleanup program
  - *Florida*: Provisional Groundwater Cleanup Target Level for PFOA and PFOS, individually or combined
  - *Maryland:* Drinking water advisory level for PFOA and PFOS as a requirement for impacted water utilities to provide alternative water to customers.[24]

[23] As of March 2022, *North Carolina* has prioritized the most prevalent PFAS found in the state's environment and is developing regulatory paths to reduce contamination in surface water, groundwater, soil, and other media.
[24] This also may include acquisition of a new source, improvements to the construction of existing wells, connection to other

- *New Mexico:* Groundwater standard for PFOA and PFOS; surface water screening level for PFOA and PFOS implemented through Clean Water Act (CWA) Section 401 conditional certification of a National Pollutant Discharge Elimination System (NPDES) permit
- *Wisconsin*: Recommended groundwater enforcement standard and recommended groundwater preventive action limit for PFOA and PFOS (individual and summed)[25] This rulemaking was stopped by the agency board.

- Reasoning:
  - Regulating PFOA and PFOS aligns with the EPA's LHA. While the EPA has developed draft toxicity factors for a few other PFAS, PFOA and PFOS remain the only analytes with federal health advisories.
  - Regulating PFOA and PFOS together can streamline processes given their similar characteristics and known toxicities. PFOA and PFOS are the most thoroughly studied of the long-chain PFAS, with a large quantity of publicly available toxicity information available, and are considered hazardous substances or listed as a similar toxicant under some states' laws.

More than 2 PFAS, Summed or Otherwise Grouped

- *11 states*
  - *California:* Identification of PFOS and its salts and transformation and degradation precursors as carcinogens, and PFNA and its salts as male reproductive toxicants, under California's Proposition 65 law. Enforcement action can be applied to any compounds within these groups.
  - *Colorado:* Policy interpreting narrative groundwater and surface water quality standards for PFAS sums PFAS constituents based on endpoint toxicity (e.g., PFOA, PFOS, PFNA, and any identified parents are added together based on developmental toxicity; PFHxS and any identified parents are added together based on endocrine toxicity; PFBS and any identified parents are added together based on renal toxicity)
  - *Connecticut:* Advisory drinking water action levels, groundwater protection criteria, groundwater pollutant mobility criteria (soil leaching to groundwater), and soil direct exposure criteria for the sum of 5 PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA)
  - *Maine:* Interim drinking water standard for the sum of 6 PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA, PFDA) for community water systems and non-transient, non-community water systems that are schools or childcare facilities; Screening levels used as groundwater remedial action guidelines for the sum of 5 PFAS (PFOA, PFOS, PFNA, PFHxS, PFHpA)
  - *Massachusetts:* MCL and groundwater cleanup standard for the sum of 6 PFAS (PFOA, PFOS, PFNA, PFHpA, PFHxS, PFDA)
  - *Minnesota*: MN's **Health Risk Limits Rules for Groundwater** require evaluation of exposure to multiple contaminants in groundwater. Hazard ratios are summed across contaminants that affect the same health endpoints. For example, PFOA, PFOS, PFHxS, and PFBA all affect the liver and there are hazard ratios for each of these contaminants and would therefore be added together to calculate a multiple contaminant health risk index.
  - *New Mexico:* Narrative groundwater standard implemented through risk assessment guidance that provides for summation of PFOS, PFOA, PFHxS
  - *Oregon:* Health Advisory Levels for PFOA, PFOS, PFNA, and PFHxS in drinking water

water systems, or installation of treatment. If a system installs treatment, they are asked to conduct quarterly monitoring to ensure that it is effective. Certain water systems may be asked to conduct semi-annual monitoring depending on the concentrations of PFOA and PFOS.

[25] This may eventually be superseded by a recommended combined enforcement standard for PFOA, PFOS, and four precursors.

- *Vermont:* MCL and promulgated groundwater standard for the sum of 5 PFAS (PFOA, PFOS, PFNA, PFHpA, PFHxS)
- *Washington:* Regulatory standard for the sum of all PFAS in state-designated hazardous waste when halogenated organic compounds are present; Regulatory standards for the sum of all PFAS in certain consumer products under the Pollution Prevention for Health People and Puget Sound Act, Class B firefighting foams, and certain food packaging.
- *Wisconsin:* Proposed groundwater enforcement standard and health advisory limit for the sum of PFOA, PFOS, and four of their precursors (FOSA, NEtFOSA, NEtFOSAA, and NEtFOSE). Wisconsin uses a **hazard index approach** to establish drinking water advisories for PFAS. Hazard quotients for detected PFAS with standards are added and compared to a value of 1.

- Reasoning: Many of the summed PFAS analytes are similar as indicated below:
  - They are long-chain compounds with similar chemical structures (+/- two carbons in chain length) to PFOA and PFOS.
  - They are often found together in the environment and have characteristically similar bioaccumulative patterns and fate and transport mechanisms.
  - Human exposures to these PFAS often are correlated, making it difficult to differentiate the contributions of the individual PFAS to health effects observed in humans.
  - Their toxicity is assumed to be additive based on a substantial body of publicly available data indicating that they cause similar toxicological effects, have long serum half-lives in humans (long-chain PFAS only), and are associated with similar health effects in humans.[26]
  - They have similar limits for lab detection via EPA Method 537.1 (see Analytical Methods on page 24), and there is a minimal cost difference between analyzing a few or 18 compounds, so regulating and requiring testing for more analytes does not increase the cost and lessens the potential for the need to resample in the future.
  - PFOA, PFOS, PFNA, PFHxS, PFHpA, and PFBS were the six PFAS included in the EPA's third round of the Unregulated Contaminant Monitoring Rule (UCMR3). These PFAS have been researched to the extent that they are regulated individually by some states. PFHpA has minimal toxicity data available and PFDA was not included in UCMR3, but some states regulate both of these PFAS with the other long-chain PFAS based on close structural similarity and their inclusion as analytes in the EPA's analytical methods for drinking water.[27]
  - Regulating more analytes can provide information on conceptual site model development and the potential for PFAS fingerprinting (forensics on the fate and transport of chemicals over time).

Evaluating Differences among States' PFAS Guidelines

One of the most common questions that states are asked to address when communicating risks to the public and co-regulators is why guidelines vary from state-to-state. Many of the states' derived values typically differ within a factor of two to three, indicating that they are similarly protective; however, this is difficult to communicate with audiences who lack a background in the scientific and regulatory basis for the guidelines. Consequently, communicating the rationale for varying guidelines among state and federal entities remains a challenge.

[26] On the other hand, though similar, these PFAS do still present differences (e.g., different levels at which toxicity occurs, different toxicological effects and modes of action) that a state might acknowledge as a reason *not* to group the chemicals, but rather to regulate them individually.

[27] This list of PFAS is expected to expand in 2023-2025 as PWSs will be required under UCMR5 to monitor for all 29 PFAS that are within the scope of EPA methods 537.1 and 533.

States report that deviations among PFAS guidelines are driven by several main factors:

- Differences in professional judgments regarding the choice of the critical study and endpoint, whether animal or human data are used, the method for animal-to-human extrapolation, the uncertainty factors, and exposure parameters such as the Relative Source Contribution. Differences in any one of these choices (described in more detail in the State Trends for the Basis of Guidelines section on page 22) will result in different numerical values for the PFAS standard being developed.[28]
- Differences in timing. *When* guidelines are developed and *when* a state looks at the available scientific information affects *what* the guidelines are. While many technically sound guidelines have been developed from older studies, toxicologists and epidemiologists continue to conduct new PFAS research that will provide states with more referential data for deriving values. In this fast-paced field, short timeframes can change what studies relevant to PFAS standard development are available.
- Differences in state legislative or rulemaking requirements. The next section of this paper will explore differences in legislative procedures, but it should also be noted that beyond legislatures, state environmental and health agency programs (e.g., drinking water, surface water, wastewater, remediation, air, and others) have varying priorities or responsibilities in the standard-setting process.
- Differences in state regulatory processes and histories. States have different histories of developing standard methods, enacting regulations, and setting policy, all of which may direct toxicologists to use specific approaches and require protection of certain human life stages/vulnerable populations or other factors. *Minnesota*, for example, is required to evaluate risks to pregnant women and children in its exposure assumptions. *Washington* chose to regulate PFAS as a class in certain consumer products under the Toxic Pollution law, Class B firefighting foams under the Firefighting Agents and Equipment – Toxic Chemical Use law, and certain food packaging under the Packages Containing Metals and Toxics Chemicals law. These factors, coupled with how well a state's standard-setting methods reflect current and evolving science, can greatly affect how guidelines are calculated and what the resulting values are.

Section I. Legislative Considerations

Rulemaking Capacities

ECOS asked states to describe what authorities and processes they had to set PFAS guidelines. Responses indicate that most state guidelines are adopted/enacted through general rulemaking processes outlined in state administrative policies or acts, while some states have bills or statutes specifically targeted to PFAS. Examples of categories of such rulemakings besides those specifically setting PFAS guidelines include:

- Consumer products. The *California* Department of Toxic Substances Control's Safer Consumer Products Program lists PFAS as Candidate Chemicals and evaluates PFAS in consumer products like carpets in accordance with its Safer Consumer Products Regulations. *Maine* is requiring all manufacturers intentionally adding PFAS to any product to report such actions to its Department of Environmental Protection by 2023; is banning PFAS in carpets, rugs, and fabric treatments by 2023; and is banning all PFAS in products (unless unavoidable) by 2030. *Washington* is in the rulemaking process to restrict PFAS as a class in carpets and rugs, furniture and furnishings, and aftermarket stain and water resistance treatments.
- Food packaging. The *California* Department of Resources Recycling and Recovery recently adopted several regulations, including one that establishes a threshold of 100 ppm total fluorine concentration for "compostable" and "recyclable" food service packaging served at food service facilities that are state-owned,

[28] An August 2020 critical review published in the Society of Environmental Toxicology and Chemistry's online journal discusses some of the toxicity and exposure considerations that lead to similarities and differences among state and federal guidelines.

operated on state property, or under contract with the state.[29] *Maine* is prohibiting the use of PFAS in food packaging if safer alternatives are available at comparable cost and function.

- AFFF. *Arizona* recently revised a statute prohibiting the use of AFFF for training or testing purposes unless those activities are conducted using proper containment, treatment, and disposal measures approved by the state. *California* legislation amended the state Health and Safety Code to prohibit AFFF beginning January 1, 2022; ban AFFF training classes; restrict unused foam disposal; and track sales of and require notice of PFAS in personal protective equipment. *Maine's* legislature enacted a law in 2021 prohibiting the discharge of firefighting or fire suppressing foam for testing or training to which PFAS have been intentionally added; requiring the reporting of discharges to the state's Department of Environmental Protection; enacting a notice and recall provision; and prohibiting the manufacture, sale, and distribution of intentionally-added PFAS to firefighting foams. Report on the Implementation of an Act to Restrict the use of PFAS Substances in Firefighting Foam was submitted to the 130th Maine legislature on March 2, 2022.
- Air toxics. Since 1997, *New Hampshire's* state air toxics regulation has contained annual and 24-hour inhalation standards for APFO, the ammonium salt of PFOA. Additionally, New Hampshire is required by state statute to write rules and require the installation of best available control technology for PFAS and PFAS precursor air emissions that may have contributed to ambient groundwater or surface water quality standards.
- Water sampling and investigation. Many states have or are in the process of enacting laws or otherwise requiring sampling of statewide public water systems. Additionally, states are sampling and investigating non-drinking water sources. For example, *Maine* is conducting statewide soil and groundwater testing for PFAS at or associated with sludge and septage land application sites and testing landfill leachate, assessing fees for sludge and septage handlers that will go towards PFAS investigation and treatment funds, and coordinating with other agencies on PFAS impacts to active agricultural operations and pesticide uses.

These examples represent only a few of the active state PFAS bills prohibiting AFFF for firefighting, regulating food packaging, and requiring PFAS sampling, among other actions. States active in PFAS regulation are typically backed by their legislators, Attorneys General, and other leadership entities that provide funding and direct the environmental agencies to take action on contamination. Such actions include forming task forces for improved coordination (see Intra-State PFAS Collaboration on page 17), setting guidelines in different media by certain dates (e.g., *Vermont*), or initiating directives or lawsuits against PFAS manufacturers or the DOD (e.g., *Minnesota*, *New Jersey*, *New Mexico*).

Enforcement of state regulations is typically a programmatic issue based on the contaminated medium and is conducted in accordance with rules or policies in effect for each regulatory program (e.g., Superfund and hazardous waste, Resource Conservation and Recovery Act [RCRA], SDWA). Consequently, enforcement efforts for PFAS in drinking water, groundwater, surface water, solid waste, biosolids, and other environmental media are led by the state agency with authority to administer the applicable rules, and would be conducted as directed by program rules, unless specific rules for PFAS have been adopted. A couple of states indicated that they may rely on the state Attorney General for broader authorities or look to primacy agreements from the EPA. Enforcement may occur if a regulatory standard is exceeded, the contamination is considered hazardous, or there is a requirement for assessment and remediation. Some states noted that PFAS enforcement is a challenge without having adequate toxicity data necessary to establish the criteria on which a permit limit or enforcement/remediation action is based.

Regulating PFAS as Hazardous

16 states (Alaska, Connecticut, Florida, Hawaii, Indiana, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Mexico, New York, Vermont, Washington, Wisconsin, and Wyoming) noted that they have emergency rulemaking

[29] Total fluorine measurements are a reliable proxy for determining the presence of PFAS in food service packaging.

powers that can be invoked in the event of a PFAS contamination event or if a specific PFAS is declared hazardous at the federal level.

Several states also regulate PFAS as hazardous under certain conditions. For example, *Alaska* includes PFOA and PFOS in a list of hazardous substances for which groundwater and soil cleanup levels are set. *Delaware's* Hazardous Substance Cleanup Act lists PFOA and PFOS as hazardous substances with screening values at 70 ppt individually or combined in groundwater through a risk-based cleanup program. *New Jersey* added PFNA to the NJ Hazardous Substance List in 2018, and added PFOA and PFOS to the list in 2020. *New York* regulates PFOA and PFOS as hazardous substances under 6 NYCRR Part 597. Although *New Mexico* cannot adopt rules more stringent than the federal government under its Hazardous Waste Act, it can include PFAS in RCRA corrective action permits and take action in response to a PFAS contamination event of which the quantity, concentration, or other characteristics of the waste threaten human health or the environment. In October 2021, the *Washington* Department of Ecology announced that PFAS are hazardous substances under the state's Model Toxics Control Act. Ecology plans to release guidance in 2022 that provides direction on how to address PFAS contamination in the state. *Maine* adopted Public Law, Chapter 117 in June 2021 redefining hazardous substances in the state to be consistent with the definition of CERCLA, including a CERCLA "pollutant or contaminant" which opens the door for PFAS contamination to be considered, evaluated, or managed under Maine's uncontrolled site law. Lastly, *Minnesota* considers PFAS to be hazardous substances under the Minnesota Environmental Response and Liability Act.

While there has been intent to explore hazardous substance definitions for PFOA and PFOS in the past, as outlined in the EPA's PFAS Action Plan and considered by Congress for the Fiscal Year 2020 National Defense Authorization Act (NDAA), it was not until recently that the federal government is moving forward with such rulemaking. In its Strategic Roadmap, the EPA proposed to designate certain PFAS as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). A proposed rule was forwarded to the Office of Management and Budget for review on January 10, 2022 and is awaiting approval for public release; a final rule is expected in Summer 2023. The EPA will also issue in Spring 2022 an Advance Notice of Proposed Rulemaking on regulating other PFAS under CERCLA, as well as updated guidance on destroying and disposing PFAS in Fall 2023.

Declaring PFAS (just PFOA and PFOS, or additional analytes) as hazardous under CERCLA would have some, though likely different, impacts on states. *North Carolina* notes that the declaration may provide more information to its rulemaking body. Other states note that empowering them to act using existing regulatory CERCLA mechanisms allows for an expedited cleanup process and prevents draining already-strained funds for site investigation and characterization. Kansas said this definition is what it needs to regulate PFAS, as the state's definition of a hazardous substance is based on its inclusion as a CERCLA hazardous substance, and that it will provide more opportunity to ensure companies evaluate PFAS impacts.

In October 2021, in response to a petition from New Mexico Governor Michelle Lujan Grisham to identify individual or a class of PFAS as hazardous wastes under RCRA, the EPA announced that it also plans to initiate rulemaking for two new actions under the Act. These actions include evaluating existing data to propose adding four PFAS (PFOA, PFOS, PFBS, and GenX) as RCRA Hazardous Constituents under Appendix VIII to ensure they are subject to corrective action requirements, and clarifying in agency regulations that PFAS can be cleaned up through the RCRA Corrective Action Program.

Intra-State PFAS Collaboration

States have varying procedures for designating who regulates PFAS. Many state environmental agencies are coordinating with their health, agriculture, and other state agency counterparts on the state's PFAS response. For example, the *Michigan* PFAS Action Response Team (MPART) was created in 2017 through an executive directive to

investigate sources and locations of PFAS and protect drinking water and public health. In 2019, MPART was signed into an executive order as an enduring advisory body of seven state agencies, led by the Michigan Department of Environment, Great Lakes, and Energy. Other states (e.g., *Arizona*, *California*, *Colorado*, *Connecticut*, *Delaware*, *Hawaii*, *Illinois*, *Maine*, *Massachusetts*, *Minnesota*, *New Mexico*, *New York*, *North Carolina*, *Ohio*, *Oregon*, *Pennsylvania*, *Washington*, *Wisconsin*) have formed similar task forces and action teams charged with recommending PFAS guidelines and/or conducting other statewide PFAS efforts.

Impacts of Federal Regulatory & Legislative Uncertainty

ECOS asked states that have already established guidelines how they think the pending federal MCL or a similarly enforceable federal PFAS standard would impact their regulations. A state may be required to modify its guidelines to be "no more stringent than" federal requirements, or a state may be required to "strengthen" its guidelines so that they are as protective as federal standards. States recognize that this may impact the number of public water systems that need to address PFAS contamination as a result of adjusted standards. *North Carolina* noted that a federal MCL could affect its groundwater and drinking water programs, *Maryland* acknowledged that a lowered reference dose may impact its fish tissue monitoring work and result in more sites needing to be revisited, and another state noted its concern that a federal MCL may or may not adequately address protection for all populations and impacted communities because MCLs are not strictly risk-based. Numerous states with advisory guidelines expressed their preference for the EPA to have the primary role in setting MCLs, which they argue will facilitate a unified approach to mitigating PFAS contamination in drinking water supplies, as well as federal standards in other media. States recognize, however, the timeline associated with setting a nationwide standard and expressed their intentions to move forward with statewide MCLs or guidance in the interim. When the EPA enacts an enforceable drinking water standard for PFOA and PFOS, some states may need to make challenging management decisions regarding how to adjust their existing guidelines and PFAS response efforts to comply with the federal standard.

In the interim, states are pursuing other federal and congressional legislative actions that might make PFAS remediation and regulation more consistent nationwide. In October 2020, a coalition of 20 attorneys general sent a letter to Congress outlining states' PFAS-related priorities for the fiscal year 2021 NDAA. In addition to again encouraging Congress to designate PFAS as hazardous substances under CERCLA, states argued for DOD to meet or exceed the PFOA and/or PFOS standards established in the state in which the military installation is located when those standards are more stringent than federal standards or health advisory levels. These provisions were not included in the final NDAA bill.[30] However, several state governors, including those from Michigan, Ohio, and Arizona, have written letters under Section 332 of the fiscal year 2020 NDAA requesting that the DOD amend and/or enter into cooperative agreements with the state environmental agencies to address PFAS contamination resulting from military installation activities. The states cite that natural gradients have caused AFFF-contaminated drinking water, surface water, or groundwater to flow to nearby communities and as such, the DOD should coordinate with the state to mitigate further migration of PFAS contamination off base, oversee the implementation of state standards, and pay for treatment technologies, among other actions.

[30] The **fiscal year 2021 NDAA** did, however, include many PFAS provisions geared towards remediating PFAS contamination and searching for suitable AFFF alternatives. It also ordered the formation of an interagency federal working group to coordinate on research and development.

Section II. Risk Assessment

State environmental and public health agencies use quantitative risk assessment to develop health-based criteria for PFAS guidelines. The processes for evaluating exposure and developing these criteria are described across several guidance documents produced by the EPA.[31]

At its core, risk assessment is used to develop the human health basis for guidance values or standards by considering the following:

$$\boldsymbol{Toxicity} \times \boldsymbol{Exposure} = \boldsymbol{Risk}$$

Risk is a function of the toxicity of a chemical and a person's exposure to that chemical. The higher one's exposure, the greater the risk; similarly, the more toxic a chemical is, the more risk there is at the same level of exposure. Both variables are fundamental to the resulting calculation of risk.

As described in more detail below, differences among state PFAS guidelines may arise from differences in toxicity factors, which include RfDs for non-cancer effects and Cancer Slope Factors (CSFs) for carcinogenic effects. These toxicity factors are developed based on animal toxicology and/or human epidemiology studies. Choices in the scientific study and toxicity endpoint used, as well as choices made in developing an RfD or CSF from the selected study and endpoint, will result in differences in the numerical values of these toxicity factors. Additionally, a cancer risk level (e.g., 10^{-5}, 10^{-6}) must be selected when using a CSF to develop a health-based criterion, and states may differ as to the cancer risk level used for guidance development.

Different guidelines may also result from variations in exposure factors, which include parameters relating to daily water ingestion, body weight of an individual, duration of exposure, and fraction of total exposure from the medium of concern (e.g., drinking water). As with toxicity factors, state agencies use evidence-based methods to characterize exposure factors.

Scientific Considerations, Professional Judgment, & Peer Review

In general, states prefer to use peer-reviewed, publicly available toxicity studies that meet risk assessment criteria (e.g., study duration, route of exposure) as the basis for their guidelines. In some cases, states will consider non-peer reviewed reports (e.g., contract lab reports). Regulators review studies to ensure that they were properly conducted and reported, and consider a study's results coupled with its relevance, degree of rigor, and importance to the question on hand. Some states routinely develop their own guidelines for chemicals of interest to their state; however, if the EPA completes this process first, states can review the agency's conclusions and decide whether to use them, saving states the effort of doing this on their own. When EPA values are not available, some states refer to ATSDR's MRLs (as they would RfDs) or use health-protective values from other agencies like the American Conference of Governmental Industrial Hygienists (ACGIH).

Toxicity Criteria & Methodology

Regulatory agencies may rely on a chemical-by-chemical approach or grouping approaches for developing PFAS toxicity criteria (e.g., RfDs for non-carcinogens and CSFs for carcinogens). Most states conducting their own evaluations do not rely solely on EPA or ATSDR risk assessments, for which there are only published documents

[31] Examples of these EPA guidance documents include the Risk Assessment Guidelines, Water Quality Standards Handbook, and Exposure Factors Handbook (2011).

supporting the EPA's LHA for PFOA and PFOS, RfDs for PFBS and GenX chemicals, and draft RfDs for PFBA and PFHxA, and the ATSDR's MRLs for PFOA, PFOS, PFHxS, and PFNA. Performing the scientific analysis needed to effectively regulate PFAS is time consuming, and regulators lack toxicological data needed to develop criteria for some PFAS detected in environmental media.

To develop health-based guidelines, agencies conduct risk assessments, which usually follow this sequence of events:

1. Review available studies (e.g., toxicological, epidemiological) to identify critical endpoints that are sensitive and relevant to humans.

   Scientists generally prefer human epidemiological information as the basis for guidelines when the data are appropriate. Previously, the EPA and most states have concluded that currently available human studies are not appropriate to use as the primary basis for PFAS guidelines. As such, most current federal and state PFAS guidelines are based on laboratory animal study data that are then translated. For PFOA and PFOS, the EPA and some states have identified developmental effects (e.g., decreased pup body weight, thyroid effects [PFOS]; accelerated puberty; delayed ossification, delayed mammary gland development, neurobehavioral and skeletal effects [PFOA]; hepatic [liver] toxicity, immune system suppression [PFOA, PFOS]) as critical endpoints. Critical endpoints can vary from state-to-state based on scientific judgment.

   California is the first (and so far only) state to use human epidemiological data (kidney cancer) to develop a draft drinking water guideline level for PFOA. While it treats PFOS as a carcinogen based on animal data, the California non-cancer health protective concentrations are also based on human data (liver toxicity for PFOA, increased total cholesterol for PFOS). Recently, the EPA released draft Reference Doses for PFOA and PFOS, as well as a cancer slope factor for PFOA, that are based on human data and will support MCL Goals for the NPDWR. These draft documents are currently undergoing review by the agency's Science Advisory Board.[32]

2. Determine a point of departure (POD), the spot on the dose-response curve from the animal or human study at which toxicologists begin to apply uncertainty factors (UFs) to obtain a dose that should not be associated with adverse effects. PODs can be a No Observed Adverse Effect Level (NOAEL), Lowest Observed Adverse Effect Level (LOAEL), or Benchmark Dose (lower confidence limit; BMDL). BMDL is the preferred POD when available, as it is less dependent on dose selection and sample size.

   Toxicologists typically adjust the POD to account for the much slower excretion rate of PFAS in humans than animals (i.e., calculating human equivalent doses [HEDs] that will result in an equivalent internal dose [serum level] at the POD in animal studies). This dosimetric adjustment can be performed using estimated human clearance values, or the ratio of estimated serum half-lives in humans and animals.[33]

[32] The European Food Safety Authority has also used **epidemiological studies** to develop acceptable intake rates of PFOA, PFOS, PFNA, and PFHxS in humans.

[33] The dosimetric adjustment is used to determine the human serum PFAS level expected from a given external (oral) dose, and is how toxicologists account for PFAS bioaccumulation in risk assessment. It can be applied to the POD to develop the HED as described, or applied to the ratio of the POD and Total UFs as shown in the RfD equation below. Both methods are mathematically equivalent and the order of operations does not affect the final result.

3. Apply UFs to the HED to determine the RfD, an estimate of the daily oral dose at which humans are expected to be without risk from repeated[34] exposure to a chemical, including PFAS. An RfD is expressed as mass of chemical per day on a body weight basis ($mg_{chemical}/kg_{body\ weight}$/day).

   Toxicologists apply UFs of 3 (i.e., the square root of 10, which rounds to 3 if a single such factor is applied; if two such factors are applied, the value equals 10), or 10 to reflect uncertainties associated with the data used. Uncertainties include extrapolation from animals to humans (interspecies), shorter duration of exposure than the intended timeframe for the RfD in the study used, use of a LOAEL as the POD, and information gaps (i.e., potentially more sensitive effects that have not been studied) in the toxicological database. Another factor covers variability in human sensitivity (intraspecies), for which a factor of 10 or 30 is generally applied. The UFs are applied selectively for each chemical as appropriate for the toxicity data being used as the basis for the RfD.

   Toxicologists multiply the UFs together to obtain the total UF, and then divide the selected (NOAEL, LOAEL, or BMDL) POD (or as adjusted, the HED) by the total UF. A dosimetric adjustment is then performed to determine the RfD (as shown in the equation below).[35]

$$\frac{\boldsymbol{POD}}{\boldsymbol{Total\ UFs}} \times \boldsymbol{dosimetric\ adjustment\ factor} = \boldsymbol{RfD}$$

   When there may be a cancer hazard, the BMDL is used to derive a cancer slope factor (as shown in the equation below).

$$\boldsymbol{CSF} = \frac{\boldsymbol{benchmark\ response}}{\boldsymbol{BMDL}}$$

   For example, if the BMDL estimates a lower bound on the dose associated with an increased cancer incidence of five percent, the CSF is 0.05 divided by the BMDL. The CSF can be used to estimate an upper bound on risk for a given level of exposure, or it can be used to derive a health-based guidance level.

4. Combine the RfD with selected exposure parameters to establish a concentration (i.e., standard or guidance value) for PFAS in a specific medium (e.g., drinking water) that is intended to be protective of human health. Exposure assumptions vary among states and can result in different guidelines despite similar RfDs.

   Some states select exposure parameters for subgroups such as pregnant women or children if they are more sensitive for the toxicological effect of concern. Exposure parameters for health-based guidelines include the exposure rate (e.g., amount of drinking water, fish, or soil assumed to be ingested each day) and representative body weights for the target population. Several states use a model that predicts exposure to the developing fetus and breastfed infant from maternal drinking water exposure. For drinking water guidelines (and groundwater guidelines based on drinking water exposure parameters) based on non-cancer effects, states consider the Relative Source Contribution (RSC), which is the percentage of the RfD allocated or allowed to

[34] The length of exposure to which the toxicity factor is intended to apply can vary depending on the chemical and regulatory agency. For example, in its toxicity values for **PFBS** and **GenX**, the EPA characterizes exposure over a lifetime (chronic RfD) or less (subchronic RfD). For the EPA's LHA for **PFOA and PFOS**, the RfDs were derived from developmental toxicity studies, where a single exposure at a critical time in development could cause an adverse effect. Thus, EPA recommended that the lifetime LHA be applied to both short-term (e.g., during pregnancy and lactation) and lifetime exposure scenarios. The ATSDR uses the term MRL instead of RfD to describe the daily dose of a chemical that is not expected to pose a risk to human health. Its PFAS **MRLs** are derived for intermediate (14-364 days) exposure.

[35] As stated in Footnote 33, the dosimetric adjustment can alternatively be made on the POD to determine a HED, to which the UFs are applied, yielding the same result for the calculated RfD.

come from drinking water. For example, the EPA's LHA allows drinking water to contribute only 20 percent of the RfD and other sources can contribute 80 percent, so the RSC is 20 percent. In the absence of adequate data to determine exposure from non-drinking water sources, default assumptions, typically a lower-bound estimate of 20 percent and an upper-bound estimate of 80 percent, may be used as the RSC. Furthermore, scientists are still learning about PFAS sources and extents/impacts of exposure levels; as such, states' assumptions about the RSC may change in the future and affect PFAS guidelines.

State Trends on the Basis of Guidelines

ECOS examined states' calculations and factors applied to oral routes of exposure to PFAS that contributed to their standard setting processes.

Appendices A-F of this report include tables of state toxicological information and exposure assumptions for setting guidelines in drinking water, groundwater, surface water, soil, air, and fish and wildlife. Some of the trends in the data are summarized below:

***Critical Studies and Endpoints*:** This is a critical first step in the process, as it indicates the most sensitive health effect identified for which toxicologists are protecting (e.g., fetal/infant growth delays, thyroid dysfunction, infertility, alterations in liver function, and/or impaired immune function). *Ten states* indicated that they use the EPA's preferred critical studies (e.g., Lau et al. [2006] for the PFOA LHA and Luebker et al. [2005] for the PFOS LHA) and pharmacokinetic model for developing a toxicity factor (i.e., modeled average animal serum levels at the POD). States also use a variety of critical studies and endpoints based on which PFAS they are evaluating. As discussed in the Human-to-Animal Extrapolation Methods section on page 23, state approaches may differ from the EPA methodology in that the POD is based on serum PFAS levels measured at the end of the animal study rather than serum levels predicted using the EPA pharmacokinetic model.

***Points of Departure*:** The choice of POD depends on the dose response data for the critical endpoint being used as the basis for risk assessment. As previously mentioned, BMDL is the preferred POD when available as it is less dependent on the dose selection and sample size than the NOAEL or LOAEL. If a BMDL cannot be derived, the NOAEL is preferred. If there is no NOAEL in the study (i.e., effects occur at all doses), the LOAEL is used. *Eleven states* and the EPA use the LOAEL and NOAEL PODs for PFOA and PFOS in drinking water. Other states indicated that they use a combination of PODs depending on which PFAS they are examining, with LOAEL the most commonly used for PFOA and NOAEL the most commonly used for PFOS. *Five states* reported using a BMDL for various PFAS in drinking water.

***Uncertainty Factors*:** States use a variety of combinations for UFs that differ based on the study used. Some states reported applying a total UF of 300 for PFOA (with a UF of 3 for interspecies; 10 for intraspecies; and other UFs for extrapolation from LOAEL to NOAEL, database limitations, duration of exposure [i.e., subchronic to chronic extrapolation], and/or sensitive developmental endpoints), and a total UF of 30 (with a UF of 3 for interspecies and 10 for intraspecies) for PFOS. Some states have applied higher UFs depending on their interpretations of the relevant scientific data. UFs selected for other PFAS vary.

Exposure Parameters:

- ***Populations at Risk*:** States including *Michigan*, *Minnesota*, *New Hampshire*, *and Washington* use Minnesota's model (Goeden et al. [2019]) to predict fetal and infant exposure from transplacental transfer, breastmilk, and prepared formula for certain PFAS. This model applies the upper-percentile age-adjusted drinking water ingestion rates in the 95th percentile for pregnant women and formula-fed infants, and the upper-percentile

ingestion rate for breast-fed infants. Other states account for populations that may be at increased risk by considering their higher intake rates, with infants and lactating women consuming more than typical adults when adjusted for body weight. Examples include, but are not limited to, a 0-1 year old body weight-adjusted drinking water intake rate of 0.175 L/kg/day *(Vermont)*, a 10 kg body weight adjusted drinking water intake rate of 0.1 L/kg/day *(Wisconsin)*, or a lifetime average drinking water intake rate of 0.053 L/kg/day that accounts for increased water consumption relative to body weight at young ages *(California)*, as compared to the default adult upper percentile water consumption rate (0.029 L/kg/day) *(New Jersey)*. The EPA's LHA assumed the drinking water ingestion rate of the 90th percentile of lactating women to be 0.053 L/kg/day. Several states look at fish consumption rates as well when developing surface water quality criteria and fish consumption advisories; these advisories are more stringent for high risk populations (e.g., infants, children, pregnant and lactating women, women of childbearing age) in some states (e.g., *Connecticut*, *Delaware*, *New Jersey*). Overall, target populations and RSCs differed among states, even if those states used the same critical endpoint or a similar RfD. The different exposure parameters resulted in different final guidelines.[36]

- ***Relative Source Contribution*:** *Fourteen states* reported using the default value for the RSC of 20 percent (as the EPA does in its LHAs for PFOA and PFOS) for various PFAS in drinking water, indicating that they allow 20 percent of the RfD to come from drinking water and 80 percent to come from other sources of exposure. *Four states* use a chemical-specific RSC of 50 percent in their drinking water guidelines. Some of these states base their guidelines on the higher exposure to breastfed infants predicted by the Goeden et al. (2019) model; in these states, the RSC of 50 percent is specific to infants. *Wisconsin* does not use an RSC for PFAS in surface water, but uses a less conservative RSC of 80 percent for PFAS in other media, meaning 80 percent of the RfD comes from the source (e.g., drinking water) and only 20 percent is allocated to exposure to all other sources like diet or consumer products. Both *Alaska and Wisconsin* do not use an RSC (i.e., an RSC of 100 percent) in groundwater; at that guideline, exposures from other sources would raise the intake above the RfD. *Washington's* uses the subtraction method and biomonitoring data to define the aggregate exposure from all other PFAS sources, resulting in a variety of RSCs used to inform its drinking water action levels depending on the PFAS and the target population. For example, it uses an RSC of 20 percent for PFBS; an RSC of 50 percent for PFOA, PFNA, and PFHxS; and an RSC of 50 percent for infants and 20 percent for adults exposed to PFOS. Several states reported that the **EPA Decision Tree** (2000) is helpful in establishing an RSC.

***Human Epidemiological Data*:** *Twelve states (California*, *Connecticut*, *Florida*, *Hawaii*, *Illinois*, *Massachusetts*, *Michigan*, *New Hampshire*, *New Jersey*, *North Carolina*, *Washington*, *Wisconsin)* reported considering both animal and human epidemiological data to support their selections of critical endpoints from animal toxicity studies and guide their risk assessments.[37] *California* used human epidemiological data to derive its proposed slope factor for PFOA and its non-cancer guidance levels for PFOA and PFOS.

***Human-to-Animal Extrapolation Methods*:** Human toxicity values for PFAS are primarily based on laboratory animal studies and rely on various approaches to account for the much longer half-lives in humans than in animals. Toxicologists consider the interspecies half-life difference in most PFAS risk assessments because the same daily dose of a PFAS results in a higher internal dose (blood serum PFAS level) in humans because of their slower excretion rate. In general, the serum PFAS levels from animal studies are converted to HEDs by applying a chemical-specific clearance factor (based on human half-life and volume of distribution) that relates serum levels to human-

[36] Some states develop groundwater standards based on the assumption that groundwater is used as drinking water, so the ingestion rates/exposure assumptions used for drinking water standards are applied to the groundwater standards.
[37] As with any risk assessment, human epidemiology is considered, at a minimum, to support using an animal study. Only one state (*California*) has relied on the human epidemiological data as the quantitative basis of an RfD derivation, based on effects that are supported by animal studies, for its proposed non-cancer drinking water guidance levels for PFOA and PFOS (see Footnote 39). The current draft EPA Reference Doses for PFOA and PFOS are also based on human epidemiological data.

administered doses. The interspecies UF is reduced from the default value of 10 to 3 when these approaches are used since interspecies pharmacokinetic differences have already been accounted for.

Seven states (Alaska, Colorado, Connecticut, Maine, Massachusetts, Vermont, Wisconsin) reported using the EPA approach (used in its derivation of the LHA for PFOA and PFOS), which estimates the HED using modeled serum concentrations at the POD in the animal study as the internal dose metric. A few other states, including *New Jersey, New Hampshire, and California*, use measured serum concentrations at the end of the dosing period in the animal study as the POD. *Washington* reported using ATSDR's modeled serum concentration when it was available for PFOA and PFNA, and measured serum concentrations at the end of the dosing period for when PFOS and PFHxS. For PFBS, it used the administered dose, not the serum level.

Carcinogenicity: *16 states (Alaska, California, Connecticut, Delaware, Florida, Hawaii, Illinois, Indiana, Massachusetts, Minnesota, New Hampshire, New Jersey, North Carolina, Vermont, Washington, Wisconsin)* reported that they consider carcinogenicity as well as non-cancer endpoints in their evaluations. *10 of those states (Alaska, California, Connecticut, Delaware, Florida, Hawaii, Illinois, New Jersey, Vermont, Wisconsin [PFOA only])* quantify cancer risk with a slope factor and a cancer risk level of 1 in 100,000 ($1x10^{-5}$) or 1 in 1,000,000 ($1x10^{-6}$).[38] *California* uses cancer as the critical endpoint for PFOA (pancreatic and liver cancer in male rats) and PFOS (liver cancer in male rats) for their guidance level, as does *Illinois* for PFOA. *California* uses human kidney cancer data in its current draft guideline for PFOA.[39]

Section III. Risk Management

Once their toxicologists assess potential health or ecological risks, states take steps to manage those risks and protect public health. This includes analyzing PFAS samples, establishing guidelines, and addressing resource issues. This could also include deciding whether to address PFAS individually or as a group (see Grouping PFAS on page 10), deciding not to act based on their conclusions of the assessed risks, or looking at broader impacts of managing PFAS such as issuing discharge permits and availability of treatment removal technologies.

Analytical Methods & Limitations

States use a variety of methods to test for PFAS in different media. The most widely used is **EPA Method 537.1** (2018/2020, applies to 18 PFAS in drinking water), which 23 *states (Alaska, Arizona, California, Connecticut, Delaware, Hawaii, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Texas, Vermont, Washington, Wisconsin)* report using. [40] This method supersedes **EPA Method 537** (2009, applies to 14 PFAS in drinking water); it analyzes the same 14 PFAS as EPA Method 537, which was used for analysis during UCMR3, and adds four other replacement PFAS, including HFPO-DA (GenX). Both methods are designed for drinking water with low total suspended or dissolved solids. Samples are prepared by using a solid phase extraction technique.

[38] Cancer risk levels used in risk assessments are policy choices that vary among states and may be specified in a state's legislation or regulation.
[39] *California*'s current draft guideline is a Public Health Goal, which serves as the scientific basis for future regulatory standard (MCL) setting. The previous guidance levels for PFOA and PFOS, based on cancer observed in animal studies, were notification level recommendations.
[40] In the previous publications of this report, *two states (Florida, New Hampshire)* reported using this method, and *nine states (Alaska, Arizona, Connecticut, Indiana, Maine, Massachusetts, New Jersey, New Mexico, New York, Texas)* reported using both this method and EPA Method 537.

Some labs perform modifications to these methods such as using isotope dilution, using a weak anion exchange (WAX) solid-phase extraction (SPE) cartridge, or not evaporating samples to dryness. These changes allow labs to analyze a greater number of analytes in additional matrices and may also allow for lower reporting limits, increased recovery, or greater accuracy. For example, *12 states (Alaska, Connecticut, Delaware, Indiana, Maine, New Hampshire, New Mexico, New York, North Carolina, Texas, Vermont, Wisconsin)* reported that they allow modifications to EPA Method 537.1 for non-drinking water media. Methods can be applied to analyze one, some, or all applicable PFAS for which the methods apply, depending on which PFAS a state considers.

Other methods and criteria for PFAS analysis include:

- **EPA Method 533**: *Alaska, Hawaii, Idaho, Maine, Minnesota, New Hampshire, New York, Oregon, and Washington* allow labs to use this method. Published in 2019, this isotope dilution method uses a WAX SPE cartridge to improve recoveries of 25 short-chain[41] and long-chain PFAS in drinking water. The method targets 25 PFAS, including all 14 PFAS from EPA Method 537 and 11 PFAS unique to this method. Additional stable labeled isotopes are added into this method.
- **EPA Solid Waste (SW)-846 Method 8327:** *Florida and Illinois* use for surface water, groundwater, and wastewater. This direct injection method for non-drinking water aqueous samples was developed in 2019 for 24 target analytes, 14 of which are also found in EPA Method 537.1. While sensitivity was found in multi-laboratory validation to measure PFOA and PFOS below federal LHA levels for drinking water, this method does not yet provide low-level detection (i.e., single ng/L) and is only intended for testing of non-potable waters. The U.S. Department of Defense (DOD) published a memo stating that this method does not meet its needs to support decision-making and advises its use for screening purposes only. The final version of this method was published in July 2021.
- **EPA SW-846 Method 8321B**: *Washington* has used for fish tissue.
- **DEP SOP LC-001-3**: *Florida* uses its own Department of Environmental Protection standard operating procedure (SOP) method for PFAS in surface water, groundwater, wastewater, soil, and other solids. The DEP SOP LC-001-3 method references the EPA method 8321B and incorporates isotope dilution mass spectrometry to report 36 PFAS analytes, whereas the EPA method does not specifically mention PFAS or isotope dilution, but allows for the addition of non-listed analytes as long as all quality control measures are achieved.
- **DOD Quality Systems Manual** Version 5.1 or later (i.e., 5.2, 5.3, 5.4): *California, Colorado, Hawaii, Maine, New Hampshire, North Carolina, and Washington* use for consideration as additional guidance and quality control requirements. *Washington* recommends, and in some cases requires, in their Quality Assurance Project Plans that labs use a method that is compliant with the DOD Quality Systems Manual PFAS criteria when analyzing samples.
- Total Oxidizable Precursor (TOP) Assay: *Connecticut* uses for groundwater, surface water, AFFF, and fluorine-free foam; *Hawaii* uses for soil and groundwater; *Maine* uses for all matrices; *New Hampshire* accepts for soil and groundwater under its waste programs; *New York* uses for soil and groundwater; *Vermont* uses for soil and groundwater; *Washington* has used for surface water and sediments.
- **EPA SW-846 Method 1312**, Synthetic Precipitation Leaching Procedure (SPLP): *New Hampshire* accepts for soil analysis under its waste programs; *New York* uses for soil; *Vermont* uses for soil and sludge.
- SGS Axys Analytical, SOP **MLA 110**: *Connecticut* uses for fish tissue; *Hawaii* uses for soil and groundwater; *Maine* uses for all matrices; *Minnesota* uses for water/effluent, soil/sediment, biosolids, and tissue; *New York* uses for biota; *Vermont* uses for sludge; *Washington* has used for groundwater, surface water, effluent, sediments, and tissue.
- **ASTM D7979-17**: *Florida* uses for surface water and sludge.
- **ASTM D7968-17a:** *Florida* uses for soil.

[41] Short-chain PFAS are those with carbon chain lengths of 5 or lower for sulfonic acids like PFBS, and carbon chain lengths of 7 or lower for carboxylic acids like PFHxA.

- ISO 25101: *New York* uses for drinking water.
- As long as the method meets program requirements and project objectives, some states defer to each lab's preferred methods[42]: *seven states (Maine and Wisconsin [all matrices except drinking water, requires use of isotope dilution where isotopes are commercially available], Minnesota [drinking water], New Hampshire, New Jersey, New York, Texas [remediation]).*

Several methods were not final when ECOS conducted the survey[43], so it is unknown if or which states may already use them:

- Draft Method 1633: The DOD and the EPA partnered to produce this single-laboratory validated method for analyzing 40 PFAS in wastewater, surface water, groundwater, soil, biosolids, sediment, landfill leachate, and fish tissue. The method can be used in various applications, such as providing a consistent PFAS method tested in a wide variety of wastewaters and containing all required quality control procedures under the CWA for NPDES permits. The DOD noted that as of December 31, 2021, all new contracts and task orders shall require the use of this method for analyzing PFAS in matrices other than drinking water. Both agencies are supporting a multi-laboratory validation study of the procedure, which is expected to be completed in 2022 and will help the EPA finalize the method and add formal performance criteria. *New Hampshire* noted that it accepts this method.
- SW-846 Isotope Dilution Methods: The EPA is developing these methods under RCRA for analyzing PFAS in solid waste under RCRA. The agency's goal is to publish a 1600 series CWA method (i.e., Draft Method 1633) and SW-846 guidance methods for preparation, cleanup, and analysis using the same validation studies. The methods are similar, but CWA methods are written in a more prescriptive manner than the SW-846 guidance methods. A state noted that isotope dilution is the gold standard for quantitation and is the only method that corrects results for potential matrix effects, and another state mentioned that this is particularly true when stable labeled internal standards are available for all analytes in an analytical method.
- EPA Other Test Method-45: This method will be used to test for 50 specific PFAS at stationary sources, as well as identify other PFAS that may be present in the air sample, which will help improve emissions characterizations and inform the need for further testing.
- The EPA is developing a number of source emission methods for measurements from industrial and combustion/incineration sources. The EPA will apply what they learn in the source sampling (stack testing) efforts to ambient measurement techniques anticipated in 2022-2024.
- Some states and the EPA are considering validating supplemental analysis (e.g., Total Organic Fluorine [TOF] and TOP assays) to more completely characterize total PFAS in various media including consumer and industrial products.
- Some states are utilizing non-targeted analysis data for identification of unknown site-related PFAS.
- Other federal agencies beyond the EPA and the DOD have developed methods, which are available on their websites.
    - Centers for Disease Control and Prevention Laboratory Procedure Manual - Matrix: Serum
    - U.S. Department of Agriculture Screening, Determination, and Confirmation of PFAS by UPLC-MS-MS and Evaluation of Blood and Tissue PFAs Levels in Unintentionally Contaminated Dairy Animals
    - U.S. Food and Drug Administration PFAS Methods
    - U.S. Geological Survey PFAS in Source Waters and Treated Public Water Supplies and Sampling Groundwater for PFAS

Challenges that confound PFAS analysis include:

[42] State agencies have method performance expectations that they use to approve labs and determine whether or not the lab's own method is considered suitable by state program standards.
[43] Additional information on EPA PFAS methods is available on their analytical methods development and sampling research webpage.

- There are few low-level detection methods that are applicable to most PFAS in complex media, and there is a lack of a TOF method with detection limits in the low nanograms per liter range.
- Sample collection and analytical interference/contamination due to the presence of PFAS in common consumer products, sampling equipment, and lab materials can create challenges concerning quality control procedures in the laboratories.
- Matrix effects can interfere with accurate PFAS quantitation, as natural biological components and coexisting chemicals are often present in environmental samples but not in the solvent standards, leading to a difference in instrument response for equal concentration standards and samples.
- There are new challenges associated with emerging PFAS. For example, there is a lack of availability for analytical standards and the stable isotope-labeled internal standards, which help optimize method accuracy, for emerging PFAS. Several emerging PFAS have also been found to be diprotic (meaning the molecule contains two acid functional groups which can cause multiple charged states) or to be early eluting PFAS (meaning the compounds elute off of the high performance liquid chromatography columns too quickly), and many require lower mass spectrometer source temperatures and capillary voltage for ionization for optimum instrument signal and enhanced analytical accuracy. In addition, trifluoroacetic acid (TFA, a common environmental contaminant) interferes in the analysis of early eluters by suppressing the ionization of other coeluting PFAS. Lastly, several PFAS have been found to contain isomer forms (with more isomer forms present with increasing PFAS chain length), complicating analysis.
- There are financial and time constraints for existing lab methods. The *Minnesota* Department of Health reports that the turnaround time for their samples is 45 days and each water sample costs more than $300. *Maine* said its water and soil samples take about 28 days (depending on the backlog) and cost about $200 and $275 per water and soil sample, respectively. *North Carolina* reports that that samples it sends to a laboratory with a two-week turnaround time costs $300, and *Wisconsin* has observed costs between $275 and $500 for most matrices.
- There are different and sometimes inconsistent laboratory procedures for non-EPA approved methods. Not every state has a state lab, and some labs are government contracted or private. Each could result in different costs, time constraints, and sampling procedures. State agencies verify labs for use based on their own criteria.
- There are concerns about sample consistency among states and federal agencies. The Hawaii Department of Health requires the collection and testing of at least 10 grams of "**Multi Increment**" samples for testing for PFAS in soil, sediment, and biosolids, in accordance with the state's **Technical Guidance Manual**. While this can increase the cost for analyzing samples, the state says the practice is more reliable than the EPA laboratory methods, which require 0.5 grams of soil or other particulate matter from a discrete sample for testing. Hawaii noted that advancements in science and data collection since the EPA established their methods warrant a review of standard procedure across all laboratories.

ECOS recommends conferring with other states and using resources like the ITRC's **Sampling and Analytical Methods fact sheet**, or the Association of State Drinking Water Administrators' (ASDWA) **PFAS Laboratory Testing Primer** for guidance on selecting an analytical method, finding a qualified laboratory, specifying PFAS analytes and reporting limits, understanding sample collection procedures, and interpreting testing results and variability.

Establishing Guidelines

States consider the health-based criteria from risk assessment and other technical factors in the establishment of their guidelines. Some states' risk assessment approaches and conclusions have resulted in the development and adoption of PFAS guidelines that are lower than guidelines for most other contaminants. Scientific considerations that may contribute to these values include:

- PFAS cause toxicological effects at very low doses.

- Risk assessments account for the higher bioaccumulation of certain PFAS in humans than in animals. The same dose given to a human will result in a much higher blood serum level than in a lab animal.
- Low levels of certain PFAS in blood serum are associated with human health effects, and some states will consider how much a certain level in drinking water will increase blood serum PFAS levels. Even low levels of PFAS in drinking water can cause considerable increases in blood serum PFAS levels.
- As mentioned in footnote 13, the health basis for standards for other contaminants of emerging concern may be as low as those for PFAS, but the final guideline is set at the analytical quantitation levels, which may be up to several orders of magnitude higher than the health-based levels. For PFAS, analytical quantitation levels are very low, such that the final standard or guidance can be set at the health-based criterion.

Additionally, some states are required to perform a cost-benefit analysis in setting their final standards.

PFAS Resource (Cost) Issues

14 states (Alaska, California, Delaware, Illinois, Indiana, Maine, Massachusetts, Michigan, New Jersey, New Mexico, New York, North Carolina, Washington, Wisconsin) have conducted, are required by a state or federal law to conduct, or plan to consider costs or conduct cost-benefit analyses to define the economic impact of establishing guidelines for certain PFAS. Some states (e.g., *Idaho*, *New Mexico*, *North Carolina*) require a cost-benefit analysis as part of their administrative procedures for developing MCLs or water quality criteria, or release compliance costs through rulemaking (*New York*). Other states are not required to conduct a cost-benefit analysis prior to adopting guidelines into state regulation but plan to factor costs into decision-making. One state noted that the operations and management costs for treatment (e.g., Granular Activated Carbon [GAC]) are detrimental to its and others' budgets, especially for small public water systems that perform carbon changeouts regularly to ensure no arsenic MCL exceedances or other background factors when undergoing PFAS treatment procedures.[44]

Seven states (California, Connecticut, Maine, Michigan, Minnesota, New Jersey, New Mexico) have conducted cost estimates for some PFAS efforts. Some actions may fall under a state's normal agency programmatic activity; others require more staff and time. For example, in 2021, *Michigan* allocated $23.4 million and 131,296 staff hours to implement **PFAS activities**. *New Mexico* estimated 2020 and 2021 drinking water sampling efforts to total $1.2 million, and the state legislature has authorized $4 million for communities in two counties to plan, design, and construct improvements to water systems with PFAS contamination. *Maine* expended approximately $0.5 million through the end of 2020 on personnel and other (mainly laboratory) expenses, not including for senior manager full-time employees (FTEs). This exponentially changed after Public Law 2021, Chapter 478 was enacted, requiring several state investigation and data collection efforts. In addition to utilizing existing staff, the Maine legislature added 11 FTEs and 6 limited period positions, as well as $20 million to fund soil and groundwater sampling and install/maintain drinking water filtration systems for private drinking water wells impacted by PFAS.[45] *New Jersey* utilizes five FTEs for PFAS standard-setting efforts. *California* has FTEs dedicated to enforcement of the regulation but does not consider FTEs for rule development in its cost estimates. In 2020, *Connecticut* estimated it needed $5

[44] Small public water systems usually contain contaminants other than PFAS, including arsenic, manganese, nitrate, or bacteria that present health risks and are naturally occurring or originate from nearby land uses. Effectiveness of PFAS treatment will depend on how often filters are replaced and what levels of these other contaminants are present in the system. See more **here**.

[45] Maine is working on obtaining additional funding during this upcoming legislative cycle, including $5 million through the American Recovery Program to provide clean drinking water to residents with PFAS impacted wells, as well as to the Maine Department of Agriculture, Conservation and Forestry, for two FTEs and $10 million to coordinate with Department of Environmental Protection on investigation of PFAS in active agricultural operations. As of December 11, 2021, Maine DEP expended over $2.3 million on PFAS, with over $1.1 million expended just in fiscal year 2022, and in 2022 is hoping to obtain and utilize additional incoming federal infrastructure dollars for drinking water/wastewater treatment and remediation and to obtain legal support for litigation through the Attorney General's Office.

million to implement a 5-year statewide monitoring plan to study surface water and fish tissue (not including staff time); $75,000 to evaluate influent and effluent PFAS values at approximately 30 publicly-owned treatment works for 1 year; and $90,000 to support the development of a geographic information system for risk assessment of groundwater, surface water, and drinking water. A couple of states noted that PFAS has required a somewhat swift and significant rebalancing of staff member projects; for example, a state may have difficulty hiring new employees to fill the previous positions of those now assigned to work on PFAS, or a state's other projects may fall by the wayside due to the demand of this issue.

Incurred costs extend beyond regulating PFAS and should factor in: expenditures for states to initially investigate whether and to what degree there are PFAS releases or contaminated media; removal methods for contaminated media; disposal or long-term storage of AFFF; lab certification process development and equipment acquisition; chemical analysis; liabilities and legal fees; risk communication; and tracking the fate and transport of PFAS once released from an active source to the environment, requiring (re)sampling and treatment. For example, *Florida* has appropriated funding to assess and remediate PFAS at state-owned fire training facilities, as well as to assist homeowners with private wells that have PFAS-related contamination. Many states, with and without PFAS guidelines, have, are currently, or are planning to sample all public water systems, requiring a large amount of resources, not including the money required to remediate contamination when discovered. *Minnesota* is still calculating its costs (the total for past, ongoing, and potential future PFAS efforts will be estimated in its pending PFAS report), but noted that an industrial facility in the state allocated about $750,000 to retrofit its operations where PFAS were used and had contaminated a nearby waterbody. *New Jersey* estimates that the average cost for lab analysis is $300 per PFAS sample at each point of entry, and that this cost is expected to decrease as additional laboratories are certified for PFAS analysis and as market competition increases. The state also estimates that the cost of installing PFAS-specific GAC treatment for a PWS treating one million gallons per day (serving about 10,000 people) ranges from $500,000 to $1,000,000, with estimated operating costs of approximately $80,000 per year. New Jersey notes that operating costs could increase depending on the number of wells requiring treatment and the level of contamination. Given PFAS ubiquity, the ability for precursors (e.g., fluorotelomers) to transform to perfluoroalkyl acids and complicate site models, and complex transport mechanisms, especially at the air-water interface, states will need to use more resources to test process-based conceptual site models and fully understand the size and source of PFAS plumes.

States identified several cost implications of regulating PFAS:

- Resource availability is driven by dedicated government appropriations. For most states, resources to investigate and address PFAS come from existing program budgets (i.e., no new funds). Some states like *Colorado* and *Michigan* have received funding from bills signed by their Governors, and *Connecticut* received $2 million in bond funding to support the development and implementation of an AFFF take-back program, limited private well sampling, and treatment where needed. *Wisconsin* allocated $1 million in their 2021-2023 biennial budget for a firefighting foam collection and disposal program. But these exemplify state-specific resources based on legislative priorities. Other states have received funding from settlements with PFAS manufacturers to use on regulation and/or restoration of contaminated sites.
- Resource disparity exists. States with the fewest resources to address PFAS may be more significantly impacted by PFAS than others. Similarly, they may only have resources to address PFAS-related risks that are most studied in existing science and most salient among the public, rather than addressing risks unique to that state. The complexities of PFAS scientific information also create a barrier to understanding risk in a public forum.
- Data gaps prevent confident decision-making on how resources are used to address PFAS. States want to develop regulations based on a sound understanding of the problem in their state and to be able to communicate that understanding to their constituents. However, various factors – the lack of information on the sources and fates of PFAS, how they can be removed from drinking water and aquifers, and resulting waste management issues – create barriers to state time and financial investment.

A few states identified the need for water quality-based effluent limits, as well as the need for a cost conversation through national MCL or National Recommended Water Quality Criteria (NRWQC) processes, as many states do not have the resources to regulate PFAS on their own. These are SDWA and CWA processes driven by the EPA and involving states as co-regulators, and are one example of how the EPA is assessing potential changes to its regulatory processes to better respond to contaminants of emerging concern and be more inclusive of state priorities.[46]

Conclusion

ECOS asked states to list considerations and unanswered questions that will affect their PFAS guidelines in the future. States noted that the greatest impacts on state PFAS regulations will be:

- How can regulators apply or develop guidelines to PFAS in less-explored media (e.g., food and agriculture, biosolids, landfills, foam, and air emissions), if at all? For example, *13 states* have or are developing guidelines or consumption advisories for fish tissue and/or deer meat.
- How can labs detect lower concentrations of PFAS for media other than drinking water?
- What new information on sensitive human subpopulations, bioaccumulation in fish and shellfish, etc. will affect PFAS regulation?
- How will shifting use and chemistries of PFAS that have yet to be addressed complicate the responses? How many PFAS exist but are unknown to regulators due to confidentiality from manufacturers, etc.?
- How will developing information about PFAS migration from soil into animal feed, food crops, etc. affect the need for guidance values and state actions in response?
- How will regulatory approaches for soil (for protection of groundwater) change based on the results of ongoing research into better understanding PFAS sorption and leaching?
- What analytical approaches and health effects data will be available to develop guidelines for replacement PFAS?
- What will happen to current and pending state guidelines if federally enforceable standards (MCLs, NRWQCs) are enacted?
- What kinds of new science are needed to more effectively regulate PFAS individually or as mixtures? How will more occurrence data help to better understand PFAS in various media including wastewater and biosolids, private drinking water supplies, soils, air, fish tissue, and surface water?
- How will guidelines affect PFAS management/cleanup liability, disposal, and other considerations? For example, what will be the impact of designating PFAS as hazardous substances or regulating discharges through the NPDES and remediation programs? Who will pay for mitigation or remediation? What role does pollution prevention play in prohibiting PFAS in consumer goods from passing through regulated facilities and entering the environment?
- How can PFAS be effectively remediated and/or disposed of, especially once designated as a hazardous substance or waste? How will data on PFAS disposal through landfills, wastewater treatment, composting, plant uptake, etc. be utilized for proper management?
- How can we effectively prioritize and harmonize policies that focus on managing upstream processes to prevent downstream contamination (e.g., mandates that will minimize or eliminate the presence of PFAS/PFOS in compost, biosolids, and consumer products)?
- How does the presence of PFAS/PFOS in packaging and organic products impact the faith of consumers and policy makers to move forward with a circular economic model?

[46] For more information on states' recommendations for contaminants of emerging concern, see the Association of Clean Water Administrators (ACWA) and ASDWA joint **Recommendations Report for Contaminants of Emerging Concern**.

- How do we ensure that new chemicals developed to replace PFAS do not end up having similar or greater impacts on public health and the environment?
- How will funding from the Bipartisan Infrastructure Law be allocated to states to monitor, remediate, and regulate PFAS contamination?

PFAS pose complex challenges that are new (e.g., drinking water contamination is not a major issue for other persistent, bioaccumulative, and toxic chemicals) and especially daunting. Their unique characteristics include mobility; persistence in the environment and the human body; toxicity to animals and human health effects at low doses; a lack of toxicological data for most PFAS detected in the environment and used in commerce; ubiquitous detection in human blood; and technical obstacles for remediation. These challenges are compounded by regulatory and policy developments that vary by state and are uncertain at the federal level. There is also heightened public pressure for swift risk management, encouraged through social media and news reports. For example, there have been large settlements of high-profile lawsuits (e.g., $850 million from 3M to Minnesota in 2018, $671 million from DuPont to plaintiffs in West Virginia and Ohio in 2017). Advocacy groups have convened community events and produced films inspired by PFAS contamination in cities like Parchment, Michigan; Decatur, Alabama; and Parkersburg, West Virginia. And public data from the UCMR3 reported that PFAS were detected in water supplies serving 16.5 million people in the U.S. and that more than six million people consumed water with PFAS concentrations above the EPA's LHA in 2015.[47] These numbers are expected rise as PWSs monitor for 29 PFAS - including the six included in UCMR3, with lower Reporting Levels - under UCMR5 in 2023-2025.

A few states followed the emerging scientific information on, evaluated occurrence of, and developed guidelines for PFAS for many years before they were widely known to the public. Some states are actively responding to the recent events mentioned above by establishing programs and guidelines to regulate PFAS-contaminated sites. Other states are aware of PFAS as a contaminant of emerging concern and addressing it as they can. Given these variations in state action and public knowledge of the issue, risk communication is going to be an increasingly important function. Additionally, regulators need more transparency about the uses of existing PFAS, the ongoing development of new PFAS by industry, and PFAS approval by the EPA under statutes like TSCA. As states seek to independently regulate PFAS, it is critical to coordinate with and learn from other states that have established and are establishing their own guidelines.

This compilation of state-developed PFAS guidelines is a moving target, as regulators are acting quickly to develop and/or update guidelines for PFAS in various environmental media. Some states are waiting to set guidelines until the EPA establishes a federally-enforceable MCL. Other states are establishing guidance at levels below the EPA's LHA and/or for PFAS other than PFOA and PFOS, indicating that some regulators and toxicologists view the existing federal approach[48] as insufficiently protective. As stated earlier, however, the EPA's current draft toxicity assessments for PFOA and PFOS are much more stringent than almost all state assessments for these two PFAS. As not all states completed the survey (including some states known to have developed guidelines) and there will likely continue to be state standard setting at concentrations below the EPA's LHA and for PFAS other than PFOA and PFOS, ECOS hopes to compile additional information in the future.

This white paper is not intended to be a comprehensive compendium of state PFAS regulations. Rather, it aims to lay the foundation for states to dig deeper into the issue. ECOS hopes this paper will serve as a basis for future conversations, and encourages state-to-state, state-federal, and state-NGO partnerships and collaboration. In June 2020, the ASDWA published a **toolkit** of modules on assessing state resources, characterizing health impacts,

[47] Hu et al., 2016. "Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants." *Environmental Science & Technology Letters*, vol. 3, no. 10, 2016, pp. 344-350. *ACS Publications*, **https://doi.org/10.1021/acs.estlett.6b00260**.

[48] I.e., its process as a whole, or in its choice of critical studies or factors for calculation.

identifying treatment, analyzing costs and benefits, and other considerations surrounding PFAS in source water. ECOS is also compiling a spreadsheet of PFAS that states monitor for, including those for which the state does not have guidelines. The spreadsheet will be available on ECOS' PFAS webpage and will be updated as often as states submit new data. ECOS encourages states to use this white paper in combination with its additional PFAS resources, the ASDWA's numerous reports, the ITRC fact sheets and Technical/Regulatory Guidance document, and other relevant documents to fully understand the current status on PFAS regulation.

State Agency Reports on PFAS Guidelines

These reports/resources were provided by state environmental and health agencies that responded to the ECOS survey. For a full list of individual state PFAS websites with information on how they developed their guidelines and on other PFAS efforts, see the "Overview" section of ECOS' PFAS Risk Communication Hub.

- Arizona
- California[49]
- Colorado
- Connecticut
- Delaware
- Florida
- Hawaii
- Illinois
- Indiana
- Maine
- Maryland
- Massachusetts
- Michigan
- Minnesota
- New Hampshire
- New Jersey
- New York
- North Carolina
- Oregon
- Texas
- Vermont
- Washington
- Wisconsin

[49] *California*'s resources are listed as individual reports and documents which, in addition to the report linked above, include that on PFBS notification level guidance, PFOA and PFOS proposed guidance based on human data, PFOS and precursor cancer hazard identification, PFOA hazard identification, and PFNA male reproductive toxicity.

Appendix A: State Drinking Water PFAS Guideline Criteria

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
CA	PFOA	0.0051 (based on health-based reference level of 0.1 ppt for cancer effects, 2 ppt for non-cancer effects [liver])	Animals (mice/liver, rats/cancer)	Li et al., 2017; NTP, 2018	Hepatotoxicity in female mice; Cancer (pancreatic and liver) in male rats	20	LOAEL (0.97 mg/L)		300	3	10	3			3		Lifetime average of 0.053 L/kg/day	Oral ingestion as significant route of exposure		https://www.waterboards.ca.gov/pfas/ https://oehha.ca.gov/water/notification-level/notification-level-recommendations-perfluorooctanoic-acid-pfoa https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/PFOA_PFOS.html
	PFOS	0.0065 (based on health-based reference level of 0.4 ppt for cancer effects, 7 ppt for non-cancer effects [immune system])	Animals (mice/liver, rats/cancer)	Dong et al., 2009 Butenhoff et al., 2012	Immunotoxicity in male mice; Cancer (liver, structural similarity to PFOA) in male rats	20	NOAEL (0.674 mg/L)		30	3	10						Lifetime average of 0.053 L/kg/day			https://oehha.ca.gov/water/notification-level/notification-level-recommendations-perfluorooctanoic-acid-pfoa
	PFBS	0.5	Animals	Feng et al., 2017	Reduction of thyroid hormone, pregnant mice	20	6 mg/kg/day	0.06	100	3	10		3			0.0006	0.237 L/kg/day	0-6 month infant drinking water intake rate		https://oehha.ca.gov/media/downloads/water/chemicals/nl/pfbsnl011321.pdf
	PFOA	(Proposed Public Health Goal) 0.007 × 10-3 (based on human kidney cancer)	Humans (kidney cancer)	Shearer et al., 2021; Vieira et al., 2013	Cancer (kidney) in humans		CSF (0.0026 per ng/kg-day)										Lifetime average of 0.053 L/kg-day	Oral ingestion as significant route of exposure		https://oehha.ca.gov/sites/default/files/media/downloads/crnr/pfoapfosphgdraft061021.pdf

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
CA	PFOA	(Proposed Health-Protective Concentration for noncancer effects) 0.003 (based on increased risk of liver damage)	Humans (increased risk of liver damage)	Gallo et al., 2012	Liver enzymes in human serum exceeding clinically based reference levels used by the International Federation of Clinical Chemistry and Laboratory Medicine	20	NOAEC (9.8 ng/ml)	9.8 ng/ml	√10		√10					0.00087	Lifetime average of 0.053 L/kg-day	Oral ingestion as significant route of exposure		https://oehha.ca.gov/sites/default/files/media/downloads/crnr/pfoapfosphgdraft061021.pdf
	PFOS	(Proposed Public Health Goal) 0.001 (based on cancer effects in animals)	Animals (liver and pancreatic tumors in rats)	Butenhoff et al., 2012	Cancer (liver and pancreatic) in rats		CSF (15.6 per mg/kg-day)										Lifetime average of 0.053 L/kg-day	Oral ingestion as significant route of exposure		https://oehha.ca.gov/sites/default/files/media/downloads/crnr/pfoapfosphgdraft061021.pdf
	PFOS	(Proposed Health-Protective Concentration for noncancer effects) 0.002 (based on increased total cholesterol)	Humans (increased total cholesterol)	Steenland et al., 2009	Total cholesterol levels in humans exceeding clinical reference level published by the American Heart Association	20	LOAEC (16.4 ng/ml)	16.4 ng/ml	10		√10	√10				0.00064	Lifetime average of 0.053 L/kg-day	Oral ingestion as significant route of exposure		https://oehha.ca.gov/sites/default/files/media/downloads/crnr/pfoapfosphgdraft061021.pdf
CT	PFOA, PFOS, PFHxS, PFHpA, PFNA	0.07*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)		EPA (2016)											

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
HI	PFOA	0.040	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				https://health.hawaii.gov/heer/files/2020/12/PFASs-Techncal-Memo-HDOH-Dec-2020.pdf
	PFOS	0.040	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFNA	0.004	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFBS	0.600	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFHxS	0.019	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFHpS	0.020	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFDS	0.020	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFBA	7.6	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFPeA	0.800	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFHxA	4.0	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFHpA	0.040	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFDA	0.004	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFUnDA	0.010	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFDoDA	0.013	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFTrDA	0.013	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFTeDA	0.130	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	PFOSA	0.024	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				
	HFPO-DA	0.160	Animals (mice)	EPA (2016)	Based on noncarcinogenic effects	20	EPA (2016)		EPA (2016)							0.54 L/kg/day				

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
IL	PFOA	0.002 (MRL)	Animals (Rats/Cancer)	NTP 2018. TR-598	Liver/Pancreatic Tumors	20	LOAEL (0.97 mg/L)		300	3	10	3		chronic	3		2	Duration: 30 years Frequency: 350 days/year	Average Adult	https://www2.illinois.gov/epa/topics/water-quality/pfas/Pages/pfas-statewide-investigation-network.aspx
	PFOS	0.014	Animals (Rats/ Developmental)	Luebker et al. 2005	Decreased body weight/Delayed eye opening	20	NOAEL (0.1 mg/kg-day)	0.000515	300	3	10	1		chronic	3	0.000002	2	Lifetime	Average Adult	
	PFBS	2.1	Animals (Mice/ Endocrine)	Feng et al. 2017	Decreased thyroid levels	20	$BMDL_{0.5SD}$	0.095	300	3	10	1		chronic	1	0.0003	2	Lifetime	Average Adult	
	PFHxS	0.14	Animals (Rats/Endocrine)	Butenhoff et al 2009	Thyroid follicular damage	20	NOAEL (1 mg/kg-day)	0.0047	300	3	10	1		chronic		0.00002	2	Lifetime	Average Adult	
	PFNA	0.021	Animals (Mice/ Developmental)	Das et al. 2015	Decreased body weight/developmental delays	20	NOAEL (1 mg/kg-day)	0.001	300	3	10	1		chronic	2	0.000003	2	Lifetime	Average Adult	
	HFPO-DA	0.021	Animals (Mice/ Developmental)	DuPont-18405-1037, 2010	Reproductive effects and developmental delays	20	NOAEL (1 mg/kg-day)	0.01	3000	3	10	1	10	chronic	2	0.000003	2	Lifetime	Average Adult	
IN	PFBS	140	Animals (mice)	EPA RSL Tables					400											
MA	PFOS, PFOA, PFNA, PFHpA, PFHxS, PFDA	0.020*	Animals	Multiple	Based on mulitple endpoints and evidence of effects below EPA PODs for PFOA and PFOS; including: immunotoxicity, hepatotoxicity, thyroid effects, developmental effects.	20; to account for dietary and other exposures to PFAS subgroup addressed as well as potentially higher infant exposures.	NOAEL for PFOS, LOAEL for PFOA, equivalent to EPA values.	Equivalent to EPA values for PFOA and PFOS	1000 for PFOA, 100 for PFOS	3	10	10 for PFOA	3 for both PFOA and PFOS			$5x10^{-6}$ based on PFOS and PFOA value, which is applied to subgroup based on similarity in chemical strutures, toxicities, long serum half-lives.	0.054 L/kg/day (same as EPA value used in LHA derivation)	Body weight and water intake of lactating women (same as EPA value used in LHA derivation)	Lactating and pregnant women; fetus; nursing infants	https://www.mass.gov/lists/development-of-a-pfas-drinking-water-standard-mcl
MD	PFOA, PFOS	0.07*																		
	PFOA, PFOS	0.035*																		
	PFHxS	0.14																		

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
ME	PFOA, PFOS, PFNA, PFHxS, PFHpA, PFDA	0.02*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)		EPA (2016)											
MI	PFOA	0.008	Animals (mice)	Onishchenko et al., 2011 and Koskela et al., 2016	Neurobehavioral effects and skeletal alterations	50	LOAEL		300	3	10	3	3	1			95th percentile, 50% RSC			https://dtmb.state.mi.us/ARS_Public/Transaction/RFRTransaction?TransactionID=29
	PFOS	0.016	Animals (mice)	Dong et al., 2009	Immunotoxicity and Hepatotoxicity	50	NOAEL		30	3	10	1	1	1			95th percentile, 50% RSC			
	PFNA	0.006	Animals (mice)	Das et al., 2015	Reduced pup body weight	50	NOAEL		300	3	10	1	10	1			95th percentile, 50% RSC			
	PFHxA	400	Animals (rats)	Klaunig et al., 2015	Renal effects	20	BMDL		300	3	10	1	10	1			95th percentile, 20% RSC			
	PFHxS	0.051	Animals (rats)	NTP 2018 Tox-96 Report	Thyroid effects	50	BMDL		300	3	10	1	10	1			95th percentile, 50% RSC			
	PFBS	0.42	Animals (mice)	Feng et al., 2017	Thyroid effects	20	BMDL		300	3	10	1	10	1			95th percentile, 20% RSC			
	Gen X	0.37	Animals (mice)	DuPont 18405-1037, 2010	Reduced pup body weight, Hepatotoxicity	20	BMDL		300	3	10	1	3	3			95th percentile, 20% RSC			
MN	PFOA (Short-	0.035	Animals (mice)	Lau et al., 2006	Developmental and	50	38 mg/L	0.0053	300	3	10	3	3			$1.8x10^{-5}$	95th percentile	Half-life 840 days;	Fetus and	https://www.health.state.
	PFOS (Short-term, Subchronic and chronic)	0.015	Animals (mice)	Dong et al., 2011	Immunotoxicity, adrenal, developmental effects, liver effects, thyroid effects	20 for older children and adults, 50 for infants/ young children	2.36 mg/L serum concentration	0.000307	100	3	10		3			$3.1x10^{-6}$	95th percentile	Half-life 1241 days; placental transfer 40%; 1.7% breastmilk transfer	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfos.pdf
	PFBA (Short-term, Subchronic and chronic)	7	Animals (rats)	NOTOX, 2007 and Butenhoff, 2007	Liver effects, Thyroid effects	50	3.01 mg/kg/day	0.38	100	3	10		3			$3.8x10^{-3}$	95th percentile	Half-life 72 hrs; placental transfer ND; breastmilk transfer ND	Infants and Adults	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfba2summ.pdf
	PFBS (Short-term and Subchronic)	3	Animals (mice)	Feng, 2017	Developmental effects, Thyroid effects, Reproduction	50	50 mg/kg/day	0.158	100	3	10		3			$1.6x10^{-3}$	95th percentile	Half-life 665 hrs; placental transfer ND; breastmilk transfer ND	Infants and Adults	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfbssummary.pdf

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
MN	PFBS (Chronic)	2	Animals (rats)	Lieder, 2009 and York, 2003	Kidney	20	45 mg/kg/day	0.129	300	3	10		3	3		$4.3x10^{-4}$	95th percentile	Half-life 665 hrs; placental transfer ND; breastmilk transfer ND	General Population	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfbssummary.pdf
	PFHxS (Short-term, Subchronic and chronic)	0.047	Animals (rats)	NTP, 2018	Thyroid effects, Liver effects	20 for older children and adults, 50 for infants/ young children	32.4 mg/L	0.00292	300	3	10		10			$9.7x10^{-6}$	95th percentile	Half-life 1935 days; placental transfer 70%; breastmilk transfer 1.4%	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfhxs.pdf
	PFHxA (Short-term, Subchronic and chronic)	0.2 [Short-term value was lower than calculated subchronic and chronic values. Therefore all durations set to short-term]	Animals (rats)	NTP, 2019	Developmental & Thyroid effects	20 for all durations	25.9 mg/kg/day	0.0958	300	3	10		10		decreased body weight	$3.2x10^{-4}$ (short-term), 0.00015 (subchronic & chronic)	95th percentile	Half-life 32 days *[TK model was not used. Placental transfer 2.26; breastmilk transfer- No data]*	General Population	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfhxa.pdf
NC	GenX	0.14	Animals (mice)	DuPont-24459, 2008; DuPont-18405-1037, 2010	Hepatotoxicity	20	0.1 mg/kg/day (NOAEL)		1000	10	10			10		0.0001	1.1 L/day (95th percentile infant)	Bottle-fed infants of median weight	Infants	https://epi.dph.ncdhhs.gov/oee/pfas/NC%20DHHS%20Health%20Goal%20Q&A.pdf
NH	PFOA	0.012	Animals (mice)	Loveless et al., 2007	Hepatotoxicity	50	BMDL10		100	3	10		3			$6.1x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	
	PFOS	0.015	Animals (mice)	Dong et al., 2011	Immunosuppression	50	NOAEL		100	3	10		3			$3x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	
	PFNA	0.011	Animals (mice)	Das et al., 2015	Hepatotoxicity	50	BMDL10		100	3	10		3			$4.3x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	
	PFHxS	0.018	Animals (mice)	Chang et al., 2018 and Ali et al., 2019	Infertility	50	BMDLSD		300	3	10		3	3		$4x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	https://pubmed.ncbi.nlm.nih.gov/31487490/
NJ	PFOA	0.014	Animals (mice)	Loveless et al., 2006	Hepatotoxicity	20	BMDL		300	3	10				10	$2x10^{-6}$	2 (70 kg body wt)	Default adult	Infants	https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixa.pdf
	PFOS	0.013	Animals (mice)	Dong et al., 2009	Immunotoxicity	20	NOAEL		30	3	10					$1.8x10^{-6}$	2 (70 kg body wt)	Default adult	Infants	https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-a.pdf
	PFNA	0.013	Animals (mice)	Das et al., 2015	Hepatotoxicity	50	BMDL		1000	3	10		3	10				200:1 serum: drinking water ratio		https://www.state.nj.us/dep/watersupply/pdf/pfna-health-effects.pdf

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
NY	PFOA	0.01																		
	PFOS	0.01			Liver, developmental, immune, thyroid effects															
OR	PFOA, PFOS, PFNA, PFHxS	0.03*														0.000017 (PFOA), 0.0000041 (PFOS), 0.0000034 (PFNA), 0.0000057 (PFHxS)		Short- and long-term exposures	All persons, including sensitive populations	https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/DRINKINGWATER/OPERATIONS/Pages/PFAS.aspx
VT	PFOA, PFOS, PFHxS, PFHpA, PFNA	0.02*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)		EPA (2016)								0.175 L/kg/day		0-1 year old	
WA	PFOA	0.01	Animals (Mice)	Koskela et al., 2016	Skeletal effects (developmental)	50	LOAEL (8.29 mg/L maternal serum)	0.000821	300	3	10	1	10	1	1	0.000003	MDH transgenerational toxicokinetic model (Goeden et al 2019)	12 months breast feeding (1st 6 months = exclusive BF); 95th percentile DW ingestion by lactating women and infants in 1st year, then 90th percentile age-specific DW ingestion rates > 1 years old.	Fetus, infants	331-673.pdf (wa.gov)
	PFOS	0.015	Animals (Mice)	Dong et al., 2011 (with support by Dong et al., 2009)	Immune effects	20 adults; 50 infants	NOAEL (2.36 mg/L serum concentration)	0.000307	100	3	10	1	3	1	1	0.0000031	MDH transgenerational toxicokinetic model (Goeden et al 2019)	Limiting population was adults at 90th percentile drinking water intake over chronic period. Infants also modelled for 12 months breast feeding (1st 6 months = exclusive BF); 95th percentile DW ingestion by lactating women and infants in 1st year, then 90th percentile age-specific DW ingestion rates > 1 years old.	Adults, fetus, infants	331-673.pdf (wa.gov)
	PFNA	0.009	Animals (mice)	Das et al. 2015	Reduced pup weight and developmental delays	0.5	NOAEL (6.8 mg/L serum concentration)	0.000734. using half-life estimate of 3.52 years (1,285 days) from Yu et al. 2021	300	3	10	1	10	1	1	0.0000025	MDH transgenerational toxicokinetic model (Goeden et al 2019)	12 months breast feeding (1st 6 months = exclusive BF); 95th percentile DW ingestion by lactating women and infants in 1st year, then 90th percentile age-specific DW ingestion rates > 1 years old.	Fetus, infants	331-673.pdf (wa.gov)

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
WA	PFHxS	0.065	Animals (rats)	NTP, 2018	Thyroid hormone level reduction	50	BMDL (32.4 mg/L serum concentration)	0.00292	300	3	10	1	10	1	1	0.0000097	MDH transgenerational toxicokinetic model (Goeden et al 2019)	12 months breast feeding (1st 6 months = exclusive BF); 95th percentile DW ingestion by lactating women and infants in 1st year, then 90th percentile age-specific DW ingestion rates > 1 years old.	Fetus, infants	331-673.pdf (wa.gov)
	PFBS	0.345	Animals (mice)	Feng et al., 2017	Thyroid hormone level reduction (developmental)	20	BMDL (22.1 mg/kg/day)	0.095	300	3	10	1	10	1	1	0.0003	0.174 L/kg/day	95th percentile water intake rate for birth - 1 year old.	Infants	331-673.pdf (wa.gov)
WI	PFOA	0.02 (combined)*	Animals (mice)	Lau et al., 2006	Developmental (reduced ossification)	100	LOAEL		300	10	3	10								
	PFOS	0.02 (combined)*	Animals (mice)	Luebker et al., 2005	Reduced pup body weight	100	NOAEL		30	3	10				10			1 (10 kg body wt)	Gestation and infancy (including breastfeeding)	
	FOSA, NEtFOSA, NEtFOSAA, NEtFOSE	0.02 (combined)*	PFOA and PFOS Precursor		Combined standard for PFOS, PFOA, FOSA, NEtFOSE, NEtFOSA, and NEtFOSAA	100												Combined		
	PFTeA	10	Animals (rats)	Hirata-Koizumi et al., 2015	Body weight	100	NOAEL (1 mg/kg/day)		1000	10	10	1	10	1	1		0.001	1		
	PFHxA	150	Animals (rats)	Klaunig, 2015	Clinical effects	100	NOAEL (15 mg/kg/day)		1000	10	10	1	10	1	1		0.015	1		
	PFUnA	3	Animals (rats)	Takahashi et al., 2014	Body weight	100	NOAEL (0.3 mg/kg/day)		1000	10	10	1	10	1	1		0.0003	1		
	PFDoA	0.5	Animals (rats)	Shi, 2009	Body weight and testosterone levels	100	NOAEL (0.05 mg/kg/day)		1000	10	10	1	10	1	1		$5x10^{-5}$	1		

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
WI	PFBA	10	Animals (rats)	van Otterdyk, Buttenholf 2012b	Hemotoxicity, hepatotoxicity, and thyroid toxicity	100	BMDL (MN) (3 mg/kg/day)		3000	10	10	1	10	3	1		0.001	1		
	PFBS	450	Animals (rats)	Lieder, 2009b	Nephrotoxicity	100	BMDL (MN) (45 mg/kg/day)		1000	10	10	1	10	1	1		0.045	1		
	PFNA	0.03	Animals (mice)	Das, 2015	Reproductive toxicty	100	NOAEL (1 mg/kg/day)	0.0011	300	3	10	1	1	1	10		$3x10^{-6}$	1		
	PFDA	0.3	Animals (mice)	Harris and Birnbaum 1989	Deveolpmental (Fetal growth)	100	NOAEL (0.03 mg/kg/day)		1000	10	10	1	10	1	1		$3x10^{-5}$	1		
	PFHxS	0.04	Animals (rats)	Cheng, 2018	Developmental and repoductive toxicity (Maternal and fetal growth)	100	NOAEL (0.3 mg/kg/day)		300	3	10	1	10	1	1		$4x10^{-6}$	1		
	PFODA	400	Animals (rats)	Hirata-Koizumi., 2012	Body weight	100	NOAEL (40 mg/kg/day)		1000	10	10	1	10	1	1		0.04	1		
	Gen X	0.3	Animals (mice)	Dupont, 2010b	Nephrotoxicity and hepatotoxicity	100	NOAEL (0.1 mg/kg/day)		3000	10	10	1	10	3	1		$3x10^{-5}$	1		
	DONA	3	Animals (rats)	Gordon, 2011	Hemotoxicity and hepatotoxicity	100	NOAEL (1 mg/kg/day)		3000	10	10	1	10	3	1		0.0003	1		

*= Advisory level is based on the total of more than one PFAS

Appendix B: State Groundwater PFAS Guideline Criteria

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
AK	PFOA	0.4	Animals (mice)	Lau et al., 2006	Decreased ossification of pup proximal phalanges, accelerated preputial separation	None (but does not include an RSC in cleanup level calculations, so essenitally use an RSC of 100)	EPA (2016)		EPA (2016)								EPA (2016)	0.78	Residential exposure for 6 yrs old child receptor	Child	http://dec.alaska.gov/media/7543/20180201_pccl.pdf
	PFOS	0.4	Animals (mice)	Luebker et al., 2005	Reduced pup body weight	None (but does not include an RSC in cleanup level calculations, so essenitally use an RSC of 100)	EPA (2016)		EPA (2016)								EPA (2016)	0.78	Residential exposure for 6 yrs old child receptor	Child	http://dec.alaska.gov/media/7543/20180201_pccl.pdf
CO	PFOA, PFOS, PFNA	0.07*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)		EPA (2016)								EPA (2016)	EPA (2016)	EPA (2016)	EPA (2016)	
	PFBS	400	Animals (mice)	EPA RSL	EPA RSL	EPA RSL	EPA RSL		EPA RSL								EPA RSL	EPA RSL	EPA RSL	EPA RSL	
	PFHxS	0.7	Animals (mice)																		
CT	PFOA, PFOS, PFHxS, PFHpA, PFNA	0.07*																			CT DEEP Remediation and Groundwater Protection Criteria
DE	PFOA, PFOS	0.07*																	Risk-based		
FL	PFOA	0.07	Animals (mice)	Lau et al., 2006	Decreased ossification of pup proximal phalanges, accelerated preputial separation	20	EPA (2016)		300	3		10			10		$2x10^{-5}$	0.054 L/kg/day		Prengant/ lactating women	
	PFOS	0.07	Animals (mice)	Luebker et al., 2005	Decreased offspring body weight	20	EPA (2016)		30	3					10		$2x10^{-5}$	0.054 L/kg/day		Prengant/ lactating women	

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
HI	PFOA-	(drinking water [DW] toxicity), 8.5 (chronic aquatic [CA] toxicity), 120 (acute																			Applicable to groundwater that is a current or potential drinking water resource, where the surface water body is located within 150 meters of a release site. See other action levels and more information: https://health.hawaii.gov/heer/guidance/ehe-and-eals/
	PFOS-	0.04 (DW), 1.1 (CA), 31 (AA)																			
	PFNA-	0.004 (DW) 8.0 (CA) 8.0 (AA)																			
	PFBS-	0.600 (DW), 130000 (CA), 130000 (AA)																			
	PFHxS-	0.019 (DW), 10 (CA), 10 (AA)																			
	PFHpS-	0.020 (DW) 0.020 (CA) 0.020 (AA)																			
	PFDS-	0.020 (DW) 0.020 (CA) 0.020 (AA)																			
	PFBA-	7.6 (DW) 830 (CA) 830 (AA)																			

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
HI	PFPeA-	0.800 (DW) 0.800 (CA) 0.800 (AA)																			Applicable to groundwater that is a current or potential drinking water resource, where the surface water body is located within 150 meters of a release site. See other action levels and more information: https://health.hawaii.gov/heer/guidance/ehe-and-eals/
	PFHxA-	4.0 (DW), 6300 (CA) 48000 (AA)																			
	PFHpA-	0.040 (DW) 0.040 (CA) 0.040 (AA)																			
	PFDA-	0.004 (DW) 10 (CA) 10 (AA)																			
	PFUnDA-	0.010 (DW) 0.010 (CA) 0.010 (AA)																			
	PFDoDA-	0.013 (DW) 20 (CA) 20 (AA)																			
	PFTrDA-	0.013 (DW) 0.013 (CA) 0.013 (AA)																			
	PFTeDA-	0.130 (DW) 0.130 (CA) 0.130 (AA)																			
	PFOSA-	0.024 (DW)																			
	HFPO-DA-	0.160 (DW) 0.160 (CA) 0.160 (AA)																			

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
IL	PFOA	0.002 (MRL)	Animals (Rats/Cancer)	NTP 2018. TR-598	Liver/Pancreatic Tumors	20	LOAEL (0.97 mg/L)		300	3	10	3		chronic	3			Child: 0.78 L/day Adult: 2.5 L/day	Child Duration: 6 years Frequency: 350 days/year	Child and Adult Exposure	
	PFOS	0.0077	Animals (Rats/Developmental)	Luebker et al. 2005	Decreased body weight/Delayed eye opening	20	NOAEL (0.1 mg/kg-day)	0.000515	300	3	10	1		chronic	3		0.000002	0.78	Child age 0-6 years	Child and Adult Exposure	
	PFBS	1.2	Animals (Mice/Endocrine)	Feng et al. 2017	Decreased thyroid levels	20	$BMDL_{0.5SD}$	0.095	300	3	10	1		chronic	1		0.0003	0.78	Child age 0-6 years	Child and Adult Exposure	https://pcb.illinois.gov/Cases/GetCaseDetailsById?caseId=17099
	PFHxS	0.077	Animals (Rats/Endocrine)	Butenhoff et al 2009	Thyroid follicular damage	20	NOAEL (1 mg/kg-day)	0.0047	300	3	10	1		chronic			0.00002	0.78	Child age 0-6 years	Child and Adult Exposure	
	PFNA	0.012	Animals (Mice/Developmental)	Das et al. 2015	Decreased body weight/developmental delays	20	NOAEL (1 mg/kg-day)	0.001	300	3	10	1		chronic	2		0.000003	0.78	Child age 0-6 years	Child and Adult Exposure	
	HFPO-DA	0.012	Animals (Mice/Developmental)	DuPont-18405-1037, 2010	Reproductive effects and developmental delays	20	NOAEL (1 mg/kg-day)	0.01	3000	3	10	1	10	chronic	2		0.000003	0.78	Child age 0-6 years	Child and Adult Exposure	
MA	PFOS, PFOA, PFNA, PFHpA, PFHxS, PFDA	0.020*	Animals	Multiple	Based on mulitple endpoints and evidence of effects below EPA PODs for PFOA and PFOS; including: immunotoxicity, hepatotoxicity, thyroid effects, developmental effects.	20; to account for dietary and other exposures to PFAS subgroup addressed as well as potentially higher infant exposures.	NOAEL for PFOS, LOAEL for PFOA, equivalent to EPA values.	Equivalent to EPA values for PFOA and PFOS	1000 for PFOA, 100 for PFOS	3	10	10 for PFOA	3 for both PFOA and PFOS				$5x10^{-6}$ based on PFOS and PFOA value, which is applied to subgroup based on similarity in chemical strutures, toxicities, long serum half-lives.	0.054 L/kg/day (same as EPA value used in LHA derivation)	Body weight and water intake of lactating women (same as EPA value used in LHA derivation)	Lactating and pregnant women; fetus; nursing infants	https://www.mass.gov/lists/development-of-a-pfas-drinking-water-standard-mcl

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
ME	PFOA	750 (construction worker)																			
	PFOS	750 (construction worker)																			
	PFBS	400 (residential), 100,000 (construction worker)																			
	PFOS, PFOA, PFNA, PFHxS, PFHpA	0.07* (residential)																			
MI	PFOA	0.008	Animals (mice)	Onishchenko et al., 2011 and Koskela et al., 2016	Neurobehavioral effects and skeletal alterations	50	LOAEL		300	3	10	3	3	1			95th percentile, 50% RSC			https://dtmb.state.mi.us/ARS_Public/Transaction/RFRTransaction?TransactionID=29	
	PFOS	0.016	Animals (mice)	Dong et al., 2009	Immunotoxicity and Hepatotoxicity	50	NOAEL		30	3	10	1	1	1			95th percentile, 50% RSC				
	PFNA	0.006	Animals (mice)	Das et al., 2015	Reduced pup body weight	50	NOAEL		300	3	10	1	10	1			95th percentile, 50% RSC				
	PFHxA	400	Animals (rats)	Klaunig et al., 2015	Renal effects	20	BMDL		300	3	10	1	10	1			95th percentile, 20% RSC				
	PFHxS	0.051	Animals (rats)	NTP 2018 Tox-96 Report	Thyroid effects	50	BMDL		300	3	10	1	10	1			95th percentile, 50% RSC				
	PFBS	0.42	Animals (mice)	Feng et al., 2017	Thyroid effects	20	BMDL		300	3	10	1	10	1			95th percentile, 20% RSC				
	Gen X	0.37	Animals (mice)	DuPont 18405-1037, 2010	Reduced pup body weight, Hepatotoxicity	20	BMDL		300	3	10	1	3	3			95th percentile, 20% RSC				
	PFOA (GSI for drinking water source)	0.42	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity	n/a	LOAEL		3000	3	10	10		10			$1.53x10^{-5}$	2			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOA (GSI)	12	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity	n/a	LOAEL		3000	3	10	10		10			$1.53x10^{-5}$	0.01			
	PFOS (GSI for drinking water source)	0.011	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatoxicity, thyroid toxicity	n/a	NOAEL		30	3	10						$1.3667x10^{-5}$	2			
	PFOS (GSI)	0.012	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatoxicity, thyroid toxicity	n/a	NOAEL		30	3	10						$1.3367x10^{-5}$	0.01			

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
MN	PFOA (Short-term, Subchronic and chronic)	0.035	Animals (mice)	Lau et al., 2006	Developmental and liver effects, kidney effects, Immunotoxicity	50	38 mg/L serum concentration	0.0053	300	3	10	3	3				$1.8x10^{-5}$	95th percentile	Half-life 840 days; placental transfer 87%, 5.2% breastmilk transfer	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfoa.pdf
	PFOS (Short-term, Subchronic and chronic)	0.015	Animals (mice)	Dong et al., 2011	Immunotoxicity, adrenal, developmental effects, liver effects, thyroid effects	20 for older children and adults, 50 for infants/ young children	2.36 mg/L serum concentration	0.000307	100	3	10		3				$3.1x10^{-6}$	95th percentile	Half-life 1241 days; placental transfer 40%; 1.7% breastmilk transfer	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfos.pdf
	PFBA (Short-term, Subchronic and chronic)	7	Animals (rats)	NOTOX, 2007 and Butenhoff, 2007	Liver effects, Thyroid effects	50	3.01 mg/kg/day	0.38	100	3	10		3				$3.8x10^{-3}$	95th percentile	Half-life 72 hrs; placental transfer ND; breastmilk transfer ND	Infants and Adults	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfba2summ.pdf
	PFBS (Short-term and Subchronic)	3	Animals (mice)	Feng, 2017	Developmental effects, Thyroid effects, Reproduction	50	50 mg/kg/day	0.158	100	3	10		3				$1.6x10^{-3}$	95th percentile	Half-life 665 hrs; placental transfer ND; breastmilk transfer ND	Infants and Adults	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfbssummary.pdf
	PFBS (Chronic)	2	Animals (rats)	Lieder, 2009 and York, 2003	Kidney	20	45 mg/kg/day	0.129	300	3	10		3	3			$4.3x10^{-4}$	95th percentile	Half-life 665 hrs; placental transfer ND; breastmilk transfer ND	General Population	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfbssummary.pdf
	PFHxS (Short-term, Subchronic and chronic)	0.047	Animals (rats)	NTP, 2018	Thyroid effects, Liver effects	20 for older children and adults, 50 for infants/ young children	32.4 mg/L	0.00292	300	3	10		10				$9.7x10^{-6}$	95th percentile	Half-life 1935 days; placental transfer 70%; breastmilk transfer 1.4%	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfhxs.pdf
	PFHxA (Short-term, Subchronic and chronic)	0.2 [Short-term value was lower than calculated subchronic and chronic values. Therefore all durations set to short-term]	Animals (rats)	NTP, 2019	Developmental & Thyroid effects	20 for all durations	25.9 mg/kg/day	0.0958	300	3	10		10		decreased body weight	$3.2x10^{-4}$ (short-term), 0.00015 (subchronic & chronic)	95th percentile	Half-life 32 days *[TK model was not used. Placental transfer 2.26; breastmilk transfer- No data]*	General Population	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfhxa.pdf	
NC	PFOA	2	Animals (rats)	York et al., 2002, Butenhoff et al., 2004	Reduced pup body weight	20	LOAEL		3000	10	10	10	3	1				Assumed body weight and water consumption of adult	Daily exposure to human population	Adults	

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
NH	PFOA	0.012	Animal (mice)	Loveless et al., 2007	Hepatotoxicity	50	BMDL10		100	3	10		3				$6.1x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	
	PFOS	0.015	Animal (mice)	Dong et al., 2011	Immunosuppression	50	NOAEL		100	3	10		3				$3x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	
	PFNA	0.011	Animal (mice)	Das et al., 2015	Hepatotoxicity	50	BMDL10		100	3	10		3				$4.3x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	
	PFHxS	0.018	Animal (mice)	Chang et al., 2018 and Ali et al., 2019	Infertility	50	BMDLSD		300	3	10		3	3			$4x10^{-6}$	95th percentile	MDH Model	Fetus and Breastfeeding Infants	Ali, et al., 2019 https://pubmed.ncbi.nlm.nih.gov/31487490/
NJ	PFOA	0.014	Animals (mice)	Loveless et al., 2006	Hepatotoxicity	20	BMDL		300	3	10				10		$2x10^{-6}$	2 (70 kg body wt)	Default adult		Note: MCLs for PFOA, PFOS, and PFNA are also used as Groundwater Quality Standards.
	PFOS	0.013	Animals (mice)	Dong et al., 2009	Immunotoxicity	20	NOAEL		30	3	10						$1.8x10^{-6}$	2 (70 kg body wt)	Default adult		Note: MCLs for PFOA, PFOS, and PFNA are also used as Groundwater Quality Standards.
	PFNA	0.013	Animals (mice)	Das et al., 2015	Hepatotoxicity	50	BMDL		1000	3	10		3	10					200:1 serum: drinking water ratio		Note: MCLs for PFOA, PFOS, and PFNA are also used as Groundwater Quality Standards.
	Chloroperfluoropolyether carboxylates (ClPFPECAs)	0.002	Animals (rats)	RTC. 2016. Posted at https://www.nj.gov/dep/dsr/13-week-oral-toxicity-study-in-rats-2016.pdf	Hepatotoxicity	20	BMDL		3000	3	10		10	10			$2.8x10^{-7}$	2.4 (80 kg body wt)			Interim Specific Ground Water Quality Standard https://www.state.nj.us/dep/wms/bears/gwqs.htm and https://www.nj.gov/dep/dsr/supportdocs/ClPFPECAs-tsd.pdf
NM	PFOA	0.07*																			
	PFOS	0.07*																			
	PFHxS	0.07*																			
NY	PFOA	0.01																			
	PFOS	0.01																			

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
TX	PFBA	71	Animals (mice)	MDH	Hepatotoxicity		NOAEL (6.9 mg/kg/d)		2400	1	10		10	3			$2.9x10^{-3}$				Note: oral dose, 0.5 acre source area) (Res GWGWIng PCLs) https://www.tceq.texas.gov/assets/public/implementation/tox/evaluations/pfcs.pdf
	PFBuS	34	Animals (mice)	Leider et al., 2009, York et al., 2002	Systemic Toxicity		NOAEL (60 mg/kg/d)		42600	1	10		10	3			$1.4x10^{-3}$				
	PFPeA	0.093	Animals (mice)	Surrogate: PFHxS	Hematotoxicity		NOAEL (0.3 mg/kg/d)		78900	1	10	3	10				$3.8x10^{-6}$				
	PFHxS	0.093	Animals (mice)	Hoberman and York, 2003	Hematotoxicity		NOAEL (0.3 mg/kg/d)		78900	1	10	3	10				$3.8x10^{-6}$				
	PFHxA	0.093	Animals (mice)	Surrogate: PFHxS	Hematotoxicity		NOAEL (0.3 mg/kg/d)		78900	1	10	3	10				$3.8x10^{-6}$				
	PFHpA	0.56	Animals (mice)	Surrogate: PFOS	Neurodevelopment		NOAEL (0.6 mg/kg/d)		26300	1	10	10	1				$2.3x10^{-5}$				
	PFOS	0.56	Animals (mice)	Zeng et al., 2011	Neurodevelopment		NOAEL (0.6 mg/kg/d)		26300	1	10	10	1				$2.3x10^{-5}$				
	PFOA	0.29	Animals (mice)	Macon et al., 2011	Mammary gland development		NOAEL (0.3 mg/kg/d)		24300	1	10	30	1				$1.2x10^{-5}$				
	PFOSA	0.29	Animals (mice)	Surrogate: PFOA	Mammary gland development		NOAEL (0.3 mg/kg/d)		24300	1	10	30	1				$1.2x10^{-5}$				
	PFNA	0.29	Animals (mice)	Fang et al., 2010	Spleen Cell Death		NOAEL (1 mg/kg/d)		81000	1	10		10	10			$1.2x10^{-5}$				
	PFDeA	0.37	Animals (mice)	Kawashima et al., 1995	Hepatotoxicity		NOAEL (1.2 mg/kg/d)		81000	1	10		10	10			$1.5x10^{-5}$				
	PFDS	0.29	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)		81000	1	10		10	10			$1.2x10^{-5}$				
	PFUA	0.29	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)		81000	1	10		10	10			$1.2x10^{-5}$				
	PFDoA	0.29	Animals (mice)	Shi et al., 2007	Reduced Body Weight		NOAEL (1 mg/kg/d)		81000	1	10		10	10			$1.2x10^{-5}$				
	PFTrDA	0.29	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)		81000	1	10		10	10			$1.2x10^{-5}$				
	PFTeDA	0.29	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)		81000	1	10		10	10			$1.2x10^{-5}$				
VT	PFOA, PFOS, PFHxS, PFHpA, PFNA	0.02*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)		EPA (2016)									0.175 L/kg/day		0-1 year old	

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	HED (mg/kg/day)	UFs								RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
									Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints/ Subpopulations	Modifying Factor					
WI	PFOA	0.02 (combined)*	Animals (mice)	Lau et al., 2006	Developmental (reduced ossification)	100	LOAEL		300	10	3	10									https://www.dhs.wisconsin.gov/water/gws.htm
	PFOS	0.02 (combined)*	Animals (mice)	Luebker et al., 2005	Reduced pup body weight	100	NOAEL		30	3	10				10			1 (10 kg body wt)	Gestation and infancy (including breastfeeding)		
	FOSA, NEtFOSA, NEtFOSAA, NEtFOSE	0.02 (combined)*	PFOA and PFOS Precursor		Combined standard for PFOS, PFOA, FOSA, NEtFOSE, NEtFOSA, and NEtFOSAA	100												Combined			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFTeA	10	Animals (rats)	Hirata-Koizumi et al., 2015	Body weight	100	NOAEL (1 mg/kg/day)		1000	10	10	1	10	1	1		0.001	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFHxA	150	Animals (rats)	Klaunig, 2015	Clinical effects	100	NOAEL (15 mg/kg/day)		1000	10	10	1	10	1	1		0.015	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFUnA	3	Animals (rats)	Takahashi et al., 2014	Body weight	100	NOAEL (0.3 mg/kg/day)		1000	10	10	1	10	1	1		0.0003	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFDoA	0.5	Animals (rats)	Shi, 2009	Body weight and testosterone levels	100	NOAEL (0.05 mg/kg/day)		1000	10	10	1	10	1	1		$5x10^{-5}$	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFBA	10	Animals (rats)	van Otterdyk, Buttenholf 2012b	Hemotoxicity, hepatotoxicity, and thyroid toxicity	100	BMDL (MN) (3 mg/kg/day)		3000	10	10	1	10	3	1		0.001	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFBS	450	Animals (rats)	Lieder, 2009b	Nephrotoxicity	100	BMDL (MN) (45 mg/kg/day)		1000	10	10	1	10	1	1		0.045	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFNA	0.03	Animals (mice)	Das, 2015	Reproductive toxicty	100	NOAEL (1 mg/kg/day)	0.0011	300	3	10	1	1	1	10		$3x10^{-6}$	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFDA	0.3	Animals (mice)	Harris and Birnbaum 1989	Deveolpmental (Fetal growth)	100	NOAEL (0.03 mg/kg/day)		1000	10	10	1	10	1	1		$3x10^{-5}$	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFHxS	0.04	Animals (rats)	Cheng, 2018	Developmental and repoductive toxicity (Maternal and fetal growth)	100	NOAEL (0.3 mg/kg/day)		300	3	10	1	10	1	1		$4x10^{-6}$	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	PFODA	400	Animals (rats)	Hirata-Koizumi., 2012	Body weight	100	NOAEL (40 mg/kg/day)		1000	10	10	1	10	1	1		0.04	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	Gen X	0.3	Animals (mice)	Dupont, 2010b	Nephrotoxicity and hepatotoxicity	100	NOAEL (0.1 mg/kg/day)		3000	10	10	1	10	3	1		$3x10^{-5}$	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm
	DONA	3	Animals (rats)	Gordon, 2011	Hemotoxicity and hepatotoxicity	100	NOAEL (1 mg/kg/day)		3000	10	10	1	10	3	1		0.0003	1			https://www.dhs.wisconsin.gov/water/gws-cycle11.htm

*= Advisory level is based on the total of more than one PFAS

Appendix C: State Surface Water PFAS Guideline Criteria

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	POD	UFs					RfD (mg/kg/day)	Drinking Water Intake Rate (L/day)	Resources & Notes
							Total	Interspecies	Intraspecies	LOAEL to NOAEL	Duration of Exposure (i.e., Subchronic to Chronic)			
CO	PFOA, PFOS, PFNA	0.07*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)					EPA (2016)	EPA (2016)	
	PFBS	400	Animals (mice)	EPA RSL	EPA RSL	EPA RSL	EPA RSL					EPA RSL	EPA RSL	
	PFHxS	0.7	Animals (mice)											
FL	PFOA	0.5										$2x10^{-5}$		Screening levels derived through a Probabilistic Risk Assessment https://floridadep.gov/sites/default/files/PFOA_PFOS_Human_Health_Surface_Water_Prob_Risk_Assessment.pdf
	PFOS	0.01										$2x10^{-5}$		Screening levels derived through a Probabilistic Risk Assessment https://floridadep.gov/sites/default/files/PFOA_PFOS_Human_Health_Surface_Water_Prob_Risk_Assessment.pdf
HI	PFOA-	water [DW] toxicity), 8.5											0.54 L/kg/day	Drinking water action levels applied if aquatic toxicity action levels not available; chronic aquatic toxicity action level also used as acute aquatic toxicity action level if latter not available. Refer to technical memorandum for additional detail: https://health.hawaii.gov/heer/guidance/ehe-and-eals/
	PFOS-	0.04 (DW), 1.1 (CA), 31 (AA)												
	PFNA-	0.004 (DW) 8.0 (CA) 8.0 (AA)												
	PFBS-	0.600 (DW), 130000 (CA), 130000 (AA)												
	PFHxS-	0.019 (DW), 10 (CA), 10 (AA)												
	PFHpS-	0.020 (DW) 0.020 (CA) 0.020 (AA)												
	PFDS-	0.020 (DW) 0.020 (CA) 0.020 (AA)												
	PFBA-	7.6 (DW) 830 (CA) 830 (AA)												
	PFPeA-	0.800 (DW) 0.800 (CA) 0.800 (AA)												

State	PFAS Analyte(s)	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	POD	UFs					RfD (mg/kg/day)	Drinking Water Intake Rate (L/day)	Resources & Notes
							Total	Interspecies	Intraspecies	LOAEL to NOAEL	Duration of Exposure (i.e., Subchronic to Chronic)			
HI	PFHxA-	4.0 (DW), 6300 (CA) 48000 (AA)												Drinking water action levels applied if aquatic toxicity action levels not available; chronic aquatic toxicity action level also used as acute aquatic toxicity action level if latter not available. Refer to technical memorandum for additional detail: https://health.hawaii.gov/heer/guidance/ehe-and-eals/
	PFHpA-	0.040 (DW) 0.040 (CA) 0.040 (AA)												
	PFDA-	0.004 (DW) 10 (CA) 10 (AA)												
	PFUnDA-	0.010 (DW) 0.010 (CA) 0.010 (AA)												
	PFDoDA-	0.013 (DW) 20 (CA) 20 (AA)												
	PFTrDA-	0.013 (DW) 0.013 (CA) 0.013 (AA)												
	PFTeDA-	0.130 (DW) 0.130 (CA) 0.130 (AA)												
	PFOSA-	0.024 (DW) 0.024 (CA) 0.024 (AA)												
	HFPO-DA-	0.160 (DW) 0.160 (CA) 0.160 (AA)												
MI	PFOA (drinking water source)	0.42	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity	LOAEL	3000	3	10	10	10	$2x10^{-5}$	2	https://www.michigan.gov/egle/0,9429,7-135-3313_3681_3686_3728-11383--,00.html
	PFOA	12	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity	LOAEL	3000	3	10	10	10	$2x10^{-5}$	0.01	
	PFOS (drinking water source)	0.011	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity	NOAEL	30	3	10			$1.3667x10^{-5}$	2	
	PFOS	0.012	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity	NOAEL	30	3	10			$1.3667x10^{-5}$ mg/kg/day	0.01	

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	POD	UFs					RfD (mg/kg/day)	Drinking Water Intake Rate (L/day)	Resources & Notes
							Total	Interspecies	Intraspecies	LOAEL to NOAEL	Duration of Exposure (i.e., Subchronic to Chronic)			
HI	PFHxA-	4.0 (DW), 6300 (CA) 48000 (AA)												Drinking water action levels applied if aquatic toxicity action levels not available; chronic aquatic toxicity action level also used as acute aquatic toxicity action level if latter not available. Refer to technical memorandum for additional detail: https://health.hawaii.gov/heer/guidance/ehe-and-eals/
	PFHpA-	0.040 (DW) 0.040 (CA) 0.040 (AA)												
	PFDA-	0.004 (DW) 10 (CA) 10 (AA)												
	PFUnDA-	0.010 (DW) 0.010 (CA) 0.010 (AA)												
	PFDoDA-	0.013 (DW) 20 (CA) 20 (AA)												
	PFTrDA-	0.013 (DW) 0.013 (CA) 0.013 (AA)												
	PFTeDA-	0.130 (DW) 0.130 (CA) 0.130 (AA)												
	PFOSA-	0.024 (DW) 0.024 (CA) 0.024 (AA)												
	HFPO-DA-	0.160 (DW) 0.160 (CA) 0.160 (AA)												
MI	PFOA (drinking water source)	0.42	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity	LOAEL	3000	3	10	10	10	$2x10^{-5}$	2	https://www.michigan.gov/egle/0,9429,7-135-3313_3681_3686_3728-11383--,00.html
	PFOA	12	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity	LOAEL	3000	3	10	10	10	$2x10^{-5}$	0.01	
	PFOS (drinking water source)	0.011	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity	NOAEL	30	3	10			$1.3667x10^{-5}$	2	
	PFOS	0.012	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity	NOAEL	30	3	10			$1.3667x10^{-5}$ mg/kg/day	0.01	

State	PFAS	Guideline Level (ug/L)	Toxicity Data	Critical Effect Study	Endpoint	POD	UFs					RfD (mg/kg/day)	Drinking Water Intake Rate (L/day)	Resources & Notes
							Total	Interspecies	Intraspecies	LOAEL to NOAEL	Duration of Exposure (i.e., Subchronic to Chronic)			
MN	PFOS (in fish tissue and surface water)	0.37 nanograms per gram (fish tissue), 0.00005 ug/L	Animals (mice)	Dong et al., 2011	Immunotoxicity, adrenal, developmental effects, liver effects, thyroid effects	2.36 mg/L serum concentration	100	3	10			$3.1x10^{-6}$	95th percentile	For this standard, MN used a relative source contribution of 0.2, a fish consumption rate of 66 grams/70 kilograms, and a bioaccumulation factor of 7210 liters/kilogram for the water based standard. For more info: MPCA Water Quality Standards/ site-specific Water Quality Criteria: https://www.pca.state.mn.us/water/site-specific-water-quality-criteria
	PFOA, PFHxS, PFBA, and PFBS (in development... see notes).													MN is updating its surface water criteria for PFOA; the existing value is outdated and should not be used. MN is also developing new criteria PFHxS, PFBA, and PFBS. These criteria are expected to be available in mid- to late 2021. Note that these are site-specific criteria for the protection of human health (fish consumption and recreation).
NM	PFOA, PFOS	0.07*												
	HFPO-DA, NEtFOSAA, NMeFOSAA, PFBS, PFDA, PFDoA, PFHpA, PFHxS, PFHxA, PFNA, PFTA, PFTrDA, PFUnA, 11 C1-PF3OUdS, 9C1-PF3ONS, ADONA													Coverage under EPA's 2021 MSGP in NM requires monitoring and analyzing for 18 PFAS compounds using modified EPA Method 537.1. Only PFOA + PFOS are used for screening.
OR	PFOA	24												Note: The Oregon wastewater initiation levels were adopted into rule (OAR 340-045-0100, Table A) in 2011. The PFAS are 5 chemicals on a list of 118 persistent priority pollutants for water that Oregon DEQ developed in response to state legislation. Municipal wastewater treatment plants with effluent exceeding initiation levels are required to develop a pollution prevention plan that becomes a part of their NPDES permit. The list and associated initiation levels were developed in consultation with a science advisory committee.
	PFOS	300												
	PFNA	1												
	PFOSA	0.2												
	PFHpA	300												

*= Advisory level is based on the total of more than one PFAS

Appendix D: State Soil PFAS Guideline Criteria

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
AK	PFOA	2.2 in Arctic Zone, 1.6 under 40" zone, 1.3 over 40" zone, 0.003 migration to groundwater	Animals (mice)	Lau et al., 2006	Decreassed ossification of pup proximal phalanges, accelerated preputial separation	100	EPA (2016)	EPA (2016)									Residential exposure for 6 yrs old child receptor	Child	http://dec.alaska.gov/media/7543/20180201_pccl.pdf
	PFOS	2.2 in Arctic Zone, 1.6 under 40" zone, 1.3 over 40" zone, 0.0017 migration to groundwater	Animals (mice)	Luebker et al., 2005	Reduced pup body weight	100	EPA (2016)	EPA (2016)									Residential exposure for 6 yrs old child receptor	Child	http://dec.alaska.gov/media/7543/20180201_pccl.pdf
CT	PFOA, PFOS, PFHxS, PFHpA, PFNA	1.35 (residential), 41 (industrial/ commercial), 1.4 ug/kg (GA pollutant mobility criteria), 14 ug/kg (GB pollutant mobility criteria)															Residential and industrial/ commercial are for direct exposure criteria		
FL	PFOA	1.3 (residential), 25 (industrial/ commercial), 0.002 (leachability) Soil Cleanup Target Levels	Animals (mice)	Lau et al., 2006	Decreassed ossification of pup proximal phalanges, accelerated preputial separation	20	5.3x10^-3 mg/kg/day	300	3		10			10	$2x10^{-5}$	0.054 L/kg/day	Children- 200 mg/day, worker- 50 mg/day, oral	Children ages 0-6	
	PFOS	1.3 (residential), 25 (industrial/ commercial), 0.007 (leachability) Soil Cleanup Target Levels	Animals (mice)	Luebker et al., 2005	decreased weight	20	5.1x10^-4 mg/kg/day	30	3					10	$2x10^{-5}$	0.054 L/kg/day	Risk target level of 10^-6 and hazard quotient of 1	Children ages 0-6	

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
HI	PFOA-	0.025 (residential), 1.1 (industrial/commercial), 0.001 (dw leaching to gw), 0.25 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL	Children ages 0-6	Applicable to soil where potentially impacted groundwater is a current or potential drinking water resource and where the surface water body is located within 150 meters of a release site. Refer to technical memorandum for additional detail: https://health.hawaii.gov/heer/files/2020/12/PFASs-Techncal-Memo-HDOH-Dec-2020.pdf
	PFOS-	0.025 (residential), 1.1 (industrial/commercial), 0.007 (dw leaching to gw), 0.20 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFNA-	0.003 (residential), 0.12 (industrial/commercial), 0.0008 (dw leaching to gw), 1.4 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFBS-	0.38 (residential), 17 (industrial/commercial), 0.003 (dw leaching to gw), 260 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFHxS-	0.012 (residential), 0.55 (industrial/commercial), 0.002 (dw leaching to gw), 0.93 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFHpS-	0.013 (residential), 0.56 (industrial/commercial), 0.004 (dw leaching to gw), 0.004 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFDS-	0.013 (residential), 0.56 (industrial/commercial), 0.013 (dw leaching to gw), 0.013 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFBA-	4.8 (residential), 210 (industrial/commercial), 0.099 (dw leaching to gw), 11 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
HI	PFPeA-	0.51 (residential), 23 (industrial/commercial), 0.003 (dw leaching to gw), 0.003 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		Applicable to soil where potentially impacted groundwater is a current or potential drinking water resource and where the surface water body is located within 150 meters of a release site. Refer to technical memorandum for additional detail: https://health.hawaii.gov/heer/files/2020/12/PFASs-Techncal-Memo-HDOH-Dec-2020.pdf
	PFHxA-	2.5 (residential), 110 (industrial/commercial), 0.013 (dw leaching to gw), 21 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFHpA-	0.025 (residential), 1.1 (industrial/commercial), 0.0003 (dw leaching to gw), 0.0003 (non-dw leaching to gw)				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFDA-	0.003 (residential), 0.11 (industrial/commercial), 0.0005 (dw leaching to gw), 1.2 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFUnDA-	0.006 (residential), 0.28 (industrial/commercial), 0.004 (dw leaching to gw), 4.5 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFDoDA-	0.008 (residential), 0.38 (industrial/commercial), use lab test for leaching to gw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFTrDA-	0.008 (residential), 0.38 (industrial/commercial), use lab test for leaching to gw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFTeDA-	0.084 (residential), 3.8 (industrial/commercial), use lab test for leaching to gw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	PFOSA-	0.015 (residential), 0.68 (industrial/commercial), 50 (dw leaching to gw), 50 (non-dw				20											Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		
	HFPO-DA-	0.1 (residential), 4.5 (industrial/commercial), 0.0003 (dw leaching to gw), 0.0003 (non-dw leaching to gw)															Noncancer HQ =0 0.5, RSC = 20% and USEPA RSL default exposure parameter values. SESOIL		

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
IN	PFBS	1800 (residential), 16000 (commercial/ industrial), 34000 (evacuation worker)	Animals (mice)	EPA RSL Tables		100											Direct contact exposure duration of 250 days/year, or 100000 mg/kg (10% by weight)		
MA	PFOA	0.720 ug/kg	Based on soil background data; 90th percentile.																Note: Method 1 standards. Based on 90th percentile value of soil background data set from Vermont soils.
	PFOS	2.000 ug/kg	Based on soil background data; 90th percentile.																
	PFNA	0.320 ug/kg	Based on soil background data; 90th percentile.																
	PFHxS	0.300 ug/kg	Based on soil background data; 90th percentile.																
	PFHpA	0.500 ug/kg	Based on soil background data; 90th percentile.																
	PFDA	0.30 ug/kg	Based on soil background data; 90th percentile.																
ME	PFOA	0.0017 (leaching to groundwater), 1.7 (residential), 22 (commercial worker), 4.9 (park user), 5.7 recreator sediment, 5.1 (construction worker), 2.5 ng/g (soil beneficial use)																	

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
ME	PFOS	0.0036 (leaching to groundwater), 1.7 (residential), 22 (commercial worker), 4.9 (park user), 5.7 recreator sediment, 5.1 (construction worker), 5.2 ng/g (soil beneficial use)																	
	PFBS	7.1 (leaching to groundwater), 1,700 (residential), 22,000 (commercial worker), 4,900 (park user), 5,700 recreator sediment, 51,000 (construction worker), 1,900 ng/g (soil beneficial use)																	
MI	PFOA	10	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity		LOAEL (3 mg/kg/day)	3000	3	10	10		10		$2x10^{-5}$	0.01			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOA (drinking water source)	0.35	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity		LOAEL (3 mg/kg/day)	3000	3	10	10		10		$2x10^{-5}$	2			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOS	0.00024	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity		NOAEL (0.03 mg/kg/day)	30	3	10					$1.3667x10^{-5}$	0.01			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOS (drinking water source)	0.00022	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity		NOAEL (0.03 mg/kg/day)	30	3	10					$1.3667x10^{-5}$	2			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
MI	PFOA	10	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity		LOAEL (3 mg/kg/day)	3000	3	10	10		10		$2x10^{-5}$	0.01			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOA (drinking water source)	0.35	Animals (primates)	Butenhoff et al., 2002	Hepatotoxicity		LOAEL (3 mg/kg/day)	3000	3	10	10		10		$2x10^{-5}$	2			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOS	0.00024	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity		NOAEL (0.03 mg/kg/day)	30	3	10					$1.3667x10^{-5}$	0.01			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
	PFOS (drinking water source)	0.00022	Animals (primates)	Seacat et al., 2002	Decreased body weight, hepatotoxicity, thyroid toxicity		NOAEL (0.03 mg/kg/day)	30	3	10					$1.3667x10^{-5}$	2			https://www.michigan.gov/egle/0,9429,7-135-3311_4109-251790--,00.html
MN	PFOA	0.24 (res/rec), 3.2 (com/ind)	Animals (mice)	Numerous	Developmental, liver, immune, kidney	20	38 mg/L serum concentration	300	3	10	3	3			$1.8x10^{-5}$		Residential/ Recreational, Commercial/ Industrial	Children and adults	Refer to MPCA website for the most up-to-date soil reference values (SRVs) https://www.pca.state.mn.us/waste/cleanup-guidance
	PFOS	0.041 (res/rec), 0.56 (com/ind)	Animals (mice)	Numerous	Developmental, liver, thyroid, immune, adrenal	20	2.36 ug/L serum concentration	100	3	10		3			$3.1x10^{-6}$		Residential/ Recreational, Commercial/ Industrial	Children and adults	
	PFBA	63 (res/rec), 280 (com/ind)	Animals (rats)	Numerous	Liver, thyroid, developmental, blood	20	6.9 mg/kg/day	300	3	10		10			$2.9x10^{-3}$		Residential/ Recreational, Commercial/ Industrial	Children and adults	
	PFBS	5.7 (res/rec), 77 (com/ind)	Animals (rats)	Numerous	Kidney	20	45 mg/kg/day	300	3	10		3	3		$1.4x10^{-3}$		Residential/ Recreational, Commercial/ Industrial	Children and adults	
	PFHxS	0.13 (res/rec), 1.7 (com/ind)	Animals (rats)	Numerous	Liver, thyroid	20	32.4 ug/mL	300	3	10		10			$9.7x10^{-6}$		Residential/ Recreational, Commercial/ Industrial	Children and adults	

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
NH	PFOA	0.2 (residential), 1.3 (maintenance worker)				0.2									$6.1x10^{-6}$		Residential (young child), Maintenance worker (outdoor)		https://www4.des.state.nh.us/nh-pfas-investigation/wp-content/uploads/PFAS-DCRB-value-121119.pdf
	PFOS	0.1 (residential), 0.6 (maintenance worker)				0.2									$3x10^{-6}$		Residential (young child), Maintenance worker (outdoor)		https://www4.des.state.nh.us/nh-pfas-investigation/wp-content/uploads/PFAS-DCRB-value-121119.pdf
	PFHxS	0.1 (residential), 0.9 (maintenance worker)				0.2									$4x10^{-6}$		Residential (young child), Maintenance worker (outdoor)		https://www4.des.state.nh.us/nh-pfas-investigation/wp-content/uploads/PFAS-DCRB-value-121119.pdf
	PFNA	0.1 (residential), 0.9 (maintenance worker)				0.2									$4.3x10^{-6}$		Residential (young child), Maintenance worker (outdoor)		https://www4.des.state.nh.us/nh-pfas-investigation/wp-content/uploads/PFAS-DCRB-value-121119.pdf
NM	PFOS	1.56 (residential) 26.0 (industrial) 7.08 (construction)																	20.6.2.4103.A of the New Mexico Administrative Code, implemented in conjunction with NMED's 2019 Risk Assessment Guidance
	PFOA	1.56 (residential) 26.0 (industrial) 7.08 (construction)																	
	PFHxS	1.56 (residential) 26.0 (industrial) 7.08 (construction)																	

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
NY	PFOA	0.66 ug/kg (unrestricted), 6.6 ug/kg (residential), 33 ug/kg (restricted residential), 500 ug/kg (commercial), 600 ug/kg (industrial), 1.1 ug/kg (protection of groundwater)																	
	PFOS	0.88 ug/kg (unrestricted), 8.8 ug/kg (residential), 44 ug/kg (restricted residential), 440 ug/kg (commercial), 440 ug/kg (industrial), 3.7 ug/kg (protection of groundwater)																	
TX	PFBA	0.2	Animals (mice)	MDH	Hepatotoxicity		NOAEL (6.9 mg/kg/d)	2400	1	10		10	3		$2.9x10^{-3}$				Note: oral dose, 0.5 acre source area) (Res GWSoiling PCLs) https://www.tceq.texas.gov/assets/public/implementation/tox/evaluations/pfcs.pdf
	PFBuS	0.11	Animals (mice)	Leider et al., 2009, York et al., 2002	Systemic Toxicity		NOAEL (60 mg/kg/d)	42600	1	10		10	3		$1.4x10^{-3}$				
	PFPeA	0.00032	Animals (mice)	Surrogate: PFHxS	Hematotoxicity		NOAEL (0.3 mg/kg/d)	78900	1	10	3	10			$3.8x10^{-6}$				
	PFHxS	0.002	Animals (mice)	Hoberman and York, 2003	Hematotoxicity		NOAEL (0.3 mg/kg/d)	78900	1	10	3	10			$3.8x10^{-6}$				
	PFHxA	0.00048	Animals (mice)	Surrogate: PFHxS	Hematotoxicity		NOAEL (0.3 mg/kg/d)	78900	1	10	3	10			$3.8x10^{-6}$				
	PFHpA	0.0046	Animals (mice)	Surrogate: PFOS	Neurodevelopment		NOAEL (0.6 mg/kg/d)	26300	1	10	10	1			$2.3x10^{-5}$				
	PFOS	0.05	Animals (mice)	Zeng et al., 2011	Neurodevelopment		NOAEL (0.6 mg/kg/d)	26300	1	10	10	1			$2.3x10^{-5}$				
	PFOA	0.003	Animals (mice)	Macon et al., 2011	Mammary gland development		NOAEL (0.3 mg/kg/d)	24300	1	10	30	1			$1.2x10^{-5}$				

State	PFAS	Guideline Level (mg/kg, unless otherwise specified)	Toxicity Data	Critical Effect Study	Endpoint	RSC (%)	POD	UFs							RfD (mg/kg/day)	Drinking Water Intake Rate (L/day unless otherwise specified)	Exposure assumptions	Target Populations	Resources & Notes
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)	Sensitive Developmental Endpoints					
TX	PFOSA	0.92	Animals (mice)	Surrogate: PFOA	Mammary gland development		NOAEL (0.3 mg/kg/d)	24300	1	10	30	1			$1.2x10^{-5}$				
	PFNA	0.0031	Animals (mice)	Fang et al., 2010	Spleen Cell Death		NOAEL (1 mg/kg/d)	81000	1	10		10	10		$1.2x10^{-5}$				
	PFDeA	0.022	Animals (mice)	Kawashima et al., 1995	Hepatotoxicity		NOAEL (1.2 mg/kg/d)	81000	1	10		10	10		$1.5x10^{-5}$				
	PFDS	0.04	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)	81000	1	10		10	10		$1.2x10^{-5}$				
	PFUA	0.018	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)	81000	1	10		10	10		$1.2x10^{-5}$				
	PFDoA	0.034	Animals (mice)	Shi et al., 2007	Reduced Body Weight		NOAEL (1 mg/kg/d)	81000	1	10		10	10		$1.2x10^{-5}$				
	PFTrDA	0.061	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)	81000	1	10		10	10		$1.2x10^{-5}$				
	PFTeDA	0.11	Animals (mice)	Surrogate: PFDoA	Reduced Body Weight		NOAEL (1 mg/kg/d)	81000	1	10		10	10		$1.2x10^{-5}$				
VT	PFOA, PFOS, PFHxS, PFHpA, PFNA	1.22*	Animals (mice)	EPA (2016)	EPA (2016)	20	EPA (2016)	EPA (2016)								0.175 L/kg/day			
WI	PFOA	1.26 (residential), 16.4 (composite [industrial] worker)		EPA RSL Tables									26 yrs, 350 days/yr, 24 hrs (residential), 25 yrs, 250 days/yr, 8 hrs (composite worker)		$2x10^{-5}$		Vary through life (residential), 80 kg wt, 100 mg/day intake (composite worker) THQ=1, cancer risk 1x10-6, other default assumptions	Residential, Composite Worker	EPA RSL calculator
	PFOS	1.26 (residential), 16.4 (composite [industrial] worker)		EPA RSL Tables									26 yrs, 350 days/yr, 24 hrs (residential), 25 yrs, 250 days/yr, 8 hrs (composite worker)		$2x10^{-5}$		Vary through life (residential), 80 kg wt, 100 mg/day intake (composite worker) THQ=1, cancer risk 1x10-6, other default assumptions	Residential, Composite Worker	EPA RSL calculator
	PFBS	19 (residential), 246 (composite [industrial] worker)		EPA RSL Tables									26 yrs, 350 days/yr, 24 hrs (residential), 25 yrs, 250 days/yr, 8 hrs (composite worker)		$3x10^{-4}$		Vary through life (residential), 80 kg wt, 100 mg/day intake (composite worker) THQ=1, cancer risk 1x10-6, other default assumptions	Residential, Composite Worker	EPA RSL calculator

*= Advisory level is based on the total of more than one PFAS

Appendix E: State Air PFAS Guideline Criteria

State	PFAS	Guideline Level (µg/m^3)	Toxicity Data	Critical Effect Study	Endpoint	POD	HED (mg/kg/day)	UFs						RfD (mg/kg/day)	Route-to-Route Extrapolation	Exposure Parameters	Target Populations	Resources
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)					
MI	PFOA (initial threshold screening level; ITSL)	0.07	Animals (mice)	EPA, 2016; Butenhoff et al., 2004; Lau, 2006	Acute, Reproductive/ Developmental		0.0053; 0.0064	300	3	10	10		2 generations +developmental	2x10^{-5}	Air Value (ITSL) = RfD x 70kg/20m^3	Continuous over time period= 24 hours	Sensitive indivuals	http://www.deq.state.mi.us/aps/downloads/ATSL/335-67-1/335-
	PFOS (initial threshold screening level; ITSL)	0.07	Animals (rats)	EPA, 2016; Luebker et al., 2005	Acute, Reproductive/ Developmental		0.00051	30	10	3			2 generations +developmental	2x10^{-5}	Air Value (ITSL) = RfD x 70kg/20m^3	Continuous over time period= 24 hours	Sensitive indivuals	http://www.deq.state.mi.us/aps/downloads/ATSL/1763-23-1/1763-23-1_24hr_ITSL.pdf
	6:2 FTS	1	Animals (rats)	ECHA, 2020; Rat, subchronic, oral	Cardiac	NOAEL 5 mg/kg	1.18	3000	3	10		10	10	0.00039	Air Value (ITSL) = RfD x 70kg/20m^3	Continuous over time period= annual (chronic)	Sensitive indivuals	http://www.deq.state.mi.us/aps/downloads/ATSL/27619-97-2/
MN	PFOS (st, sc, c)	0.011	Animals (mice)	Dong et al., 2011	Adrenal, Developmental, Hepatic (liver) system, Immune, Thyroid	2.36 mg/L serum conc	0.000307	100	3	10		3		0.0000031	RfD (mg/kg-d) x (70 kg/20 m3-d) x (1000 µg/mg)	inhalation rate per day of 20m3/d and average body weight of 70kg	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfos.pdf
	PFHxS (st, sc, c)	0.034	Animals (rat)	NTP, 2018	Hepatic (liver) system, Thyroid	32.4 mg/L serum conc	0.00292	300	3	10		10		0.0000097	RfD (mg/kg-d) x (70 kg/20 m3-d) x (1000 µg/mg)	inhalation rate per day of 20m3/d and average body weight of 70kg	Fetus and Breastfeeding Infants	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfhxs.pdf
	PFBA (st, sc, c)	10	Animals (rat)	NOTOX, 2007 and Butenhoff, 2007	st -liver and thyroid; sc and c - Developmental, blood system, liver system, Thyroid	st = 3.01 sc = 6.9 c = 6.9	st = 0.38 sc = 0.86 c = 0.86	st =100 sc = 300 c = 300	st = 3 sc = 3 c = 3	st = 10 sc = 10 c = 10		st = 3 sc = 10 c = 10		st = 0.0038 sc = 0.0029 c = 0.0029	RfD (mg/kg-d) x (70 kg/20 m3-d) x (1000 µg/mg)	inhalation rate per day of 20m3/d and average body weight of 70kg	Infants and Adults	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfba.pdf

State	PFAS	Guideline Level (µg/m^3)	Toxicity Data	Critical Effect Study	Endpoint	POD	HED (mg/kg/day)	UFs						RfD (mg/kg/day)	Route-to-Route Extrapolation	Exposure Parameters	Target Populations	Resources
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)					
NH	APFO (CAS #3825-26-1; 24-hr Ambient Air Limit)	Regulatory Level 0.05	Animals (rats)	ACGIH TLV	Acute, Reproductive/ Developmental													
	APFO (CAS #3825-26-1; Annual Ambient Air Limit)	Regulatory Level 0.024	Animals (rats)	ACGIH TLV	Acute, Reproductive/ Developmental													
NJ	PFOA (Reference Concentration)	0.007	Animals (mice)	Loveless et al., 2006	Hepatotoxicity	BMDL		300	3	10			10	$2x10^{-6}$	Reference Concentration = RfD x 70kg/20m^3	30 day averaging time	Infants and Adults	Based on route-to-route extrapolation from RfD (2 ng/kg/day) used for NJ MCL https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixa.pdf
	PFOS (Reference Concentration)	0.006	Animals (mice)	Dong et al., 2009	Immunotoxicity	NOAEL		30	3	10				$1.8x10^{-6}$	Reference Concentration = RfD x 70kg/20m^3	30 day averaging time	Infants and Adults	Based on route-to-route extrapolation from RfD (1.8 ng/kg/day) used for NJ MCL https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-a.pdf
	HFPO-DA (GenX) (Screening Reference Concentration)	0.01	Animals (mice)	DuPont 18405-1037, 2010; NTP, 2019.	Hepatotoxicity	BMDL		3000	3	10		10	10	$3x10^{-6}$	Reference Concentration = RfD x 70kg/20m^3		Infants and Adults	Based on route-to-route extrapolation from EPA RfD (3 ng/kg/day) https://www.epa.gov/system/files/documents/2021-10/genx-chemicals-toxicity-assessment_tech-edited_oct-21-508.pdf

State	PFAS	Guideline Level (µg/m^3)	Toxicity Data	Critical Effect Study	Endpoint	POD	HED (mg/kg/day)	UFs						RfD (mg/kg/day)	Route-to-Route Extrapolation	Exposure Parameters	Target Populations	Resources
								Total	Interspecies	Intraspecies	LOAEL to NOAEL	Database Limitation	Duration of Exposure (i.e., Subchronic to Chronic)					
TX	PFOA (ESL) (CAS #335-67-1; based on annual average)	0.005		Republic of Germany DFG Maximum Concentration at the Workplace				1000								Occupational Exposure Limit		
	PFOS (ESL) (CAS #1763-23-1; based on annual average)	0.01		Republic of Germany DFG Maximum Concentration at the Workplace				100								Occupational Exposure Limit		

*= Advisory level is based on the total of more than one PFAS

Appendix F: State Fish and Wildlife Consumption PFAS Guideline Criteria

State	Media	PFAS	Guideline Level (unit specified)	Frequency	Target Populations	Resources & Notes
AL	Fish	PFOS	>156 ppb	1 meal per week	General Population	
	Fish	PFOS	>800 ppb	Do Not Eat	General Population	
CT	Fish and Shellfish	PFOA, PFOS	<20 ppb	No consumption advice (unlimited consumption)	General Population	
	Fish and Shellfish	PFOA, PFOS	20 to <40 ppb	No more than 1 meal per week	General Population	
	Fish and Shellfish	PFOA, PFOS	40 to <159 ppb	No more than 1 meal per month	General Population	
	Fish and Shellfish	PFOA, PFOS	≥159 ppb	Do Not Eat	General Population	
ME	Fish	PFOA	0.052 mg/kg		Recreational Angler	
	Fish	PFOS	0.052 mg/kg		Recreational Angler	
	Fish	PFBS	52 mg/kg		Recreational Angler	
	Milk	PFOS	210 ug/L			
	Beef	PFOS	3.4 ng/g			
MI	Fish	PFOS	≤9 ppb	16 meals per month	All Populations	
	Fish	PFOS	>9-13 ppb	12 meals per month	All Populations	
	Fish	PFOS	>13-19 ppb	8 meals per month	All Populations	
	Fish	PFOS	>19-38 ppb	4 meals per month	All Populations	
	Fish	PFOS	>38-75	2 meals per month	All Populations	
	Fish	PFOS	>75-150	1 meal per month	All Populations	
	Fish	PFOS	>150-300	6 meals per year	All Populations	
	Fish	PFOS	>300 ppb	Do Not Eat	All Populations	
	Deer	PFOS	>300 ppb	Do Not Eat	All Populations	

State	Media	PFAS	Guideline Level (unit specified)	Frequency	Target Populations	Resources & Notes
MN	Fish	PFOS	>10-20 ppb	2 meals per week	All Populations	
	Fish	PFOS	>20-50 ppb	1 meal per week	All Populations	
	Fish	PFOS	>50-200 ppb	1 meal per month	All Populations	
	Fish	PFOS	>200 ppb	Do Not Eat	All Populations	
NJ	Fish	PFOS	0.56 ng/g; ppb	Unlimited (based on daily)	General Population and High Risk Population	
	Fish	PFOS	3.9 ng/g; ppb	1 meal per week	General Population and High Risk Population	
	Fish	PFOS	17 ng/g; ppb	1 meal per month	General Population and High Risk Population	
	Fish	PFOS	>17 ng/g; ppb	Do Not Eat	High Risk Population	
	Fish	PFOS	51 ng/g; ppb	1 meal every 3 months	General Population	
	Fish	PFOS	204 ng/g; ppb	1 meal per year	General Population	
	Fish	PFOS	>204 ng/g; ppb	Do Not Eat	General Population	
	Fish	PFNA	0.23 ng/g; ppb	Unlimited (based on daily)	General Population and High Risk Population	
	Fish	PFNA	1.6 ng/g; ppb	1 meal per week	General Population and High Risk Population	
	Fish	PFNA	6.9 ng/g; ppb	1 meal per month	General Population and High Risk Population	
	Fish	PFNA	>6.9 ng/g; ppb	Do Not Eat	High Risk Population	
	Fish	PFNA	21 ng/g; ppb	1 meal every 3 months	General Population	
	Fish	PFNA	84 ng/g; ppb	1 meal per year	General Population	
	Fish	PFNA	>84 ng/g; ppb	Do Not Eat	General Population	
	Fish	PFOA	0.62 ng/g; ppb	Unlimited (based on daily)	General Population and High Risk Population	
	Fish	PFOA	4.3 ng/g; ppb	1 meal per week	General Population and High Risk Population	
	Fish	PFOA	19 ng/g; ppb	1 meal per month	General Population and High Risk Population	
	Fish	PFOA	>19 ng/g; ppb	Do Not Eat	High Risk Population	
	Fish	PFOA	57 ng/g; ppb	1 meal every 3 months	General Population	
	Fish	PFOA	226 ng/g; ppb	1 meal per year	General Population	
	Fish	PFOA	>226 ng/g; ppb	Do Not Eat	General Population	

State	Media	PFAS	Guideline Level (unit specified)	Frequency	Target Populations	Resources & Notes
NY	Fish	PFOS	<50 ppb	4 meals per month	General Population	
	Fish	PFOS	>50-200 ppb	1 meal per month	General Population	
	Fish	PFOS	>50 ppb	Do Not Eat	Sensitive Population	
	Fish	PFOS	>200 ppb	Do Not Eat	General Population	
WA	Fish	PFOS	23 ng/g		General Population	In process
	Fish	PFOS	8 ng/g		High consumers	In process
WI	Fish	PFOS	10-50 ppb	1 meal per week	All Populations	
	Fish	PFOS	50-200 ppb	1 meal per month	All Populations	
	Fish	PFOS	>200 ppb	Do Not Eat	All Populations	
	Wildlife	PFOS	10-50 ppb	1 meal per week	All Populations	
	Wildlife	PFOS	50-200 ppb	1 meal per month	All Populations	
	Wildlife	PFOS	>200 ppb	Do Not Eat	All Populations	