VERMONT AGENCY OF NATURAL RESOURCES

State of Vermont Plan

Deriving Ambient Water Quality Standards for the Emerging Chemicals of Concern: Per- and Polyfluoroalkyl Substances (PFAS)

Prepared for the Vermont General Assembly in Accordance with No. 21 of the Acts and Resolves of 2019 (Session 2019).

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AGENCY OF NATURAL RESOURCES
Department of Environmental Conservation

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Executive Summary

Act No. 21 of 2019 requires the Vermont Agency of Natural Resources (ANR) to develop a plan for the adoption of surface water quality standards for certain per- and polyfluoroalkyl substances (PFAS) by January 15, 2020. Additionally, Act 21 requires that ANR file a final rule to adopt surface water quality standards for certain PFAS no later than January 1, 2024.[i]

> Sec. 5. VERMONT WATER QUALITY STANDARDS; PER AND POLYFLUOROALKYL SUBSTANCES
>
> (a) On or before January 15, 2020, the Secretary of Natural Resources shall publish a plan for public review and comment for adoption of surface water quality standards for per and polyfluoroalkyl substances (PFAS) that shall include, at a minimum, a proposal for standards for:
>
> > (1) perfluorooctanoic acid ["PFOA"]; perfluorooctane sulfonic acid ["PFOS"]; perfluorohexane sulfonic acid ["PFHxS"]; perfluorononanoic acid ["PFNA"]; and perfluoroheptanoic acid ["PFHpA"]; and
> >
> > (2) the PFAS class of compounds or subgroups of the PFAS class of compounds.
>
> (b) On or before January 1, 2024, the Secretary of Natural Resources shall file a final rule with the Secretary of State to adopt surface water quality standards for, at a minimum, perfluorooctanoic acid, perfluorooctane sulfonic acid, perfluorohexane sulfonic acid, perfluorononanoic acid, and perfluoroheptanoic acid.

This plan describes the framework that ANR uses to establish surface water quality standards, and how this framework may apply to the development of state-specific water quality standards to protect both human health and aquatic life from PFAS. Developing water quality standards for PFAS would represent ANR's first undertaking to establish water quality standards for a group of chemical contaminants that currently are not included in the Environmental Protection Agency's (EPA) Clean Water Act Section 304(a) National Recommended Water Quality Criteria. This plan also outlines potential challenges, data gaps, and potential costs associated with developing Vermont-specific standards in the absence of EPA-established PFAS criteria.

In summary, in light of the technical, logistical, and resource-driven challenges in deriving Vermont-specific PFAS water quality criteria, ANR recommends against developing Vermont-specific criteria for the PFAS identified in Act 21 at this time. The plan outlines a three-phased approach to meet Act 21's directive. This approach proposes to integrate the question as to whether to establish surface water quality standards for a class or subgroups of PFAS into the Advance Notice of Proposed Rulemaking (ANPR) process pertaining to the regulation of PFAS as a class or subgroup within the Water Supply Rule.

ANR makes the following recommendations:

1. Initiate State fish contaminant monitoring for PFAS to evaluate the impacts of PFAS on aquatic resources and provide data in support of a fish consumption advisory and future numeric standard.
    - Currently, Vermont has limited data on PFAS concentrations in surface water and in fish tissues. In order to further understand the scope of harm that PFAS presents to human health and natural resources, the ANR will propose a testing program for PFAS as a part of the third statewide sampling plan expected to be issued in July 2020. Sampling done as a part of this plan will be coordinated with other states and regionally to maximize the value of the data.
2. Establish Human Health Criteria Using Fish Tissue Concentrations.

- The State has sufficient data to establish fish consumption advisories for Vermont-regulated PFAS. Fish consumption advisories have been used in the past with other contaminants of concern to limit exposure to known contaminants. The data needed to implement this approach is available and ANR will use data gathered in the monitoring program to issue advisories when the monitoring data warrants.

- In order to establish a numeric water quality standard for the Vermont-regulated PFAS, the ANR would need to develop toxicity data for several of the Vermont-regulated PFAS (PFHxS, PFHpA, and PFNA) and develop bioaccumulation factors for all Vermont-regulated PFAS. The estimated costs associated with developing this information ranges from $2.8 million to $5.9 million.

3. Establish programs to control PFAS sources to wastewater treatment plants.

   - In light of the pervasive nature of PFAS contamination in industrial and commercial applications, the State should develop programs to identify the sources of PFAS discharges to wastewater treatment plants and explore options for eliminating the use of PFAS or treating prior to discharging to a wastewater treatment facility.

   - The ANR proposes to develop a working group consisting of Agency experts, municipal wastewater treatment facility operators, and outside experts with expertise in industrial and commercial processes that use PFAS to develop educational and outreach materials for wastewater treatment facilities, commercial and industrial PFAS users, and state regulators on what processes use PFAS, what alternatives exist for PFAS, and how to effectively treat PFAS.

   - The ANR also proposes to test additional wastewater treatment facilities' influent and effluent for the presence of Vermont-regulated PFAS and provide technical assistance to municipalities to identify PFAS sources and tools to manage them.

4. Work with federal and state partners to develop aquatic biota criteria for PFAS.

   - EPA has developed an Action Plan for PFAS[ii] that includes research to support development of ambient water quality criteria for aquatic life for PFOA and PFOS by 2022. Once EPA has developed ambient water quality criteria, they could be utilized as a foundation to modify Vermont's Water Quality Standards.

   - The ANR and New Hampshire Department of Environmental Services (NHDES) have been working closely as each Agency develops a plan to adopt ambient water quality criteria for aquatic life. This shared sense of commitment will continue as each state develops plans and source control strategies to help manage the threats of PFAS into the future.

1. Introduction

1.1. Overview of this Plan

Act 21 requires ANR to issue a plan by January 15, 2020 (Act 21, 2019)[iii] to develop surface water quality standards for five PFAS: perfluorooctanoic acid ("PFOA"); perfluorooctane sulfonic acid ("PFOS"); perfluorohexane sulfonic acid ("PFHxS"); perfluorononanoic acid ("PFNA"); and perfluoroheptanoic acid ("PFHpA") (hereinafter collectively referred to as "Vermont-regulated PFAS"). The Act also requires ANR to adopt these PFAS standards through the state's formal rule-making process by January 1, 2024. This plan is developed to meet the requirements of Act 21.

- The remainder of Chapter One provides background on PFAS chemicals: what they are, how they are used, their chemical properties, and associated risks pertaining to human health and the environment. Table 1 of this chapter (below) provides an overview of tasks and associated timelines (including those required by Act 21) that would be involved in the development of Vermont-specific surface water quality standards for PFAS. These steps are further discussed in subsequent chapters of this plan.
- Chapter Two provides background on the process for establishing water quality standards at both the state and federal level.
- Chapter Three outlines the regulatory and resource-related challenges in adopting state-specific PFAS criteria in the absence of federal water quality criteria and more generally.
- Chapter Four addresses a requirement of Act 21 to propose water quality standards for the class of compounds or subgroups of the PFAS class of compounds. This chapter includes a proposal by ANR to implement three phases with respect to the question of managing PFAS as a class or subgroups pertaining to water quality standards
- Chapter Five describes the steps to establish PFAS-specific human health water quality criteria for purposes of a state-specific surface water standard, and current data needs associated with implementing those steps.
- Chapter Six describes the steps to establish PFAS-specific aquatic life water quality criteria for purposes of a state-specific surface water standard, and current data needs associated with implementing those steps.
- Chapter Seven summarizes Vermont's data needs, resource constraints, and conclusions and recommendations associated with development of surface water quality standards for PFAS.
- Chapter Eight is a bibliography of information resources referenced during the development of this plan.

Table 1: ANR Timeline for the Development of Vermont Water Quality Standards Pertaining to PFAS (* = Act 21 Requirement)			
No.	Category	Task Description	Timeline
1	Plan Development/ Monitoring	Collaborate with NH, other states, tribes, and research institutions in development and implementation of this plan. Collaborate with NH to monitor progress of other states and EPA in water quality standards development	On-going
2*	Plan Development	Publish public draft plan to adopt surface water quality standards for five PFAS and PFAS class/subgroups.	February 1, 2020
3	Plan Development	Publish final plan to adopt surface water quality standards including public response to public comments.	June 1, 2020
4*	Evaluation of PFAS as a Class or Subgroups	Publish for public notice and comment an advanced notice of proposed rulemaking on the regulation of PFAS as a class or subclasses under the Water Supply Rule and Vermont Water Quality Standards.	August 1, 2020 (for Water Supply Rule)
5*	Evaluation of PFAS as a Class or Subgroups	Submission of (including response to public comments) either: (a) Proposed Water Supply Rule to regulate PFAS as a class or subclasses with Secretary of State and confirm similar proposed update to Environmental Protection Rule Chapter 29A Water Quality Standards; or (b) Notice of decision not to regulate PFAS as a class or subclasses under the Water Supply and Environmental Protection Rules.	March 1, 2021 (deadline pertains to Water Supply Rule)
6*	Evaluation of PFAS as a Class or Subgroups	If ANR proposes update to Water Supply and Environmental Protection Rules by March 1, 2021 (Task 5a above), file final proposed rules regarding the regulation of PFAS as a class or subclasses.	December 31, 2021
7	WQS Development	Continue to collaborate with NH and seek opportunities to work with other states on plan implementation for the protection of human health and aquatic life from PFAS risks. Evaluate aquatic organism tissue concentrations as alternative to water column human health criteria.	2020-2023
8	Rule-Making Process	File with the Interagency Committee on Administrative Rules (ICAR) the proposed update to the Environmental Protection Rule Chapter 29A Vermont Water Quality Standards to include PFAS	2023
9	Rule-Making Process	File the proposed Environmental Protection Rule Chapter 29A Vermont Water Quality Standards with Secretary of State	2023
10	Rule-Making Process	Hold public hearings to receive comments on the Proposed Update to the Environmental Protection Rule Chapter 29A Vermont Water Quality Standards	2023
11	Rule-Making Process	Publish response to public comments on Proposed Update to the Environmental Protection Rule Chapter 29A Vermont Water Quality Standards	2023
12	Rule-Making Process	File the Proposed Update to the Environmental Protection Rule Chapter 29A Vermont Water Quality Standards with the Legislative Committee on Administrative Rules (LCAR)	2023
13*	Rule-Making Process	File a final update to the Environmental Protection Rule Chapter 29A Vermont Water Quality Standards with the Secretary of State	January 1, 2024

1.2. What are PFAS Chemicals?

Per- and polyfluoroalkyl substances (PFAS) are a large group of human-made chemicals that have been used in industry and in many consumer products for decades to manufacture household and commercial products that resist heat, oil, stains, grease, and water. PFAS have been used in many consumer products, including non-stick cookware, stain-resistant furniture and carpets, waterproof clothing, microwave popcorn bags, fast food wrappers, pizza boxes, shampoo, cosmetics, and dental floss. PFAS also have been used in certain firefighting foams and various industrial processes. Because of their widespread use, many PFAS have been found in our environment and are expected to be found in virtually every human. Some of these PFAS are known to have toxic effects and pose health risks even at very low levels.

PFAS can be found in drinking water, food, indoor dust, and in the workplace. While some PFAS chemicals are no longer used in manufacturing, many consumer products likely still contain PFAS, including:

- Food wrappers, pizza boxes
- Microwave popcorn bags
- Baking papers
- Nonstick cookware
- Pet food bags
- Water & stain resistant fabrics, leather
- Stain resistant carpets and upholstery
- Cleaning products
- Paints, varnishes, and sealants
- Firefighting foam
- Cosmetics
- Metal plating with corrosion prevention
- Wire manufacturing with coating & insulation
- Industrial plastics, resins, and molds

PFAS pathways to the environment include industrial manufacturing and disposal of products containing PFAS (Liu, 2013) (EPA, 2017b, p. 1).[iv] :[v,vi] PFAS are generally stable and persistent in the environment. Because they do not easily breakdown into simpler molecules, PFAS contamination will remain for a long time, and human and environmental exposure to PFAS will continue to be a concern (Ritscher, et al., 2018).[vii] Perfluoroalkyls are particularly mobile in soil, making groundwater vulnerable to contamination (ATSDR, 2015).[viii]

Once in the human body, PFAS can pose several health-related risks, even at very low levels. The Vermont Department of Health (VDH) reports that exposure to PFAS has been associated with the following health impacts:

- Affecting the growth, learning, and behavior of infants and older children;
- Lowering a person's chance of getting pregnant;
- Interfering with the body's natural hormones;
- Increasing cholesterol levels;
- Affecting the immune system; and
- Increasing the risk of cancer (VDH, 2019, p. 2).[ix]

Vermont currently has in place drinking water health advisories[x], groundwater enforcement standards, and direct contact soil standards for five specific PFAS compounds: PFOA, PFOS, PFHxS, PFNA, and PFHpA.

2. Surface Water Quality Standards

2.1. Overview

The principal objective of the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act or "CWA")[xi] is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters.[xii] To meet this objective, the CWA directs states[xiii] and eligible tribes[xiv] to adopt water quality standards, which are then incorporated into state and tribal laws, accordingly. As discussed further below, states establish these standards by describing the desired condition of water bodies and the means by which that condition will be protected or achieved. States and tribes establish specific water quality standards to protect both human health and aquatic life in these waters. Establishment of human health and aquatic life criteria is discussed further in Chapters 5 and 6.

Water quality standards are comprised of three main parts:

1) Designated Uses: desired uses of a waterbody (e.g., swimming, fishing, boating, aquatic life).
2) Water Quality Criteria: (often referred to as "ambient water quality criteria" or AWQC) numeric measures and/or narrative criteria that are used to determine if the designated uses are being attained (EPA, 2017a, p. 2).[xv] Types of criteria that can be adopted include aquatic life, human health, and recreational.
3) Antidegradation Policy: a policy that preserves high quality waters and prevents all water quality from being degraded below levels needed to meet designated and existing uses.

Further discussion of the designated uses and water quality criteria components of surface water quality standards follows. A discussion of the antidegradation policy component of water quality standards is not relevant to the purpose of this plan and therefore is not further discussed herein.

Vermont's current Water Quality Standards can be found in the Environmental Protection Rule Chapter 29A and the Vermont Water Pollution Control Regulations.[xvi] ANR conducts a review of its Water Quality Standards, with public meetings and comment periods, a minimum of once every three years. [xvii]

2.1.1. Designated Uses of Water Bodies

Water quality standards describe the desired condition of a water body and the means by which the condition will be protect or achieved. All of Vermont's surface waters are classified based on their designated condition (or use). Classifications include Class A(1), A(2), B(1), or B(2).[xviii] A majority of Vermont's waters are Class B(2). Water quality standards are adopted to protect human health and aquatic life of these waters by controlling pollutants entering them. If water quality criteria are exceeded in a waterbody, one or more of the designated uses are not being attained.

Table 3 below describes Vermont's water body classification system.

Table 4 below outlines types of designated uses for Vermont's water bodies.

Table 3: Classifications to Support Designated Uses for Vermont Surface Waters	
Classification	Statutory reference: 10 V.S.A. §1252
Class A(1)	Waters in a natural condition that have significant ecological value.
Class A(2)	Waters that are suitable for public water source with filtration and disinfection or other required treatment; character uniformly excellent.
Class B(1)	Waters in which one or more uses are of demonstrably and consistently higher quality than Class B(2) waters.
Class B(2)	(Most Vermont water bodies) Waters that are suitable for swimming and other primary contact recreation; irrigation and agricultural uses; aquatic life and aquatic habitat; good aesthetic value; boating, fishing and other recreational uses and suitable for public water source with filtration and disinfection or other required treatment.

Table 4: Designated Uses for Vermont Surface Waters	
Topic	Designated Uses
Aquatic Life & Wildlife	Aquatic life and wildlife that may utilize or are present in the waters
Aquatic Habitat	Aquatic habitat to support aquatic life, wildlife or plant life
Primary Contact Recreation	The use of waters for swimming and other primary contact recreation
Recreation-Boating	The use of waters for boating and related recreational uses
Recreation-Fishing	The use of waters for fishing and related recreational uses
Aesthetic Condition	The use of waters for the enjoyment of aesthetic conditions
Public water source	The use of the water for public water source
Agriculture	The use of water for irrigation of crops and other agricultural uses

2.1.2. Establishment of Water Quality Criteria

A great deal of scientific research goes into establishing water quality criteria. EPA is required by the CWA to provide recommended water quality criteria for several chemical pollutants (referred to as the National Recommended Water Quality Criteria[xix] or "304(a) Criteria Recommendations"). The 304(a) Criteria Recommendations are the result of multidisciplinary task groups, public input, and peer review. The recommendations are well-researched and vetted by the scientific and regulated community (EPA, 2017a, p. 2).[xx]

The process for state adoption of a new or updated EPA water quality criteria is rigorous and typically occurs during the Triennial Review of the state's water quality standards (EPA, 2014b). The process typically involves the following steps:[xxi]

1) An evaluation of recent EPA CWA Section 304(a) Criteria Recommendations, if any;[xxii]
2) Review of data on the effects of pollutants of concern;
3) A process to receive public input including a public hearing;[xxiii]
4) A submittal of the review to EPA;
5) A formal state administrative rule-making process;
6) A submittal of the final new or revised water quality standards to EPA for review and approval.

EPA must approve a state's proposed standards before those standards can be applied by the state in discharge permits and other regulatory actions.[xxiv]

States may also establish state-specific water quality criteria for certain chemical pollutants in order to protect designated uses of water bodies in the state. [xxv] These criteria may be based on:

1) EPA's 304(a) Criteria Recommendations (numeric criteria);
2) EPA's 304(a) Criteria Recommendations that reflect localized conditions (numeric criteria);
3) Numeric criteria based on other scientifically-defensible methods (which must be at least as protective as the 304(a) Criteria Recommendations); [xxvi] or
4) A state-derived narrative criteria if numeric criteria cannot be determined (EPA, 2000, p. iii).[xxvii]

Though states can establish state-specific water quality criteria, states typically are reliant on EPA guidance for setting toxic criteria given the complexity of the science and analysis and the high cost of development involved in doing so. Therefore, States and tribes infrequently establish new surface water quality standards for a pollutant when there is no EPA 304(a) Criteria Recommendation for that pollutant. Challenges to developing state-specific surface water quality standards for chemicals likes PFAS are outlined below in Chapter 3. A more detailed description of the process for adopting a state-specific surface water quality standard is outlined in Chapters 5 and 6.

3. Challenges in Managing PFAS via Surface Water Quality Standards

To date, EPA has not established a 304(a) Criteria Recommendations to address PFAS. Without federal criteria, states are on their own to develop surface water quality criteria and underlying human health and aquatic life values. As of 2017, only two states, Michigan and Minnesota, have adopted surface water quality criteria. Michigan derived its human health and aquatic life values for PFOS in 2014, the human health values for PFOA in 2011, and aquatic life values for PFOA in 2010. Minnesota's criteria for PFOS and PFOA are specific to Lake Calhoon and the Mississippi River (MNDH, 2019). [xxviii]

The development of state-specific PFAS surface water standards would be ANR's first effort to establish state surface water quality standards for a group of chemical contaminants for which EPA 304(a) Criteria Recommendations have not been established. Some of the significant challenges to developing Vermont criteria to manage PFAS in surface waters are discussed below.

1) No federal PFAS standards exist. While EPA has issued a drinking water health advisory (EPA, 2016a)[xxix] of 70 ppt for lifetime exposure for the sum of two compounds (PFOA and PFOS), the lack of CWA 304(a) Criteria Recommendations for PFAS and other media-based standards places the burden on states to invest the significant resources required to develop surface water quality and other health-related standards to protect public and environmental health from the risks associated with PFAS. In addition, relying on EPA's drinking water health advisory to help inform surface water quality standards is not advised here as EPA's 70 ppt threshold is set too high and is not sufficiently protective of human health.[xxx]

2) Additional information is needed related to PFAS risks. Much of the existing research on PFAS has focused on PFOA and PFOS, specifically. In part, based on the information related to PFOA and PFOS, some U.S. manufacturers have voluntarily phased out use of these compounds, but instead have begun to rely on other PFAS compounds (EPA, 2019).[xxxi] There are over 4,700 PFAS[xxxii] currently manufactured and approximately 600 PFAS in commercial use today (CRS, 2019).[xxxiii] Due to the lack of comprehensive regulation of this class of compounds, there is limited data available on the usage of these compounds (including types and quantities) in Vermont that may be posing risks. Vermont currently regulates five PFAS based on the characteristics expected to be exhibited by each member of this group. However, there may be potential health effects associated with other PFAS or mixtures of PFAS that would be helpful to more fully understand prior to establishing compound-specific water quality standards.[xxxiv,xxxv] Additionally, evolving and growing science on human and environmental health effects from PFAS exposure will require periodic re-evaluation of state standards over time (Bartell S. J., 2018, p. 14).[xxxvi]

3) Additional information is needed to derive aquatic biota and human health criteria. As discussed later in this plan, in order to derive aquatic biota criteria for purposes of establishing a surface water quality standard, EPA requires toxicity testing data for at least one species of freshwater animal in at least eight different families. There may be enough data to satisfy this minimum data requirement for PFOA and PFOS. To the extent PFAS are not regulated as a class or by subgroups, additional aquatic toxicity testing may be necessary for the other three Vermont-regulated PFAS (PFHxS, PFHpA, and PFNA). It will require significant resources and time to address these toxicity data gaps. Specific data-related challenges are further discussed below.

4) There is no federal standard methodology for sampling surface waters. EPA has approved laboratory Method 537 version 1.1 (Method 537.1) to measure some PFAS analytes in drinking water only. Some laboratories have modified EPA Method 537 to test for surface water, fish, and other environmental media. However, most of these modified methods developed by private laboratories are proprietary.

5) <u>Contaminants of Emerging Concern necessitate evaluation of alternative approaches</u>. Contaminants of Emerging Concern (or CECs) are chemical pollutants or substances that are known to be present in the environment, whose presence warrant evaluation, but that are not typically part of a state's water quality monitoring program and/or may not have in place regulatory standards to control their release. PFAS are considered a CEC. (EPA, 2008, pp. 1-2; EPA, 2017b; ASTHO, 2019).[xxxvii, xxxviii, xxxix] As described in EPA's draft White Paper on aquatic life criteria for CECs, these chemicals present challenges in applying EPA's 1985 methodology to establish aquatic life criteria.[xl] Many CEC's are extremely potent and these very low biologically-active concentrations present substantial challenges for analytical determinations associated with lab-based effects or field monitoring of in situ exposures.

Chapters 5 and 6 discuss the process that ANR may follow to adopt a water quality standard for PFAS.

4. Establishment of Water Quality Standards for PFAS as a Class or Subgroups

4.1. *Management of PFAS as a Class of Compounds*

Act 21 directs ANR to include in this plan a proposal for PFAS water quality standards for the PFAS class of compounds or subgroups of the PFAS class of compounds.

Some chemicals are members of the same family or group and have been shown to exhibit similar toxicological properties. It may be appropriate to regulate such chemicals as a class or group even though each individual chemical may differ in the degree of toxicity (EPA, 2019). In such cases, the reported concentrations of each member of the group may be converted based on risk-based values for the index chemical of the group. ANR typically relies on EPA published guidance for establishing toxicity values for members of a chemical class, family, or group for classes of chemicals such Dioxins, Polychlorinated Biphenyls (PCBs), and Polycyclic Aromatic Hydrocarbons (PAHs). Additionally, ANR typically relies on EPA and the World Health organization (WHO) published guidance on regulation of these compounds as a class. However, no such guidance exists for PFAS as a class.

ANR does not have the capacity to conduct the types of scientific and technical analyses that are normally provided by EPA or WHO to evaluate regulating PFAS as a class at this time. However, as the next section addresses, ANR outlines an approach to regulate PFAS as a class or subgroup.

4.2. *Proposal for Managing PFAS as a Class or Subgroups*

ANR proposes implementation of the following three phases to manage PFAS as a class or subgroups pertaining to water quality standards:

- Phase I: Closely monitor the progress made on the EPA PFAS Action Plan. (Note: The priority actions in the Plan are currently written to evaluate a select set of individual PFAS chemical-by-chemical, which will take decades and alone is not an effective way to manage PFAS as a class.)

- Phase 2: Closely monitor the work by the National Toxicology Program (NTP) and the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate PFAS as a class. The NTP has published a framework for evaluating PFAS as a class using computational toxicology methods (Patlewicz, et al., 2019).[xli] These methods recognize that a chemical-by-chemical approach will not result in meaningful data to support regulation of PFAS as a class. The NTP approach starts with two lists of 75 PFAS that are evaluated for structural similarities and potency of biological response. The NTP plans to select "anchor" PFAS upon which to build classes or subclasses of PFAS.[xlii] This work involves hundreds of NTP and EPA scientists, and reflects a level of effort and resources that ANR could not independently invest in a similar process.

  Phase 3: Integrate the process to consider regulating water quality standards as a class or subgroups of PFAS into the advance notice of proposed rulemaking (ANPR) process under the Water Supply Rule (Act 21, 2019).[xliii] This strategy will allow ANR to gain information relevant to setting standards for PFAS as a class. It also offers the state the opportunity to more fully evaluate this question of regulating classes or subclasses of PFAS across media types.

5. Setting Water Quality Standards – Protection of Human Health

As discussed in Chapter 2, EPA develops surface water quality criteria under Section 304(a) of the CWA to protect human health and aquatic life. These criteria are used in developing surface water quality standards to protect the designated uses of surface waters. The CWA requires states to adopt water quality criteria for toxics that have EPA-published criteria and whose presence or discharge will interfere with a surface water body's designated uses. [xliv]

As discussed in Chapter 3, since no federal criteria have been established for PFAS in EPA's 304(a) Criteria Recommendations, Vermont would need to develop its own criteria based on other scientifically defensible methods. EPA strongly encourages states to rely on EPA-published methodologies when deriving state water quality standards. EPA sees these methodologies as important to enhance the scientific basis of the water quality criteria, while affording states and tribes flexibility to address unique water quality issues and risk management decisions (EPA, 2000).[xlv]

Sections 5.1-5.2 of this chapter describe the steps to establish PFAS-specific human health water quality criteria. A human health water quality criterion is the highest concentration of a pollutant in water that is not expected to pose a significant risk to human health (EPA, 2000).[xlvi] These criteria would be used to protect designated uses pertaining to human ingestion of water and/or fish or other water-based exposure from these surface waters. For example, the criteria would protect a water body's designated uses pertaining to drinking water and recreational fishing.

Chapter 6 describes the steps to establish PFAS-specific aquatic life criteria to protect and allow for the propagation of fish and wildlife (EPA-1, n.d.).[xlvii] An aquatic life criterion for toxic chemicals are the highest instream concentration of a pollutant or water conditions that are not expected to cause a significant risk to organisms (EPA-2, n.d.).[xlviii] A narrative aquatic life criterion is a description of the desired condition of water bodies that would avoid negative conditions. To develop this standard, ANR may rely on relevant EPA methodology to derive criteria for the protection of aquatic life (EPA, 2010).[xlix]

Table 8: VT Data Collection Needs to support Development of PFAS Water Quality standards		
Criteria	Spatial Scope	Description of Sampling
Human Health Criteria: Fish Consumption	State-wide	Water column and fish tissue sampling at lotic and lentic sites
Human Health Criteria: Water and Fish Consumption	State-wide	Water column and fish tissue sampling at lotic and lentic sites
Human Health Criteria: Fish Tissue Concentration	State-wide	Fish tissue sampling
Recreational Screening Levels for Surface Water & Sediment	State-wide	Site specific sediment and/or water column sampling

5.1. *Human Health Water Quality Standards Criteria; Purpose*

Deriving ambient water quality criteria for the protection of human health requires information about the pollutant's toxicological endpoint, that is, how dangerous the substance is and how the substance affects human health (such as toxicity to kidney, thyroid, liver, or immune system function). Deriving human health criteria also considers the pathway of human exposure to these pollutants (how humans are exposed to these pollutants). The human health criteria are used to limit the pollutant in surface waters to ensure that exposure to the pollutant from exposure from activities like ingesting water and consumption of fish will not result in human intake of that pollutant at levels high enough to reach the toxicological endpoint of concern. The human health criteria are based on chronic health effects data, but are intended to also be protective against adverse effects that may occur as a result of elevated acute or short-term exposures. Through the use of conservative assumptions with respect to both toxicity and exposure parameters, the criteria should provide adequate protection over a lifetime of exposure, but also be protective for special subpopulations who may have higher water and/or fish intake rates.

Human health water quality criteria address the primary route of PFAS exposure for humans, which is through ingestion of contaminated water and food. Studies have documented absorption of two PFAS compounds, perfluorooctanoic acid (PFOA) (EPA, 2016b) [l] and perfluorooctane sulfonic acid (PFOS) (EPA, 2016c),[li] from ingestion of contaminated food or water across a wide-array of organisms. Therefore, PFAS contamination of surface water, particularly if it is a source of drinking water or habitat for game fish, can be a source of exposure for humans and wildlife. The major exposure from recreational contact with surface water, such as swimming, is through incidental ingestion.

5.2. *Steps for Deriving Water Quality Criteria based on Human Health*

As described above, the water quality criteria for the protection of human health are designed to minimize the risk of adverse effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish obtained from surface waters.

Establishing human health criteria for the five Vermont-regulated PFAS would likely involve the following steps:

1) Determine methodology to use for deriving human health criteria.

2) Confer with VDH regarding additional toxicity assessments expected to be released by EPA by 2020 (EPA, 2019).[lii]

3) Confer with the VDH to determine appropriate fish consumption rates (considering EPA's Estimated Fish Consumption Rates for U.S. Population (EPA, 2014a),[liii] EPA's Human Health Ambient Water Quality Criteria: 2015 Update (EPA, 2015)[liv] or VDH fish consumption advisory ingestion rate).

   Note: Fish consumption rate data are essential in developing water quality standards and play an integral role in developing fish consumption advisories. Protecting specific sensitive populations, such as pregnant women and young children, or highly exposed population subgroups (such as tribes in subsistence fishing) may require a modification of the general EPA default parameters (body weight), drinking water intake (in liters per day), and fish consumption rate or intake (in grams per day) used to describe human exposure to the pollutants of concern.

4) Evaluate existing data from peer-reviewed articles and government reports to assess the potential to derive bioaccumulation factors (BAFs) that reflect the concentration of PFAS in tissue of aquatic organisms such as fish (EPA, 2003).[lv]

   Note: Aquatic organisms can take up and retain pollutants of concern from their surroundings including the water, its food source, and sediment ("bioaccumulation"). The extent of bioaccumulation depends on the species of aquatic organism and chemical of concern. Bioaccumulation for some chemicals can be quite high which can cause human health risks from eating fish exposed to these chemicals even if pollutant concentrations in the water are low enough to pose no health risks from drinking the water. Studies are reporting the bioaccumulation potential of some PFAS to be significant (Birnbaum, 2019).[lvi]

   Currently, there are no nationally representative bioaccumulation factors (BAFs) for the five Vermont-regulated PFAS. BAFs are necessary to derive human health criteria (also referred to as water column criteria) for bioaccumulative pollutants such as PFAS. The criteria are used to limit the health risk associated with eating contaminated fish. BAFs are calculated from paired field studies measuring surface water and fish tissue concentrations. To derive the human health (water column) criteria, ANR would need these studies for each of the five PFAS for representative aquatic species and water bodies. Furthermore, technology does not yet allow for the detection of all PFAS in the environment, including surface waters. Where PFAS is below the detection limit in the water column, it is not possible to derive a BAF. Additionally, many of the PFAS have been shown to have highly variable BAFs, and these contaminants do not reflect typical BAF patterns.

Although most current CWA Section 304(a) Recommended Criteria are expressed as water column values, the criteria may also be expressed as fish tissue concentrations (such as the methylmercury criterion). Fish tissue values are very useful when bioaccumulation is highly variable, and they allow for direct measurement when assessing compliance monitoring. This may be the appropriate strategy for addressing the human health (water column) criteria for the five Vermont-regulated PFAS.

5) Consider field sampling and analysis to support derivation of PFAS bioaccumulation factors (BAFs) following EPA's guidance (EPA, 2009b) (EPA, 2015) (EPA, 2016d).[lvii,lviii,lix]

   Note: Vermont and New Hampshire are working collaboratively to conduct a literature review of peer-reviewed data and reports regarding BAFs in aquatic organisms and to design complementary field and/or laboratory studies to supplement literature to derive BAFs and/or BCFs for the states' PFAS chemicals of concern.

6) Work with VDH to confirm reference doses (RfDs) for the five Vermont-regulated PFAS.

   Note: EPA defines the reference dose as "an estimate (with uncertainty spanning approximately an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects over a lifetime." (EPA, 1993).[lx]

7) Confer with VDH to determine appropriate relative source contributions (RSC).

   Note: The relative source concentration (RSC) represents the portion or percentage of the reference dose (RfD) attributed to water and fish consumption, to account for non-water sources of exposure to PFAS. When deriving water quality criteria for pollutants, this factor (RSC) is included to account for other non-water exposure sources (e.g., food) so that the entire RfD is not apportioned to drinking water and fish consumption alone. Will confer with VDH and follow guidance provided by in EPA 2000 Human Health Methodology for to help determine these factors for each of the five Vermont-regulated PFAS. An Exposure Decision Tree procedure will be used to support the determination of the appropriate RSC value for each contaminant.

5.3. *Data Needs for Deriving Human Health Criteria*

The process for deriving human health water quality criteria includes consideration of noncancer effects and cancer effects and includes toxicological and exposure assessment parameters which are derived from scientific analysis, science policy, and risk management decisions. The noncancer effects equation shown below would be used to derive the water quality criteria, since the Reference Doses for Vermont-regulated PFAS are based on noncancer effect levels. ANR will work with VDH and follow EPA guidance as needed (EPA, 2016d) to determine appropriate input parameters.

Noncancer Effects (EPA, 2000):[lxi]

$$\mathrm{AWQC} = \mathrm{RfD} \times \mathrm{RSC} \times \left[\frac{\mathrm{BW}}{\mathrm{DI} + \sum_{i=2}^{4}(\mathrm{FI}_i \times \mathrm{BAF}_i)}\right]$$

KEY

AWQC= Ambient Water Quality Criteria (mg/L)
RfD= Reference dose for noncancer effects (mg/kg-day)
RSC= Relative source contribution factor to account for non-water sources of exposure
BW= Human body weight (default = 80 kg for adults)
DI= Drinking water intake (default = 2.4 L /day for adults[lxii])
FI_i= Fish intake at trophic level (TL) I (I= 2, 3 and 4) (defaults for total intake = .032 kg/day for general population and sport anglers
BAF_i= Bioaccumulation factor at trophic level I (I = 2,3 and 4), lipid normalized (L/kg)

Data needs for deriving human health criteria typically would include the following:

1) The default fish consumption rates and drinking water intake for protection of a certain percentage (i.e., the 90th percentile) of the general population which is a risk management decision and would be determined with consultation with VDH. The AWQC will need to identify the population subgroup that it should protect;

2) A procedure to determine Trophic Level Bioaccumulation Factors (BAFs), in recognition that BAFs can be measured or predicted using different methods. Trophic position in the aquatic food web can have an important effect on the magnitude of bioaccumulation of chemicals, as such BAFs need to be determined and applied on a trophic level-specific basis (e.g. forage fish, predatory fish). EPA's highest preference in developing BAFs are based on field-measured data from local/regional fish;

3) Field-Measured BAF is the most direct measure of bioaccumulation. A field-measured BAF is determined from a field study using measured chemical concentrations in the aquatic organism and its surrounding water. A field-measured BAF reflects an organism's exposure to a chemical through all relevant exposure pathways (i.e., water, sediment, and diet);

4) Lab-measured BCF can be used to estimate a BAF for chemicals, however unlike a field-measured BAF, a laboratory-measured BCF only reflects the accumulation of chemical through the water exposure route. Therefore, laboratory-measured BCFs may under-estimate BAFs for chemicals where accumulation from sediment or dietary sources is important. Laboratory measured BCFs can be multiplied by Food Chain Multiplier (FCM) to reflect accumulation from non-aqueous pathways of exposure;

5) For highly bioaccumulative chemicals where ingestion from water might be considered negligible, and BAFs are highly variable and not scientifically defensible, ANR would consider developing and implementing AWQC that are expressed as fish tissue concentrations. Tissue concentration criteria (used for methyl mercury, for example) could be used as alternative to AWQCs which are typically expressed as water column concentrations. This approach has been applied in situations where AWQCs are at or below the practical limits for quantifying a chemical in water.

6. Setting Water Quality Standards – Protection of Aquatic Life

6.1. Aquatic Life Water Quality Standards Criteria

Aquatic life (or biota) criteria in water quality standards are necessary to support the designated uses of water bodies that pertain to the propagation of fish and wildlife. The aquatic life criteria of surface water quality standards for toxic chemicals represent the highest instream concentration of a pollutant or water conditions that are not expected to cause a significant risk to organisms. Aquatic life criteria are estimates of concentrations of pollutants in ambient water that, if not exceeded, are expected to protect fish, invertebrates, and other aquatic life from adverse effects associated with the exposure.

The criteria are expressed in two forms, acute and chronic (EPA, 2017a):[lxiii]

1) Acute aquatic life criteria: derived using short-term standard laboratory toxicity tests (48 to 96-hour exposure). These criteria protect against severe acute effects such as mortality from short-term exposures (1-hour) to a toxic chemical; and

2) Chronic aquatic life criteria: derived using longer-term laboratory toxicity tests (7-day to over 28-day exposure). These criteria protect against longer term effects on survival, growth, and reproduction from long-term exposure to a toxic chemical.

To develop aquatic criteria, ANR may rely on EPA's published methodology (Stephen, et al., 1985)[lxiv] to establish aquatic life criteria for PFAS and other technical sources that are helpful in addressing the challenges of establishing water quality standards for PFAS as contaminants of emerging concern (CECs), as described in EPA's 2008 draft White Paper (EPA, 2008).[lxv] This methodology relies on laboratory toxicity data from eight taxonomic groups to represent a wide distribution of species being protected by the standards.

ANR may also evaluate whether these criteria need to be differentiated by other water quality characteristics when relevant to toxicity, such as acidity (pH), total and dissolved organic carbon, temperature (cold water vs warm water surface waters), and hardness (the amount of calcium and magnesium in the water which can affect the toxicity of certain metals). A detailed description of the steps involved in deriving aquatic life criteria is set forth next in Section 6.2.

6.2. Steps for Deriving Aquatic Life Criteria

ANR may undertake the following steps to establish aquatic life criteria for the five PFAS, in accordance with EPA Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (Stephen, et al., 1985):[lxvi]

1) Determine methodology to use for deriving aquatic life criteria.

2) Collect and assess all available laboratory toxicity test data including bioaccumulation information.

   Note: ANR may rely on EPA's ECOTOX Knowledgebase (EPA-3, n.d.)[lxvii] to identify and evaluate existing peer-reviewed data and journal articles and evaluate other state data.

3) Assess any additional ecological risk information expected to be released by EPA by 2021 (EPA, 2019).[lxviii]

4) Determine if minimum data requirements for acute toxicity studies are met for at least one species of freshwater species in a minimum of eight different families, according to EPA guidance (EPA, 2019).[lxix]

Note: These minimum data requirements include three vertebrates (a salmonid fish, a fish from a family other than Salmonidae, and a species from a third chordate family) and five invertebrates (a planktonic crustacean, a benthic crustacean, an insect, a species from a phylum other than Chordata or Arthropoda, and a species from another order of insect or a fourth phylum).

5) Determine if minimum data requirements for chronic toxicity studies are met for at least one species of freshwater species in a minimum of three families of aquatic animals for which acceptable acute data are available and one being an acutely sensitive species.

   Note: This approach utilizes acute to chronic rations (ACRs).

6) Determine the quality and completeness of collected data.

   Note: This involves screening the data for validity based on criteria such as use of control, use of single species and compound for each test, use of species from north America, reporting of water characteristics (e.g., hardness or pH) when relevant to toxicity.

7) Evaluate the acute and chronic available data to ensure that each of the four major kinds of possible adverse effects (e.g. growth, reproduction, mortality) receives adequate consideration.

   Note: Results of acute and chronic tests with representative species of aquatic animals are necessary so that data available for tested species can be considered a useful indication of the sensitivities of appropriate untested species. If chronic data are limited or absent, acute-to-chronic ratios (ACR) will be used to estimate chronic toxicity in aquatic organisms. The ACR will be used when acute toxicity profile indicates that the most sensitive surrogate aquatic species was not tested in chronic study or data gaps exist.

8) Determine if acute-chronic ratios with species of aquatic animals in at least three different families are represented and that at least one is a fish, at least one is invertebrate, and at least one is an acutely sensitive freshwater species.

   Note: If sufficient data on acute toxicity to aquatic animals are available, the highest one-hour average concentration (acute) that should not result in unacceptable effects on aquatic organisms will be derived following protocols established in EPA Guidelines. If sufficient data on chronic toxicity to aquatic animals are available, the highest four-day average concentration (chronic) that should not cause unacceptable toxicity during a long-term exposure will be derived following protocols established in EPA Guidelines.

6.3. Data Needs for Deriving Aquatic Life Criteria

If following the EPA methodology to derive toxicity-based aquatic life criteria for the five Vermont-regulated PFAS, ANR would need to meet the Minimum Data Requirements (MDRs) for developing toxicity-based aquatic life criteria for the five PFAS following the EPA methodology. If a thorough review of the applicable toxicity data indicates that enough acceptable data are available, numerical water quality criteria can be derived to protect aquatic organisms and their uses from unacceptable effects due to acute and chronic exposures.

ANR would need to:

1) First, document all useful acute and chronic toxicity studies on aquatic animals for the five Vermont-regulated PFAS.

2) For acute criteria, achieve a minimum toxicity dataset of at least one species of freshwater animal in at least eight different families for the five PFAS, representing possible adverse effects and sensitive aquatic organisms. For chronic criteria, a minimum toxicity dataset of at least one species of freshwater animal in at least three different families for the five PFAS, for which acceptable acute data are available and one being an acutely sensitive species such that acute-to-chronic-ratios can be utilized.

3) If minimum data requirements for developing toxicity based aquatic life criteria are not met, ANR would need to determine specific toxicity data gaps (e.g. species, endpoints) and derive a plan for addressing these data gaps.

   Note: Significant resources may be needed to fund these toxicity tests and fulfill minimum data requirements. Toxicity testing costs for these novel contaminants will be significantly higher than conventional pollutants due to much higher analytical cost and the need for PFAS-free laboratory environment. Costs could be exponentially more than conventional toxicity testing cost. Estimates for single species toxicity test would be $75,000 - $100,000 for acute testing and $150,000 - $250,000 for chronic testing. New Hampshire estimated the cost to satisfy these freshwater toxicity data gaps would be $11.8 – $20.7 million dollars in that state.

4) Find usable BCF/BAF information for the five Vermont-regulated PFAS.

Identifying PFAS Aquatic Toxicity Studies

ECOTOX Knowledgebase is a curated database providing chemical environmental toxicity data on aquatic life, terrestrial plants, and wildlife. ECOTOX is maintained by EPA and has curated data for more than 48,000 publications. Queries are interactive by chemical, species, effect (e.g. growth, mortality, reproduction) and concentration endpoints (e.g. LC50, EC50) and test conditions (e.g. field, lotic, lentic). The database is updated quarterly. ECOTOX has been used for every National Ambient Water Quality Criterion for aquatic life since 1985.

ECOTOX has curated data for PFAS from 374 publications representing 82 fluorinated chemicals, 189 species, and 879 effect measurements with a total of 12,168 records.

ECOTOX queries for the five Vermont-regulated PFAS are presented in Table 10. Query results for all effects, endpoints, species, and test conditions are shown for a total of 187 references. Queries used Chemical Abstract System (CAS) numbers for the acid form and anionic form, as well as acronym search names (e.g. PFOA).

Table 10: All ECOTOX Records for Five PFAS - Records for all Effects, Endpoints, Species, Test Conditions* *as of September 12, 2019			
Chemical	CAS #'s	Records	References
PFOA	335671	2031	84
	45285516	41	4
	Total	2072	86
PFOS	1763231	823	33
	45298906	1044	38
	Total	1867	71
PFHxS	355464	3	1
	108427538	45	2
	Total	48	3
PFHpA	375859	14	3
	120885292	0	0
	Total	14	3
PFNA	375951	406	24
	72007682	0	0
	Total	406	24

EPA's applicability criteria for water quality standards development are robust and require studies to be excluded when criteria are not met, such as when taxa are not ecologically relevant, when chemical exposure involves more than a single chemical, and when exposure concentration or dose rates are not included. Based on these criteria, a preliminary review of these studies indicated that very few met applicability criteria, resulting in the rejection of all but 45 references for purposes of developing aquatic life criteria.

Tables 11 and 12 below show the number of references and the number of test animals and concentration-based endpoints (e.g., LC50, EC50), respectively, that reveal toxicological concerns for each of the five Vermont-regulated PFAS.

Table 11: ECOTOX References for Five PFAS that Meet Applicability Criteria for Relevant Test Animals and Endpoints* *as of September 12, 2019			
Chemical	CAS #'s	References	Number of test animals
PFOA	335671/45285516	30	25
PFOS	1763231/45298906	13	9
PFHxS	355464/108427538	1	1
PFHpA	375859/120885292	1	2
PFNA	375951/72007682	9	7

Table 12: ECOTOX Studies and Relevant Test Animals /Groups for Five PFAS* *as of September 12, 2019							
Chemical	References	Fish	Mollusca	Amphibian	Invertebrate	Crustacea	Algae
PFOA	30	5	3	1	4	7	5
PFOS	13	1	1	1	3	3	-
PFHxS	1	-	-	1	-	-	-
PFHpA	1	-	-	-	-	1	-
PFNA	9	1	1	-	-	2	1

This preliminary review of the applicable ECOTOX studies for all of the five Vermont-regulated PFAS indicates that there are some significant toxicity data gaps that would be necessary to meet EPA's Minimum Data Requirements for establishing criteria for freshwater aquatic organisms, which includes at least one species of freshwater animal in at least (8) different families (Stephen, et al., 1985).[lxx] For instance, PFHxS had only one applicable study, PFHpA studies included just one reference for one taxon, and PFNA studies include five taxa representing four groups. However, ANR's preliminary assessment of ECOTOX data indicates that the EPA Minimum Data Requirements may be met for PFOA and PFOS. ANR anticipates conducting further review of these and other available studies and further evaluation of toxicity data to determine if available data are acceptable for use in aquatic biota criteria development for these compounds.

In summary, the current data gaps for the five Vermont-regulated PFAS, with the exception of PFOA and PFOS, are significant and would impede development of aquatic biota criteria for these PFAS under EPA's current methodology, until these toxicity data gaps are addressed. Gaps in PFAS aquatic toxicity data are a national issue, and significant resources would be required of Vermont to address these data gaps independently. For acute and chronic criteria endpoints to protect aquatic life, it is recommended that ANR encourages and contributes to these data gaps utilizing regional taxa but ultimately waits for national efforts to satisfy data gaps before calculating aquatic life criteria.

6.4. Recreational Contact

As mentioned above, the major exposure to PFAS from recreational contact with surface water, such as swimming, is through incidental ingestion. Incidental ingestion is a small percentage of daily water intake, as such, the current drinking water advisory for the five Vermont-regulated PFAS would be protective of this limited exposure. This approach is aligned with conservative screening levels developed by other state agencies, which have found that concentrations of PFAS that present a risk via recreational exposures such as swimming are orders of magnitude higher than levels that would be protective for drinking water and fish consumption.

ANR acknowledges recent studies that suggest human exposure via other pathways including inhalation and dermal absorption (Birnbaum, 2019, pp. 3-4).[lxxi] ANR will further evaluate the available data and confer with the VDH for guidance in developing recreational sediment and surface water screening levels. These screening levels would incorporate the risk of ingestion and dermal contact pathways for adult and child recreational wading and swimming exposure scenarios.

7. Summary of Data Needs, Resource Constraints, Estimated Costs, and Conclusions and Recommendations

Table 14 outlines the steps ANR proposes to take to derive human health and aquatic life criteria:

Table 14: Summary of Steps to Derive Ambient Water Quality Criteria for the Five PFAS Pertaining to: a) Human Health (from Chapter 5), and b) Aquatic Life (from Chapter 6)

Criteria	Steps	Description
a) Human Health	1	Determine methodology to use to derive criteria
	2	Collect and conduct assessment of available toxicity data
	3	Evaluate additional toxicity assessments when available
	4	Work with VDH to evaluate fish consumption rates
	5	Research existing articles & reports on BAFs in aquatic organisms
	6	Work with VDH to determine reference doses
	7	Conduct assessment of the relative source contributions
b) Aquatic Life	1	Determine methodology to use to derive criteria
	2	Collect and conduct assessment of available laboratory toxicity data
	3	Assess additional ecological risk information when available
	4	Conduct analysis to determine if minimum data requirements for toxicity studies are met (minimum of one species in at least eight taxonomic families)
	5	Evaluate available acute and chronic data sets
	6	Estimate chronic toxicity in aquatic organisms
	7	Determine whether there are chronic toxicity data available that are representative of the minimum number of taxonomic families
	8	If adequate acute toxicity data are available, derive aquatic life criteria for acute exposure
	9	If adequate chronic toxicity data are available, derive aquatic life criteria for long-term exposure

Table 15 summarizes the data needs for deriving the human health and aquatic life criteria, which are also described in Chapters 5 and 6:

Table 15: Summary of Data Needs to Derive Ambient Water Quality Criteria for the Five PFAS Pertaining to: a) Human Health (from Chapter 5), and b) Aquatic Life (from Chapter 6)		
Criteria	Data Needs	Description
a) Human Health	1	Determine fish consumption rates & drinking water intake values
	2	Establish a procedure to determine trophic level Bioaccumulation Factors (BAFs)
	3	Develop field-measured BAFs from a field work to collect & analyze aquatic organisms and surrounding water column
	4	Evaluate aquatic organism tissue for PFAS concentrations for highly bioaccumulative PFAS analytes
b) Aquatic Life	1	Research and evaluate all acute & chronic toxicity studies on aquatic organisms
	2	Develop a toxicity dataset for a minimum of one species in at least eight taxonomic families
	3	Determine toxicity data gaps and plan to address these gaps
	4	Research Bioconcentration and bioaccumulation information

The work and data needs to accomplish steps in Table 14 and to address the data needs in Table 15 are substantial. ANR currently has limited technical staff and laboratory capacity to complete these tasks.

The New Hampshire Department of Environmental Services (NHDES) is also developing a plan to generate water quality standards for PFAS. Vermont may look to NHDES's recent efforts to estimate costs associated with the steps and data needs above. Part of the NHDES plan involves determining cost estimates for multiple approaches to aid in plan implementation. NHDES acknowledges that there are numerous decisions associated within each approach that will affect final cost estimates. NHDES' preliminary cost estimates (in part) for developing human health water quality criteria, including sampling costs, are summarized on Table 16.

Table 16: NHDES Preliminary Summary of Approaches and Associated Costs to Develop Human Health Water Quality Criteria for Freshwater		
Human Health Approaches	Criteria Development Costs ($) per Approach	Assessment Costs ($) per Waterbody (sampling 50 - 100 waterbodies)
Fish Consumption Advisory – Tissue Consumption Limit	$9,000	$547,000 – $4.7M
Fish Consumption Criteria – Tissue Concentration Criteria	$47,000	$547,000 – $4.7M
Fish/Shellfish Consumption Only (Water Concentration Criteria)	$75,000 - $741,000	$153,000
Water and Fish/Shellfish Consumption (Water Concentration Criteria)	$75,000 -$741,000	$153,000

As discussed in Section 3.2 (Challenges of Managing PFAS), most Section 304(a) Human Health criteria are expressed as water column values, however when the challenges of deriving BAFs are significant (e.g. BAFs variable, water column concentrations below detection) the criteria may also be expressed as fish tissue concentrations (such as in the case with methyl mercury criterion). This may be a useful approach for deriving the human health criteria for the five PFAS. Additionally, this approach removes the need to derive BAFs for the five PFAS.

The fish tissue criterion would be derived utilizing the established reference doses (RfD) for the five PFAS with VDH consultation to determine appropriate input values for deriving the criterion. This derived criterion would allow for direct measurement when assessing compliance monitoring. It would also be used as screening value to ensure that consumption of fish tissue (e.g. monthly consumption limits) are protective, following EPA Guidance for Assessing Chemical Contaminant Data and consultation with VDH. Screening studies would be utilized to identify sites where concentrations of these contaminants in edible portions of fish indicate the potential for health risks to consumers.

NHDES proposes to follow the EPA Guidelines in the development of water quality standards for the protection of aquatic life (Stephen, et al., 1985).[lxxii] This method requires a minimum of eight acute toxicity studies representing eight families of aquatic biota. In addition, EPA guidance requires a minimum of three chronic toxicity studies for the chemical of concern for the development of the Acute Chronic Ratio (ACR). NHDES and ANR are collaborating to review the available data to identify data gaps. As indicated in Chapters Five and Six above, preliminary assessment indicates data gaps relating to aquatic life under EPA's current water quality criteria methodology for some of the five Vermont-regulated PFAS chemicals. NHDES estimates that the cost to satisfy these freshwater toxicity data gaps would be $11.8M - $20.7M for the five PFAS chemicals. NH and VT are considering working with other New England states to address these toxicity data gaps; the estimate for sharing the cost would be approximately $1.2M, which would include 1 fish acute toxicity test, 1 invertebrate acute toxicity test and 1 early life stage fish chronic toxicity test.

The cost estimates for aquatic toxicity testing (acute and chronic) to satisfy the toxicity data gaps identified is high. The PFAS aquatic toxicity data gaps are a national issue, and it is not rationale for Vermont to take on the full burden of these data gaps. For acute and chronic criteria endpoints to protect aquatic life, it is recommended that Vermont, will help encourage and contribute to some of these data gaps utilizing regional taxa but waits for national efforts to satisfy data gaps before calculating aquatic life criteria.

7.1. Conclusions/Recommendations

As discussed in this plan, the technical challenges and constraints of deriving water quality criteria for the five PFAS are logistically difficult, would take a long time and be very expensive for both human health and aquatic biota. These challenges have formed the following conclusions and recommendations for moving forward.

Recommendation for Establishing a Human Health Criteria Using Fish Tissue Concentrations

1. Due to the constraints for deriving bioaccumulation factors (BAFs) needed for deriving water column criteria for the five Vermont-regulated PFAS under EPA's current methodology, ANR recommends that the human health criteria be expressed as fish tissue concentrations. This fish consumption advisory screening level would be based on the amount of PFAS in fish that can be consumed by a sensitive person per week.
2. State fish contaminant monitoring should be conducted to evaluate the need to issue fish consumption advisories.

Recommendation to Track EPA Development of Aquatic Biota Criteria for PFAS

1. The current aquatic toxicity data gaps for three Vermont-regulated PFAS (PFHxS, PFHpA, and PFNA) under EPA's current methodology are significant and may impede development of aquatic biota criteria for these PFAS. Based on available data, aquatic life criteria derived for these chemicals are projected to be orders of magnitudes higher than the highest values observed in Vermont surface waters.

2. The EPA Action Plan for PFAS[lxxiii] includes research to support development of ambient water quality criteria for aquatic life for PFOA and PFOS by 2022. Once EPA criteria are developed, they could be incorporated into Vermont's Water Quality Standards.

3. ANR recommends continued monitoring of EPA's progress at deriving aquatic life use criteria for PFAS and continued review of updated studies available through EPA (i.e., EPA's ECOTOX Knowledgebase) and elsewhere to ensure that surface waters are not at risk.

Recommendation to Continue Collaboration with New England States

ANR will continue to collaborate with NH and other New England states through New England Interstate Water Pollution Control Commission (NEIWPCC) on developing plans for deriving water quality standards. These plans may include sharing the cost of acute and chronic toxicity testing on regionally appropriate taxa, designing complimentary State-wide surface water and fish tissue sampling to address data gaps needed to develop PFAS water column and/or fish tissue criteria. Other New England states have expressed interest in working with VT and NH to address these data gaps as well, which will further regional efforts and cost sharing.

Regional organizations such as NEIWPCC, New England Water Environment Association (NEWEA) and North East Biosolids and Residuals Association (NEBRA) have been providing forums and conferences for sharing “source control” strategies and data. ANR will continue to collaborate with NH, other states, federal agencies, and local communities to limit PFAS in the environment.

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[x] VDH, 2018, Drinking Water Advisory for Five PFAS, *supra* note.
[xi] 33 U.S.C. §§1251 et seq. (1972).
[xii] 33 U.S.C. §1251(a), FWPCA, §101(a).

[xiv] 33 U.S.C. §1377; Federal Register Vol. 81, Issue 94 (May 16, 2016). Retrieved from: https://www.govinfo.gov/app/details/FR-2016-05-16/2016-11511
[xv] The water quality of that waterbody poses risks to human health and/or aquatic life, which may require action to restore the waterbody. EPA. 2017a. Water Quality Standards Handbook: Chapter 3: Water Quality Criteria, p2. Retrieved from: https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter3.pdf.
[xvi] 10 V.S.A. Chapter 47. Retrieved from: https://legislature.vermont.gov/statutes/chapter/10/047.
[xvii] 33 U.S.C. §1313(c)(1) (1994), FWPCA §303(c)(1), 40 CRF 131.20.
[xviii] Vermont in 2016 completed rulemaking and received EPA approval to expand its classes from two (Class A and B) to four classes. 10 V.S.A. §§1252 and 1253.

[xix] 33 U.S.C. §1314(a), FWPCA, §304(a). *See* National Recommended Water Quality Criteria -Human Health Criteria: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table and Aquatic Life Criteria: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table.
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[xxii] 33 U.S.C. §1314(a), FWPCA, §304(a).
[xxiii] 33 U.S.C. §1313(c), FWPCA §303(c), 40 CFR 131.20.
[xxiv] EPA has 60 days to approve the state water quality standards or 90 days to disapprove and specify modifications. If the state has 90 days following the EPA's notification of disapproval to adopt the modifications and resubmit for EPA approval. Otherwise, EPA must the promptly promulgate the necessary federal water quality standards. 33 U.S.C. §1313(c), FWPCA §303(c), 40 CFR 131.22.
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[xxvi] 40 CFR 131.11(a)(1), (b)(iii) (1998).
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[xxx] VDH Drinking Water Health Advisory for Five PFAS, July 10, 2018, at 4. ANR's Response to Comments on original rule 2, 3, and 4, pp. 4012-14 (explaining why EPA's level is too high and VT's is not). Additionally, the State of Michigan's PFAS Scientific Panel reports adverse health effects at blood serum levels for PFOA when exposed to the 70 ppt drinking water concentrations (Bartell S. J., 2018, pp. 55-59).[xxx] Additionally, the New Jersey Drinking Water Quality Institute concluded that EPA's health advisory is not protective of human health (NJDEP, n.d.).[xxx] Moreover, the Agency for Toxic Substances and Disease Registry (ATSDR) draft Toxicological Profile for perfluoroalkyls includes limits on a body-weight basis that are lower than the EPA health advisory (ATSDR, Toxicological Profile for Perfluoroalkyls Draft for Public Comment, 2018).[xxx]
[xxxi] EPA, 2019, EPA's PFAS Action Plan, *supra* note at 9.
[xxxii] OECD, 2018, Toward a New Comprehensive Global Database of PFAS, *supra* note.
[xxxiii] Congressional Research Service. 2019, PFAS and Drinking Water, *supra* note.
[xxxiv] EPA, 2019, EPA's PFAS Action Plan, *supra* note at 10.
[xxxv] Bartell, S. et. al., 2018, Michigan PFAS Science Advisory Panel, *supra* note at 15.
[xxxvi] Bartell, S. et. al., 2018, Michigan PFAS Science Advisory Panel, *supra* note at 14.
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[xlii] Ibid.
[xliii] See Table 1 Numbers 4-6 above on p. 6.
[xliv] 33 USC 1313(c)(2)(B).
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[xlvi] Ibid., at iii, 1-1.
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