Appendix A: Toxicological Summary Information and Derivation of Surface Water Quality Standards

NC PFAS Rulemaking Proposal
Attachment A

Toxicological Summary Information
and
Derivation of
Surface Water Quality Numerical Standards

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All information is current as of June 25, 2024

Attachment A:
Proposed PFAS Water Quality Standards Supporting Information:
Toxicological Summary and Derivation of Numerical Standards

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1. Overview

The intended purpose of this document is to provide a summary of the toxicological basis for the development of the PFAS surface water quality standards that are being proposed for the state of North Carolina. This document highlights the principal studies and health effects used in the determination of the toxicological values used in the derivation of the proposed PFAS surface water quality standards. A complete description of the toxicological values and the Federal guidance that was followed for the derivation of the standards are described in subsequent sections.

There are eight PFAS compounds that are included in the Rulemaking Proposal. These PFAS were selected for rulemaking because all eight of these PFAS compounds have a significant literature base, from which health effects can be determined; the literature bases for all eight PFAS compounds have been evaluated by a federal agency; all eight PFAS compounds have health effects data to support the derivation of the necessary toxicological values; all eight PFAS compounds have been detected in NC's environmental media; and there is a final US Environmental Protection Agency (EPA) test method for measuring chemicals in different environmental media (EPA, 2024d). The PFAS compounds that are included in the Rulemaking Proposal are:

1. Perfluorooctane sulfonic acid (PFOS, CASRN 1763-23-1),
2. Perfluorooctanoic acid (PFOA, CASRN 335-67-1),
3. Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX; CASRN 13252-13-6),
4. Perfluorobutane Sulfonic Acid (PFBS; CASRN 375-73-5),
5. Perfluorononanoic acid (PFNA, CASRN 375-95-1),
6. Perfluorohexanesulfonic acid (PFHxS, CASRN 355-46-4),
7. Perfluorobutanoic Acid (PFBA; CASRN 375-22-4),
8. Perfluorohexanoic Acid (PFHxA, CASRN 307-24-4).

Six of the eight PFAS compounds that are included in the Rulemaking Proposal are included in the EPA National Primary Drinking Water Regulation (NPDWR). The PFAS compounds included in the NPDWR are PFOS, PFOA, HFPO-DA, PFBS, PFNA, and PFHxS (89 FR 32532, 2024). The other two PFAS that are included in the Rulemaking Proposal are PFBA and PFHxA, which have been comprehensively evaluated after the EPA proposed the NPDWR. Surface water quality standard have been developed for all eight of these PFAS compounds following the procedures in EPA's Methodology for Deriving Ambient Water Quality Standard for the Protection of Human Health, hereafter referred to as the EPA 2000 Methodology (EPA, 2000).

2. Toxicological Information

The toxicological information that was used to support the Rulemaking Proposal was provided in toxicological evaluations and reports issued by a federal agency, specifically the EPA or the Centers for Disease Control and Prevention's (CDC) Agency for Toxic Substances and Disease Registry (ATSDR). When the EPA and ATSDR conduct toxicological evaluations, specific reference values that indicate the toxicity of that chemical are derived from all toxicological literature and data available for that chemical. Reviewing the existing toxicological information is a lengthy process and is done following a systematic method to achieve consistency between the reference values of each chemical and each program or agency that conducts the review. Both the EPA and ATSDR federal programs follow the Guidelines for Development of Toxicological Profiles that were developed by the EPA and the US Department of Health and Human Services (DHHS) (52 FR 12866, 1987). The Guidelines provide a high-level description of the systematic process that the toxicological profiles follow. Each agency has since developed guidelines that provide greater detail throughout all steps in the process.

The Guidelines include a list of general principles that the Agencies will follow, including, that the *"primary function of the profiles is to present and interpret the available toxicological and human data on the substances being profiled; these data may be used to evaluate the significance to individuals and the public-at-large of current or potential exposures to the subject hazardous substances. The profiles also will review the adequacy of available data on the substances and will identify toxicological data needs for which research programs should be designed".* The Guidelines provide extensive details regarding the development of toxicological profiles and can be found in the Federal Register. There is a specific list of required information that the toxicological profiles must include, at a minimum (52 FR 12866, 1987). The required information is:

(A) An examination, summary, and interpretation of available toxicological information and epidemiologic evaluations on a hazardous substance in order to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects.

(B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure which present a significant risk to human health of acute, subacute, and chronic health effects.

(C) Where appropriate, an identification of toxicological testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans.

All federal toxicological evaluations that are used to support the Rulemaking Proposal were published in 2021 or more recently. The titles and citations of each evaluation are provided below in the individual PFAS descriptive sections and can be found in the reference list. Six of the eight PFAS that are included in the Rulemaking Proposal are also included in the EPA's National Primary Drinking Water Regulation (NPDWR). The remaining two of the eight PFAS compounds have been thoroughly evaluated by the EPA's Integrated Risk Information System (IRIS) program, which provides a high level of confidence in the toxicological information.

EPA National Primary Drinking Water Regulation (NPDWR) PFAS Compounds

The six PFAS compounds included in the final NPDWR that was proposed on March 14, 2023 and finalized on April 9, 2024 under the Safe Drinking Water Act (SDWA) are PFOS, PFOA, HFPO-DA, PFBS, PFNA, and PFHxS (88 FR 18667, 2023; 89 FR 32532, 2024). The toxicological details for each of these compounds have been thoroughly evaluated by the EPA and were deemed robust enough for inclusion in the federal drinking water regulation.

The EPA's Toxicity Assessments for PFOS, PFOA, HFPO-DA, and PFBS were prepared by the Health and Ecological Criteria Division, in the Office of Science and Technology, within the Office of Water (OW) of the EPA. The pertinent toxicological information, including the reference dose (RfD) and cancer slope factor (CSF) where available, were published in the Federal Register with the final NPDWR and is further discussed below (89 FR 32532, 2024).

The EPA included PFNA and PFHxS in the NPDWR based on the Toxicological Profile for Perfluoroalkyls provided by the CDC's Agency for Toxic Substance and Disease Registry (ATSDR) (ATSDR, 2021; 89 FR 32532, 2024). The profile provided by ATSDR was conducted in accordance with both ATSDR and EPA guidelines that were originally published in the Federal Register on April 17, 1987, and met recent updates regarding content and evaluation (52 FR 12866, 1987). The pertinent toxicological information, specifically, the RfDs for these PFAS, are discussed below.

EPA Integrated Risk Information System (IRIS) PFAS Compounds

The EPA's Integrated Risk Information System (IRIS) Assessments for PFBA and PFHxA were prepared by the Center for Public Health and Environmental Assessment (CPHEA) in the Office of Research and Development (ORD) at the EPA. The IRIS assessments provide toxicity values for health effects resulting from chronic chemical exposure as well as the RfD and CSF. The IRIS assessments meet the 1987 Guidelines as well as the recently updated guidance from EPA specific to IRIS assessments (EPA, 2022e).

Comparison of Toxicological Evaluations

DEQ conducted a comparative review of the ATSDR, EPA Health and Ecological Criteria Division, and EPA IRIS programs methods and derived PFAS values and determined that the information provided by each program was of equivalent quality. DEQ also requested feedback from the NC Secretaries Science Advisory Board (SSAB). The NC SSAB discussed the differences in methodologies between the toxicity assessments that the EPA and ATSDR conducted at their meeting held on April 3, 2024. The tables that the NC SSAB reviewed are provided in Appendix Section 6.2. The NC SSAB concluded that the non-IRIS EPA assessments and the EPA's RfDs based on the CDC ATSDR assessments are adequate and of comparable fit-for-purpose to the EPA's IRIS assessments. The meeting recording where this discussion can be found here, between the 40 minute and 2-hour time stamp: April 3, 2024, NCSSAB Meeting Recording.

2.1. Types of Toxicological Values

There are three types of toxicological values that are relevant to deriving water quality standards using the EPA 2000 Methodology (EPA, 2000). They are the Reference Dose (RfD), the Cancer Slope Factor (CSF), and the Bioaccumulation Factor (BAF). The RfD and the CSF come from the federal toxicity assessments. The BAFs can come from multiple sources. Each of these values and their derivation process is described below.

2.1.1. *Reference Dose (RfD)*

The Reference Dose (RfD) is an estimate of a daily exposure to the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA, 1993). The RfDs that are provided for the PFAS compounds in this document were derived by the EPA and the CDC's ATSDR. Both of these federal programs follow the Guidelines for Development of Toxicological Profiles that were developed by the EPA and the DHHS (52 FR 12866, 1987). Following the Guideline requirements, the available literature, and the studies that are of the highest quality and/or most appropriate toxicological endpoints are selected for further evaluation and comparison to derive a RfD. The initial evaluation of these studies requires the identification of adverse effects in a dose-response experiment, or dose-dependent epidemiology study. The concentration at which the adverse effects are observed becomes the point of departure (POD), where the model system departs homeostasis and adverse effects occur instead. The PODs from these studies are converted to a Human Equivalency Dose (POD_{HED}) using the pre-determined human clearance factor for each chemical and/or standardized modeling approaches. The most appropriate POD_{HED} is selected for derivation of the RfD.

The uncertainty of the studies that were evaluated for the POD_{HED} is accounted for systematically. There are several individual Uncertainty Factors (UF) for each type of uncertainty, all of which are combined for the total UF. The individual UFs account for:

- UF_H = the variation in sensitivity of the human population.
- UF_A = the uncertainty in extrapolating animal data to humans.
- UF_S = the uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure to lifetime exposure (i.e., subchronic to chronic exposure).
- UF_L = the uncertainty in extrapolating from the Lowest Observable Adverse Effect Level (LOAEL) rather than from No Observable Adverse Effect Level (NOAEL).
- UF_D = the uncertainty associated with extrapolation from animal data when the database is incomplete.

The value chosen for each UF depends on the quality of the studies available, the extent of the database, and scientific judgement. The UFs are assigned a value of 1, 3, or 10, and justification of the assigned value is always provided in the EPA documentation where RfDs are derived (EPA, 2002).

$$RfD = POD_{HED}/UF_C$$

The RfD is calculated by dividing the POD_{HED} by the total or composite UF (UF_C). The overall chronic RfD is then selected from the health specific RfDs derived for each of the high-quality studies, if more than one health outcome is identified. The overall RfD that is derived is available for use in health risk assessments (EPA, 2012).

2.1.2. *Cancer Slope Factor (CSF)*

The CSF denotes the cancer risk per unit of chemical dose and is expressed as concentration of chemical dose per kilogram body weight per day (dose [mg or ng]/kg/day). The CSF can be used to compare the relative potency of different chemical substances (EPA, 1992). The CSFs that are provided for the PFAS compounds in this document were derived by the EPA following the Guidelines for Development of Toxicological Profiles developed by the EPA and the Department of Health and Human Services (DHHS) (52 FR 12866, 1987).

The carcinogenicity of a chemical is described in the designated "*Toxicity*" section of the profiles alongside a summary of the relevant scientific studies and exposure scenarios (52 FR 12866, 1987). Following the Guideline requirements listed above, the existing literature and available data were evaluated for derivation of a CSF, in the same method that is used to evaluate literature and data for a RfD. The calculation of a CSF begins with identification of the minimum dose that led to an adverse effect, the POD, since this is the dose that caused the system to depart from homeostasis. EPA's 2005 Guidelines for Carcinogen Risk Assessment recommends modeling the dose-response data from each high-quality study based on the adverse effects observed using the widely accepted method from the publicly available Benchmark Dose Software (BMDS) program which makes use of the Benchmark Dose Approach (both described below) (EPA, 2005). The software fits models to the data from the studies to extrapolate to lower doses than those that were used in the studies.

2.1.2.1. Benchmark Dose (BMD) Approach

Health risk assessments often include an analysis of the toxicological dose-response data and health-related outcomes. The dose-response analysis includes defining a POD and extrapolating the POD for relevance to human populations (POD_{HED}). The Benchmark Dose (BMD) approach is named for modeling the dose-response data to determine the specific doses that are related to the chosen health outcome at the low end of the dose-response data – these are called "benchmark doses" or "benchmark responses" (BMDs or BMRs). The BMDs identified can be used as PODs for extrapolation of health effects data, and for comparison of the dose-response results across studies and health outcomes. The approach is similar for non-cancer and cancer outcomes. The difference in the approach between the two types of outcomes can be the selected POD, and whether a linear or non-linear extrapolation is used for dose-response modeling. The identification of a POD and the applied modeling leads to the calculation of a RfD or a CSF for use in health risk assessments (EPA, 2012).

The BMD approach was developed to address the recognized limitations of the previously used method for non-cancer outcomes, since it incorporates and conveys more information than the preceding method (i.e., the NOAEL/LOAEL method). The NOAEL/LOAEL method is still used when there is not enough data to facilitate the BMD method. When applicable, the BMD approach provides a consistent methodology for both cancer and non-cancer outcomes, and a calculated RfD or CSF that is independent of the study design that the data was extracted from (for a more detailed comparison, see Table A-1).

2.1.2.2. BMDS Software

The Benchmark Dose Software (BMDS) has been freely available to the public from the EPA since 2000 and is routinely updated (EPA, 2022c). The BMDS facilitates the calculation of the BMD through application of mathematically fitted models to the dose-response data and makes a technical toxicological analysis and complex modeling approach seem simple. The application of the BMDS results can have far-reaching implications and should be examined by an experienced toxicologist that understands the statistical approaches used and the underlying methods of the BMD approach.

The BMDS software determines a Benchmark Response (BMR) in the dataset (typically at the lower end of the dataset) which allows for the identification of the POD and to derive a protective RfD or CSF that may be based on a POD that is below the POD that was calculated only using the experimental data, if appropriate. If the POD has been identified from an experimental animal study, dosimetric adjustments are used to convert the doses used in the animal to lifetime continuous human-equivalent doses (HEDs).

The dosimetric adjustment factors (DAF) can account for different chemical clearance rate across species; converting an internal (serum) concentration to a dose concentration (mg/kg/day) that is applicable to humans; and other conversions necessary to interpret an animal-based study for lifetime human exposures (EPA, 2012). For the purposes of this document, the DAFs used in each PFAS compounds toxicity assessment are described in their respective sections, and when applicable an Overall Dosimetric Adjustment Factor (oDAF) is presented.

Non-carcinogenic Endpoints

If the toxicological endpoint of the selected POD comes from a non-carcinogenic mode of action (MOA), a variety of models can be applied to the experimental animal data, and the model that best fits the data is used to select the BMR (EPA, 2012). The selected POD can then be converted to a POD_{HED} with DAFs, if appropriate, and the RfD can be calculated as described above.

Carcinogenic Endpoints

If the toxicological endpoint of the selected POD occurs from a carcinogenic mode of action (MOA) different models are used to suit the various carcinogenic MOAs. If the mode of action is unknown or mutagenic, a linear model is used, and the slope of the line results in the CSF. Mutagenic modes of action also require the evaluation of age-dependent adjustment factors to account for the sensitivity of children to carcinogenic outcomes. If the MOA is not mutagenic or another MOA is consistent with linear extrapolation at low doses, a non-linear model is used for low dose extrapolation. In non-linear models, the POD is determined based on the key events of carcinogenesis reported in the study. The DAFs are applied to convert the POD into the POD_{HED}. Then the CSF is calculated by dividing the selected BMR by the POD_{HED}.

$$CSF = BMR / POD_{HED}$$

2.1.2.3. Cancer Classification

During the process of evaluating a chemical for carcinogenicity, the Guidelines for Carcinogenic Risk Assessment require a discussion of the weight of the carcinogenic evidence evaluated within the assessment, and a description of the conditions for carcinogenicity based on the evidence evaluated to be provided (EPA, 2005). The five carcinogenicity descriptors and a brief description of the evidence required for each descriptor are provided below. A detailed definition of each descriptor is available in the Guidelines for Carcinogenic Risk Assessment (EPA, 2005).

- ***"Carcinogenic to Humans"*** – indicates strong evidence of human carcinogenicity and covers different combinations of evidence.
- ***"Likely to be Carcinogenic to Humans"*** – appropriate when the weight of the evidence from animal studies is adequate to demonstrate carcinogenic potential to humans but does not reach the weight of evidence for the descriptor "Carcinogenic to Humans."; evidence covers a broad spectrum.
  - ➢ The term "likely" can have a probabilistic connotation in other contexts, but its use here does not correspond to a quantifiable probability of whether the chemical is carcinogenic. This is because the data that support cancer assessments generally are not suitable for numerical calculations of the probability that an agent is a carcinogen.
  - ➢ Other health agencies have expressed a comparable weight of evidence using terms such as "Reasonably Anticipated to Be a Human Carcinogen" (NTP) or "Probably Carcinogenic to Humans" (International Agency for Research on Cancer).
- ***"Suggestive Evidence of Carcinogenic Potential"*** – appropriate when the weight of evidence is suggestive of carcinogenicity; a concern for potential carcinogenic effects in humans is raised, but the data are judged not sufficient for a stronger conclusion.
- ***"Inadequate Information to Assess Carcinogenic Potential"*** – appropriate when available data are judged inadequate for applying one of the other descriptors. Additional studies generally would be expected to provide further insights.
- ***"Not Likely to Be Carcinogenic to Humans***" - appropriate when the available data are considered robust for deciding that there is no basis for human hazard concern.

The 2005 guidelines are the most recent guidance document for carcinogenic risk assessment from the EPA, which updates the 1986 guidance document and the guidance provided in the Federal Register in 1980 (45 FR 79318, 1980; EPA, 1986). Previously in the 1986 document, the cancer classifications were provided in the form of hierarchical categories that should include a narrative summary of the weight of evidence. At the time of the 1986 hierarchical categories' inception, the EPA noted that for well-studied substances, the scientific data base will have a complexity that cannot be captured by any classification scheme, and emphasized the need for an overall, balanced judgment of the totality of the available evidence (EPA, 1986). The 2005 guidelines and cancer classifications described here formally replaced the 1986 hierarchical categories, are used to succinctly communicate the strength of the database related to carcinogenic outcomes, and should always be used in tandem with the weight of evidence evaluation and the rest of the specific toxicological documentation (EPA, 2005).

2.1.3. *Bioaccumulation Factor (BAF)*

Bioaccumulation Factors (BAF) and Bioconcentration Factors (BCF) account for the accumulation of chemicals in the tissue of aquatic organisms and are required to calculate surface water quality standard that are protective of the Fish Consumption (FC), and Water Supply (WS) designated uses. BCF values are derived from laboratory experimental data based solely on water exposures to chemicals and not dietary sources. Therefore, a BCF is a conservative estimate of accumulation in the laboratory animal and must meet guidelines set forth by the EPA to be considered robust enough for use in a BCF calculation (EPA, 2020). A BAF is based on field measurements and includes all possible exposure sources (e.g., respiratory, dietary, dermal, etc.), which is a more realistic estimate of accumulation. Both factors are calculated similarly, as defined below (ITRC, 2023). The EPA has moved toward the use of a BAF to reflect the uptake of a contaminant from all sources (e.g., ingestion, sediment) by fish and shellfish, rather than just from the water column as reflected by the use of a BCF (EPA, 2000). The technical information used to select the BAFs used in the Rulemaking Proposal is further described herein.

- Bioconcentration factor (BCF) — the direct uptake of PFAS by an organism from the water column (e.g., through the gills). This is measured in the laboratory. It is defined as the ratio of the concentration in an organism to that in the exposure water (typically in units of ng/kg, ng/L, or L/kg).

- Bioaccumulation factor (BAF) — the amount of PFAS taken up from water plus the contribution of PFAS in the diet of the organism. Both the organism and its diet are simultaneously exposed to the same exposure sources. This is generally measured in the field (typically in units of ng/kg, ng/L, or L/kg).

2.1.3.1. Sources of Data

The EPA provides national BAFs that are used by the EPA to calculate the nationally recommended water quality standard that the States implement following federal guidance (EPA, 2016). These BAF values serve as the main source of BAF information for states and they are typically published in the EPA Human Health Ambient Water Quality Criteria guidance for that chemical (EPA, 2015). When there is not BAF information available from the EPA, the States may conduct site-specific studies, and/or conduct literature reviews to derive BAFs, however these uniquely derived BAFs can only be used in state-level regulations. Most states developing water quality standards under the Clean Water Act rely on EPA to provide BAF values. The best available data should be used, and in most cases, there is only one source of this information.

To assign BAF values for the eight PFAS chemicals included in the Rulemaking Proposal, all available bioaccumulation information for the selected PFAS compounds was identified and evaluated.

The available PFAS bioaccumulation datasets were:

a. Interstate Technology and Regulatory Council's (ITRC) Aquatic Organisms PFAS BCF-BAF Table (ITRC, 2021, 2023)
b. EPA Aquatic Life Ambient Water Quality Criteria for PFOS and PFOA (EPA, 2022a, 2022b)
c. Evaluation of Published Bioconcentration Factor (BCF) and Bioaccumulation Factor (BAF) Data for Per- and Polyfluoroalkyl Substances Across Aquatic Species (Burkhard, 2021)
d. DEQ's Cape Fear Water and Fish collection and analytical data (NCDEQ, 2023)

These data sources were assessed based on the number of research studies included, if the included studies were assessed for quality, and if relevant species were included, as shown below.

Table 1: A summary of the evaluation process used for each of the BAF datasets available.

PFAS BAF DATA SOURCE	MANY STUDIES INCLUDED	STUDIES QUALITY ASSESSED	ONLY RELEVANT SPECIES INCLUDED
ITRC PFAS BAF Table	Yes	No	No
EPA Aquatic Life Criteria for PFOS and PFOA	Yes	Yes	Yes
Published BAF Data from EPA/Burkhard	Yes	Yes	Yes
DEQ'S Cape Fear Water and Fish Data	*Primary Research Conducted in North Carolina*		Yes

2.1.3.2. Examination of Data:

The datasets were initially evaluated based on three main criteria to determine if each dataset was appropriate for further evaluation. The datasets were evaluated based on the number of studies that comprised the dataset, if quality metrics were applied to the included studies, and if studies that were relevant to NC were included. Based on these three initial criteria, the ITRC BAF Table was eliminated from further consideration, as it included many species not relevant to NC, and the quality of the studies or data that was entered into the table could not be assured (ITRC, 2021).

The EPA Aquatic Life Ambient Water Quality Criteria for PFOS and PFOA BAF data appendices (EPA, 2022a, 2022b), and DEQ's Cape Fear Water and Fish data (NCDEQ, 2023) were selected as the primary sources of data for further examination as they incorporated both an evaluation of nationally relevant BAFs by EPA that was conducted as part of 304(a) standard development and a site-specific study conducted by NCDEQ.

Information from both sources were compared and presented to the NC Secretaries' Science Advisory Board (NCSSAB) for technical discussion. DEQ presented a charge to the Board to determine if use of the EPA's BAF data and/or the Cape Fear River data would be appropriate for PFOS and PFOA. The official recommendation by the Board is that "the values from the three datasets are similar and determined that using either the EPA's entire BAF dataset, the dataset filtered for species specific to NC, or the DEQ Cape Fear River (CFR) BAF data is appropriate and scientifically sound to represent NC waterbodies" (NCSSAB, 2023).

The publication “Evaluation of Published Bioconcentration Factor (BCF) and Bioaccumulation Factor (BAF) Data for Per- and Polyfluoroalkyl Substances Across Aquatic Species” (Burkhard, 2021) was evaluated by DEQ staff following the guidelines set by the NCSSAB’s recommendations for PFOA and PFOS BAF values. The publication includes BAFs for a wide variety of PFAS compounds that were scrutinized by the EPA’s Great Lakes Toxicology and Ecology Division senior Chemist, Lawrence Burkhard, PhD. One of the primary goals of this publication was to provide PFAS bioaccumulation data for BCFs and BAFs in a centralized location that states could use without having to spend significant resources to examine the existing scientific literature while advancing our understanding of PFAS bioaccumulation (Burkhard, 2021). The data were examined by specific metrics to determine their quality and appropriateness for use in deriving BAFs. The BAFs presented in the publication are similar to the BAFs derived in DEQ’s Cape Fear River study and are comprised of data from many studies across many species. The BAFs from the three adequate data sources are detailed below.

Table 2: The BAFs for each of the PFAS compounds included in the Rulemaking Proposal from each data source available**.**

PFAS	EPA Aquatic Life Data	Burkhard EPA 2021	CFR BAF
PFOS	1585	1514	1539
PFOA	10	8.5	36
HPFO-DA	-	4.1	-
PFBS	-	22	-
PFNA	-	144	381
PFHxS	-	20	39
PFBA	-	3	54
PFHxA	-	1.6	-

2.1.3.3. Selection of Data:

Among the three datasets [EPA Aquatic Life Ambient Water Quality Criteria for PFOS and PFOA (EPA, 2022a, 2022b), Evaluation of Published Bioconcentration Factor (BCF) and Bioaccumulation Factor (BAF) Data for Per- and Polyfluoroalkyl Substances Across Aquatic Species (Burkhard, 2021), DEQ’s Cape Fear Water and Fish data (NCDEQ, 2023)] BAF values for the eight PFAS compounds selected for surface water standards development were compared. The dataset presented in Burkhard, 2021 is the most robust dataset in terms of number of studies and species and includes all eight of the PFAS compounds selected for rulemaking. To provide a consistent approach to all PFAS compounds selected for rulemaking, the Burkhard, 2021 BAF dataset was selected for use in deriving the proposed surface water quality standards.

3. Water Quality Standards Development Information

Section 304(a) of the Clean Water Act (CWA) and Title 40 of the Code of Federal Regulations Part 131 require that surface water standards be based on sound scientific principles using current scientific knowledge (33 U.S.C. §1251 et seq, 1972; 48 FR 51405, 1983; 40 CFR Part 131). DEQ has derived the surface water standard values presented below using the methodology provided by the EPA 2000 Methodology (EPA, 2000). The EPA methodology details specific requirements and procedures for the application of relevant toxicological values to derive water quality standard to protect designated uses by using the most current exposure factor information. These requirements and procedures are discussed below.

3.1. Surface Water Numerical Standard Derivation

Section 303 of the Clean Water Act (CWA) and Title 40 of the Code of Federal Regulations Part 131 require states to adopt water quality standards to protect the designated uses of surface waters, including the drinking water supply, fish consumption, and recreation human health uses. The CWA, 40 CFR and NC General Statute also require that water quality standards must "protect human health and welfare" (33 U.S.C. §1251 et seq, 1972; 40 CFR Part 131; NC G.S. § 143-211). The process and calculations for deriving numeric standard to protect the fish consumption and water supply uses are described in the EPA 2000 Methodology (EPA, 2000). Water supply standard can be calculated using the equations provided in the EPA 2000 Methodology or may be based on drinking water standards as described in EPA's 2000 Revisions to the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (65 FR 66444, 2000).

3.1.1. *Toxicological Requirements for Deriving Human Health Criteria*

The derivation of human health criteria for the protection of the fish consumption and water supply designated uses requires specific toxicological information as described in the EPA 2000 Methodology and shown in the calculations below (EPA, 2000).

The derivation of human health criteria for carcinogenic substances (i.e., those substances with carcinogenic health effects), involves the use of Cancer Slope Factors (CSF) and an appropriate cancer risk level that is protective of the general population as well as sensitive sub-populations. The development of CSFs is described in Section 2.1.2 and the specific CSFs used to derive the standard are described in Section 4. The EPA 2000 Methodology and the Revision to the 2000 Human Health Methodology (65 FR 66444, 2000) indicate that the appropriate risk level for carcinogens to protect the general population is a risk level of 10^{-6}. EPA routinely uses the risk level of 10^{-6} for derivation of national human health criteria and NC has historically adopted fish consumption and water supply standards this level.

The derivation of human health criteria for non-carcinogenic substances (i.e., substances that cause non-cancer related health effects) involves the use of Reference Doses (RfDs) and Relative Source Contributions (RSC) as described in the EPA 2000 Methodology. The development of RfDs is described in Section 2.1.1, and the specific RfDs used to derive the standard are described in Section 4. The basis of the selected RSC is discussed in Section 3.1.2 below.

The derivation of fish tissue and water supply standard also require the use of a Bioaccumulation Factor (BAF) or Bioconcentration Factor (BCF). These factors estimate the ability of a chemical to accumulate in fish tissue and serve to estimate the potential exposure that people face when consuming fish. More detail on BAFs and BCFs is provided in Section 2.1.3 of this document.

The toxicological values for eight PFAS compounds that are included in the Rulemaking Proposal were all derived using this required information.

- The RfD values were provided by the appropriate EPA programs and followed the IRIS Handbook Methodology (EPA, 2022e) and in some cases were evaluated by a second federal agency (CDC).
- The available CSF (formerly designated as a Cancer Potency Factor or CPF) by EPA and changed to CSF to reflect more accurately the derivation) values are provided by the EPA and were based on the updated version of the Linearized Multistage Model (that forced non-negativity on model coefficients and ensuring linearity as an upper limit in the low-dose area), the BMDS Multistage Model that enables values at lower doses that are not linear to be considered for POD selection because it only limits the model's coefficients to be non-negative and does not significantly change the model results.
    - There was a comparison of the two model types conducted with 102 datasets and showed that they both provide virtually identical BMD data (Subramaniam, White and Cogliano, 2006). The similarity in the results of the two models is likely due to the similarity of the model application to the data; when the Linearized Multistage Model is applied to the data, a Multistage Model is fitted to the data before applying the linearization (EPA, 1992).
- The BAF values were provided in a comprehensive review publication by the EPA that was conducted by the Great Lakes National Program Office.
- The RSC values were based on the recommendations in the EPA 2000 Methodology.

3.1.2. *Surface Water Standard Equations*

The EPA 2000 Methodology provides equations that are to be used to derive fish consumption and water supply standard for non-carcinogenic and carcinogenic contaminants (EPA, 2000). The equations provided by the EPA 2000 Methodology use slightly different variables in the equations than those that are used by NC, so the equations are presented using the NC variables for ease of comprehension. These equations are shown below and include the most current exposure factors provided by EPA (EPA, 2015).

For non-carcinogens, the equations are provided by the EPA in Equations and 1-1 (EPA, 2000).

Fish Consumption (FC) standard equation:

FC = [(RfD x WT x RSC) / (FCR x BAF)] * 1000

Water Supply (WS) standard equation:

WS = [(RfD x WT x RSC) / (WI + (FCR x BAF))] * 1000

For carcinogens, the equations are provided by the EPA in Equations and 1-3 (EPA, 2000),

Fish Consumption (FC) standard equation:

FC = [(RL x WT) / (q1* x FCR x BAF)] * 1000

Water Supply (WS) standard equation:

WS = [(RL x WT) / (q1* x (WI + (FCR x BAF))] * 1000

Acronyms

RfD = Reference Dose
RL = Risk Level
WT = Adult Body Weight
RSC = Relative Source Contribution
FCR = Daily Fish Tissue Intake
BAF = Bioaccumulation Factor
q1* = Carcinogenic Slope (potency) Factor
WI = Adult Water Intake

Surface water exposure factors

WT= 80 kg
WI = 2.4 L / day
FCR = 0.022 g / day
RSC = 0.2 for organics
RL = 10^{-6}

Exposure Factors used in NC Water Quality Standard Equations

The exposure factors that are included in the water quality standards equations in the preceding section are important to note. The average adult human body weight (WT), average adult water intake based on the per capita estimate of community water ingestion at the 90th percentile for adults ages 21 and older (WI), and average daily fish tissue intake based on the 90th percentile consumption rate of fish and shellfish from inland and nearshore waters for the US adult population 21 years of age and older. (FCR) have been updated based on the most recent national health data and the appropriate values for the groundwater and surface water standards are listed in those respective sections (EPA, 2015).

The relative source contribution (RSC) and the risk level (RL) are provided in the EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health guidance document (EPA, 2000). The RSC is the percentage of the total exposure that comes from the source that the calculation pertains to, in this case, groundwater and surface water. The RSC is used for non-carcinogenic chemicals and there is a 10% or 20% value assigned for the RSC which is dependent upon the type of chemical (organic vs. inorganic) being calculated, since the majority of exposure generally comes from dietary sources and drinking water (EPA, 2000). Since PFAS are organic substances, the RSC of 0.2 (20%) is used to define the standard for Surface Water Standards. The RSC of 0.2 (or 20%) is used in federal drinking water regulations and is the most common and appropriate number used in water quality regulations under the Clean Water Act. The EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health harmonized the criteria for the CWA and the SDWA, and an RSC of 0.2 is the lowest allowable RSC under the SDWA, as it is a conservative approach to public health and has become standard practice in this application (EPA, 2000).

The RL is used when a chemical is known to be carcinogenic and corresponds to lifetime excess cancer risk levels. Previously, the EPA has provided guidance that surface water programs should use an RL of 10^{-7} to 10^{-5} however the publication of the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health EPA published its national 304(a) water quality standard at a 10^{-6} risk level, which EPA considers appropriate for the general population (EPA, 2000).

3.2. EPA Analytical Method 1633

The EPA Analytical Method that will be used to detect and report the eight PFAS compounds included in the Rulemaking Proposal is Method 1633. Method 1633 is the analytical method for detecting PFAS in a variety of media, including drinking water, surface water, groundwater, and complex matrix environmental mediums (EPA, 2024d). Method 1633 was validated in a multi-lab validation study that was conducted across ten independent laboratories (Willey *et al.*, 2023). Using the data gathered during the inter-lab validation study, the minimum detection limit (MDL) and the limit of quantitation (LOQ) for each PFAS included in the analytical method were determined. Method 1633's quality control requirements are meeting the acceptable percent relative standard deviation (%RSD) metrics for each of the PFAS compounds through determination of a laboratory specific MDL and LOQ. The lab-specific LOQ must fall within the range of verified LOQs from the multi-lab validation report that are provided in Method 1633 (EPA, 2024d).

For PFOS and PFOA, the range of LOQs span 1 – 4 ng/L (Table A-2, EPA, 2024). The Multi-laboratory Validation Study demonstrated that Method 1633 can verifiably quantitate PFOS and PFOA at an LOQ of 0.95 ng/L reliably (Willey *et al.*, 2023). To ensure that all laboratories that are analyzing PFAS samples with 1633 can accurately detect and report PFOS and PFOA concentrations, the EPA has set the LOQ for PFOS and PFOA at 4.0 ng/L, which was the highest LOQ reported in the Multi-laboratory Validation Study (Willey *et al.*, 2023; 89 FR 32532, 2024).

The Clean Water Act requires the water quality standard to be based on a health protective toxicological value. The defined standard for PFOS and PFOA are lower than both the analytical method LOQ set by the EPA (89 FR 32532, 2024; EPA, 2024d). However, the limitation in laboratory capability to accurately report the health-based defined criteria value is used to regulate PFOS and PFOA at 4.0 ng/L during NPDES permit issuance and compliance.

4. Proposed Surface Water Quality Numerical Standards

The proposed water quality standards for the eight PFAS chemicals included in the Rulemaking Proposal and outlined above are supported by the Section 304(a) CWA and the EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, the proposed standards are individually discussed here. Each PFAS compound is presented in the same fashion for ease of comparison. The sections are organized as a summary of the proposed NC Surface Water Quality Standards based on the toxicological values (RfD, CSF) taken from the relevant federal guidance document, following EPA guidance. After the initial summary in each section, the detailed section discussing the relevant toxicological information that the EPA used to derive the RfD and CSF for each of the PFAS compounds is presented. This information is summarized in Tables 3 and 4 below.

Table 3: The proposed NC Surface Water Quality Numerical Standards for eight PFAS compounds by water body classification.

PFAS	Federal Guidance Document	Proposed Water Quality Standard[a] (ng/L)	
		Non-Water Supply[b]	Water Supply[c]
PFOS	EPA OW Toxicity Assessment (EPA, 2024b)	0.06 (CSF)	0.06 (CSF)
PFOA	EPA OW Toxicity Assessment (EPA, 2024c)	0.01 (CSF)	0.001 (CSF)
HPFO-DA	EPA OW Toxicity Assessment (EPA, 2021a)	500	10[d]
PFBS	EPA OW Toxicity Assessment (EPA, 2021b)	10,000	2,000
PFNA	ATSDR Toxicity Profile (ATSDR, 2021); EPA NPDWR (EPA, 2024a)	20	10
PFHxS		70	10
PFBA	EPA IRIS Assessment (EPA, 2022d)	200,000	6,000
PFHxA	EPA IRIS Assessment (EPA, 2023)	200,000	3,000

[a] Rounded using the EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (EPA, 2000).
[b]Used for fish consumption and other designated.
[c]Used for drinking water consumption and other designated uses.
[d]Value based on EPA established a maximum contaminant level (MCL) in April 2024 (EPA, 2024a).

Table 4: The toxicological information used to derive the RfD (and CSF if appropriate) for each of the PFAS compounds included in the Rulemaking Proposal.

PFAS	Critical Effect	POD	Overall Dosimetry Adjustment Factor (oDAF)	POD_{HED} (mg/kg/day)	Total UF	RfD[f] (mg/kg/day)	Federal Guidance Document
PFOS	**Developmental:** PFOA in first and second trimesters and decreased birth weight (Wikström *et al.*, 2020) **Cardiovascular:** Increased serum total cholesterol (Dong *et al.*, 2019)	*Not Applicable, POD_{HED} was identified from human epidemiology studies.*		0.000001	10 [b]	0.0000001; (CSF = 39.5)	EPA OW Toxicity Assessment (EPA, 2024b)
PFOA	**Immune:** PFOA at age 5 on anti-diphtheria antibody concentrations at age 7; PFOA at age 5 and anti-tetanus antibody concentrations at age 7 (Budtz-Jørgensen and Grandjean, 2018) **Developmental:** PFOA in first and second trimesters and decreased birth weight (Wikström *et al.*, 2020) **Cardiovascular:** Increased serum total cholesterol (Dong *et al.*, 2019)	*Not Applicable, POD_{HED} was identified from human epidemiology studies.*		0.000000275	10 [b]	0.00000003; (CSF = 0.0000000293)	EPA OW Toxicity Assessment (EPA, 2024c)
HPFO-DA	**Hepatic:** Liver constellation of lesions in parental female mice (Dupont, 2010)	0.09*	0.14	0.01	3000 [b-e]	0.000003	EPA OW Toxicity Assessment (EPA, 2021a)
PFBS	**Developmental:** Decreased serum total T4 in newborn (PND1) mice (Feng *et al.*, 2017)	22*	0.0043	0.095	300 [b-d]	0.0003	EPA OW Toxicity Assessment (EPA, 2021b)
PFNA	**Developmental:** Decreased body weight and developmental delays in mice (Das *et al.*, 2015)	6.8 ^	0.0001518	0.001	300 [c]	0.000003	ATSDR Toxicity Profile (ATSDR, 2021); EPA NPDWR (EPA, 2024a)
PFHxS	**Thyroid:** Thyroid follicular epithelial hypertrophy/hyperplasia in rats (Butenhoff *et al.*, 2009)	73.2^	0.000064	0.0047	3000 [b-e]	0.000002	
PFBA	**Hepatic:** Increased hepatocellular (liver) hypertrophy **Thyroid:** Decreased total T4 (Butenhoff *et al.*, 2012)	5.6*	0.229	1.27	1000	0.001	EPA IRIS Assessment (EPA, 2022d)
PFHxA	**Developmental:** Decreased F1 body weight at PND 0 in rats (Loveless *et al.*, 2009)	10.6*	0.0045	0.048	100	0.0005	EPA IRIS Assessment (EPA, 2023)

[*] Dose concentration (mg/kg/day); [^] Internal serum concentration (ug/ml); [b] UF based on interspecies extrapolation; [c] UF based on database limitations; [d] UF based on variation in the human population; [e] UF based on experimental duration extrapolation. [f] RfDs were rounded to one significant figure by EPA and ATSDR; [g] BAFs taken from Burkhard, 2021.

4.1 Perfluorooctane sulfonic acid (PFOS, CASRN 1763-23-1)

NC Water Quality Standard Proposed Values

The proposed values for 02B Fish Consumption (FC) and Water Supply (WS) standard are 0.06 and 0.06 ng/L, respectively (Table 3).

The EPA published the CSF and RfD for PFOS in the *Toxicity Assessment and Proposed Maximum Contaminant Level Goal for Perfluorooctane Sulfonic Acid (PFOS) in Drinking Water* (EPA, 2024b). The CSF was derived from studies that reported carcinomas in rodents, and the RfD was derived from two human epidemiology studies. When the surface water standard are calculated using each the CSF and the RfD, they produce a nearly identical value (Table 3; Appendix Section 6.3.1). Since PFOS has been classified as a "*Likely Human Carcinogen*" by the EPA, and the EPA has established a Maximum Contaminant Level Goal of zero for PFOS due to its carcinogenic classification, PFOS is labeled as a carcinogen under 02B (EPA, 2024b)(Table 4). The equations to define the Water Quality standard are presented in Section 6.3.1.

Both of the resulting health-based standard (CSF-based or RfD-based) are below the limits of quantitation (LOQ) or practical limit of analytical quantitation (PQL) based on the national multi-laboratory validation conducted by the Department of Defense (DOD) and EPA in developing the final test method 1633 (Willey *et al.*, 2023). The multi-laboratory range of validated limits of quantitation (LOQ) for PFOS by Method 1633 ranges from 1 – 4 ng/L (Willey *et al.*, 2023; EPA, 2024d).

Rule 02B .0404(f) is proposed to be added as part of the Rulemaking Proposal to allow effluent limitations developed pursuant to Paragraph 02B .0404 (a) for NPDES permits to be set at the LOQ of EPA's analytical method 1633 (Willey *et al.*, 2023; EPA, 2024d).

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

There were two high-quality studies identified for PFOS out of the ten studies that were evaluated for RfD development. These two critical studies are epidemiological studies that report the relationship between PFOS exposure and decreased birth weight following maternal exposure, and elevated cholesterol in a highly exposed human population (Dong *et al.*, 2019; Wikström *et al.*, 2020), Table A-3).

The developmental effects were identified by an association between PFOS concentration in maternal serum and infant birth outcomes, specifically decreased birth weight (Wikström *et al.*, 2020). The POD where the decreased birth weight was observed was 1.13×10^{-6} mg/kg/day (EPA, 2024b). The POD was divided by a UF of 10 to account for human variability, which resulted in an RfD of 1.13×10^{-7}, which was rounded to one significant figure for the final value of the RfD to be 1.0×10^{-7}, or 0.0000001 mg/kg/day PFOS.

The cardiovascular effect of increased cholesterol was identified in both the Center for Disease Control and Prevention's (CDC) National Health and Nutrition Examination Survey (NHANES) population and a highly exposed population (The C8 Health Project study population). The candidate RfDs from each study were similar and the overall RfD calculated for this cardiovascular outcome was the same as both studies (1.0×10^{-7}, or 0.0000001 mg/kg/day PFOS). Dong *et al.*, 2019 was chosen as the principal study since there was greater confidence in the analysis of this study in comparison to the other C8 population study that was evaluated by the EPA (EPA, 2023; Table A-3).

There were seven other studies and health outcomes evaluated for selection as the critical effect and principal study to support the PFOS RfD. The health outcomes evaluated in these other studies included immune effects, specifically diminished vaccine response in children, and hepatic effects that resulted in liver enzyme changes. Both health outcome specific RfDs are 2.0×10^{-7}, which is slightly greater than the selected RfD of 1.0×10^{-7} based on the Dong et al. 2019 study that reported increased cholesterol with PFOS exposure.

Cancer Slope Factor (CSF) Development

There were two studies identified for CSF development by the EPA. These two studies highlight the carcinogenic effect of PFOS in rodents, specifically hepatocellular adenomas and carcinomas, and pancreatic cell carcinomas (Table A-4). The data from both studies was determined to be of high quality by the US EPA (EPA, 2024b).

The CSF for PFOS was developed following the method described previously in section *2.1.2. Cancer Slope Factor (CSF).* The POD for dosed animals was converted into a POD_{HED} by multiplying the POD by the human clearance value for PFOS (0.128; EPA, 2023c). The POD_{HED} is equivalent to the constant exposure, by bodyweight, that would result in a serum concentration equal to the POD based on the study (EPA, 2024b). The BMDL for PFOS was calculated using the standardized method in EPA's BMDS program with multistage models for tumor dose-response data. A BMR of 10% was chosen based on EPA's BMD Technical Guidance to account for additional risk factors unaccounted for in the data or subsequent calculations (EPA, 2024b). The CSF was calculated by dividing the BMR of 10% by the POD_{HED}. The CSF was selected based on the lowest POD reported from the animal studies, which was calculated to be 39.5 mg/kg/day (Table A-4).

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) with an MCLG for PFOS of 0 ng/L as it is a carcinogenic compound. The carcinogenic classification is reflected in the proposed standard equal to 0.06 ng/L (Table 3). For the NPDWR, EPA accounted for the laboratory limitations and other feasibility issues to set the PFOS MCL at 4.0 ng/L. North Carolina has addressed this analytical limitation through flexibility in permitting and compliance.

4.2 Perfluorooctanoic acid (PFOA, CASRN 335-67-1)

NC Water Quality Criteria Proposed Values

The proposed PFOA values for 02B Fish Consumption (FC) and Water Supply (WS) criteria are 0.01 and 0.001 ng/L, respectively (Table 3).

The EPA published the CSF and RfD for PFOA in the *Toxicity Assessment and Proposed Maximum Contaminant Level Goal for Perfluorooctanoic Acid (PFOA) in Drinking Water* (EPA, 2024c). The CSF and the RfD were both derived from human epidemiology studies (Table 4). Since PFOA has been classified as a "*Likely Human Carcinogen*" by the EPA, and the EPA has established a Maximum Contaminant Level Goal of zero for PFOS due to its carcinogenic classification, PFOA is labeled as a carcinogen under 02B (EPA, 2024b). The equations to define the Water Quality criteria are presented in Section 6.3.2.

Both of the resulting health-based standards (CSF-based or RfD-based) are below the limits of quantitation (LOQ) or practical limit of analytical quantitation (PQL) based on the national multi-laboratory validation conducted by the Department of Defense (DOD) and EPA in developing the final test method 1633 (Willey *et al.*, 2023). The multi-laboratory range of validated limits of quantitation (LOQ) for PFOA by Method 1633 ranges from 1 – 4 ng/L (Willey *et al.*, 2023; EPA, 2024d).

Rule 02B .0404(f) is proposed to be added as part of the PFAS Rulemaking to allow effluent limitations developed pursuant to Paragraph 02B .0404 (a) for NPDES permits to be set at the LOQ of EPA analytical method 1633 (Willey *et al.*, 2023; EPA, 2024d).

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

There were three high quality studies identified for PFOA out of the nine studies that were initially evaluated for RfD development. These studies documented the relationship between PFOA exposure and (i) decreased vaccine response in children, (ii) decreased birth weight following maternal exposure, and (iii) increased cholesterol levels in a highly exposed human population, respectively (Budtz-Jørgensen and Grandjean, 2018; Dong *et al.*, 2019; Wikström *et al.*, 2020). All three of these adverse health outcomes had the same POD and health-effect specific derived RfD (Table A-5).

The developmental effects were identified through an association between PFOA concentration in maternal serum and infant birth outcomes. Specifically, two studies documented a reduction in birth weight that was correlated with increasing PFOA concentration in maternal serum (Sagiv *et al.*, 2018; Dong *et al.*, 2019; Wikström *et al.*, 2020). The POD for birth outcomes was chosen from the Wikström *et al.*, 2020 study (2.92×10^{-7} mg/kg/day) because it was more conservative and protective than the POD reported in the Sagiv *et al.*, 2018 study (1.21×10^{-6} mg/kg/day). The POD value of 2.92×10^{-7} mg/kg/day was divided by an uncertainty factor of 10 to account for human variability, which resulted in the health-outcome specific RfD of 3.0×10^{-8} mg/kg/day PFOA (EPA, 2023b; Table A-5).

The cardiovascular effect of increased cholesterol was identified in both the NHANES population and a highly exposed population, the C8 Health Project study population (Steenland and Woskie, 2012; Dong *et al.*, 2019). The POD value was chosen from the Dong *et al.*, 2019 based on higher confidence in the analysis of this study and that the POD of 2.75×10^{-7} mg/kg/day was more protective. The POD was divided by an uncertainty factor of 10 to account for human variability, which resulted in the health-outcome specific RfD of 3.0 x 10^{-8} mg/kg/day PFOA, which is the same value as the developmental health outcome RfD.

The immune effects that were identified in response to PFOA exposure included decreased vaccine response in children, specifically decreased anti-tetanus and anti-diphtheria antibody responses. The PODs for the immune-related health outcomes were 3.05 x 10^{-7} mg/kg/day and 2.92 x 10^{-7} mg/kg/day, respectively (Budtz-Jørgensen and Grandjean, 2018). Each POD was divided by an uncertainty factor of 10 to account for human variability, which resulted in the health-outcome specific RFD value of 3.0 x 10^{-8} mg/kg/day PFOA for both immune outcomes.

As the health-outcome specific RfDs from each of the three high-quality studies were the same (3.0 x 10^{-8} mg/kg/day), this value was selected as the overall RfD for PFOA. All other health-outcome specific RfDs that were considered were within one order of magnitude of this value (EPA, 2023b, Table A-5).

Cancer Slope Factor (CSF) Development

Both human epidemiology studies and animal model studies were evaluated in determining the CSF for PFOA. The animal-derived CSFs ranged from 8 to 53 mg/kg/day PFOA based on testicular, hepatocellular, and pancreatic adenomas (EPA, 2024c). Two human epidemiology studies were examined, and both demonstrated a positive relationship between PFOA exposure and kidney cancer (EPA, 2023b; Table A-6).

The CSF for PFOA was developed following the method described in section *2.1.2. Cancer Slope Factor (CSF).* The study that reported the most conservative POD for kidney cancer was chosen for use in the calculation of the CSF for PFOA. The POD reported in this study was 3.52 x 10^{-3} ng/kg/day PFOA. Since this value was derived from a human study, the POD does not need to be converted to a POD_{HED}. The POD was divided by the human clearance value for PFOA (0.120; EPA, 2023b) to convert the internal dose-derived POD to an external dose CSF, resulting in a calculated CSF value of 0.0293 ng/kg/day PFOA.

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) with an MCLG for PFOA of 0 ng/L as it is a carcinogenic compound. The carcinogenic classification is reflected in the proposed Standard equal to 0.001 ng/L (Table 3). For the NPDWR, EPA accounted for the laboratory limitations and other feasibility issues to set the PFOA MCL at 4.0 ng/L. North Carolina has addressed this analytical limitation through flexibility in permitting and compliance.

4.3. Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX; CASRN 13252-13-6)

NC Water Quality Standard Proposed Values

The proposed HFPO-DA values for 02B Fish Consumption (FC) and Water Supply (WS) standards are 500 and 10 ng/L, respectively (Table 3).

The EPA published an RfD for HFPO-DA in the *Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt (CASRN 13252-13-6 and CASRN 62037-80-3) Also Known as "GenX Chemicals"* (EPA, 2021a). This RfD was determined based on liver effects (constellation of lesions including cytoplasmic alteration, hepatocellular single-cell and focal necrosis, and hepatocellular apoptosis) reported in an oral reproductive and developmental toxicity study with exposure of 53 - 64 days in mice (Dupont, 2010) (Table 4). The equations to define the Water Quality Standards are presented in Section 6.3.3.

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

Several studies were evaluated to identify specific health outcomes to use for RfD development by the EPA. The studies evaluated report a consensus that the liver is the most sensitive organ to HFPO-DA exposure. To filter the data for the effects that had systemic impact on the hepatic system, and were therefore considered more adverse, the effects that were observed at a gross and histological or pathological level were selected for further evaluation. Adverse liver effects were observed at low doses (5 mg/kg/day) in 28/day, 90/day, and reproduction/developmental oral exposure studies in mice (Dupont, 2010). The 28/day study was not considered any further since the longer duration studies also demonstrated adverse effects at low doses (EPA, 2021, Table A-7). The EPA's BMDS program was used to calculate the PODs based on 10% of the BMDL of the three doses used in the 90/day study. The BMDS software provided a POD for the male and female responses observed in the study, 0.14 and 0.09 mg/kg/day, respectively (EPA, 2021a).

The POD_{HED} values were calculated in two steps following EPA's guidance. First, by applying a dosimetry adjustment factor (DAF) specific to body weight (rather than clearance factors as used in PFHxA's DAF calculation) to the animal POD dose.

$$DAF = (BWa^{1/4}/BWh^{1/4})$$

where:
BWa = Animal Bodyweight.
BWh = Human Bodyweight.

A BWh of 80 kg was used with male and female mouse body weights of 0.0372 and 0.0349, and yielded DAFs of 0.15 and 0.14 mg/kg/day, respectively. Second, by using the DAF in the POD_{HED} calculation below, the POD_{HED}s for males and female were calculated to be 0.02 and 0.01 mg/kg/day, respectively.

$$POD_{HED} = \text{POD animal dose (mg/kg/day)} \times DAF$$

The RfDs were then calculated by dividing the total UF of 3000 (3 for interspecies extrapolation, 10 for human variability, 10 for duration extrapolation, and 10 for database deficiencies) from the POD_{HED} (Table A-7). The resulting candidate RfDs were 7×10^{-6} and 3×10^{-6}, for males and females respectively. The more conservative candidate RfD was chosen as the overall chronic RfD for HFPO-DA, at 3 x 10^{-6} mg/kg/day of HFPO-DA.

Cancer Slope Factor (CSF) Development

The EPA has not classified HFPO-DA for carcinogenicity. The cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1 x 10^{-6} cannot be calculated according to the requirements of the EPA's 2000 Methodology (EPA, 2000).

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) with an MCLG and MCL for HFPO-DA of 10 ng/L, since HFPO-DA is not currently classified as carcinogenic. This MCL value is lesser than the calculated numerical standard using the RfD, and about the LOQ for analytical Method 1633, so the MCL value of 10 ng/L is proposed for rulemaking in accordance with EPA requirements, since the MCL is as protective as the MCLG (also 10 ng/L) (65 FR 66444, 2000; 89 FR 32532, 2024).

4.4 Perfluorobutane Sulfonic Acid (PFBS; CASRN 375-73-5)

NC Water Quality Standard Proposed Values

The proposed PFBS values for 02B Fish Consumption (FC) and Water Supply (WS) Standards are 10,000 and 2,000 ng/L, respectively (Table 3).

The EPA published an RfD for PFBS in the *Human Health Toxicity Values for Perfluorobutane Sulfonic Acid (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3)* (EPA, 2021b). This RfD was determined based on developmental effects (decreased thyroid hormones in newborn mice) reported in an oral reproductive and developmental toxicity study (Feng *et al.*, 2017) (Table 4). The equations to define the Water Quality standard are presented in Section 6.3.4.

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

There were three high-quality studies evaluated to derive the RFD from. These studies reported the relationship between PFBS exposure and numerous developmental effects, kidney effects, and thyroid effects (Lieder, Chang, *et al.*, 2009; Lieder, York, *et al.*, 2009; Feng *et al.*, 2017; NTP, 2019) (Table A-8). The EPA's BMDS program was used to calculate the POD_{HED} based on 10% of the BMDL for all health outcomes associated with these three critical studies (EPA, 2021b). Since the thyroid effects were observed in two species, in both sexes, and across life stages and different exposure durations in two separate high-quality studies, the thyroid effects were selected as the health outcome that the overall RfD would be based on (Feng *et al.*, 2017; NTP, 2019). The thyroid effects observed in the Feng *et al.*, 2017 study that included gestational exposure to PFBS for 20 days were more biologically significant than the NTP, 2019 study, so it was selected as the principal study the RfD would be based on.

The DAF that was used to convert the POD to the POD_{HED} included the sex-specific animal half-life values for both mouse and rat, and the average serum elimination half-life value for humans (EPA, 2021b). The BMDS software was used to determine the dose concentration that is ½ of a standard deviation from the control dose, since there is no information regarding what a biologically significant level of change is for PFBS in the sensitive developmental life stage. The developmental endpoints were entered into the BMDS software separately to find the best fit model and data for RfD derivation. The female mouse thyroid endpoints yielded the best fit model in the BDMS process, do the species and sex-specific DAF = 0.0043 was used to convert the POD to the POD_{HED} (EPA, 2021b).

The calculated POD_{HED} for PFBS based on the doses used in the Feng *et al.*, 2017 study was 0.095 mg/kg/day. The POD_{HED} was then divided by the total UF of 300 (3 for interspecies differences, 10 for database deficiencies, and 10 for human variability) and resulted in the overall RfD of 3 x 10^{-4} mg/kg/day PFBS.

Cancer Slope Factor (CSF) Development

The EPA has not classified PFBS for carcinogenicity since there are not enough studies to properly evaluate PFBS for carcinogenic classification and a cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1 x 10^{-6} cannot be calculated according to the requirements of the EPA 2000 Methodology (EPA, 2000).

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) for PFAS mixtures containing at least two or more of PFHxS, PFNA, HFPO-DA, and PFBS using a unitless Hazard Index (89 FR 32532, 2024). No individual MCLG or MCL has been established for PFBS, so the value defined using the RfD is proposed for rulemaking, in accordance with the methodology for compounds that have not been evaluated for carcinogenic classification (EPA, 2000) (2,000 ng/L; Table 3).

4.5 Perfluorononanoic acid (PFNA, CASRN 375-95-1)

NC Water Quality Standard Proposed Values

The proposed PFNA values for 02B Fish Consumption (FC) and Water Supply (WS) Standards are 20 and 10 ng/L, respectively (Table 3).

The EPA published the RfD for PFNA in the NPDWR in the Federal Register, and the CDC published the intermediate MRL in the ATSDR Toxicological Profile for Perfluoroalkyls (ATSDR, 2021; 89 FR 32532, 2024). This RfD was determined based on decreased body weight and developmental delays in mice (Das *et al.*, 2015)(Table 4). The RfD was not changed from the ATSDR MRL as developmental delays are sensitive endpoints that are relevant to humans, a full discussion of the EPA's review is available in the Federal Register (89 FR 32532, 2024). The equations to define the Water Quality standard are presented in Section 6.3.5.

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

There were three developmental studies evaluated to derive the MRL from. These studies reported the relationship between PFNA exposure and effects on offspring weight, survival, and postnatal development (Wolf *et al.*, 2010; Rogers *et al.*, 2014; Das *et al.*, 2015). The lowest internal serum concentration in mice that corresponded to the Lowest Observable Adverse Effects Level (LOAEL) for developmental effects was 10.9 ug.ml and the value corresponding to the No Observable Adverse Effects Level (NOAEL) was 6.8 ug/ml PFNA in mouse serum (Das *et al.*, 2015, Table A-9). Since the lowest observable adverse effects were seen in the Das *et al.*, 2015 study it was selected as the principal study that the MRL and subsequent RfD would be derived from , (ATSDR, 2021; 89 FR 32532, 2024). Since the NOAEL was identified in mouse serum, which represents the internal dose the mouse received, rather than the dose given orally, different adjustment factors are used to account for the internal dose conversion into a HED. The $NOAEL_{HED}$ was calculated by multiplying the internal mouse serum concentration (6.8 ug/ml) by the 2.5-year elimination half-life (7.59×10^{-4}) and the volume distribution (0.2 ml/kg) and dividing the result by the gastrointestinal absorption factor (1). This results in the $NOAEL_{HED}$ of 0.001 mg/kg/day (ATSDR, 2021).

The calculated MRL was derived by multiplying the total UF of 30 (3 UF for extrapolation from animals to humans with dosimetry adjustment, 10 UF for human variability) by the modifying factor (MF) of 10 (for database limitations), and then dividing the $NOAEL_{HED}$ by the quotient. The calculated MRL for PFNA is 0.001 mg/kg/day.

$$MRL = NOAEL_{HED} \div (UFs \times MF)$$

The EPA notes that ATSDR MRLs and EPA RfDs are not necessarily equivalent (e.g., intermediate-duration MRL vs. chronic RfD; EPA and ATSDR may apply different uncertainty/modifying factors) and are developed for different purposes. In this case, EPA did not apply an additional UFs to calculate the HBWC for PFNA because the critical effect is identified in a developmental population (EPA, 2000). The MF used by ATSDR is equivalent to the database UF term used by the EPA, so that form of uncertainty was already accounted for in the ATDSR calculation. To derive the EPA's NPDWR value for PFNA of 10 ng/L, the 90th percentile two/day average water ingestion for lactating women (13 to < 50 years), 0.0469 L/kg/day, was used in their calculation, to match the developmental effects of the principal study and critical effect in the ATSDR profile.

Cancer Slope Factor (CSF) Development

The EPA and ATSDR have not classified PFNA for carcinogenicity since there are not enough studies to properly evaluate PFBS for carcinogenic classification and a cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1 x 10^{-6} cannot be calculated according to the requirements of the EPA 2000 Methodology (EPA, 2000).

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established the NPDWR with an MCLG and MCL for PFNA of 10ng/L (EPA, 2024). Since the MCL value is equal to the value defined using the RfD, value defined using the RfD is proposed for rulemaking in accordance with methodology for compounds that have not been evaluated for carcinogenic classification (EPA, 2000) (10 ng/L; Table 3).

4.6. Perfluorohexanesulfonic acid (PFHxS, CASRN 355-46-4)

NC Water Quality Standard Proposed Values

The proposed PFHxS values for 02B Fish Consumption (FC) and Water Supply (WS) Standards are 70 and 10 ng/L, respectively (Table 3).

The EPA published the RfD for PFHxS in the NPDWR in the Federal Register, and the CDC published the intermediate MRL in the ATSDR Toxicological Profile for Perfluoroalkyls (ATSDR, 2021; 89 FR 32532, 2024). There is an order of magnitude difference between the ATSDR MRL and the EPA RfD, which is described in detail below and in the Federal Register (89 FR 32532, 2024). Both the RfD and MRL values were based on the same critical thyroid effects observed in rats (Butenhoff et al 2009a, Table 4). The equations to define the Water Quality Standard are presented in Section 6.3.6.

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

There were four laboratory studies that were evaluated to derive the MRL from. These studies reported the relationship between PFHxS exposure and effects on the thyroid and liver of exposed rodents, and decreased litter size in (Butenhoff *et al.*, 2009; Bijland *et al.*, 2011; Chang *et al.*, 2018; Ramhøj *et al.*, 2018) The health effect that was selected as the critical effect was changes to the thyroid, since some epidemiology studies have shown a link between thyroid effects and PFHxS exposure in humans (Wen *et al.*, 2013). The laboratory study that the thyroid effects were observed in, Buttenhoff et al 2009, was selected as the principal study. The LOAEL in this study was 3 mg/kg/day of PFHxS, and the NOAEL was 1 mg/kg/day (ATSDR, 2021). The $NOAEL_{HED}$ was calculated by multiplying the internal mouse serum concentration (73.22 ug/ml) by the human clearance value (2.23×10^{-4}) and the volume distribution (0.2 ml/kg) and dividing the result by the gastrointestinal absorption factor (1). For the purposes of this document, the oDAF in Table 3 is 0.000064, which is the product of the human clearance value and the volume distribution. The $NOAEL_{HED}$ of 0.0047 mg/kg/day is the product of the internal serum concentration and the oDAF. (ATSDR, 2021).

The calculated MRL was derived by multiplying the total UF of 30 (3 UF for extrapolation from animals to humans with dosimetry adjustment, 10 UF for human variability) by the modifying factor (MF) of 10 (for database limitations), and then dividing the $NOAEL_{HED}$ by the quotient. The calculated MRL for PFHxS is 0.00002 mg/kg/day.

$$MRL = NOAEL_{HED} \div (UFs \times MF)$$

The EPA notes that ATSDR MRLs and EPA RfDs are not necessarily equivalent (e.g., intermediate-duration MRL vs. chronic RfD; EPA and ATSDR may apply different uncertainty/modifying factors) and are developed for different purposes. In this case, EPA did apply an additional UF to calculate the HBWC for PFHxS because the critical effect is identified in an adult rat population and not a developmental population, which was the case for PFNA (EPA, 2000). The MF used by ATSDR is equivalent to the database UF term used by the EPA, so that form of uncertainty was already accounted for in the ATDSR calculation. The EPA added a UF of 10 for extrapolation of the exposure duration, since the laboratory study was a sub chronic exposure (ATSDR, 2021; 89 FR 32532, 2024). To derive the EPA's NPDWR value for PFHxS all the combined UFs were divided from the

$NOAEL_{HED}$, resulting in an RfD of 0.000002 mg/kg/day, a value one order of magnitude smaller than the ATSDR MRL (89 FR 32532, 2024)(Table A-10).

Cancer Slope Factor (CSF) Development

The EPA and ATSDR have not classified PFHxS for carcinogenicity since there are not enough studies to properly evaluate PFBS for carcinogenic classification and a cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of the EPA's 2000 Methodology (EPA, 2000).

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established the NPDWR with an MCLG and MCL for PFHxS of 10ng/L (EPA, 2024). The MCL value is the same as the value defined using the RfD, so the RfD-based value is proposed for rulemaking in accordance with methodology for compounds that have not been evaluated for carcinogenic classification (EPA, 2000)(10 ng/L; Table 3).

4.7. Perfluorobutanoic Acid (PFBA; CASRN 375-22-4)

NC Water Quality Standard Proposed Values

The proposed PFBA values for 02B Fish Consumption (FC) and Water Supply (WS) Standards are 200,000 and 6,000 ng/L, respectively (Table 3).

The EPA published the RfD for PFBA in the *IRIS Toxicological Review of Perfluorobutanoic Acid (PFBA, CASRN 375-22-4) and Related Salts* (EPA, 2022d). The RfD was determined based on decreased thyroid hormones and increased liver weight and hypertrophy (Butenhoff *et al.*, 2012) (Table 4). The equations to define the Water Quality criteria are presented in Section 6.3.7.

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

Two high-quality studies were selected for further evaluation and RfD calculation. These studies report liver and thyroid effects from a 90/day exposure to PFBA in rodents (Butenhoff *et al.*, 2012; Feng *et al.*, 2017) and developmental effects from a gestational exposure lasting 17 days in rodents (Das *et al.*, 2015). The specific endpoints that were considered for RfD development in the Buttenhoff et al. 2012a study were increased liver weight and hypertrophy and decreased thyroid hormones (EPA, 2022d). The endpoints that were considered for RfD derivation from the Das et al. 2008 study were perinatal mortality, and delayed developmental effects including eye opening, vaginal opening, and preputial separation (EPA, 2022d), Table A-11).

The PODs were determined using the EPA's BMDS where the BMD and 95% lower confidence limit on the BMD (BMDL) were estimated using a BMR to represent a minimal, biologically significant level of change of 10% based on the data presented in the Buttenhoff et al. 2012a study. The POD was determined to be 5.56 mg/kg/day PFBA. The DAF used was the quotient of the human clearance value and the species and sex-specific animal clearance value (0.229). The POD_{HED} of 1.27 was calculated by multiplying the POD by the DAF. The RfD was derived by dividing the POD_{HED} of 1.27 mg/kg/day by an uncertainty factor of 1000 (10 for variation in sensitivity among the human population, 3 for interspecies extrapolation, 10 for extrapolation of a subchronic effect level to a chronic effect level, and 3 for database deficiencies).

Cancer Slope Factor (CSF) Development

The EPA has not classified PFBA for carcinogenicity since there are not enough studies to properly evaluate PFBA for carcinogenic classification, and a cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of the EPA 2000 Methodology (EPA, 2000).

Maximum Contaminant Level (MCL) Information

There is currently no MCLG or MCL for PFBA provided in the NPDWR, so the value defined using the RfD is proposed for rulemaking in accordance with methodology for compounds that have not been evaluated for carcinogenic classification (EPA, 2000) (6,000 ng/L; Table 3).

4.8. Perfluorohexanoic Acid (PFHxA, CASRN 307-24-4)

NC Water Quality Standard Proposed Values

The proposed PFHxA values for 02B Fish Consumption (FC) and Water Supply (WS) Standards are 200,000 and 3,000 ng/L, respectively (Table 3).

The EPA published the RfD for PFHxA in the *IRIS Toxicological Review of Perfluorohexanoic Acid [PFHxA, CASRN 307-24-4] and Related Salts* (EPA, 2023). This RfD was determined based on developmental effects, specifically decreased postnatal weight, observed in a gestational 12/day oral exposure study in rodents (Loveless *et al.*, 2009) (Table 4). The equations to define the Water Quality Standards are presented in Section 6.3.8.

Principal Study, Critical Effect, and Reference Dose (RfD) Selection

There were five high-quality studies evaluated for RfD derivation. Of these five studies, two of the studies included early life exposures related to developmental health effects, which are most appropriate for estimating effects of lifetime exposure, so those two studies were evaluated further as well as the study that detailed decreases in female adult rodent red blood cell counts ((Loveless *et al.*, 2009; Iwai and Hoberman, 2014; Klaunig *et al.*, 2015), Table A-12).

These studies exposed rodents to PFHxA during critical windows of development. The developmental effects evaluated for POD derivation were decreased postnatal body weight and increased perinatal mortality (EPA, 2023).

The PODs were determined using the EPA's BMDS where the BMD and BMDL were estimated using a BMR of 5% relative deviation from the control mean, instead of the 95% used in the derivation of the PFBA values. The BMR of 5% is used for developmental effects to account for health impacts occurring at this sensitive life stage (EPA, 2012). The POD derived based on these BMDS calculations was 10.62 (mg/kg-d), which was then multiplied by a Dosimetry Adjustment Factor (DAF) which was calculated from the ratio of human to animal clearance factors for PFHxA (1.84×10^{-3} L/kg-hr divided by 0.383 L/kg-hr [based on the Loveless *et al.*, 2009 study] = 0.0048 DAF) and applied to the POD.

$$\text{DAF} = \frac{\text{Human Clearance Factor}}{\text{Animal Clearnce Factor}}$$

To calculate the POD_{HED} of PFHxA, the POD of 10.62 mg/kg/day was multiplied by the DAF of 0.0048 L/kg-hr and then multiped by the normalization factor to convert the dosed chemical from sodium salt to free acid (molecular weight of the free acid divided by the molecular weight of the salt; 314/336 = 0.935), to result in a POD_{HED} of 0.048 mg/kg/day of PFHxA.

$$\text{POD}_{\text{HED}} = \text{POD animal dose (mg/kg/day)} \times \text{DAF}$$

The RfD of 0.0005 mg/kg/day was derived by dividing the POD_{HED} of 0.048 mg/kg/day by an uncertainty factor of 100 (3 for variation in sensitivity among the human population, 10 for interspecies extrapolation, 1 for extrapolation of a subchronic effect level to a chronic effect level, and 1 for database deficiencies).

Cancer Slope Factor (CSF) Development

The EPA has not classified PFHxA for carcinogenicity since there are not enough studies to properly evaluate PFHxA for carcinogenic classification, and a cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of the EPA 2000 Methodology (EPA, 2000).

Maximum Contaminant Level (MCL) Information

There is currently no MCLG or MCL for PFHxA provided in the NPDWR, so the value defined using the RfD is proposed for rulemaking in accordance with methodology for compounds that have not been evaluated for carcinogenic classification (EPA, 2000) (3,000 ng/L; Table 3).

5. References

33 U.S.C. §1251 et seq (1972) 'WATER POLLUTION PREVENTION AND CONTROL'. Available at: https://www.govinfo.gov/content/pkg/USCODE-2018-title33/pdf/USCODE-2018-title33-chap26.pdf (Accessed: 24 June 2024).

40 CFR Part 131 (no date) 'PART 131—WATER QUALITY STANDARDS'. Available at: https://www.ecfr.gov/current/title-40/part-131 (Accessed: 24 June 2024).

45 FR 79318 (1980) 'Environmental Protection Agency Water Quality Criteria Documents'. Available at: https://www.federalregister.gov/citation/45-FR-79318 (Accessed: 3 June 2024).

48 FR 51405 (1983) 'PART 131—WATER QUALITY STANDARDS'. Available at: https://archives.federalregister.gov/issue_slice/1983/11/8/51391-51423.pdf#page=15 (Accessed: 24 June 2024).

52 FR 12866 (1987) 'Notice of the First Priority List of Hazardous Substances That Will Be the Subject of Toxicological Profiles and Guidelines for Development of Toxicological Profiles'. Federal Register. Available at: https://tile.loc.gov/storage-services/service/ll/fedreg/fr052/fr052074/fr052074.pdf (Accessed: 22 December 2023).

65 FR 66444 (2000) 'Revisions to the Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)'.

88 FR 18667 (2023) 'Environmental Protection Agency. 40 CFR Parts 141 and 142. PFAS National Primary Drinking Water Regulation Rulemaking.' Federal Register. Available at: https://www.govinfo.gov/content/pkg/FR-2023-03-29/pdf/2023-05471.pdf (Accessed: 2 January 2024).

89 FR 32532 (2024) *ENVIRONMENTAL PROTECTION AGENCY. 40 CFR Parts 141 and 142. PFAS National Primary Drinking Water Regulation.* Available at: https://www.govinfo.gov/content/pkg/FR-2024-04-26/pdf/2024-07773.pdf (Accessed: 14 May 2024).

ATSDR, C. (2021) 'Toxicological Profile for Perfluoroalkyls'. Available at: https://www.atsdr.cdc.gov/ToxProfiles/tp200.pdf (Accessed: 22 December 2023).

Bijland, S. *et al.* (2011) 'Perfluoroalkyl sulfonates cause alkyl chain length–dependent hepatic steatosis and hypolipidemia mainly by impairing lipoprotein production in APOE* 3-Leiden CETP mice', *Toxicological Sciences*, 123(1), pp. 290–303.

Budtz-Jørgensen, E. and Grandjean, P. (2018) 'Application of benchmark analysis for mixed contaminant exposures: Mutual adjustment of perfluoroalkylate substances associated with immunotoxicity', *PLoS One*, 13(10), p. e0205388.

Burkhard, L.P. (2021) 'Evaluation of Published Bioconcentration Factor (BCF) and Bioaccumulation Factor (BAF) Data for Per- and Polyfluoroalkyl Substances Across Aquatic Species', *Environmental Toxicology and Chemistry*, 40(6), pp. 1530–1543. Available at: https://doi.org/10.1002/etc.5010.

Butenhoff, J.L. *et al.* (2009) 'Gestational and lactational exposure to potassium perfluorooctanesulfonate (K+PFOS) in rats: Developmental neurotoxicity', *Reproductive Toxicology*, 27(3–4), pp. 319–330. Available at: https://doi.org/10.1016/j.reprotox.2008.12.010.

Butenhoff, J.L. *et al.* (2012) 'Chronic dietary toxicity and carcinogenicity study with potassium perfluorooctanesulfonate in Sprague Dawley rats', *Toxicology*, 293(1), pp. 1–15. Available at: https://doi.org/10.1016/j.tox.2012.01.003.

Chang, S. *et al.* (2018) 'Reproductive and developmental toxicity of potassium perfluorohexanesulfonate in CD-1 mice', *Reproductive toxicology*, 78, pp. 150–168.

Darrow, L.A., Stein, C.R. and Steenland, K. (2013) 'Serum Perfluorooctanoic Acid and Perfluorooctane Sulfonate Concentrations in Relation to Birth Outcomes in the Mid-Ohio Valley, 2005–2010', *Environmental Health Perspectives*, 121(10), pp. 1207–1213. Available at: https://doi.org/10.1289/ehp.1206372.

Das, K.P. *et al.* (2015) 'Developmental toxicity of perfluorononanoic acid in mice', *Reproductive toxicology*, 51, pp. 133–144.

DeWitt, J.C. *et al.* (2009) 'Immunotoxicity of Perfluorooctanoic Acid and Perfluorooctane Sulfonate and the Role of Peroxisome Proliferator-Activated Receptor Alpha', *Critical Reviews in Toxicology*, 39(1), pp. 76–94. Available at: https://doi.org/10.1080/10408440802209804.

Dong, Z. *et al.* (2019) 'Using 2003–2014 US NHANES data to determine the associations between per- and polyfluoroalkyl substances and cholesterol: Trend and implications', *Ecotoxicology and environmental safety*, 173, pp. 461–468.

Dupont, D.C.C. (2010) *DuPont-18405-1037: An Oral (Gavage) Reproduction/Developmental Toxicity Screening Study of H-28548 in Mice.*

EPA (1986) 'Guidelines for Carcinogen Risk Assessment'. Available at: https://cfpub.epa.gov/ncea/raf/car2sab/guidelines_1986.pdf.

EPA (1992) 'EPA's Approach for Assessing the Risks Associated with Chronic Exposure to Carcinogens. Background Document 2.' Available at: https://www.epa.gov/iris/epas-approach-assessing-risks-associated-chronic-exposure-carcinogens (Accessed: 22 December 2023).

EPA (1993) 'Reference Dose (RfD): Description and Use in Health Risk Assessments Background Document 1A'. Available at: https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments (Accessed: 22 December 2023).

EPA (2000) 'Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health'. Office of Science and Technology, Office of Water. Available at: https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf (Accessed: 2 January 2024).

EPA (2002) 'A Review of the Reference Dose and Reference Concentration Process'. Available at: https://www.epa.gov/sites/default/files/2014-12/documents/rfd-final.pdf.

EPA (2005) 'Guidelines for Carcinogen Risk Assessment'. Available at: https://archive.epa.gov/raf/web/pdf/cancer_guidelines_final_3-25-6.pdf (Accessed: 3 January 2024).

EPA (2012) 'Benchmark Dose Technical Guidance'. Available at: https://www.epa.gov/sites/default/files/2015-01/documents/benchmark_dose_guidance.pdf (Accessed: 22 December 2023).

EPA (2015) 'Human Health Ambient Water Quality Criteria: 2015 Update'. Available at: https://www.epa.gov/sites/default/files/2015-10/documents/human-health-2015-update-factsheet.pdf (Accessed: 31 January 2024).

EPA (2016) 'Development of National Bioaccumulation Factors: Supplemental Information for EPA's 2015 Human Health Criteria Update'. Available at: https://www.epa.gov/sites/default/files/2016-01/documents/national-bioaccumulation-factors-supplemental-information.pdf (Accessed: 31 January 2024).

EPA (2020) 'Fish Bioconcentration Data Requirement: Guidance for Selection of Number of Treatment Concentrations [Supplement to OCSPP Test Guideline 850.1730]'. Available at: https://www.epa.gov/sites/default/files/2020-07/documents/bcf-study-july-15-2020.pdf (Accessed: 22 December 2023).

EPA (2021a) 'Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt (CASRN 13252-13-6 and CASRN 62037-80-3) Also Known as "GenX Chemicals"'. Available at: https://www.epa.gov/system/files/documents/2021-10/genx-chemicals-toxicity-assessment_tech-edited_oct-21-508.pdf (Accessed: 22 December 2023).

EPA (2021b) 'Human Health Toxicity Values for Perfluorobutane Sulfonic Acid (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3)'. Available at: https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=542393 (Accessed: 22 December 2023).

EPA (2022a) 'AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA FOR PERFLUOROOCTANE SULFONATE (PFOS)'. Available at: https://www.epa.gov/system/files/documents/2022-04/pfos-report-2022.pdf (Accessed: 22 December 2023).

EPA (2022b) 'AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA for PERFLUOROOCTANOIC ACID (PFOA)'. Available at: https://www.epa.gov/system/files/documents/2022-04/pfoa-report-2022.pdf (Accessed: 22 December 2023).

EPA (2022c) 'Benchmark Dose Software VERSION 3.3 USER GUIDE'. Available at: https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=545595 (Accessed: 22 December 2023).

EPA (2022d) 'IRIS Toxicological Review of Perfluorobutanoic Acid (PFBA, CASRN 375- 22-4) and Related Salts'. Available at: https://iris.epa.gov/static/pdfs/0701tr.pdf (Accessed: 22 December 2023).

EPA (2022e) 'ORD Staff Handbook for Developing IRIS Assessments'. Available at: https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=545991 (Accessed: 16 February 2024).

EPA (2023) 'IRIS Toxicological Review of Perfluorohexanoic Acid [PFHxA, CASRN 307-24-4] and Related Salts'. Available at: https://iris.epa.gov/static/pdfs/0704tr.pdf (Accessed: 22 December 2023).

EPA (2024a) 'Final PFAS National Primary Drinking Water Regulation'. Available at: https://www.epa.gov/system/files/documents/2024-04/pfas-npdwr-presentation_4.9.24_overview.pdf.

EPA (2024b) 'Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts'. Available at: https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfos_2024-04-09-refs-formatted_508c.pdf (Accessed: 3 May 2024).

EPA (2024c) 'Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts'. Available at: https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfoa_2024-04-09-refs-formatted.pdf (Accessed: 3 May 2024).

EPA (2024d) 'Method 1633; Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS. .' Available at: https://www.epa.gov/system/files/documents/2024-01/method-1633-final-for-web-posting.pdf (Accessed: 2 January 2024).

Feng, X. *et al.* (2017) 'Exposure of Pregnant Mice to Perfluorobutanesulfonate Causes Hypothyroxinemia and Developmental Abnormalities in Female Offspring', *Toxicological Sciences*, 155(2), pp. 409–419. Available at: https://doi.org/10.1093/toxsci/kfw219.

Gallo, V. *et al.* (2013) 'Serum perfluoroalkyl acids concentrations and memory impairment in a large cross-sectional study', *BMJ Open*, 3(6), p. e002414. Available at: https://doi.org/10.1136/bmjopen-2012-002414.

ITRC (2021) 'Per- and Polyfluoroalkyl Substances Technical and Regulatory Guidance by the Interstate Technology & Regulatory Council PFAS Team. Table 5-1 Partitioning of PFAS into Fish - BCF and BAF'. Available at: https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fpfas-dev.itrcweb.org%2Fwp-content%2Fuploads%2F2023%2F10%2FITRC_PFAS_-BCF-BAF_compilation_Table5-1_Oct2021.xlsx&wdOrigin=BROWSELINK (Accessed: 3 January 2024).

ITRC (2023) 'Per- and Polyfluoroalkyl Substances Technical and Regulatory Guidance by the Interstate Technology & Regulatory Council PFAS Team.' Available at: https://pfas-1.itrcweb.org/wp-content/uploads/2023/12/Full-PFAS-Guidance-12.11.2023.pdf (Accessed: 3 January 2024).

Iwai, H. and Hoberman, A.M. (2014) 'Oral (gavage) combined developmental and perinatal/postnatal reproduction toxicity study of ammonium salt of perfluorinated hexanoic acid in mice', *International Journal of Toxicology*, 33(3), pp. 219–237.

Klaunig, J.E. *et al.* (2015) 'Evaluation of the chronic toxicity and carcinogenicity of perfluorohexanoic acid (PFHxA) in Sprague-Dawley rats', *Toxicologic pathology*, 43(2), pp. 209–220.

Lau, C. *et al.* (2006) 'Effects of Perfluorooctanoic Acid Exposure during Pregnancy in the Mouse', *Toxicological Sciences*, 90(2), pp. 510–518. Available at: https://doi.org/10.1093/toxsci/kfj105.

Lieder, P.H., York, R.G., *et al.* (2009) 'A two-generation oral gavage reproduction study with potassium perfluorobutanesulfonate (K+ PFBS) in Sprague Dawley rats', *Toxicology*, 259(1–2), pp. 33–45.

Lieder, P.H., Chang, S.-C., *et al.* (2009) 'Toxicological evaluation of potassium perfluorobutanesulfonate in a 90-day oral gavage study with Sprague–Dawley rats', *Toxicology*, 255(1–2), pp. 45–52.

Loveless, S.E. *et al.* (2009) 'Toxicological evaluation of sodium perfluorohexanoate', *Toxicology*, 264(1), pp. 32–44. Available at: https://doi.org/10.1016/j.tox.2009.07.011.

Luebker, D.J. *et al.* (2005) 'Neonatal mortality from in utero exposure to perfluorooctanesulfonate (PFOS) in Sprague–Dawley rats: dose–response, and biochemical and pharamacokinetic parameters', *Toxicology*, 215(1–2), pp. 149–169.

NC G.S. § 143-211, D. of public policy (no date) 'Article 21. Water and Air Resources. Part 1. Organization and Powers Generally; Control of Pollution.' Available at: https://www.ncleg.gov/EnactedLegislation/Statutes/PDF/BySection/Chapter_143/GS_143-211.pdf (Accessed: 24 June 2024).

NCDEQ (2023) '2022 Water and Fish Collection Project'. *NC Secretaries' Science Advisory Board Meeting*, Raleigh, NC. Available at: https://www.deq.nc.gov/media/37213/download?attachment (Accessed: 3 January 2024).

NCSSAB (2023) 'North Carolina's Secretaries' Science Advisory Board Official Recommendation on the Use of EPA's Bioaccumulation Factors (BAF) in North Carolina's Waterbodies'.

Nian, M. *et al.* (2019) 'Liver function biomarkers disorder is associated with exposure to perfluoroalkyl acids in adults: Isomers of C8 Health Project in China', *Environmental Research*, 172, pp. 81–88. Available at: https://doi.org/10.1016/j.envres.2019.02.013.

NTP (2019) *NTP Technical Report on the Toxicity Studies of Perfluoroalkyl Carboxylates (Perfluorohexanoic Acid, Perfluorooctanoic Acid, Perfluorononanoic Acid, and Perfluorodecanoic Acid) Administered by Gavage to Sprague Dawley (Hsd: Sprague Dawley SD) Rats (Revised)*. Toxicity Report 97. Research Triangle Park, North Carolina, USA: National Toxicology Program Public Health Service U.S. Department of Health and Human Services, p. 241. Available at: https://www.ncbi.nlm.nih.gov/books/NBK551546/pdf/Bookshelf_NBK551546.pdf (Accessed: 3 January 2024).

Ramhøj, L. *et al.* (2018) 'Perfluorohexane sulfonate (PFHxS) and a mixture of endocrine disrupters reduce thyroxine levels and cause antiandrogenic effects in rats', *Toxicological Sciences*, 163(2), pp. 579–591.

Rogers, J.M. *et al.* (2014) 'Elevated blood pressure in offspring of rats exposed to diverse chemicals during pregnancy', *toxicological sciences*, 137(2), pp. 436–446.

Sagiv, S.K. *et al.* (2018) 'Early-pregnancy plasma concentrations of perfluoroalkyl substances and birth outcomes in project viva: confounded by pregnancy hemodynamics?', *American journal of epidemiology*, 187(4), pp. 793–802.

Shearer, J.J. *et al.* (2021) 'Serum concentrations of per-and polyfluoroalkyl substances and risk of renal cell carcinoma', *JNCI: Journal of the National Cancer Institute*, 113(5), pp. 580–587.

Song, X. *et al.* (2018) 'Emissions, Transport, and Fate of Emerging Per- and Polyfluoroalkyl Substances from One of the Major Fluoropolymer Manufacturing Facilities in China', *Environmental Science & Technology*, 52(17), pp. 9694–9703. Available at: https://doi.org/10.1021/acs.est.7b06657.

Steenland, K. *et al.* (2009) 'Association of Perfluorooctanoic Acid and Perfluorooctane Sulfonate With Serum Lipids Among Adults Living Near a Chemical Plant', *American Journal of Epidemiology*, 170(10), pp. 1268–1278. Available at: https://doi.org/10.1093/aje/kwp279.

Steenland, K. and Woskie, S. (2012) 'Cohort Mortality Study of Workers Exposed to Perfluorooctanoic Acid', *American Journal of Epidemiology*, 176(10), pp. 909–917. Available at: https://doi.org/10.1093/aje/kws171.

Subramaniam, R.P., White, P. and Cogliano, V.J. (2006) 'Comparison of cancer slope factors using different statistical approaches', *Risk analysis*, 26(3), pp. 825–830.

Thomford, P.J. (2002) '104-week dietary chronic toxicity and carcinogenicity study with perfluorooctane sulfonic acid potassium salt (PFOS; T-6295) in rats. 6329-183', *Covance Laboratories Inc* [Preprint].

Timmermann, C.A.G. *et al.* (2020) 'Serum Perfluoroalkyl Substances, Vaccine Responses, and Morbidity in a Cohort of Guinea-Bissau Children', *Environmental Health Perspectives*, 128(8), p. 087002. Available at: https://doi.org/10.1289/ehp6517.

Vieira, V.M. *et al.* (2013) 'Perfluorooctanoic acid exposure and cancer outcomes in a contaminated community: a geographic analysis', *Environmental health perspectives*, 121(3), pp. 318–323.

Wen, L.-L. *et al.* (2013) 'Association between serum perfluorinated chemicals and thyroid function in US adults: the National Health and Nutrition Examination Survey 2007–2010', *The Journal of Clinical Endocrinology & Metabolism*, 98(9), pp. E1456–E1464.

Wikström, S. *et al.* (2020) 'Maternal serum levels of perfluoroalkyl substances in early pregnancy and offspring birth weight', *Pediatric Research*, 87(6), pp. 1093–1099.

Willey, J. *et al.* (2023) *Report on the Multi-Laboratory Validation Study of PFAS by Isotope Dilution LC-MS/MS Wastewater, Surface Water, and Groundwater*. Strategic Environmental Research and Development Program (SERDP) Project ER19-1409. Available at: https://www.epa.gov/system/files/documents/2023-07/MLVS%20Aqueous%20Draft%2007252023%20508.pdf (Accessed: 31 January 2024).

Wolf, C.J. *et al.* (2010) 'Developmental Effects of Perfluorononanoic Acid in the Mouse Are Dependent on Peroxisome Proliferator-Activated Receptor-Alpha', *PPAR Research*, 2010, pp. 1–11. Available at: https://doi.org/10.1155/2010/282896.

Zhong, J. *et al.* (2016) 'Coating morphology and surface composition of acrylic terpolymers with pendant catechol, OEG and perfluoroalkyl groups in varying ratio and the effect on protein adsorption', *Colloids and Surfaces B: Biointerfaces*, 140, pp. 254–261. Available at: https://doi.org/10.1016/j.colsurfb.2015.12.051.

6. Supporting Documentation

6.1. Supplementary Tables

Table A - 1: A comparison between the BMD and NOAEL or LOAEL approaches to modeling Cancer Slope Factors (CSF).

BMD Approach	NOAEL or LOAEL Approach
Modeling extrapolates dose-response data to provide lower doses than were used in the experiments.	Limited to one of the doses used in the experiment and is dependent on study design.
Includes goodness-of-fit information on the model used, the confidence limits, and other descriptive statistics.	Does not account for variability in the estimate of the dose-response from the experimental data.
Goodness-of-fit information describes the slope of the curve.	does not account for the slope of the dose-response curve.
Can be applied if there is not a NOAEL in the experimental data.	Cannot be applied when there is no NOAEL, except through the application of an uncertainty factor

Table A - 2: The required quality control metrics for EPA Method 1633.

PFAS Compound	Range of LOQs (ng/L)	% RSD	% Mean Recovery
PFOS	1 – 4	29	70 – 140
PFOA	1 – 4	27	65 – 155
HFPO-DA	2 – 8	23	70 – 135
PFBA	4 – 16	21	70 – 135
PFHxA	1 – 4	24	70 – 135
PFBS	1 – 4	23	70 – 140
PFNA	1 – 4	28	70 – 140
PFHxS	1 – 4	27	70 – 135

%RSD taken from Table 5; Aqueous LOQs taken from Table 9 in Method 1633 (EPA, 2024d).

Table A - 3: The candidate RfDs for PFOS, excerpted from the EPA Toxicity Assessment for PFOS (EPA, 2024b).

Endpoint	**Reference Confidence**	**Strain Species Sex**	**POD_{HED} (mg /kg/day)**	**UF_A**	**UF_H**	**UF_S**	**UF_L**	**UF_D**	**UF_C**	**Candidate RfD[a] (mg/kg/day)**
Immune Effects										
Decreased Serum Anti Tetanus Antibody Concentration in Children	(Budtz-Jørgensen and Grandjean, 2018) Medium	Human, male and female	2.71×10^{-6}	1	10	1	1	1	10	3×10^{-7}
	(Timmermann *et al.*, 2020) Medium		1.78×10^{-6}	1	10	1	1	1	10	2×10^{-7}
Decreased Serum Anti-Diphtheria Antibody Concentration in Children	(Budtz-Jørgensen and Grandjean, 2018) Medium	Human, male and female	1.83×10^{-6}	1	10	1	I	1	10	2×10^{-7}
	(Timmermann *et al.*, 2020) Medium		1.03×10^{-6}	1	10	1	1	1	10	1×10^{-7}
Decreased Plaque Forming Cell (PFC) Response to SRBC	(Zhong *et al.*, 2016) Medium	C57BL/6 Mice, PNW 4 F_1 males	5.32×10^{-4}	3	10	1	1	1	30	2×10^{-5}
Extramedullary Hematopoiesis in the Spleen	(NTP, 2019) High	Sprague-Dawley rats, female	2.91×10^{-4}	3	10	10	I	1	300	1×10^{-6}
Developmental Effects										
Low Birth Weight	(Sagiv *et al.*, 2018) High	Human, male and female	6.00×10^{-6}	1	10	1	1	I	10	6×10^{-7}
	(Wikström *et al.*, 2020) High		**1.13×10^{-6}**	**1**	**10**	**1**	**1**	**1**	**10**	**1×10^{-7}**
Decreased Pup Body Weight	(Luebker *et al.*, 2005) Medium	Sprague - Dawley Rats, F_1 male and female	3.96×10^{-3}	3	10	1	I	1	30	1×10^{-4}
Cardiovascular Effects										
Increased Serum Total Cholesterol	(Dong *et al.*, 2019) Medium	Human, male and female, excluding individuals prescribed cholesterol medication	**1.20×10^{-6}**	**1**	**10**	**I**	**1**	**1**	**10**	**1×10^{-7}**
	(Steenland *et al.*, 2009) Medium		1.22×10^{-6}	1	10	1	1	1	10	1×10^{-7}
Hepatic Effects										
Increased Serum ALT	(Gallo *et al.*, 2013) Medium	Human, female	7.27×10^{-6}	1	10	1	1	I	10	7×10^{-7}
	(Nian *et al.*, 2019) Medium		1.94×10^{-6}	1	10	1	1	1	10	2×10^{-7}
Individual Cell Necrosis in the Liver	(Thomford, 2002; Butenhoff *et al.*, 2012)[b] High	Sprague-Dawley rats, females	3.45×10^{-3}	3	10	1	1	1	30	1×10^{-4}

Notes: ALT = alanine transaminase; UF_A = interspecies uncertainty factor; UF_D = database uncertainty factor, UF_H = intraspecies uncertainty factor; UFs = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_C = composite uncertainty factor.
[a] RfDs were rounded to one significant figure.
[b] (Butenhoff *et al.*, 2012) and (Thomford, 2002) reported data from the same experiment.
Endpoint is bold to indicate that it was selected as the basis for RfD.

Table A - 4: The candidate CSF for PFOS excerpted from the EPA Toxicity Assessment for PFOS (EPA, 2024b).

Tumor Type	Sex	POD Type, Model	POD Internal Dose /Internal Dose Metric	POD_{HED}	Candidate CSF (BMR/POD_{HED})
Hepatocellular Adenomas	Male	$BMDL_{10}$ Multistage Degree 4 Model	25.6 mg/L normalized per day	3.28×10^{-3} mg/kg/day	30.5 (mg/kg/day)
Hepatocellular Adenomas	Female	$BMDL_{10}$ Multistage Degree 1 Model	21.8 mg/L normalized per day	2.79×10^{-3} mg/kg/day	35.8 (mg/kg/day)
Combined Hepatocellular Adenomas and Carcinomas	**Female**	**$BMDL_{10}$ Multistage Degree 1 Model**	**19.8 mg/L normalized per day**	**2.53×10^{-3} mg/kg/day**	**39.5 (mg/kg/day)**
Pancreatic Islet Cell Carcinomas	Male	$BMDL_{10}$ Multistage Degree 1 Model	26.1 mg/L normalized per day	3.34×10^{-3} mg/kg/day	29.9 (mg/kg/day)

Notes: $BMDL_{10}$ = benchmark dose level corresponding to the 95% lower confidence limit of a 10% change.
Endpoint is bold to indicate that it was selected as the basis for the cancer slope factor.

Table A - 5: The candidate RfDs for PFOA, table excerpted from EPA Tox Assessment for PFOA (EPA, 2024c).

Endpoint	Study, Confidence	Strain/Species Sex	POD_{HED} (mg /kg/day)	UF_A	UF_H	UF_S	UF_L	UF_D	UF_C	Candidate RfD[a] (mg/kg/day)
Immune Effects										
Decreased serum Anti tetanus Antibody concentration in children	(Budtz-Jørgensen and Grandjean, 2018) Medium	Human, male and female	**3.05×10^{-7}**	**1**	**10**	**1**	**1**	**1**	**10**	**3×10^{-8}**
	(Timmermann *et al.*, 2020) Medium		2.92×10^{-6}	1	10	1	1	1	10	3×10^{-8}
Decreased Serum Anti-diphtheria Antibody concentration in children	(Budtz-Jørgensen and Grandjean, 2018) Medium	Human, male and female	1.83×10^{-6}	1	10	1	1	1	10	3×10^{-8}
	(Timmermann *et al.*, 2020) Medium		1.03×10^{-6}	1	10	1	1	1	10	2×10^{-8}
Decreased IgM response to SRBC	(DeWitt *et al.*, 2009) Medium	Mouse, Female Study 1	2.18×10^{-3}	3	10	10	1	1	300	7×10^{-6}
Developmental Effects										
Low Birth Weight	(Sagiv *et al.*, 2018)) High	Human, male and female	1.21×10^{-6}	1	10	1	1	1	10	1×10^{-7}
	(Wikström *et al.*, 2020) High		**2.92×10^{-7}**	**1**	**10**	**1**	**1**	**1**	**10**	**3×10^{-8}**
Decreased Offspring Survival	(Song *et al.*, 2018) Medium	Kunming Mice, F_1 males and females	6.40×10^{-4}	3	10	1	1	1	30	2×10^{-5}
Delayed Time to Eye Opening	(Lau *et al.*, 2006) Medium	CD - 1 Mice, F_1 males and females	1.71×10^{-3}	3	10	1	I	1	30	6×10^{-5}
Cardiovascular Effects										
Increased Serum Total Cholesterol	(Dong *et al.*, 2019) Medium	Human, male and female, excluding individuals prescribed cholesterol medication	**2.75×10^{-7}**	**1**	**10**	**1**	**1**	**1**	**10**	**1×10^{-8}**
	(Steenland *et al.*, 2009) Medium		5.10×10^{-7}	1	10	1	1	1	10	1×10^{-8}
Hepatic Effects										
Increased Serum ALT	(Gallo *et al.*, 2013) Medium	Human, female	2.15×10^{-6}	1	10	1	1	1	10	2×10^{-7}
	(Darrow, Stein and Steenland, 2013) Medium		7.92×10^{-6}	1	10	1	1	1	10	8×10^{-7}
	(Nian *et al.*, 2019) Medium		4.51×10^{-7}	1	10	1	1	1	10	5×10^{-8}
Necrosis	(NTP, 2019) High	Sprague-Dawley rats, perinatal and postweaning, male	3.23×10^{-3}	3	10	1	1	1	30	1×10^{-4}

Notes: ALT = alanine aminotransferase; NTP = National Toxicology Program; POD_{HED} = point-of-departure human equivalence dose; RfD = reference dose; SRBC = sheep red blood cells; UF_A = interspecies uncertainty factor; UF_H = intraspecies uncertainty factor; UF_S = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_D = database uncertainty factor; UF_C = composite uncertainty factor.

[a] RfDs were rounded to one significant figure.

Endpoint is bold to indicate that it was selected as the basis for RfD.

Table A - 6: The candidate CSFs for PFOA, excepted from the EPA Tox Assessment on PFOA (EPA, 2024c).

Tumor Type	Reference, Confidence	Strain/ Species/Sex	POD Type, Model	Internal CSF[1]	CSF[2]
Renal cell carcinoma (RCC)	**(Shearer *et al.*, 2021) Medium**	**Human, male and female 55-74 years**	**CSF serum in adults (per ng/mL of serum PFOA); upper limit of the 95 % CI**	**3.52×10-3 (ng/mL)**	**0.0293 (ng/kg/day)**
Kidney cancer	(Vieira *et al.*, 2013) Medium	Human, male and female	CSF serum in adults (per ng/mL of serum PFOA); upper limit of the 95 % CI, highest	4.81×10 (ng/mL)	0.00401 (ng/kg/day)

[1]Internal CSF - Increase in cancer risk per 1 ng/mL serum increase
[2]CSF - Increase in cancer risk per 1 (ng/kg/day) increase in dose.
Endpoint is bold to indicate that it was selected as the basis for the cancer slope factor.

Table A - 7: The candidate RfDs for HFPO-DA (GenX), excepted from the EPA Tox Assessment of GenX (EPA, 2021a).

Endpoint and reference	POD_{HED}[a] (mg/kg/day)	POD Type	UF_L	UF_S	UF_A	UF_H	UF_D	UF_{TOT}	Candidate RfD (mg/kg/day)
Liver constellation of lesions in parental male mice (Dupont, 2010)	0.02	$BMDL_{10}$	1	10	3	10	10	3000	7×10^{-6}
Liver constellation of lesions in parental female mice (Dupont, 2010)	**0.01**	**$BMDL_{10}$**	**1**	**10**	**3**	**10**	**10**	**3000**	**3×10^{-6}**

UF_A = interspecies uncertainty factor; UF_H = intraspecies uncertainty factor; UF_S = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_D = database uncertainty factor; UF_C = composite uncertainty factor.
Endpoint is bold to indicate that it was selected as the basis for RfD.

Table A - 8: The candidate RfDs for PFBS, excepted from EPA HH Tx Values for PFBS (EPA, 2021b).

Endpoint/Reference	Species/Life Stage/Sex	POD_{HED} (mg/kg-d)	UF_A	UF_H	UF_S	UF_L	UF_D	UF_C	Candidate RfD (mg/kg/day)
Thyroid effects									
Total T_4 (Feng *et al.*, 2017)	Mouse/Po - female	$BMDL_{1SD}$ = 0.093	3	10	1	1	10	300	3×10^{-4}
Total T_4 PND 1(Feng *et al.*, 2017)	**Mouse/F1 - female**	**$BMDL_{1SD}$ = 0.095**	3	10	1	1	10	300	**3×10^{-4}**
Total T_4 (NTP, 2019)	Rat - female	$BMDL_{1SD}$ = 0.037	Not calculated as the biological significance of decreased T4 in adults without overt thyroid toxicity is unclear (EPA, 2021b)						
Free T_4 (NTP, 2019)	Rat - female	$BMDL_{1SD}$ = 0.027							

UF_A = interspecies uncertainty factor; UF_H = intraspecies uncertainty factor; UF_S = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_D = database uncertainty factor; UF_C = composite uncertainty factor.
Endpoint is bold to indicate that it was selected as the basis for RfD.

Table A - 9: The RfD information that the ATDSR MRL and EPA RfD for PFNA are based on, excerpted from the ATSDR Toxicological Profile for Perfluoroalkyls (ATSDR, 2021).

Oral exposure	MRL (mg/kg/day)	Critical effect	POD_{HED}	UF_A	UF_H	UF_D	UF_C	Reference
Acute	*NA*	Inadequate acute - *duration* study (exposure ≤14 days)						
Intermediate	3×10^{-6}	Decreased body weight and developmental delays in mice	0.001	3	10	10	300	(Das *et al.*, 2015)
Chronic	*NA*	Inadequate chronic - duration study (exposure ≥365 *days*)						

UF_A = interspecies uncertainty factor; UF_H = intraspecies uncertainty factor; UF_S = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_D = database uncertainty factor; UF_C = composite uncertainty factor.

Table A - 10: The RfD information that the ATDSR MRL and EPA RfD for PFHxS are based on, excerpted from the ATSDR Toxicological Profile for Perfluoroalkyls (ATSDR, 2021).

Oral exposure	MRL (mg/kg/day)	Critical effect	POD_{HED}	UF_A	UF_H	UF_D	UF_C	Reference
Acute	*NA*	*Inadequate acute-duration study (exposure ≤14 days)*						
Intermediate	2×10^{-5}	Thyroid follicular epithelial hypertrophy/ hyperplasia in rats	0.0047	3	10	10	300	(Butenhoff *et al.*, 2009)
Chronic	*NA*	*Inadequate chronic - duration study (exposure ≥365 days)*						

Table A - 11: The candidate RfD values based on organ/system specific effects of PFBA exposure; excerpted from the EPA IRIS Assessment of PFBA (EPA, 2022d).

System	Basis	POD	UF_A	UF_H	UF_S	UF_L	UF_D	UF_C	Candidate RfD (mg/kg/day)
Hepatic	Increased hepatocellular hypertrophy in adult male S-D rats	$BMDL_{HED}$ from (Butenhoff *et al.*, 2012)	**3**	**10**	**10**	**1**	**3**	**1000**	**1×10^{-3}**
Thyroid	Decreased total T4 in adult male S-D rats	$NOAEL_{HED}$ from (Butenhoff *et al.*, 2012)	**3**	**10**	**10**	**1**	**3**	**1000**	**1×10^{-3}**
Developmental	Developmental delays after gestational exposure in CD1 mice	$BMDL_{HED}$ from (Das *et al.*, 2015)	3	10	1	1	3	100	6×10^{-3}

UF_A = interspecies uncertainty factor; UF_H = intraspecies uncertainty factor; UFs = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_D = database uncertainty factor; UF_C = composite uncertainty factor.
Endpoint is bold to indicate that it was selected as the basis for RfD.

Table A - 12: The candidate RfD values based on organ/system specific effects of PFHxA exposure; excerpted from the EPA IRIS Assessment of PFHxA (EPA, 2023).

System	Basis	POD	UF_A	UF_H	UF_S	UF_L	UF_D	UF_C	Candidate RfD (mg/kg/day)
Hepatic	Increased hepatocellular hypertrophy in adult male S-D rats	0.11 mg/kg/day based on $BMDL_{10ER}$ and free salt normalization (Loveless *et al.*, 2009)	3	10	3	1	3	300	4×10^{-4}
Hematopoietic	Decreased red blood cells in adult female S-D rats	0.52 mg/kg/day based on $BMDL_{1SD}$ (Klaunig *et al.*, 2015)	3	10	1	1	3	100	5×10^{-3}
Developmental (selected as RfD)	Decreased postnatal body weights in F1 SD male and female rats exposed throughout gestation and lactation	0.048 mg/kg/day based on BMDL5RD and free salt normalization (Loveless *et al.*, 2009)	**3**	**10**	**1**	**1**	**3**	**100**	**5×10^{-4}**

UF_A = interspecies uncertainty factor; UF_H = intraspecies uncertainty factor; UFs = subchronic-to-chronic extrapolation uncertainty factor, UF_L = extrapolation from a LOAEL to a NOAEL uncertainty factor; UF_D = database uncertainty factor; UF_C = composite uncertainty factor.
Endpoint is bold to indicate that it was selected as the basis for RfD.

6.2. NC SSAB PFAS Toxicity Assessment Methodology Comparison

				EPA MCL PFAS Compounds					
Category	**IRIS Handbook method (EPA 2022)**	**PFHxA (EPA ORD CPHEA IRIS 2023)**	**PFBA (EPA ORD CPHEA IRIS 2022)**	**PFOS (EPA OW 2022)**	**PFOA (EPA OW 2022)**	**PFBS (EPA ORD CPHEA 2021)**	**HFPO-DA (EPA OW 2021)**	**PFHxS (ATSDR 2021)**	**PFNA (ATSDR 2021)**
Stated that the IRIS Handbook was followed or conducted by IRIS Program?	ORD Staff Handbook for Developing IRIS Assessments 2022	✓	✓	✓	✓	Published before handbook was drafted/published	Texet states that the draft IRIS handbook was followed, final was not published at this time	ATSDR's Guidance for the Preparation of Toxicological Profiles	
Literature Search	Using Health and Environmental Research Online (HERO) database andworkflow	✓	✓	PFOS and PFOA HERO webpage PFOS and PFOA MCLG Approaches HERO webpage		PFBS HERO webpage	GenX HERO webpage	ATSDR utilized a slight modification of NTP's Office of Health Assessment and Translation (OHAT) systematic review methodology.	
	Retrieve results from each database using HERO in this order: • PubMed • Web of Science • SCOPUS • Other resources (e.g., NTP, ECHA, TSCATS)	✓	✓	Web of Science, PubMed,ToxLine, and, TSCATS	Web of Science, PubMed,ToxLine, and, TSCATS	PubMed, Web of Science, TOXLINE, and TSCATS via TOXLINE were searched by HERO	PubMed, Toxline, Web of Science (WOS), and Toxic Substances Control Act Test Submissions (TSCATS) searched by HERO	PubMed, National Library of Medicine's TOXLINE, Scientific and Technical Information Network's TOXCENTER	
	Dates of Literature Search								
Study Screening	Use the Distiller SR software to screen studies in a systematic and unbiased way	✓	✓	Used Distiller SR	Used Distiller SR	Used Distiller SR	Used Distiller SR	A two-step process was used to screen the literature search to identify relevant studies on	
Study Evaluation	IRIS study evaluation approach. (a) individual evaluation domains organized by evidence type, and (b) individual evaluation domain judgments and definitions for overall ratings (i.e., domain and overall judgments are performed on an outcome-specific basis).	✓	✓	Two or more quality assurance (QA) reviewers, working independently, assigned ratings about the reliability of study results (good, adequate, deficient (or "not reported"), or critically deficient) for different evaluation domains.		For each study in each evaluation domain, reviewers reached a consensus rating regarding the utility of the study for hazard identification, with categories of good, adequate, deficient, not reported, or critically deficient. These ratings were then combined across domains to reach an overall classification of high, medium, or low confidence or uninformative.	The twelve studies providing dose-response information were then evaluated for study quality using an approach consistent with the draft ORD Handbook for developing IRIS assessments	Expert peer-review panel	
Study Quality	Key concerns for the review of epidemiological, controlled human exposure, animal, and in vitro studies are risk of bias (RoB), which is the assessment of internal validity (factors that might affect the magnitude or direction of an effect in either direction), and sensitivity (factors that limit the ability of a study to detect a true effect; low sensitivity is a bias toward the null when an effect exists).	✓	✓	Considerations when evaluating the available studies included risk of bias, sensitivity, consistency, strength (effect magnitude) and precision, biological gradient/dose-response, coherence, and mechanistic evidence related to biological plausibility.		The evaluation process focused on assessing aspects of the study design and conduct through three broad types of evaluations: reporting quality, risk of bias, and study sensitivity.	Study quality was determined by two independent reviewers who assessed risk of bias and sensitivity for the following domains: reporting quality, risk of bias (selection or performance bias, confounding/variable control, and reporting or attrition bias), and study sensitivity (exposure methods sensitivity, and outcome measures and results display)	The properties of the body of evidence were considered are: Risk of bias, Unexplained inconsistency, indirectness, imprecision, publication bias, magnitude of effect, dose response, confouding bias, consistency	
				HAWC Quailty Tables	HAWC Quality Tables	HAWC Quality Table	HAWC Quality Table		
Data Extraction	Health Assessment Workspace Collaborative (HAWC) - interface that allows the data and decisions supporting an assessment to be managed in modules (e.g., study evaluation, summary study data, etc.) that can be publicly accessed online	✓	✓	Used HAWC and info is online		Used HAWC and info is online	Used HAWC and the info is online	Relevant data extracted from the individual studies selected for inclusion in the systematic review were collected in customized data forms	
vidence Integration	Evidence Integration Judgment: one of five phrases is used: evidence demonstrates, evidence indicates (likely), evidence suggests, evidence is inadequate, or strong evidence supports no effect	✓	✓	"EPA determined that either evidence indicates or evidence demonstrates that oral PFOS exposure is associated with adverse effects"	"EPA determined that either evidence indicates or evidence demonstrates that oral PFOA exposure is associated with adverse effects"	"Taken together, the evidence indicates that the developing reproductive system, particularly in females, might be a target for PFBS toxicity"	"Taken together, the available data indicate that a PPARα MOA is plausible in the liver in response to GenX chemical exposure…"	"There is strong evidence that many of the adverse effects observed in laboratory animals involve the activation of peroxisome proliferator-activated receptor-α (PPARα), which can mediate a broad range of biological responses"	
Approach for deriving reference values	Systematic Assesment of Study Attributes to Support Derivation of Toxicity Values	✓	✓	✓	✓	✓	✓	Integration of the evidence streams for the human studies and animal studies	
	Selecting Benchmark Dose Response Values for Dose-Response Modeling	✓	✓	✓	✓	✓	✓	MRLs are derived for hazardous substances using the NOAEL/uncertainty factor approach.	
	Conduct Dose-Response Modeling	✓	✓	✓	✓	✓	✓		
	Characterization of Exposure for Extrapolation to Humans	✓	✓	✓	✓	✓	✓	Discuss qualitative and quantitative differences in	
	Characterizing Uncertainty and Confidence	✓	✓	✓	✓	✓	✓	UFs similar to EPA's UF categories	
	Selecting Final Toxicity Values	✓	✓	✓	✓	✓	✓	MRLs are derived for acute (1–14 days),	
Assessment used to support EPA's proposed PFAS MCLs		no	no	✓	✓	✓	✓	✓	✓

6.3. Surface Water Quality Numerical Standard Calculation Sheets

This section of the Appendix contains copies of the calculation sheets that the NC DEQ Division of Water Resources used for derivation of the Surface Water Standards.

6.3.1. *PFOS Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorooctanesulfonic acid (PFOS)		CASRN	1763-23-1
Fish Consumption (FC) Standard =	0.06 ng/L*		
Water (SW) Water Supply (WS) Standard =	0.06 ng/L*		

SW FC standard based on noncancer endpoint			
SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000			
RfD = reference dose[1]	1.0E-07	mg/kg/day	
WT = average adult human body weight[2]	80	kg	
RSC= relative source contribution[3]	0.2	unitless value	
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1514	L/kg	
1000 = conversion factor	1000	µg/mg	
Calculated SW FC Standard using noncancer endpoint	**0.000048**	**µg/L (ppb)**	**0.0480 ng/L (ppt)**
SW FC standard based on cancer endpoint			
SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	80	kg	
q1* = carcinogenic potency factor (slope factor)[1]	39.5	$(mg/kg/day)^{-1}$	
FC = average daily adult human fish tissue intake[3]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1514	L/kg	
1000 = conversion factor	1000	µg/mg	
Calculated SW FC Standard using cancer endpoint	**0.00006**	**µg/L (ppb)**	**0.061 ng/L (ppt)**
SW WS standard based on noncancer endpoint			
SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000			
RfD = reference dose[1]	1.0E-07	mg/kg/day	
WT = average adult human body weight[2]	80	kg	
RSC= relative source contribution[3]	0.2	unitless value	
WI = average adult water intake[6]	2.4	L/day	
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1514	L/kg	
1000 = conversion factor	1000	µg/mg	
Calculated SW FC Standard using noncancer endpoint	**0.000045**	**µg/L (ppb)**	**0.0448 ng/L (ppt)**
SW WS standard based on cancer endpoint			
SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	80	kg	
q1* = carcinogenic potency factor (slope factor)[1]	39.5	$(mg/kg/day)^{-1}$	
WI = average adult water intake[6]	2.4	L/day	
FC = average daily adult human fish tissue intake[3]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1514	L/kg	
1000 = conversion factor	1000	µg/mg	
Calculated SW FC Standard using cancer endpoint	**0.000057**	**µg/L (ppb)**	**0.0567 ng/L (ppt)**

References

[1] Final PFAS National Primary Drinking Water Regulation, April 2024. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

[2] Adult body weight per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion

ppt= parts per trillion

6.3.2. *PFOA Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorooctanoic acid (PFOA) CASRN 335-67-1

Fish Consumption (FC) Standard = 0.01 ng/L*

Water (SW) Water Supply (WS) Standard = 0.001 ng/L*

SW FC standard based on noncancer endpoint			
SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000			
RfD = reference dose[1]	3.0E-08	mg/kg/day	
WT = average adult human body weight[2]	80	kg	
RSC= relative source contribution[3]	0.2	unitless value	
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	8.5	L/kg	
1000 = conversion factor	1000	µg/mg	
Calculated SW FC Standard using noncancer endpoint	**0.002567**	**µg/L (ppb)**	**2.567 ng/L (ppt)**
SW FC standard based on cancer endpoint			
SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	80	kg	
q1* = carcinogenic potency factor (slope factor)[1]	0.0293	$(ng/kg/day)^{-1}$	
FC = average daily adult human fish tissue intake[3]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	8.5	L/kg	
1000 = conversion factor	0.001	ng/ug	
Calculated SW FC Standard using cancer endpoint	**0.000015**	**µg/L (ppb)**	**0.0146 ng/L (ppt)**
SW WS standard based on noncancer endpoint			
SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000			
RfD = reference dose[1]	3.0E-08	mg/kg/day	
WT = average adult human body weight[2]	80	kg	
RSC= relative source contribution[3]	0.2	unitless value	
WI = average adult water intake[6]	2.4	L/day	
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	8.5	L/kg	
1000 = conversion factor	1000	µg/mg	
Calculated SW FC Standard using noncancer endpoint	**0.000186**	**µg/L (ppb)**	**0.1855 ng/L (ppt)**
SW WS standard based on cancer endpoint			
SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	80	kg	
q1* = carcinogenic potency factor (slope factor)[1]	0.0293	$(ng/kg/day)^{-1}$	
WI = average adult water intake[6]	2.4	L/day	
FC = average daily adult human fish tissue intake[3]	0.022	g/person-day	
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	8.5	L/kg	
1000 = conversion factor	0.001	ng/ug	
Calculated SW FC Standard using cancer endpoint	**0.000001**	**µg/L (ppb)**	**0.00106 ng/L (ppt)**

References

[1] Proposed PFAS National Primary Drinking Water Regulation; March 2023; https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

[2] Adult body weight per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion
ppt= parts per trillion

6.3.3. *HFPO-DA Numerical Standard Calculations*

North Carolina Surface Water Standard

Hexafluoropropylene oxide dimer acid (HFPO-DA)			CASRN 13252-13-6
Fish Consumption (FC) Standard =	0.5 µg/L*		
Water (SW) Water Supply (WS) Standard =	0.02 µg/L*		

SW FC standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000

RfD = reference dose[1]	3.0E-06	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	4.1	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**0.532151**	**µg/L (ppb)**	**532.15**	**ng/L (ppt)**

SW FC standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	4.1	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

SW WS standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000

RfD = reference dose[1]	3.0E-06	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	4.1	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**0.019276**	**µg/L (ppb)**	**19.2756**	**ng/L (ppt)**

SW WS standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation (BAF) or Bioconcentration Factoı	4.1	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

References

[1] US EPA Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt (CASRN 13252-13-6 and CASRN 62037-80-3) Also Known as "GenX Chemicals". EPA Document Number: 822R-21-010.

[2] Adult body weight per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion
ppt= parts per trillion

6.3.4. *PFBS Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorobutanesulfonic acid (PFBS)		CASRN 375-73-5
Fish Consumption (FC) Standard =	10 µg/L*	
Water (SW) Water Supply (WS) Standard =	2 µg/L*	

SW FC standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000

RfD = reference dose[1]	3.0E-04	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	22	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**9.917355**	**µg/L (ppb)**	**9917**	**ng/L (ppt)**

SW FC standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	(mg/kg/day) $^{-1}$		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	22	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

SW WS standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000

RfD = reference dose[1]	3.0E-04	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	22	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**1.664355**	**µg/L (ppb)**	**1664.4**	**ng/L (ppt)**

SW WS standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	(mg/kg/day) $^{-1}$		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation (BAF) or Bioconcentration Factor (BCF)[5]	22	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

References

[1] U.S. EPA. (2021). Human Health Toxicity Values for Perfluorobutane Sulfonic Acid (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3). U.S. Environmental Protection Agency, Office of Water (4304T), Health and Ecological Criteria Division. EPA Document Number: EPA/600/R-20/345F

[2] Adult body weight per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion

ppt= parts per trillion

6.3.5. *PFNA Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorononanoic acid (PFNA) CASRN 375-95-1

Fish Consumption (FC) Standard = 0.02 µg/L*

Water (SW) Water Supply (WS) Standard = 0.009 µg/L*

SW FC standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000

RfD = reference dose[1]	3.0E-06	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	144	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**0.015152**	**µg/L (ppb)**	**15**	**ng/L (ppt)**

SW FC standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	144	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

SW WS standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000

RfD = reference dose[1]	3.0E-06	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	144	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**0.0086207**	**µg/L (ppb)**	**8.6207**	**ng/L (ppt)**

SW WS standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation (BAF) or Bioconcentration Factor (BCF	144	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

References

[1] Agency for Toxic Substances and Disease Registry (ATSDR). 2021. Toxicological profile for Perfluoroalkyls. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. DOI: 10.15620/cdc:59198

[2] Adult body weight per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion

ppt= parts per trillion

6.3.6. *PFHxS Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorohexanesulfonic acid (PFHxS)		CASRN 355-46-4		
Fish Consumption (FC) Standard =	0.07 µg/L*			
Water (SW) Water Supply (WS) Standard =	0.01 µg/L*			
SW FC standard based on noncancer endpoint				
SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000				
RfD = reference dose[1]	2.0E-06	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	20	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**0.072727**	**µg/L (ppb)**	**73**	**ng/L (ppt)**
SW FC standard based on cancer endpoint				
SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000				
RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	20	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**
SW WS standard based on noncancer endpoint				
SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000				
RfD = reference dose[1]	2.0E-06	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	20	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**0.011268**	**µg/L (ppb)**	**11.268**	**ng/L (ppt)**
SW WS standard based on cancer endpoint				
SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000				
RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	g/person-day		
BAF or BCF = Bioaccumulation (BAF) or Bioconcentration Factor (B	20	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

References

[1] Agency for Toxic Substances and Disease Registry (ATSDR). 2021. Toxicological profile for Perfluoroalkyls. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. DOI: 10.15620/cdc:59198

[2] Adult body weight per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion
ppt= parts per trillion

6.3.7. *PFBA Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorobutanoic Acid (PFBA) CASRN 375-22-4

Fish Consumption (FC) Standard = 200 µg/L*

Water (SW) Water Supply (WS) Standard = 6 µg/L*

SW FC standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000

RfD = reference dose[1]	1.0E-03	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
FC = average daily adult human fish tissue intake[4]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	3	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**242.424**	**µg/L (ppb)**	**242424**	**ng/L (ppt)**

SW FC standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[4]	NA	(mg/kg/day) $^{-1}$		
FC = average daily adult human fish tissue intake[3]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[6]	54	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

SW WS standard based on noncancer endpoint

SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000

RfD = reference dose[1]	1.0E-03	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[3]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	3	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**6.48824**	**µg/L (ppb)**	**6488.24**	**ng/L (ppt)**

SW WS standard based on cancer endpoint

SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000

RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	(mg/kg/day) $^{-1}$		
WI = average adult water intake[b]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	54	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

References

[1] IRIS Toxicological Review of Perfluorobutanoic Acid (PFBA, CASRN 375-22-4) and Related Salts; https://iris.epa.gov/static/pdfs/0701tr.pdf

[2] Adult body weigh per EPA 2015 Human Health Criteria Updates.

[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf

[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.

[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010

[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion
ppt= parts per trillion

6.3.8. *PFHxA Numerical Standard Calculations*

North Carolina Surface Water Standard

Perfluorohexanoic Acid (PFHxA) CASRN 307-24-4

Fish Consumption (FC) Standard =	200 µg/L*			
Water (SW) Water Supply (WS) Standard =	3 µg/L*			
SW FC standard based on noncancer endpoint				
SWQS = [(RfD x WT x RSC) / (FC x BAF)] * 1000				
RfD = reference dose[1]	5.0E-04	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
FC = average daily adult human fish tissue intake[4]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1.6	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**227.272727**	**µg/L (ppb)**	**227273**	**ng/L (ppt)**
SW FC standard based on cancer endpoint				
SWQS = [(RL x WT) / (q1* x FC x BAF)] * 1000				
RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
FC = average daily adult human fish tissue intake[3]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[6]	1.6	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**
SW WS standard based on noncancer endpoint				
SWQS = [(RfD x WT x RSC) / (WI + (FC x BAF))] * 1000				
RfD = reference dose[1]	5.0E-04	mg/kg/day		
WT = average adult human body weight[2]	80	kg		
RSC= relative source contribution[3]	0.2	unitless value		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[3]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1.6	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using noncancer endpoint	**3.285151**	**µg/L (ppb)**	**3285.1511**	**ng/L (ppt)**
SW WS standard based on cancer endpoint				
SWQS = [(RL x WT) / (q1* x (WI + (FC x BAF))] * 1000				
RL = risk level	1.0E-06			
WT = average adult human body weight[2]	80	kg		
q1* = carcinogenic potency factor (slope factor)[1]	NA	$(mg/kg/day)^{-1}$		
WI = average adult water intake[6]	2.4	L/day		
FC = average daily adult human fish tissue intake[4]	0.022	kg/person-day		
BAF or BCF = Bioaccumulation or bioconcentration Factor[5]	1.6	L/kg		
1000 = conversion factor	1000	µg/mg		
Calculated SW FC Standard using cancer endpoint	**NA**	**µg/L (ppb)**	**NA**	**ng/L (ppt)**

References

[1] IRIS Toxicological Review of Perfluorohexanoic Acid [PFHxA, CASRN 307-24-4] and Related Salts; https://iris.epa.gov/static/pdfs/0704tr.pdf
[2] Adult body weight per EPA 2015 Human Health Criteria Updates.
[3] RSC = EPA's Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health, 2000; https://www.epa.gov/sites/default/files/2018-10/documents/methodology-wqc-protection-hh-2000.pdf
[4] Fish consumption rate per EPA 2015 Human Health Criteria Updates.
[5] BAF or BCF = Taken from EPA publication by Dr L Burhard 2021; DOI: 10.1002/etc.5010
[6] Adult water intake rate per EPA 2015 Human Health Criteria Updates.

*Rounded using conventions from EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (Office of Water, EPA 822-B-00-004, October 2000)

ppb= parts per billion
ppt= parts per trillion

Appendix B: Proposed Surface Water Quality PFAS Standards and Implementation Plan

15A NCAC 02B .0211 is proposed for amendment as follows:

15A NCAC 02B .0211 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS C WATERS

In addition to the standards set forth in Rule .0208 of this Section, the following water quality standards shall apply to all Class C waters. Additional standards applicable to other freshwater classifications are specified in Rules .0212, .0214, .0215, .0216, .0218, .0219, .0223, .0224, .0225, and .0231 of this Section.

(1) The best usage of waters shall be aquatic life propagation, survival, and maintenance of biological integrity (including fishing and fish); wildlife; secondary contact recreation; agriculture; and any other usage except for primary contact recreation or as a source of water supply for drinking, culinary, and food processing purposes. All freshwaters shall be classified to protect these uses at a minimum.

(2) The conditions of waters shall be such that waters are suitable for all best uses specified in this Rule. Sources of water pollution that preclude any of these uses on either a short-term or long-term basis shall be deemed to violate a water quality standard;

(3) Chlorine, total residual: 17 ug/l;

(4) Chlorophyll a (corrected): except as specified in Sub-Item (a) of this Item, not greater than 40 ug/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters, and not greater than 15 ug/l for lakes, reservoirs, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters (not applicable to lakes or reservoirs less than 10 acres in surface area). The Commission or its designee may prohibit or limit any discharge of waste into surface waters if the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

 (a) Site-specific High Rock Lake Reservoir [Index Numbers 12-(108.5), 12-(114), 12-117-(1), 12-117-(3), 12-118.5, and the uppermost portion of 12-(124.5) to the dam of High Rock Lake] Chlorophyll a (corrected): not greater than one exceedance of a growing season geometric mean of 35 ug/L in the photic zone within a three-year period.

 (b) For the purpose of Sub-Item (a) of this Item:

  (i) The growing season is April 1 through October 31;

  (ii) Samples shall be collected in a minimum of five different months within each growing season with a minimum of two growing season geometric means collected in a three-year period;

  (iii) The photic zone shall be defined as the surface down to twice the Secchi depth;

  (iv) Samples shall be collected as a composite sample of the photic zone; and

  (v) Samples that do not satisfy the requirements in Sub-Item (iv) of this Sub-Item shall be excluded from the calculation of the geometric mean.

(5) Cyanide, available or total: 5.0 ug/l;

(6) Dissolved oxygen: not less than 6.0 mg/l for trout waters; for non-trout waters, not less than a daily average of 5.0 mg/l with an instantaneous value of not less than 4.0 mg/l; swamp waters, lake coves, or backwaters, and lake bottom waters may have lower values if caused by natural conditions;

(7) Fecal coliform: shall not exceed a geometric mean of 200/100ml (MF count) based upon at least five samples taken over a 30-day period, nor exceed 400/100ml in more than 20 percent of the samples examined during such period. Violations of this Item are expected during rainfall events and may be caused by uncontrollable nonpoint source pollution. All coliform concentrations shall be analyzed using the membrane filter technique. If high turbidity or other conditions would cause the membrane filter technique to produce inaccurate data, the most probable number (MPN) 5-tube multiple dilution method shall be used.

(8) Floating solids, settleable solids, or sludge deposits: only such amounts attributable to sewage, industrial wastes, or other wastes as shall not make the water unsafe or unsuitable for aquatic life and wildlife or impair the waters for any designated uses;

(9) Fluoride: 1.8 mg/l;

(10) Gases, total dissolved: not greater than 110 percent of saturation;

(11) Metals:

(a) With the exception of mercury, acute and chronic freshwater aquatic life standards for metals shall be based upon measurement of the dissolved fraction of the metal. Mercury water quality standards shall be based upon measurement of the total recoverable metal;

(b) With the exception of mercury, aquatic life standards for metals listed in this Sub-Item shall apply as a function of the pollutant's water effect ratio (WER). The WER shall be assigned a value equal to one unless any person demonstrates to the Division's satisfaction in a permit proceeding that another value is developed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA-823-B-12-002), which is hereby incorporated by reference, including subsequent amendments and editions, and can be obtained free of charge at http://water.epa.gov/scitech/swguidance/standards/handbook/. Alternative site-specific standards may also be developed when any person submits values that demonstrate to the Commission that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species Procedure", which is hereby incorporated by reference including subsequent amendments and can be obtained free of charge at http://water.epa.gov/scitech/swguidance/standards/handbook/.

(c) Freshwater metals standards that are not hardness-dependent shall be as follows:

(i) Arsenic, dissolved, acute: WER· 340 ug/l;

(ii) Arsenic, dissolved, chronic: WER· 150 ug/l;

(iii) Beryllium, dissolved, acute: WER· 65 ug/l;

(iv) Beryllium, dissolved, chronic: WER· 6.5 ug/l;

(v) Chromium VI, dissolved, acute: WER· 16 ug/l;

(vi) Chromium VI, dissolved, chronic: WER· 11 ug/l;

(vii) Mercury, total recoverable, chronic: 0.012 ug/l;

(viii) Silver, dissolved, chronic: WER· 0.06 ug/l;

(d) Selenium, chronic: The standard for chronic selenium has the following components: fish egg/ovary tissue, fish whole body or muscle tissue, and water column (lentic and lotic). These components shall be used in the following order of preference provided data is available:

(i) Fish egg/ovary tissue;

(ii) Fish whole body or muscle tissue;

(iii) Water column.

Fish tissue concentrations are determined as dry weight and water column concentrations are based on the dissolved fraction of selenium. Fish tissue components are expressed as steady-state concentrations and provide instantaneous point measurements that reflect integrative accumulation of selenium over time and space in fish populations at a given site. Fish tissue components supersede the water column component when both fish tissue and water concentrations are measured. Egg-ovary tissue results, where available, supersede all other tissue and water column components. The chronic selenium standards are as follows:

<table>
<tr><th colspan="2">Component</th><th>Magnitude</th><th>Duration</th></tr>
<tr><td rowspan="3">Fish tissue</td><td>Fish egg/ovary tissue</td><td>15.1 mg/kg</td><td>Instantaneous</td></tr>
<tr><td rowspan="2">Fish whole body or muscle tissue</td><td>8.5 mg/kg whole body</td><td>Instantaneous</td></tr>
<tr><td>11.3 mg/kg muscle</td><td>Instantaneous</td></tr>
<tr><td rowspan="2">Water column</td><td rowspan="2">Lentic or Lotic</td><td>1.5 ug/l lentic</td><td>30-day average</td></tr>
<tr><td>3.1 ug/l lotic</td><td>30-day average</td></tr>
</table>

(e) Hardness-dependent freshwater metals standards shall be derived using the equations specified in Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals. If the actual instream hardness (expressed as $CaCO_3$ or Ca+Mg) is less than 400 mg/l, standards shall be calculated based upon the actual instream hardness. If the instream hardness is greater than 400 mg/l, the maximum applicable hardness shall be 400 mg/l.

Table A: Dissolved Freshwater Standards for Hardness-Dependent Metals

Numeric standards calculated at 25 mg/l hardness are listed below for illustrative purposes. The Water Effects Ratio (WER) is equal to one unless determined otherwise under Sub-Item (11)(b) of this Rule.

Metal	Equations for Hardness-Dependent Freshwater Metals (ug/l)	Standard at 25 mg/l hardness (ug/l)
Cadmium, Acute	WER·[{1.136672-[ln hardness](0.041838)} · e^{0.9789 [ln hardness]-3.443}]	0.75
Cadmium, Acute, Trout waters	WER·[{1.136672-[ln hardness](0.041838)} · e^{0.9789 [ln hardness]-3.866}]	0.49
Cadmium, Chronic	WER·[{1.101672-[ln hardness](0.041838)} · e^{0.7977[ln hardness]-3.909}]	0.25
Chromium III, Acute	WER· [0.316 · e^{0.8190[ln hardness]+3.7256}]	180
Chromium III, Chronic	WER· [0.860 · e^{0.8190[ln hardness]+0.6848}]	24
Copper, Acute	WER· [0.960 · e^{0.9422[ln hardness]-1.700}] Or, Aquatic Life Ambient Freshwater Quality Criteria-Copper 2007 Revision (EPA-822-R-07-001)	3.6 NA
Copper, Chronic	WER· [0.960 · e^{0.8545[ln hardness]-1.702}] Or, Aquatic Life Ambient Freshwater Quality Criteria-Copper 2007 Revision (EPA-822-R-07-001)	2.7 NA
Lead, Acute	WER· [{1.46203-[ln hardness](0.145712)} · e^{1.273[ln hardness]-1.460}]	14
Lead, Chronic	WER· [{1.46203-[ln hardness](0.145712)} · e^{1.273[ln hardness]-4.705}]	0.54
Nickel, Acute	WER· [0.998 · e^{0.8460[ln hardness]+2.255}]	140

Nickel, Chronic	$WER \cdot [0.997 \cdot e^{0.8460[\ln hardness]+0.0584}]$	16
Silver, Acute	$WER \cdot [0.85 \cdot e^{1.72[\ln hardness]-6.59}]$	0.30
Zinc, Acute	$WER \cdot [0.978 \cdot e^{0.8473[\ln hardness]+0.884}]$	36
Zinc, Chronic	$WER \cdot [0.986 \cdot e^{0.8473[\ln hardness]+0.884}]$	36

(f) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards, except for selenium shall only be evaluated using an average of a minimum of four samples taken on consecutive days or as a 96-hour average;

(12) Oils, deleterious substances, or colored or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses. For the purpose of implementing this Rule, oils, deleterious substances, or colored or other wastes shall include substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines, as described in 40 CFR 110.3(a)-(b), incorporated by reference including subsequent amendments and editions. This material is available, free of charge, at: http://www.ecfr.gov/;

(13) Per- and Polyfluoroalkyl substances that are carcinogens:

(a) Perfluorooctanoic Acid (PFOA): 0.01 ng/l;

(b) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

(14) Per- and Polyfluoroalkyl substances that are non-carcinogens:

(a) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 500 ng/l;

(b) Perfluorobutane Sulfonic Acid (PFBS): 10,000 ng/l;

(c) Perfluorobutanoic Acid (PFBA): 200,000 ng/l;

(d) Perfluorohexanesulfonic Acid (PFHxS): 70 ng/l;

(e) Perfluorohexanoic Acid (PFHxA): 200,000 ng/l;

(f) Perfluorononanoic Acid (PFNA): 20 ng/l;

~~(13)~~(15) Pesticides:

(a) Aldrin: 0.002 ug/l;

(b) Chlordane: 0.004 ug/l;

(c) DDT: 0.001 ug/l;

(d) Demeton: 0.1 ug/l;

(e) Dieldrin: 0.002 ug/l;

(f) Endosulfan: 0.05 ug/l;

(g) Endrin: 0.002 ug/l;

(h) Guthion: 0.01 ug/l;

(i) Heptachlor: 0.004 ug/l;

(j) Lindane: 0.01 ug/l;

(k) Methoxychlor: 0.03 ug/l;

(l) Mirex: 0.001 ug/l;

(m) Parathion: 0.013 ug/l; and

(n) Toxaphene: 0.0002 ug/l;

~~(14)~~(16) pH: shall be between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

~~(15)~~(17) Phenolic compounds: only such levels as shall not result in fish-flesh tainting or impairment of other best usage;

~~(16)~~(18) Polychlorinated biphenyls (total of all PCBs and congeners identified): 0.001 ug/l;

~~(17)~~(19) Radioactive substances, based on at least one sample collected per quarter:

(a) Combined radium-226 and radium-228: the average annual activity level for combined radium-226 and radium-228 shall not exceed five picoCuries per liter;

(b) Alpha Emitters: the average annual gross alpha particle activity (including radium-226, but excluding radon and uranium) shall not exceed 15 picoCuries per liter;

(c) Beta Emitters: the average annual activity level for strontium-90 shall not exceed eight picoCuries per liter, nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring radionuclides) exceed 50 picoCuries per liter, nor shall the average annual activity level for tritium exceed 20,000 picoCuries per liter;

~~(18)~~(20) Temperature: not to exceed 2.8 degrees C (5.04 degrees F) above the natural water temperature, and in no case to exceed 29 degrees C (84.2 degrees F) for mountain and upper piedmont waters and 32 degrees C (89.6 degrees F) for lower piedmont and coastal plain waters; the temperature for trout waters shall not be increased by more than 0.5 degrees C (0.9 degrees F) due to the discharge of heated liquids, but in no case to exceed 20 degrees C (68 degrees F);

~~(19)~~(21) Toluene: 0.36 ug/l in trout classified waters or 11 ug/l in all other waters;

~~(20)~~(22) Trialkyltin compounds: 0.07 ug/l expressed as tributyltin;

~~(21)~~(23) Turbidity: the turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in streams, lakes, or reservoirs designated as trout waters; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard shall be deemed met when land management activities employ Best Management Practices (BMPs), as defined by Rule .0202 of this Section, recommended by the Designated Nonpoint Source Agency, as defined by Rule .0202 of this Section.

~~(22)~~(24) Toxic Substance Level Applicable to NPDES Permits: Chloride: 230 mg/l. If chloride is determined by the waste load allocation to be exceeded in a receiving water by a discharge under the specified 7Q10 criterion for toxic substances, the discharger shall monitor the chemical or biological effects of the discharge. Efforts shall be made by all dischargers to reduce or eliminate chloride from their effluents. Chloride shall be limited as appropriate in the NPDES permit if sufficient information exists to indicate that it may be a causative factor resulting in toxicity of the effluent.

History Note: Authority G.S. 143-214.1; 143-215.3(a)(1);
Eff. February 1, 1976;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; August 1, 2000; October 1, 1995; August 1, 1995; April 1, 1994; February 1, 1993;
Readopted Eff. November 1, 2019;
Amended Eff. Xx; September 1, 2022; June 1, 2022.

15A NCAC 02B .0212 is proposed for amendment as follows:

15A NCAC 02B .0212 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-I WATERS

The following water quality standards shall apply to surface waters within water supply watersheds classified as WS-I. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-I waters.

(1) The best usage of waters classified as WS-I shall be as a source of water supply for drinking, culinary, or food processing purposes for those users desiring maximum protection of their water supplies in the form of the most stringent WS classification, and any best usage specified for Class C waters. Class WS-I waters are waters located on land in public ownership and waters located in undeveloped watersheds.

(2) The best usage of waters classified as WS-I shall be maintained as follows:

(a) Water quality standards in a WS-I watershed shall meet the requirements as specified in Item (3) of this Rule.

(b) Wastewater and stormwater point source discharges in a WS-I watershed shall meet the requirements as specified in Item (4) of this Rule.

(c) Nonpoint source pollution in a WS-I watershed shall meet the requirements as specified in Item (5) of this Rule.

(d) Following approved treatment, as defined in Rule .0202 of this Section, the waters shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, and food-processing purposes that are specified in 40 CFR Part 141 National Primary Drinking Water Regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500, incorporated by reference including subsequent amendments and editions.

(e) Sources of water pollution that preclude any of the best uses on either a short-term or long-term basis shall be deemed to violate a water quality standard.

(f) The Class WS-I classification may be used to protect portions of Class WS-II, WS-III, and WS-IV water supplies. For reclassifications occurring after the July 1, 1992 statewide reclassification, a WS-I classification that is requested by local governments shall be considered by the Commission if all local governments having jurisdiction in the affected areas have adopted a resolution and the appropriate ordinances as required by G.S. 143-214.5(d) to protect the watershed or if the Commission acts to protect a watershed when one or more local governments has failed to adopt protective measures as required by this Sub-Item.

(3) Water quality standards applicable to Class WS-I Waters shall be as follows:

(a) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(b) Total coliforms shall not exceed 50/100 ml (MF count) as a monthly geometric mean value in watersheds serving as unfiltered water supplies;

(c) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems from chlorinated phenols;

(d) Solids, total dissolved: not greater than exceed 500 mg/l;

(e) Total hardness: not greater than 100 mg/l as calcium carbonate ($CaCO_3$ or Ca + Mg);

(f) Toxic and other deleterious substances that are non-carcinogens:

(i) Barium: 1.0 mg/l;

(ii) Chloride: 250 mg/l;

(iii) Nickel: 25 ug/l;

(iv) Nitrate nitrogen: 10.0 mg/l;

(v) 2,4-D: 70 ug/l;

(vi) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 10 ng/l;

(vii) Perfluorobutane Sulfonic Acid (PFBS): 2,000 ng/l;

(viii) Perfluorobutanoic Acid (PFBA): 6,000 ng/l;

(ix) Perfluorohexanesulfonic Acid (PFHxS): 10 ng/l;

(x) Perfluorohexanoic Acid (PFHxA): 3,000 ng/l;

(xi) Perfluorononanoic Acid (PFNA): 9 ng/l;

~~(vi)~~(xii) 2,4,5-TP (Silvex): 10 ug/l; and

~~(vii)~~(xiii) Sulfates: 250 mg/l;

(g) Toxic and other deleterious substances that are carcinogens:

(i) Aldrin: 0.05 ng/1;

(ii) Arsenic: 10 ug/l;

(iii) Benzene: 1.19 ug/1;

(iv) Carbon tetrachloride: 0.254 ug/l;

(v) Chlordane: 0.8 ng/1;

(vi) Chlorinated benzenes: 488 ug/l;

(vii) DDT: 0.2 ng/1;

(viii) Dieldrin: 0.05 ng/1;

(ix) Dioxin: 0.000005 ng/l;

(x) Heptachlor: 0.08 ng/1;

(xi) Hexachlorobutadiene: 0.44 ug/l;

(xii) Perfluorooctanoic Acid (PFOA): 0.001 ng/l;

(xiii) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

~~(xii)~~(xiv) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

~~(xiii)~~(xv) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

~~(xiv)~~(xvi) Tetrachloroethylene: 0.7 ug/l;

~~(xv)~~(xvii) Trichloroethylene: 2.5 ug/l; and

~~(xvi)~~(xviii) Vinyl Chloride: 0.025 ug/l.

(4) Wastewater and stormwater point source discharges in a WS-I watershed shall be permitted pursuant to 15A NCAC 02B .0104.

(5) Nonpoint source pollution in a WS-I watershed shall not have an adverse impact, as defined in 15A NCAC 02H .1002, on use as a water supply or any other designated use.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; October 1, 1995; February 1, 1993; March 1, 1991; October 1, 1989;
Readopted Eff. November 1, ~~2019.~~2019;
Amended Eff. xx.

15A NCAC 02B .0214 is proposed for amendment as follows:

15A NCAC 02B .0214 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-II WATERS

The following water quality standards shall apply to surface waters within water supply watersheds classified as WS-II. Water quality standards applicable to Class C waters as described in Rule .0211of this Section shall also apply to Class WS-II waters.

(1) The best usage of waters classified as WS-II shall be as a source of water supply for drinking, culinary, or food-processing purposes for those users desiring maximum protection for their water supplies where a WS-I classification is not feasible as determined by the Commission in accordance with Rule .0212 of this Section and any best usage specified for Class C waters.

(2) The best usage of waters classified as WS-II shall be maintained as follows:

(a) Water quality standards in a WS-II watershed shall meet the requirements as specified in Item (3) of this Rule.

(b) Wastewater and stormwater point source discharges in a WS-II watershed shall meet the requirements as specified in Item (4) of this Rule.

(c) Nonpoint source pollution in a WS-II watershed shall meet the requirements as specified in Item (5) of this Rule.

(d) Following approved treatment, as defined in Rule .0202 of this Section, the waters shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, and food-processing purposes that are specified in 40 CFR Part 141 National Primary Drinking Water Regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500.

(e) Sources of water pollution that preclude any of the best uses on either a short-term or long-term basis shall be deemed to violate a water quality standard.

(f) The Class WS-II classification may be used to protect portions of Class WS-III and WS-IV water supplies. For reclassifications of these portions of Class WS-III and WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, a WS-II classification that is requested by local governments shall be considered by the Commission if all local governments having jurisdiction in the affected areas have adopted a resolution and the appropriate ordinances as required by G.S. 143-214.5(d) to protect the watershed or if the Commission acts to protect a watershed when one or more local governments has failed to adopt protective measures as required by this Sub-Item.

(3) Water quality standards applicable to Class WS-II Waters shall be as follows:

(a) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(b) Odor producing substances contained in sewage or other wastes: only such amounts, whether alone or in combination with other substances or wastes, as shall not cause organoleptic effects in water supplies that cannot be corrected by treatment, impair the palatability of fish, or have an adverse impact, as defined in 15A NCAC 02H .1002, on any best usage established for waters of this class;

(c) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems from chlorinated phenols;

(d) Total hardness: not greater than 100 mg/l as calcium carbonate ($CaCO_3$ or Ca + Mg);

(e) Solids, total dissolved: not greater than 500 mg/l;

(f) Toxic and other deleterious substances that are non-carcinogens:

(i) Barium: 1.0 mg/l;

(ii) Chloride: 250 mg/l;

(iii) Nickel: 25 ug/l;

(iv) Nitrate nitrogen: 10.0 mg/l;

(v) 2,4-D: 70 ug/l;

(vi) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 10 ng/l;

(vii) Perfluorobutane Sulfonic Acid (PFBS): 2,000 ng/l;

(viii) Perfluorobutanoic Acid (PFBA): 6,000 ng/l;

(ix) Perfluorohexanesulfonic Acid (PFHxS): 10 ng/l;

(x) Perfluorohexanoic Acid (PFHxA): 3,000 ng/l;

(xi) Perfluorononanoic Acid (PFNA): 9 ng/l;

~~(vi)~~(xii) 2,4,5-TP (Silvex): 10 ug/l; and

~~(vii)~~(xiii) Sulfates: 250 mg/l;

(g) Toxic and other deleterious substances that are carcinogens:

(i) Aldrin: 0.05 ng/1;

(ii) Arsenic: 10 ug/l;

(iii) Benzene: 1.19 ug/1;

(iv) Carbon tetrachloride: 0.254 ug/l;

(v) Chlordane: 0.8 ng/1;

(vi) Chlorinated benzenes: 488 ug/l;

(vii) DDT: 0.2 ng/1;

(viii) Dieldrin: 0.05 ng/1;

(ix) Dioxin: 0.000005 ng/l;

(x) Heptachlor: 0.08 ng/1;

(xi) Hexachlorobutadiene: 0.44 ug/l;

(xii) Perfluorooctanoic Acid (PFOA): 0.001 ng/l;

(xiii) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

~~(xii)~~(xiv) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

~~(xiii)~~(xv) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

~~(xiv)~~(xvi) Tetrachloroethylene: 0.7 ug/l;

~~(xv)~~(xvii) Trichloroethylene: 2.5 ug/l; and

~~(xvi)~~(xviii) Vinyl Chloride: 0.025 ug/l.

(4) Wastewater and stormwater point source discharges in a WS-II watershed shall meet the following requirements:

(a) Discharges that qualify for a General NPDES Permit pursuant to 15A NCAC 02H .0127 shall be allowed in the entire watershed.

(b) Discharges from trout farms that are subject to Individual NPDES Permits shall be allowed in the entire watershed.

(c) Stormwater discharges that qualify for an Individual NPDES Permit pursuant to 15A NCAC 02H .0126 shall be allowed in the entire watershed.

(d) No discharge of sewage, industrial, or other wastes shall be allowed in the entire watershed except for those allowed by Sub-Items (a) through (c) of this Item or Rule .0104 of this Subchapter, and none shall be allowed that have an adverse effect on human health or that are not treated in accordance with the permit or other requirements established by the Division pursuant to G.S. 143-215.1. Upon request by the Commission, a discharger shall disclose all chemical constituents present or potentially present in their wastes and chemicals that could be spilled or be present in runoff from their facility that may have an adverse impact on downstream water quality. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances.

(e) New domestic and industrial discharges of treated wastewater that are subject to Individual NPDES Permits shall not be allowed in the entire watershed.

(f) No new landfills shall be allowed in the Critical Area, and no NPDES permits shall be issued for landfills that discharge treated leachate in the remainder of the watershed.

(g) No new permitted sites for land application of residuals or petroleum contaminated soils shall be allowed in the Critical Area.

(5) Nonpoint source pollution in a WS-II watershed shall meet the following requirements:

(a) Nonpoint source pollution shall not have an adverse impact on waters for use as a water supply or any other designated use.

(b) Class WS-II waters shall be protected as water supplies that are located in watersheds that meet average watershed development density levels specified for Class WS-II waters in Rule .0624 of this Subchapter.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*

Eff. May 10, 1979;

Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; January 1, 1996; October 1, 1995;

Readopted Eff. November 1, ~~2019.~~2019;

Amended Eff. xx.

15A NCAC 02B .0215 is proposed for amendment as follows:

15A NCAC 02B .0215 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-III WATERS

The following water quality standards shall apply to surface waters within water supply watersheds classified as WS-III. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-III waters.

(1) The best usage of waters classified as WS-III shall be as a source of water supply for drinking, culinary, or food-processing purposes for those users where a more protective WS-I or WS-II classification is not feasible as determined by the Commission in accordance with Rules .0212 and .0214 of this Section and any other best usage specified for Class C waters.

(2) The best usage of waters classified as WS-III shall be maintained as follows:

(a) Water quality standards in a WS-III watershed shall meet the requirements as specified in Item (3) of this Rule.

(b) Wastewater and stormwater point source discharges in a WS-III watershed shall meet the requirements as specified in Item (4) of this Rule.

(c) Nonpoint source pollution in a WS-III watershed shall meet the requirements as specified in Item (5) of this Rule.

(d) Following approved treatment, as defined in Rule .0202 of this Section, the waters shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, or food-processing purposes that are specified in 40 CFR Part 141 National Primary Drinking Water Regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500.

(e) Sources of water pollution that preclude any of the best uses on either a short-term or long-term basis shall be deemed to violate a water quality standard.

(f) The Class WS-III classification may be used to protect portions of Class WS-IV water supplies. For reclassifications of these portions of WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, a WS-II classification that is requested by local governments shall be considered by the Commission if all local governments having jurisdiction in the affected areas have adopted a resolution and the appropriate ordinances as required by G.S. 143-214.5(d) to protect the watershed or if the Commission acts to protect a watershed when one or more local governments has failed to adopt protective measures as required by this Sub-Item.

(3) Water quality standards applicable to Class WS-III Waters shall be as follows:

(a) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(b) Odor producing substances contained in sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances or wastes, as shall not cause organoleptic effects in water supplies that cannot be corrected by treatment, impair the palatability of fish, or have an adverse impact, as defined in 15A NCAC 02H .1002, on any best usage established for waters of this class;

(c) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems from chlorinated phenols;

(d) Total hardness: not greater than 100 mg/l as calcium carbonate ($CaCO_3$ or Ca + Mg);

(e) Solids, total dissolved: not greater than 500 mg/l;

(f) Toxic and other deleterious substances that are non-carcinogens:

(i) Barium: 1.0 mg/l;

(ii) Chloride: 250 mg/l;

(iii) Nickel: 25 ug/l;

(iv) Nitrate nitrogen: 10.0 mg/l;

(v) 2,4-D: 70 ug/l;

(vi) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 10 ng/l;

(vii) Perfluorobutane Sulfonic Acid (PFBS): 2,000 ng/l;

(viii) Perfluorobutanoic Acid (PFBA): 6,000 ng/l;

(ix) Perfluorohexanesulfonic Acid (PFHxS): 10 ng/l;

(x) Perfluorohexanoic Acid (PFHxA): 3,000 ng/l;

(xi) Perfluorononanoic Acid (PFNA): 9 ng/l;

~~(vi)~~(xii) 2,4,5-TP (Silvex): 10 ug/l; and

~~(vii)~~(xiii) Sulfates: 250 mg/l;

(g) Toxic and other deleterious substances that are carcinogens:

(i) Aldrin: 0.05 ng/1;

(ii) Arsenic: 10 ug/l;

(iii) Benzene: 1.19 ug/1;

(iv) Carbon tetrachloride: 0.254 ug/l;

(v) Chlordane: 0.8 ng/1;

(vi) Chlorinated benzenes: 488 ug/l;

(vii) DDT: 0.2 ng/1;

(viii) Dieldrin: 0.05 ng/1;

(ix) Dioxin: 0.000005 ng/l;

(x) Heptachlor: 0.08 ng/1;

(xi) Hexachlorobutadiene: 0.44 ug/l;

(xii) Perfluorooctanoic Acid (PFOA): 0.001 ng/l;

(xiii) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

~~(xii)~~(xiv) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

~~(xiii)~~(xv) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

~~(xiv)~~(xvi) Tetrachloroethylene: 0.7 ug/l;

~~(xv)~~(xvii) Trichloroethylene: 2.5 ug/l; and

~~(xvi)~~(xviii) Vinyl Chloride: 0.025 ug/l.

(4) Wastewater and stormwater point source discharges in a WS-III watershed shall meet the following requirements:

(a) Discharges that qualify for a General NPDES Permit pursuant to 15A NCAC 02H .0127 shall be allowed in the entire watershed.

(b) Discharges from trout farms that are subject to Individual NPDES Permits shall be allowed in the entire watershed.

(c) Stormwater discharges that qualify for an Individual NPDES Permit pursuant to 15A NCAC 02H .0126 shall be allowed in the entire watershed.

(d) New domestic wastewater discharges that are subject to Individual NPDES Permits shall not be allowed in the Critical Area and are allowed in the remainder of the watershed.

(e) New industrial wastewater discharges that are subject to Individual NPDES Permits except non-process industrial discharges shall not be allowed in the entire watershed.

(f) No discharge of sewage, industrial, or other wastes shall be allowed in the entire watershed except for those allowed by Sub-Items (a) through (e) of this Item or Rule .0104 of this Subchapter, and none shall be allowed that have an adverse effect on human health or that are not treated in accordance with the permit or other requirements established by the Division pursuant to G.S. 143-215.1. Upon request by the Commission, a discharger shall disclose all chemical constituents present or potentially present in their wastes and chemicals that could be spilled or be present in runoff from their facility that may have an adverse impact on downstream water quality. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances.

(g) No new landfills shall be allowed in the Critical Area, and no NPDES permits shall be issued for landfills to discharge treated leachate in the remainder of the watershed.

(h) No new permitted sites for land application of residuals or petroleum contaminated soils shall be allowed in the Critical Area.

(5) Nonpoint source pollution in a WS-III watershed shall meet the following requirements:

(a) Nonpoint source pollution shall not have an adverse impact on waters for use as a water supply or any other designated use.

(b) Class WS-III waters shall be protected as water supplies that are located in watersheds that meet average watershed development density levels specified Class WS-III waters in Rule .0624 of this Subchapter.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*

Eff. September 9, 1979;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; January 1, 1996; October 1, 1995; October 1, 1989;
Readopted Eff. November 1, ~~2019.~~2019;
Amended Eff. xx.

15A NCAC 02B .0216 is proposed for amendment as follows:

15A NCAC 02B .0216 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-IV WATERS

The following water quality standards shall apply to surface waters within water supply watersheds classified as WS-IV. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-IV waters.

(1) The best usage of waters classified as WS-IV shall be as a source of water supply for drinking, culinary, or food-processing purposes for those users where a more protective WS-I, WS-II or WS-III classification is not feasible as determined by the Commission in accordance with Rules .0212 through .0215 of this Section and any other best usage specified for Class C waters.

(2) The best usage of waters classified as WS-IV shall be maintained as follows:

(a) Water quality standards in a WS-IV watershed shall meet the requirements as specified in Item (3) of this Rule.

(b) Wastewater and stormwater point source discharges in a WS-IV watershed shall meet the requirements as specified in Item (4) of this Rule.

(c) Nonpoint source pollution in a WS-IV watershed shall meet the requirements as specified in Item (5) of this Rule.

(d) Following approved treatment, as defined in Rule .0202 of this Section, the waters shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, or food-processing purposes that are specified in 40 CFR Part 141 National Primary Drinking Water Regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500.

(e) Sources of water pollution that preclude any of the best uses on either a short-term or long-term basis shall be deemed to violate a water quality standard.

(f) The Class WS-II or WS-III classifications may be used to protect portions of Class WS-IV water supplies. For reclassifications of these portions of WS-IV water supplies occurring after the July 1, 1992 statewide reclassification, a WS-IV classification that is requested by local governments shall be considered by the Commission if all local governments having jurisdiction in the affected areas have adopted a resolution and the appropriate ordinances as required by G.S. 143-214.5(d) to protect the watershed or if the Commission acts to protect a watershed when one or more local governments has failed to adopt protective measures as required by this Sub-Item.

(3) Water quality standards applicable to Class WS-IV Waters shall be as follows:

(a) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(b) Odor producing substances contained in sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances or waste, as will not cause organoleptic effects in water supplies that cannot be corrected by treatment, impair the palatability of fish, or have an adverse impact, as defined in 15A NCAC 02H .1002, on any best usage established for waters of this class;

(c) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems due to chlorinated phenols shall be allowed. Specific phenolic compounds may be given a different limit if it is demonstrated not to cause taste and odor problems and not to be detrimental to other best usage;

(d) Total hardness: not greater than 100 mg/l as calcium carbonate ($CaCO_3$ or Ca + Mg);

(e) Solids, total dissolved: not greater than 500 mg/l;

(f) Toxic and other deleterious substances that are non-carcinogens:

(i) Barium: 1.0 mg/l;

(ii) Chloride: 250 mg/l;

(iii) Nickel: 25 ug/l;

(iv) Nitrate nitrogen: 10.0 mg/l;

(v) 2,4-D: 70 ug/l;

(vi) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 10 ng/l;

(vii) Perfluorobutane Sulfonic Acid (PFBS): 2,000 ng/l;

(viii) Perfluorobutanoic Acid (PFBA): 6,000 ng/l;

(ix) Perfluorohexanesulfonic Acid (PFHxS): 10 ng/l;

(x) Perfluorohexanoic Acid (PFHxA): 3,000 ng/l;

(xi) Perfluorononanoic Acid (PFNA): 9 ng/l;

~~(vi)~~(xii) 2,4,5-TP (Silvex): 10 ug/l; and

~~(vii)~~(xiii) Sulfates: 250 mg/l;

(g) Toxic and other deleterious substances that are carcinogens:

(i) Aldrin: 0.05 ng/1;

(ii) Arsenic: 10 ug/l;

(iii) Benzene: 1.19 ug/1;

(iv) Carbon tetrachloride: 0.254 ug/l;

(v) Chlordane: 0.8 ng/1;

(vi) Chlorinated benzenes: 488 ug/l;

(vii) DDT: 0.2 ng/1;

(viii) Dieldrin: 0.05 ng/1;

(ix) Dioxin: 0.000005 ng/l;

(x) Heptachlor: 0.08 ng/1;

(xi) Hexachlorobutadiene: 0.44 ug/l;

(xii) Perfluorooctanoic Acid (PFOA): 0.001 ng/l;

(xiii) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

~~(xii)~~(xiv) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

~~(xiii)~~(xv) Tetrachloroethane (1,1,2,2): 0.17 ug/l;

~~(xiv)~~(xvi) Tetrachloroethylene: 0.7 ug/l;

~~(xv)~~(xvii) Trichloroethylene: 2.5 ug/l; and

~~(xvi)~~(xviii) Vinyl Chloride: 0.025 ug/l.

(4) Wastewater and stormwater point source discharges in a WS-IV watershed shall meet the following requirements:

(a) Discharges that qualify for a General NPDES Permit pursuant to 15A NCAC 02H .0127 shall be allowed in the entire watershed.

(b) Discharges from domestic facilities, industrial facilities and trout farms that are subject to Individual NPDES Permits shall be allowed in the entire watershed.

(c) Stormwater discharges that qualify for an Individual NPDES Permit pursuant to 15A NCAC 02H .0126 shall be allowed in the entire watershed.

(d) No discharge of sewage, industrial wastes, or other wastes shall be allowed in the entire watershed except for those allowed by Sub-Items (a) through (c) of this Item or Rule .0104 of this Subchapter, and none shall be allowed that have an adverse effect on human health or that are not treated in accordance with the permit or other requirements established by the Division pursuant to G.S. 143-215.1. Upon request by the Commission, dischargers or industrial users subject to pretreatment standards shall disclose all chemical constituents present or potentially present in their wastes and chemicals that could be spilled or be present in runoff from their facility which may have an adverse impact on downstream water supplies. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances.

(e) New industrial discharges of treated wastewater in the critical area shall meet the provisions of Rule .0224(c)(2)(D), (E), and (G) of this Section and Rule .0203 of this Section.

(f) New industrial connections and expansions to existing municipal discharges with a pretreatment program pursuant to 15A NCAC 02H .0904 shall be allowed in the entire watershed.

(g) No new landfills shall be allowed in the Critical Area.

(h) No new permitted sites for land application residuals or petroleum contaminated soils shall be allowed in the Critical Area.

(5) Nonpoint source pollution in a WS-IV watershed shall meet the following requirements:

(a) Nonpoint source pollution shall not have an adverse impact on waters for use as a water supply or any other designated use.

(b) Class WS-IV waters shall be protected as water supplies that are located in watersheds that meet average watershed development density levels specified for Class WS-IV waters in Rule .0624 of this Subchapter.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. February 1, 1986;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; June 1, 1996; October 1, 1995; August 1, 1995; June 1, 1994;
Readopted Eff. November 1, ~~2019.~~2019;
Amended Eff. xx.

15A NCAC 02B .0218 is proposed for amendment as follows:

15A NCAC 02B .0218 FRESH SURFACE WATER QUALITY STANDARDS FOR CLASS WS-V WATERS

The following water quality standards shall apply to surface waters within water supply watersheds classified as WS-V. Water quality standards applicable to Class C waters as described in Rule .0211 of this Section shall also apply to Class WS-V waters.

(1) The best usage of waters classified as WS-V shall be as waters that are protected as water supplies which are generally upstream and draining to Class WS-IV waters; waters previously used for drinking water supply purposes; or waters used by industry to supply their employees, but not municipalities or counties, with a raw drinking water supply source, although this type of use is not restricted to WS-V classification; and all Class C uses.

(2) The best usage of waters classified as WS-V shall be maintained as follows:

(a) Water quality standards in a WS-V water shall meet the requirements as specified in Item (3) of this Rule.

(b) Wastewater and stormwater point source discharges in a WS-V water shall meet the requirements as specified in Item (4) of this Rule.

(c) Nonpoint source pollution in a WS-V water shall meet the requirements as specified in Item (5) of this Rule.

(d) Following approved treatment, as defined in Rule .0202 of this Section, the waters shall meet the Maximum Contaminant Level concentrations considered safe for drinking, culinary, or food-processing purposes that are specified in 40 CFR Part 141 National Primary Drinking Water Regulations and in the North Carolina Rules Governing Public Water Supplies, 15A NCAC 18C .1500.

(e) The Commission or its designee may apply management requirements for the protection of waters downstream of receiving waters provided in Rule .0203 of this Section.

(f) The Commission shall consider a more protective classification for the water supply if a resolution requesting a more protective classification is submitted from all local governments having land use jurisdiction within the affected watershed.

(g) Sources of water pollution that preclude any of the best uses on either a short-term or long-term basis shall be deemed to violate a water quality standard;

(3) Water quality standards applicable to Class WS-V Waters shall be as follows:

(a) MBAS (Methylene-Blue Active Substances): not greater than 0.5 mg/l to protect the aesthetic qualities of water supplies and to prevent foaming;

(b) Odor producing substances contained in sewage, industrial wastes, or other wastes: only such amounts, whether alone or in combination with other substances or waste, as will not cause organoleptic effects in water supplies that can not be corrected by treatment, impair the palatability of fish, or have an adverse impact, as defined in 15A NCAC 02H .1002, on any best usage established for waters of this class;

(c) Chlorinated phenolic compounds: not greater than 1.0 ug/l to protect water supplies from taste and odor problems due to chlorinated phenols. Specific phenolic compounds may be given a different limit if it is demonstrated not to cause taste and odor problems and not to be detrimental to other best usage;

(d) Total hardness: not greater than 100 mg/l as calcium carbonate ($CaCO_3$ or Ca + Mg);

(e) Solids, total dissolved: not greater than 500 mg/l;

(f) Toxic and other deleterious substances that are non-carcinogens:

(i) Barium: 1.0 mg/l;

(ii) Chloride: 250 mg/l;

(iii) Nickel: 25 ug/l;

(iv) Nitrate nitrogen: 10.0 mg/l;

(v) 2,4-D: 70 ug/l;

(vi) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 10 ng/l;

(vii) Perfluorobutane Sulfonic Acid (PFBS): 2,000 ng/l;

(viii) Perfluorobutanoic Acid (PFBA): 6,000 ng/l;

(ix) Perfluorohexanesulfonic Acid (PFHxS): 10 ng/l;

(x) Perfluorohexanoic Acid (PFHxA): 3,000 ng/l;

(xi) Perfluorononanoic Acid (PFNA): 9 ng/l;

~~(vi)~~(xii) 2,4,5-TP (Silvex): 10 ug/l; and

~~(vii)~~(xiii) Sulfates: 250 mg/l;

(g) Toxic and other deleterious substances that are carcinogens:

(i) Aldrin: 0.05 ng/1;

(ii) Arsenic: 10 ug/l;

(iii) Benzene: 1.19 ug/1;

(iv) Carbon tetrachloride: 0.254 ug/l;

(v) Chlordane: 0.8 ng/1;

(vi) Chlorinated benzenes: 488 ug/l;

(vii) DDT: 0.2 ng/1;

(viii) Dieldrin: 0.05 ng/1;

(ix) Dioxin: 0.000005 ng/l;

(x) Heptachlor: 0.08 ng/1;

(xi) Hexachlorobutadiene: 0.44 ug/l;

(xii) Perfluorooctanoic Acid (PFOA): 0.001 ng/l;

(xiii) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

~~(xii)~~(xiv) Polynuclear aromatic hydrocarbons (total of all PAHs): 2.8 ng/l;

~~(xiii)~~(xv) Tetrachloroethane (1,1,2,2): 0.17 ug/l;
~~(xiv)~~(xvi) Tetrachloroethylene: 0.7 ug/l;
~~(xv)~~(xvii) Trichloroethylene: 2.5 ug/l; and
~~(xvi)~~(xviii) Vinyl Chloride: 0.025 ug/l.

(4) No discharge of sewage, industrial wastes, or other wastes shall be allowed that have an adverse effect on human health or that are not treated in accordance with the permit or other requirements established by the Division pursuant to G.S. 143-215.1. Upon request by the Commission, dischargers or industrial users subject to pretreatment standards shall disclose all chemical constituents present or potentially present in their wastes and chemicals that could be spilled or be present in runoff from their facility which may have an adverse impact on downstream water quality. These facilities may be required to have spill and treatment failure control plans as well as perform special monitoring for toxic substances.

(5) Nonpoint Source pollution in a WS-V water shall not have an adverse impact on waters for use as water supply or any other designated use.

History Note: Authority G.S. 143-214.1; 143-215.3(a)(1);
Eff. October 1, 1989;
Amended Eff. January 1, 2015; May 1, 2007; April 1, 2003; October 1, 1995;
Readopted Eff. November 1, ~~2019.~~2019;
Amended Eff. xx.

15A NCAC 02B .0220 is proposed for amendment as follows:

15A NCAC 02B .0220 TIDAL SALT WATER QUALITY STANDARDS FOR CLASS SC WATERS

In addition to the standards set forth in Rule .0208 of this Section, the following water quality standards shall apply to all Class SC waters. Additional standards applicable to other tidal salt water classifications are specified in Rules .0221 and .0222 of this Section.

(1) The best usage of waters classified as SC shall be aquatic life propagation, survival, and maintenance of biological integrity (including fishing, fish, and Primary Nursery Areas (PNAs)); wildlife; secondary contact recreation as defined in Rule .0202 in this Section; and any usage except primary contact recreation or shellfishing for market purposes. All saltwaters shall be classified to protect these uses at a minimum.

(2) The best usage of waters classified as SC shall be maintained as specified in this Rule. Any source of water pollution that precludes any of these uses on either a short-term or a long-term basis shall be deemed to violate a water quality standard;

(3) Chlorophyll a (corrected): not greater than 40 ug/l in sounds, estuaries, and other waters subject to growths of macroscopic or microscopic vegetation. The Commission or its designee may prohibit or limit any discharge of waste into surface waters if the Director determines that the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired;

(4) Cyanide: 1 ug/l;

(5) Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions;

(6) Enterococcus, including Enterococcus faecalis, Enterococcus faecium, Enterococcus avium and Enterococcus gallinarium: not exceed a geometric mean of 35 enterococci per 100 ml based upon a minimum of five samples taken over a 30-day period. For the purposes of beach monitoring and notification, "Coastal Recreational Waters Monitoring, Evaluation and Notification" regulations (15A NCAC 18A .3400), available free of charge at: http://www.ncoah.com/, are incorporated by reference including subsequent amendments and editions;

(7) Floating solids, settleable solids, or sludge deposits: only such amounts attributable to sewage, industrial wastes, or other wastes as shall not make the waters unsafe or unsuitable for aquatic life and wildlife, or impair the waters for any designated uses;

(8) Gases, total dissolved: not greater than 110 percent of saturation;

(9) Metals:

(a) With the exception of mercury and selenium, acute and chronic tidal salt water quality standards for metals shall be based upon measurement of the dissolved fraction of the metals. Mercury and selenium shall be based upon measurement of the total recoverable metal;

(b) With the exception of mercury and selenium, acute and chronic tidal saltwater quality aquatic life standards for metals listed in this Sub-Item shall apply as a function of the pollutant's water effect ratio (WER). The WER shall be assigned a value equal to one unless any person demonstrates to the Division in a permit proceeding that another value is developed in accordance with the "Water Quality Standards Handbook: Second Edition" published by the US Environmental Protection Agency (EPA-823-B-12-002). Alternative site-specific standards may also be developed when any person submits values that demonstrate to the Commission that they were derived in accordance with the "Water Quality Standards Handbook: Second Edition, Recalculation Procedure or the Resident Species Procedure."

(c) Acute and chronic tidal salt water quality metals standards shall be as follows:

(i) Arsenic, acute: WER· 69 ug/l;
(ii) Arsenic, chronic: WER· 36 ug/l;
(iii) Cadmium, acute: WER· 33 ug/l;
(iv) Cadmium, chronic: WER· 7.9 ug/l;
(v) Chromium VI, acute: WER· 1100 ug/l;
(vi) Chromium VI, chronic: WER· 50 ug/l;
(vii) Copper, acute: WER· 4.8 ug/l;
(viii) Copper, chronic: WER· 3.1 ug/l;
(ix) Lead, acute: WER· 210 ug/l;
(x) Lead, chronic: WER· 8.1 ug/l;
(xi) Mercury, total recoverable, chronic: 0.025 ug/l;
(xii) Nickel, acute: WER· 74 ug/l;
(xiii) Nickel, chronic: WER· 8.2 ug/l;
(xiv) Selenium, total recoverable, chronic: 71 ug/l;
(xv) Silver, acute: WER· 1.9 ug/l;
(xvi) Silver, chronic: WER· 0.1 ug/l;
(xvii) Zinc, acute: WER· 90 ug/l; and
(xviii) Zinc, chronic: WER· 81 ug/l;

(d) Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected within one hour. Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on consecutive days, or as a 96-hour average;

(10) Oils, deleterious substances, or colored or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation, aquatic life, and wildlife or adversely affect

the palatability of fish, aesthetic quality, or impair the waters for any designated uses. For the purpose of implementing this Rule, oils, deleterious substances, or colored or other wastes shall include substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines, as described in 40 CFR 110.3, incorporated by reference including any subsequent amendments and editions. This material is available free of charge at https://www.govinfo.gov.

(11) Per- and Polyfluoroalkyl substances that are carcinogens:

(a) Perfluorooctanoic Acid (PFOA): 0.01 ng/l;

(b) Perfluorooctane Sulfonic Acid (PFOS): 0.06 ng/l;

(12) Per- and Polyfluoroalkyl substances that are non-carcinogens:

(a) Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX): 500 ng/l;

(b) Perfluorobutane Sulfonic Acid (PFBS): 10,000 ng/l;

(c) Perfluorobutanoic Acid (PFBA): 200,000 ng/l;

(d) Perfluorohexanesulfonic Acid (PFHxS): 70 ng/l;

(e) Perfluorohexanoic Acid (PFHxA): 200,000 ng/l;

(f) Perfluorononanoic Acid (PFNA): 20 ng/l;

~~(11)~~(13) Pesticides:

(a) Aldrin: 0.003 ug/l;

(b) Chlordane: 0.004 ug/l;

(c) DDT: 0.001 ug/l;

(d) Demeton: 0.1 ug/l;

(e) Dieldrin: 0.002 ug/l;

(f) Endosulfan: 0.009 ug/l;

(g) Endrin: 0.002 ug/l;

(h) Guthion: 0.01 ug/l;

(i) Heptachlor: 0.004 ug/l;

(j) Lindane: 0.004 ug/l;

(k) Methoxychlor: 0.03 ug/l;

(l) Mirex: 0.001 ug/l;

(m) Parathion: 0.178 ug/l; and

(n) Toxaphene: 0.0002 ug/l;

~~(12)~~(14) pH: shall be between 6.8 and 8.5, except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

~~(13)~~(15) Phenolic compounds: only such levels as shall not result in fish-flesh tainting or impairment of other best usage;

~~(14)~~(16) Polychlorinated biphenyls: (total of all PCBs and congeners identified) 0.001 ug/l;

~~(15)~~(17) Radioactive substances, based on at least one sample collected per quarter:

(a) Combined radium-226 and radium-228: the average annual activity level for combined radium-226, and radium-228 shall not exceed five picoCuries per liter;

(b) Alpha Emitters: the average annual gross alpha particle activity (including radium-226, but excluding radon and uranium) shall not exceed 15 picoCuries per liter;

(c) Beta Emitters: the average annual activity level for strontium-90 shall not exceed eight picoCuries per liter, nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring radionuclides exceed 50 picoCuries per liter, nor shall the average annual activity level for tritium exceed 20,000 picoCuries per liter;

~~(16)~~(18) Salinity: changes in salinity due to hydrological modifications shall not result in removal of the functions of a PNA. Projects that are determined by the Director to result in modifications of salinity such that functions of a PNA are impaired shall employ water management practices to mitigate salinity impacts;

~~(17)~~(19) Temperature: shall not be increased above the natural water temperature by more than 0.8 degrees C (1.44 degrees F) during the months of June, July, and August, shall not be increased by more than 2.2 degrees C (3.96 degrees F) during other months, and shall in no case exceed 32 degrees C (89.6 degrees F) due to the discharge of heated liquids;

~~(18)~~(20) Trialkyltin compounds: 0.007 ug/l expressed as tributyltin;

~~(19)~~(21) Turbidity: the turbidity in the receiving water shall not exceed 25 Nephelometric Turbidity Units (NTU); if turbidity exceeds this level due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard shall be deemed met when land management activities employ Best Management Practices (BMPs), defined by Rule .0202 of this Section, recommended by the Designated Nonpoint Source Agency, as defined by Rule .0202 of this Section.

History Note: *Authority G.S. 143-214.1; 143-215.3(a)(1);*
Eff. October 1, 1995;
Amended Eff. January 1, 2015; May 1, 2007; August 1, 2000;
Readopted Eff. November 1, 2019;
Amended Eff. Xx; June 1, 2022.

15A NCAC 02B .0404 WATER QUALITY BASED EFFLUENT LIMITATIONS

(a) Effluent limitations, except as specified in Paragraph (f) of this Rule, shall be developed by the staff for all existing or proposed discharges to the surface waters of the state. Water quality based effluent limitations shall be established for discharges that are found, through mathematical modeling of water quality impacts, statistical analysis of stream characteristics and effluent data or other appropriate means, to have a reasonable potential to cause or contribute to exceedance of applicable water quality standards; except that, if the discharge is subject to both technology based and water quality based effluent limitations for a parameter, the more stringent limit shall apply.

(b) The staff may on a casebycase basis develop seasonal limitations on the discharge of oxygenconsuming wastes when a treatment facility complies with applicable limitations on these wastes in the summer season but does not consistently comply in the winter season due to the effects of cooler temperatures or other seasonal factors beyond its control. A discharger may request seasonal effluent limitations by submitting a written request to the Director with justification for such limitations. In no case shall seasonal limitations cause or be expected to cause a receiving water body to violate applicable water quality standards.

(c) For the purpose of determining seasonal effluent limitations, the year shall consist of a summer and a winter discharge period. The summer period shall begin April 1 and extend through October 31. The winter period shall begin November 1 and extend through March 31. The summer oxygen-consuming wasteload allocation shall be developed using the flow criteria specified in 15A NCAC 02B .0206. The winter oxygen-consuming wasteload allocation shall not exceed two times the summer oxygen-consuming wasteload limitations nor shall it be less restrictive than minimum treatment requirements.

(d) No domestic sewage regardless of the treatment proposed and no other wastes that could adversely affect the taking of shellfish for market purposes shall be discharged into water classified "SA", into unnamed waters tributary to "SA" waters classified "C" or "SC" in accordance with 15A NCAC 02B .0301(i)(1)(B) and (C), or into other waters in such close proximity as to adversely affect such "SA" waters. Wastes discharged into other waters tributary to waters classified "SA" shall be treated in such manner as to assure that no impairment of water quality in the "SA" segments shall occur. No permits shall be issued for discharges into waters classified "SA" unless Shellfish Sanitation, Division of Marine Fisheries, Department of Environmental Quality, provides written concurrence that the discharge would not adversely affect shellfish water quality or the propagation of shellfish.

(e) The discharge of wastewaters to the Atlantic Ocean shall follow the guidelines and requirements set forth in 40 CFR Part 125, Subpart M, Ocean Discharge Criteria.

(f) In implementing the PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section, the following shall apply:

(1) Monitoring. When EPA test Method 1633 for PFAS is promulgated in 40 CFR Part 136, existing dischargers will be required to monitor their effluent using test Method 1633 within six months after promulgation and report concentrations for all PFAS listed in test Method 1633 as specified in their NPDES permit or pursuant to Rule .0508 of this Section.

(2) Permitting for Existing Dischargers. NPDES permits for existing industrial direct dischargers, Major POTWs, and Major and Minor POTWs with pretreatment programs shall be renewed or

modified (after notification by the Division) to include PFAS effluent limits and compliance schedules based on PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section according to the following two tiers:

(A) Tier One. After the test Method 1633 for PFAS is promulgated in 40 CFR Part 136, the Division shall modify or renew NPDES permits for existing industrial direct dischargers, Major POTWs, and Major and Minor POTWs with pretreatment programs to include PFAS effluent limits and compliance schedules based on PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218. .0220 of this Section for facilities having a minimum of eight effluent samples (using Method 1633) with at least two sample results showing the sum of PFOA and PFOS equal to or greater than 20 ng/L within the last 4.5 years or demonstrating a Reasonable Potential to cause or contribute to an exceedance of the HFPO-DA (GenX) water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section. Discharges with a surface water intake where the raw water influent concentration is equal to or greater than 20 ng/L for the sum of PFOA and PFOS and showing a corresponding effluent concentration sum not greater than 10 percent of the influent concentration, or equivalent mass loading in pounds per day, may submit a request with supporting documentation to the Division to designate the discharge a Tier Two discharger. If the Division determines the discharger has demonstrated it meets the criteria in this Subparagraph for designation as a Tier Two discharger, the Division shall designate the discharge as a Tier Two discharger. “Reasonable Potential” is where an effluent is projected or calculated to cause or contribute to an excursion above a water quality standard based on a number of factors including as a minimum of the four factors listed in 40 CFR 122.44(d)(1)(ii).

(B) Tier Two. After reissuance or modification of 90% of the permits in Tier One, or eleven years after the test Method 1633 for PFAS is promulgated in 40 CFR Part 136, whichever occurs first, the Division shall modify or renew NPDES permits for existing industrial direct dischargers, Major POTWs, and Major and Minor POTWs with pretreatment programs to include PFAS effluent limits and compliance schedules based on PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section for facilities that have a Reasonable Potential to cause or contribute to exceedance of any PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section. Additionally, the Division shall modify or renew NPDES permits for discharges that the Division designated as Tier Two discharger to include PFAS effluent limits and compliance schedules based on PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section. “Reasonable Potential” is where an effluent is projected or calculated to cause or contribute to an excursion above a water quality standard based on a number of factors including as a minimum of the four factors listed in 40 CFR 122.44(d)(1)(ii).

(3) Limit of Quantitation. For PFOA and PFOS, the Limit of Quantitation based on the national Multi-Laboratory Validation Study of PFAS by Isotope Dilution LC-MS/MS Wastewater, Surface Water, and Groundwater as reported in EPA test Method 1633 is 4.0 ng/L.

(4) PFOA and PFOS Permit Limits. Effluent limits for PFOA or PFOS that are calculated to be less than the Limit of Quantitation shall be given a permitted effluent limit of the Limit of Quantitation.

(5) PFOA or PFOS Reporting. For PFOA or PFOS values reported less than the Limit of Quantitation, the discharger shall report to the Division the actual numerical lab measurement for all samples in accordance with the reporting requirements outlined in Rule .0506 of this Section.

(6) New Dischargers or New Sources pursuant to 40 CFR 122.29. NPDES permits for new sources or new dischargers for industrial direct dischargers, Major POTWs or Major and Minor POTWs with pretreatment programs, the Division shall include PFAS effluent limits based on PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section for facilities that have a Reasonable Potential to cause or contribute to exceedance of any PFAS water quality standards in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220 of this Section.

(7) Programs Not Included. Minor POTWs without pretreatment programs, 100 percent domestic non-municipal wastewater treatment plants, and NPDES dischargers with General Permits shall not be evaluated by the Division for PFAS limits unless data using EPA Method 1633 shows presence of wastewaters containing PFAS listed in Rules .0211, .0212, .0214, .0215, .0216, .0218, and .0220, and their discharge impacts a downstream water use designation.

(8) Exceptions. The requirements in Subparagraphs (1) through (7) of this Paragraph do not apply to Technology Based Effluent Limits nor PFAS effluent guidelines promulgated by EPA.

History Note: *Authority G.S. 143-214.2(c); 143-215; 143-215.1; 143-215.3(a)(1);*
Eff. February 1, 1976;
Amended Eff. August 12, 1979;
Readopted Eff. May 1, 2020.

Appendix C: NCDEQ - Costs and Benefits to Industry, the Public, and the Environment Associated with NCDEQ's Proposed Per- and Polyfluoroalkyl Substances (15A NCAC, Subchapter 2B Standards)

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Technical Memorandum

Prepared for: North Carolina Department of Environmental Quality (NCDEQ)

Project Title: NCDEQ - Costs and Benefits to Industry, the Public, and the Environment Associated with NCDEQ's Proposed Per- and Polyfluoroalkyl Substances (15A NCAC, Subchapter 2B Standards)

Project No.: 195202

Technical Memorandum

Subject: General Methodology Used to Estimate PFAS Management Cost for Treated Wastewater (2B)

Date: May 23, 2024

To: Stephanie C. Bolyard, Ph.D., Senior Engineer to the Assistant Secretary, NCDEQ

Jessica Montie, Environmental Program Consultant, Division of Waste Management, NCDEQ

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Section 1: Introduction

The North Carolina Department of Environmental Quality (NCDEQ) and North Carolina Office of Strategic Partnerships (OSP) want to evaluate the potential economic impacts of proposed rules that will regulate certain per- and polyfluoroalkyl substances (PFAS) in treated wastewater. This evaluation requires identifying affected wastewater discharge facilities, determining effective treatment methods and best management practices for PFAS removal, and analyzing the costs and benefits of implementing proposed PFAS standards and associated outcomes.

PFAS comprise a large group of synthetic chemicals that can be present in multiple media including water, soil, air, and consumer products. Both long-chain (e.g., C7 (7 carbon atoms) and higher and short-chain (e.g., C6 and lower) PFAS compounds may be present in wastewater streams based on NCDEQ information. PFAS compounds are a concern to NCDEQ due to potential adverse health impacts.

For this study, different treatment technologies were evaluated to remove PFAS from wastewater at Publicly-Owned Treatment Works (POTWs) and wastewater streams that are generated and treated by various significant industrial users (SIUs). Well-established and mature technologies – those that have been deployed in full-scale applications and were proven to be effective in removing PFAS – were given priority rather than other emerging technologies. Although other emerging technologies may be future viable options (e.g., advanced oxidation/reduction processes [AOP/ARP], electrochemical oxidation), some of these chemical destructive techniques have limited full scale application and require further field verification.

Effective PFAS removal can be achieved through media sorption (via granular activated carbon [GAC] or ion-exchange [IX], filtration (via nanofiltration [NF] or reverse osmosis [RO] membranes) or through phase separation (via foam fractionation) particularly for long-chain PFAS. For wastewater streams that contain short-chain PFAS, treatment technologies such IX and RO are known to be more effective compared to the others. Note that these technologies primarily separate PFAS from the bulk wastewater stream but do not degrade or transform the concentrated compound. PFAS destruction through residuals management is typically achieved using accepted destruction technologies such as high temperature incineration and other thermal treatment methods.

Although the actual cost for PFAS management is site-specific, the potential economic impact of regulating PFAS and requiring treatment of contaminated wastewater may be informed by estimating associated cost for a general treatment train that is applicable to multiple sites with similar wastewater characteristics. This strategy was used to predict collective wastewater management costs for each type of industry. A recommended PFAS treatment approach for a given industry (categorized using the Standard Industrial Classification [SIC] codes) was first determined based on average wastewater quality (i.e., NCDEQ's data on PFAS compounds and concentrations for a specific SIC). The capital expenditure (CAPEX) required to build the PFAS treatment system and the operation expenditure (OPEX) needed to operate and maintain the treatment system were estimated using at least three different design flow criteria. Resulting values were used to plot treatment train cost curves, which were then used to estimate the industry-specific cost expenditures based on the average wastewater flow for the industry.

The general methodology used by Brown and Caldwell (BC) to develop these cost opinions are detailed in this technical memorandum. The cost curves developed, included as Figure 4, may be used to estimate potential costs for PFAS management of various treated industrial wastewaters. Note that these estimates are considered Association for the Advancement of Cost Engineering International (AACE) Class 5 with a range of -50% to +100% given available information. Appropriate considerations should be taken in applying cost curve values.

1.1 Basis for Cost Opinion

Different PFAS treatment technologies and residuals handling options were evaluated to determine an optimal PFAS management approach for a given industry. As previously mentioned, well-established and mature technologies were given preference since these applications have been employed full-scale and field-tested to be effective in removing PFAS from different waste streams. A summary of these technologies is presented in Table 1.

Table 1. PFAS Treatment Technologies

Treatment Option	Description	Applicability
Granular Activated Carbon (GAC)	PFAS removal via adsorption to GAC media (typically in lead-lag configuration)	• Mostly effective in removing long chain PFAS compounds. • Pretreatment (filtration) may be needed for wastewater that contains constituents that could cause media fouling.
Ion Exchange (IX)	PFAS removal via adsorption to IX resins (lead-lag configuration also common)	• Effective in removing long chain and short chain PFAS compounds. • Performance dependent on the type of resin used. • Pretreatment may be needed to extend resin longevity and improve PFAS removal.
GAC followed by IX	Combination of GAC and IX in series configuration for enhanced PFAS removal	• Combined treatment system for wastewater contaminated with high concentrations of long-chain and short-chain PFAS. • Pretreatment preferred for optimal performance and media longevity.
Filtration via Nanofiltration and/or Reverse Osmosis (RO)	High-pressure membrane technology used to remove PFAS	• Effective in removing long-chain and short-chain PFAS compounds. • May be cost-prohibitive to some sites due to pretreatment requirements and high membrane cost.
Foam Fractionation	PFAS separation and removal via capture in the air-liquid interface	• Relatively simple technology with variable PFAS removal efficiency. • Applicable to low to medium flow criteria but may be challenging for high flow capacity.

For evaluation of potential economic impact to industries, media sorption technologies were mainly chosen due to their relatively lower costs compared to other technologies. In general, these treatment technologies are able to treat to laboratory practical quantification limits (PQLs) or non-detect levels (generally < 1 nanogram per Liter [ng/L]) for most common long-chain and short-chain PFAS at optimal operating conditions. Typical schematics of these different treatment trains are presented in Figures 1 to 3. A dual (lead-lag) system was employed and recommended for effective PFAS removal. Note that in all cases, it was assumed that the required treatment to comply with current discharge limits is in place and will continue in operation. However, because wastewater quality may vary from site to site, pretreatment steps via filtration were included as part of each treatment train based on the potential need to remove solids prior to PFAS removal. PFAS removed from the wastewater are concentrated in media which are then destroyed using high-temperature incineration of the spent media as part of residuals management.

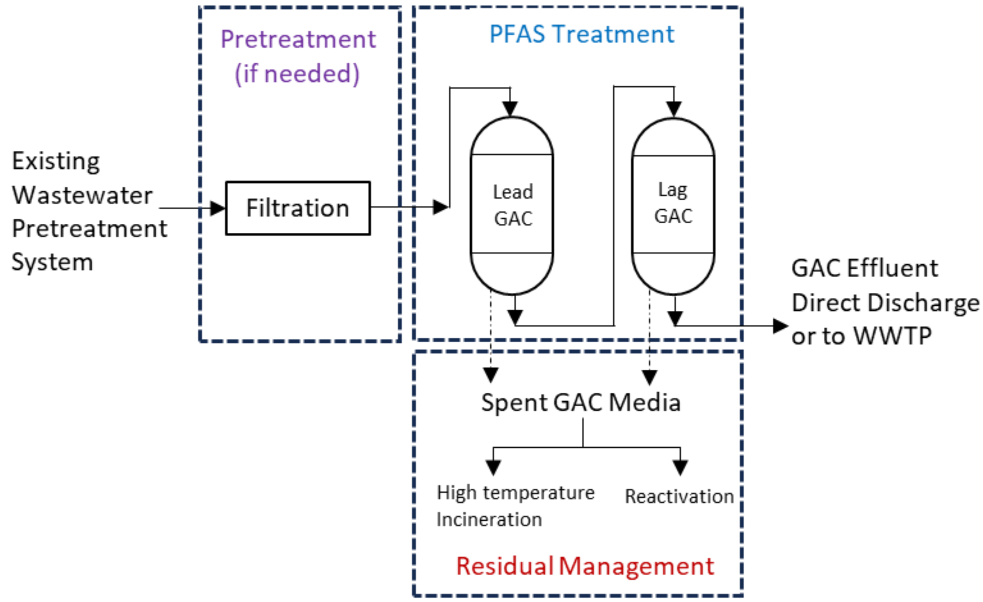


Figure 1. Treatment via GAC media for removal of long-chain PFAS compounds.

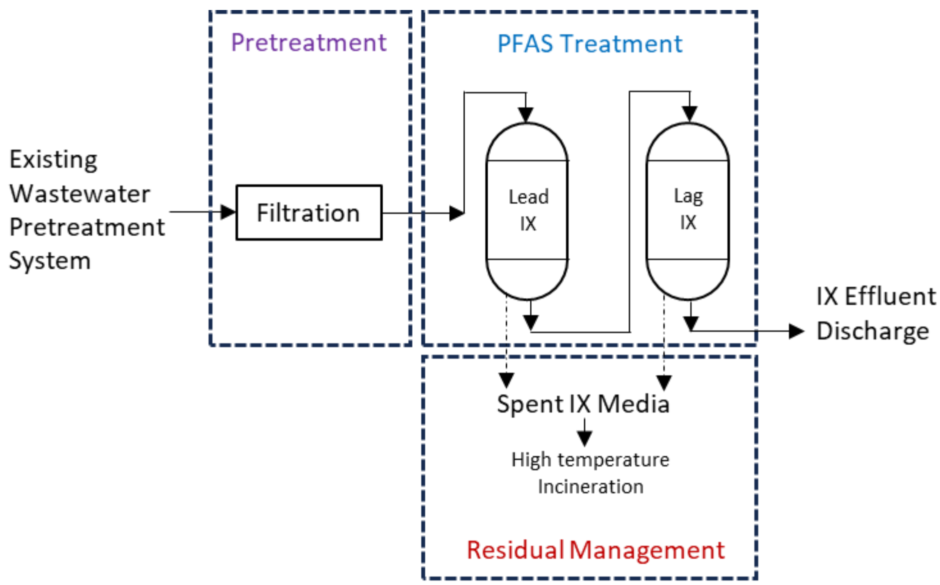


Figure 2. Treatment via IX media for removal of long-chain and short-chain PFAS compounds.

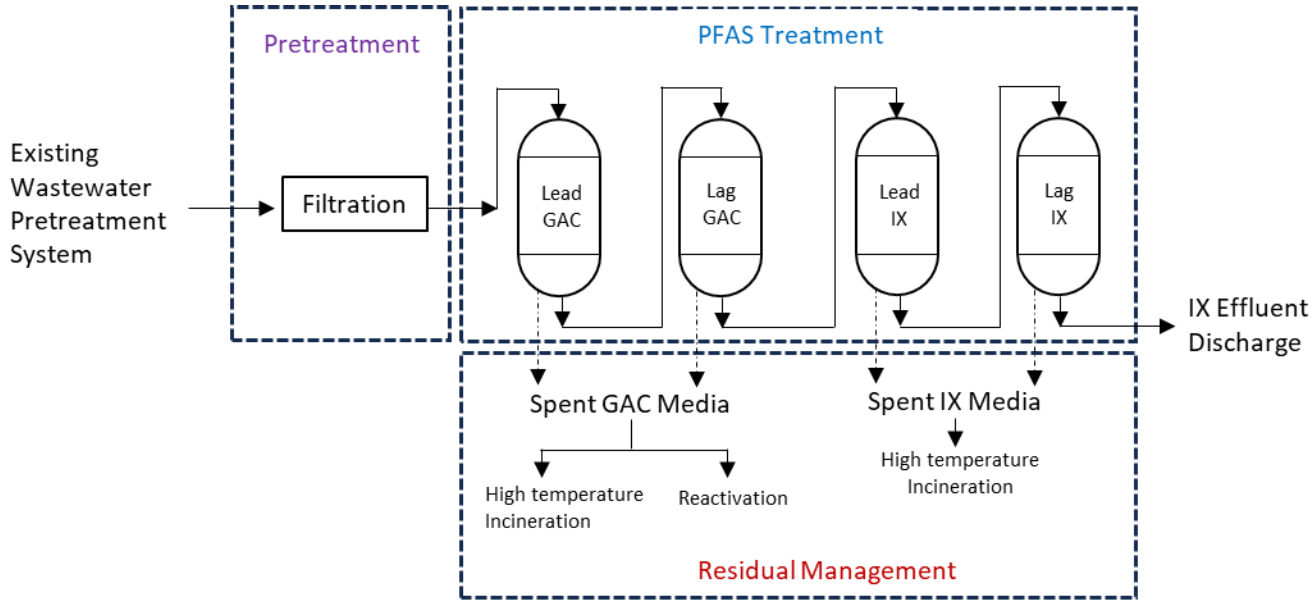


Figure 3. Treatment via GAC followed by IX for removal of relatively high concentrations of long-chain and short-chain PFAS compounds

Section 2: General Cost Estimating Methodology

This section discusses the general methodology used to develop the CAPEX and OPEX cost estimates and the resulting cost curves for PFAS treatment as a function of required design flow. The estimates were prepared using BC's internal conceptual cost estimating tool and supplemented by BC's estimating system and database, historical project data, available vendor and material cost information, and other costs obtained from published references identified in this document.

2.1 Class of Estimate

In accordance with the AACE criteria, the cost opinion provided in this technical memorandum is considered a Class 5 estimate. A Class 5 estimate is defined as a Conceptual Level or Project Viability Estimate and where engineering is typically from 0 to 2 percent complete. Class 5 estimates are used to prepare planning level cost scopes, evaluation of alternative schemes, or for long range capital outlay planning. This type of estimate can also form the base work for the Class 4 Planning Level or Design Technical Feasibility Estimate. A Class 5 estimate typically has a range of -50% to +100% around the stated value.

2.2 Capital Cost Estimate Approach

Capital cost estimates or CAPEX were prepared using quantity take-offs, vendor quotes, and equipment pricing furnished by BC. Major equipment costs that were used in estimating probable construction costs are based on vendor-supplied budgetary price quotes and on historical pricing of similar equipment compiled by BC. Equipment pricing developed using BC's database are adjusted to present day cost (November 2023) using Engineers News Record (ENR) Construction Cost Index (CCI) 20-cities average and scaled up using the “sixtenths“ scaling factor whenever applicable. The sixtenths rule is commonly applied to get a rough estimate of capital cost when there is insufficient data to determine a specific scaling index for the particular process (Remer [1990] and Chilton [1950]).

$$Cost_B = Cost_A \times (Size_B/Size_A)^{0.6}$$

When necessary, an n+1 redundancy was included in the equipment costing to provide backup to on-duty equipment (i.e., pumps).

For most cases, the recommended PFAS treatment train is assumed to be an add-on to existing treatment at the management site. As such, it was assumed that there is enough electrical power for any new equipment and that there is sufficient land onsite to accommodate the added footprint for the PFAS treatment system installation. Further, onsite soil was presumed to be of adequate nature and not require remediation due to soil contamination and will support structures for equipment to be added such that no geotechnical improvement activities have been included in this estimate.

Typical direct cost mark-ups such as installation of purchased equipment and supply and installation of instrumentation and controls (I&C), electrical components, piping, buildings, yard improvements, and service utility connections are included in the conceptual cost estimate as a percent markup applied to the purchased equipment delivered subtotal cost. The percent markups used are within recommended ranges based on Peters et al. (2002) or based on current industry practice and are summed to the estimates total direct cost. Where variable mark-ups are shown, a value was selected to reflect system type and complexity. Total indirect costs are based on percentage markups on the total direct cost for items such as Contractor's Fee, Contractor's General Conditions, Legal Fees, etc. While annual escalation rate was excluded in the capital cost estimate, a project contingency of 35 percent was applied to these costs to cover unknowns. Table 2 provides a summary of the cost mark-ups.

Table 2. Cost Mark-ups Used for Capital Cost Estimate of Different PFAS Treatment Systems

Item	Rate (%)	Definition
Direct Cost Markups		
Freight	10	Material shipping and handling
Purchased Equipment Installation	25	Installation of all equipment listed on complete flow sheet, structural supports, insulation, paint
Instrumentation and Controls (Installed)	Variable (10-18)	Purchase, installation, calibration, computer tie-ins
Piping (Installed)	Variable (20-40)	Process piping, pipe hangers, fittings, valves, insulation, equipment
Electrical systems (installed)	Variable (30-40)	Electrical equipment, switches, conduit, wire, fittings, feeders, grounding, lighting, panels, etc.
Yard Improvements	10	Site development, clearing, grading, roads, walkways, etc.
Service Utilities (installed)	10	Includes when applicable steam, potable water, power, refrigeration, compressed air, fuel, waste disposal.
Indirect Cost Markups		
Engineering and Supervision	Variable (8-15)	Engineering cost-administrative, process, design and general engineer, drafting, cost engineering, procuring, expediting, reproduction, communications, scale models, consultant fees, travel.
Legal Expenses, Permits	2	Identification of applicable federal, state, and local regulations. Preparation and submission of forms required by regulatory agencies Acquisition of regulatory approval; Contract negotiations
Contractors Fee	15	Contractor profits and mark-ups
Construction Expenses – General Conditions	20	Costs associated with general contractor's overhead (tools, resources, equipment) pertaining to site management, material handling, project management, etc.
Contingency	35	Contingency for project/construction

2.3 Operation and Maintenance Cost Estimate Approach

Although each treatment technology will have specific operation and maintenance (O&M) requirements, common cost elements used in developing the OPEX are as follows:

- Equipment and building maintenance
- Labor
- Power (electric)
- Chemical usage (when applicable)
- Media replacement
- Residuals management
- PFAS Monitoring

To determine cost for the different O&M cost elements, BC applied various cost items listed in Table 3.

Table 3. Operation and Maintenance Cost Estimating Cost Assumptions

Cost Item	Value	Unit
Equipment Maintenance	3%	% of Equipment Cost
Building Maintenance	$2.5	Per square foot
Labor	$85,000	FTE loaded annual rate
Electrical	$0.11	Per kilowatt-hr
Media Replacement	Variable	Pricing varies depending on media type and replacement frequency
Residual management	Variable	Pricing varies depending on management option and total volume. Excludes hauling cost due to unknown distance to/from site.
Monitoring	$3,839	Cost per monthly PFAS sampling event

The media replacement cost included in the estimate relies heavily on estimated media replacement frequency dictated by influent water quality (concentrations and type of PFAS present) and specific media and O&M requirements for effective treatment. No treatability testing was conducted to determine treatment performance therefore design criteria for the GAC and IX systems obtained from literature were used in the estimate. For example, the required media empty bed contact times (EBCT) and bed volumes prior to breakthrough for effective PFAS treatment applied in this evaluation were obtained from the Minnesota Pollution Control Agency PFAS report (*Evaluation of Current Alternatives and Estimated Cost Curves for PFAS Removal and Destruction from Municipal Wastewater, Biosolids, Landfill, and Compost Contact Water*, *Barr Engineering Co. Hazen and Sawyer, May 2023*.) and are summarized in Table 4.

Table 4. GAC and IX Design and Operation Assumptions

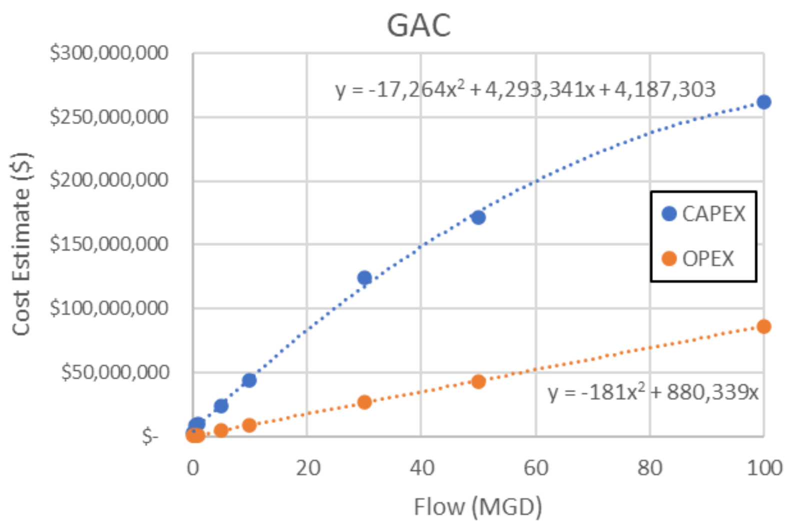
Parameter	Value
GAC media empty bed contact time (EBCT) requirement	15 mins
Number of GAC bed volumes prior to PFAS contaminant breakthrough	8,100
IX media empty bed contact time (EBCT) requirement	4 mins
Number of IX bed volumes prior to PFAS contaminant breakthrough	20,000

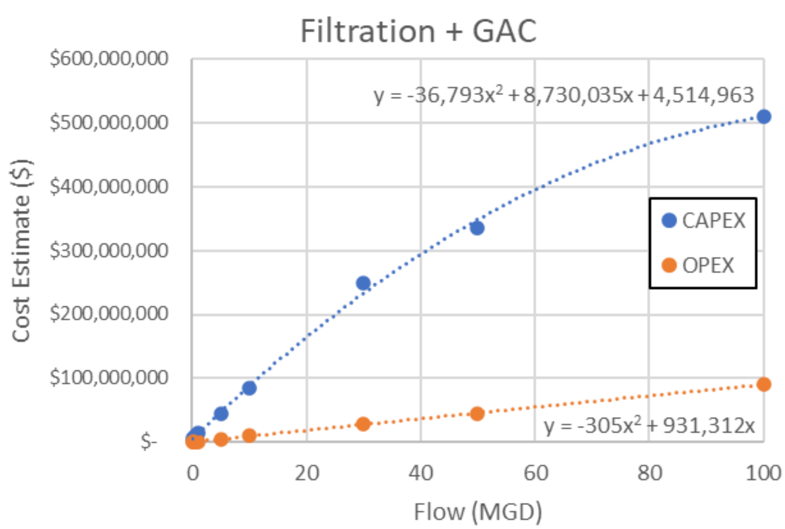
Thermal destruction (incineration) of spent GAC and IX was selected as a conservative approach over other spent media residuals management options such as landfilling (with or without encapsulation) or GAC reactivation.

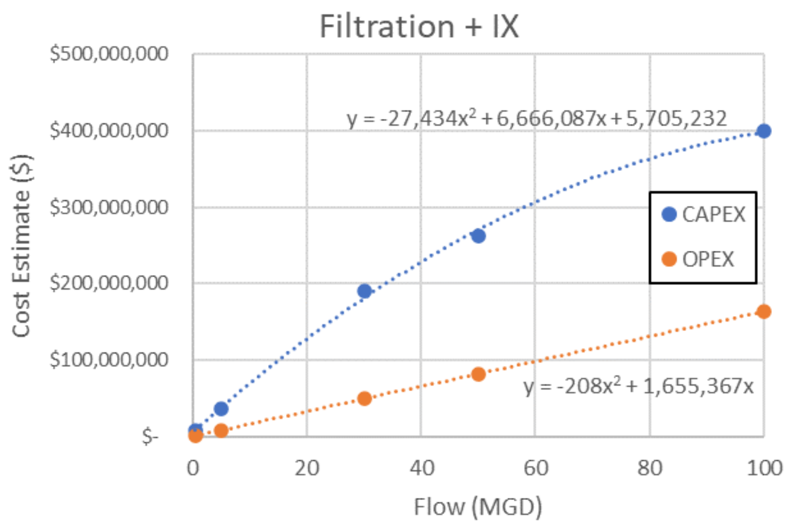
Section 3: Cost Curves for Estimating Cost Impacts

The CAPEX and OPEX cost curves for the different treatment trains were developed by estimating treatment system costs for (at least three) different design flow criteria. A summary of the cost estimates is presented in Table 5 and the resulting cost curves are presented in Figure 4.

Table 5. CAPEX and OPEX for Different PFAS Treatment Systems						
PFAS Treatment Train	Flow Criteria	Flow Design Basis (MGD)	CAPEX	CAPEX ($ per gallon)	OPEX	OPEX (Unit cost (daily) $ per 1000 gallon)
GAC	0.05 to 100 MGD	0.05	$ 2,592,000	$ 52	$ 151,000	$ 8.27
		0.2	$ 4,126,000	$ 21	$ 291,000	$ 3.99
		0.5	$ 8,305,000	$ 17	$ 569,000	$ 3.12
		1	$ 9,671,000	$ 10	$ 1,027,000	$ 2.81
		5	$ 23,876,000	$ 5	$ 4,558,000	$ 2.50
		10	$ 43,904,000	$ 4	$ 9,083,000	$ 2.49
		30	$ 123,978,000	$ 4	$ 26,386,000	$ 2.41
		50	$ 170,928,000	$ 3	$ 43,302,000	$ 2.37
		100	$ 261,507,000	$ 3	$ 86,278,000	$ 2.36
Filtration-GAC	0.05 to 100 MGD	0.05	$ 3,167,000	$ 63	$ 164,000	$ 8.99
		0.2	$ 5,788,000	$ 29	$ 313,000	$ 4.29
		0.5	$ 10,077,000	$ 20	$ 599,000	$ 3.28
		1	$ 14,332,000	$ 14	$ 1,079,000	$ 2.96
		5	$ 43,820,000	$ 9	$ 4,814,000	$ 2.64
		10	$ 85,573,000	$ 9	$ 9,733,000	$ 2.67
		30	$ 250,252,000	$ 8	$ 28,126,000	$ 2.57
		50	$ 336,309,000	$ 7	$ 45,212,000	$ 2.48
		100	$ 511,279,000	$ 5	$ 90,181,000	$ 2.47
Filtration-IX	0.5 to 100 MGD	0.5	$ 8,154,000	$ 16	$ 968,000	$ 5.3
		5	$ 36,011,000	$ 7	$ 8,737,000	$ 4.79
		30	$ 191,226,000	$ 6	$ 49,578,000	$ 4.53
		50	$ 262,295,000	$ 5	$ 82,071,000	$ 4.5
		100	$ 399,094,000	$ 4	$ 163,495,000	$ 4.48
Filtration-GAC-IX	0.05 to 100 MGD	0.05	$ 3,553,000	$ 71	$ 230,000	$ 12.6
		0.2	$ 6,805,000	$ 34	$ 537,000	$ 7.36
		0.5	$ 11,523,000	$ 23	$ 1,176,000	$ 6.44
		1	$ 16,398,000	$ 16	$ 2,152,000	$ 5.9
		10	$ 100,264,000	$ 10	$ 19,830,000	$ 5.43
		30	$ 282,697,000	$ 9	$ 58,973,000	$ 5.39
		50	$ 386,573,000	$ 8	$ 96,598,000	$ 5.29
		100	$ 587,464,000	$ 6	$ 191,491,000	$ 5.25


GAC
$300,000,000
$250,000,000
$200,000,000
$150,000,000
$100,000,000
$50,000,000
$-
Cost Estimate ($)
y = -17,264x² + 4,293,341x + 4,187,303
CAPEX
OPEX
y = -181x² + 880,339x
0
20
40
60
80
100
Flow (MGD)


Filtration + GAC
$600,000,000
$500,000,000
$400,000,000
$300,000,000
$200,000,000
$100,000,000
$-
Cost Estimate ($)
y = -36,793x² + 8,730,035x + 4,514,963
CAPEX
OPEX
y = -305x² + 931,312x
0
20
40
60
80
100
Flow (MGD)



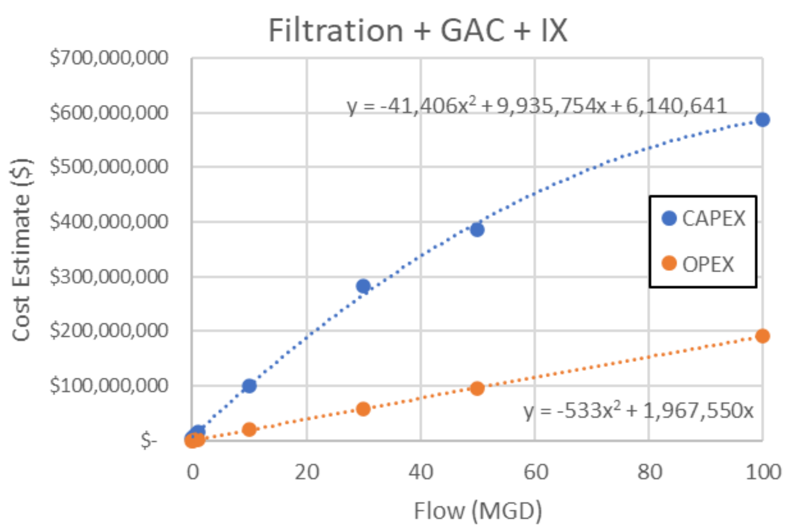


Figure 4. CAPEX and OPEX Cost Curves for granular activated carbon (GAC), filtration (cloth) and GAC, filtration and ion exchange (IX), and filtration, GAC and IX PFAS treatment trains applicable to treated wastewater (2B).

References

Romero, M. L., Sierra, N., and Nangle, T. (2023). "Biosolids management challenges – the PFAS dilemma", *NC Currents*, Winter 2023, 37-40.

Winchell, L. J., Wells, M. J. M., Ross, J. J., Fonoll, X., Norton, J. W., Kuplicki, S., Khan, M., & Bell, K. Y. (2021). "Per- and polyfluoroalkyl substances presence, pathways, and cycling through drinking water and wastewater treatment", Journal of Environmental Engineering, 148(1). https://doi.org/10.1061/(ASCE)EE.1943-7870.0001943

EPA (2024). U.S. Environmental Protection Agency. *Best Available Technologies and Small System Compliance Technologies for Per- and Polyfluoroalkyl Substances (PFAS) in Drinking Water (EPA-815R24011). (March).*

Evaluation of Current Alternatives and Estimated Cost Curves for PFAS Removal and Destruction from Municipal Wastewater, Biosolids, Landfill, and Compost Contact Water, Barr Engineering Co. Hazen and Sawyer, May 2023.

Peters, M. S., Timmerhaus, K. D., & West, R. E. (2002). Plant design and economics for chemical engineers (5th ed.). McGraw-Hill Professional.

Remer, D.S. (1990). "Design cost factors for scaling-up engineering equipment", *Chemical Engineering Progress*. 77.

Chilton, C.H. (1950), "Six-tenths factor applies to complete plant costs", *Chemical Engineering* 57:112-114.

Appendix D: Summary of Affected NPDES Direct and Indirect Dischargers

Summary of Affected NPDES Direct and Indirect Dischargers

The tables below summarize the associated SIC codes that match to NDPES permits and associated facilities (SIUs).

Table 1. Summary of SIC Codes Associated with Potential PFAS Industrial Direct Dischargers

SIC Code	Count Industrial Dischargers	SIC Description
2821	4	Plastics Materials, Synthetic Resins, and Nonvulcanizable Elastomers
2621	3	Paper Mills
2819	3	Industrial Inorganic Chemicals, Not Elsewhere Classified
2221	2	Broadwoven Fabric Mills, Manmade Fiber and Silk
2257	2	Weft Knit Fabric Mills
2262	2	Finishers of Broadwoven Fabrics of Manmade Fiber and Silk
2824	2	Manmade Organic Fibers, Except Cellulosic
9711	2	National Security
2011	1	Meat Packing Plants
2082	1	Malt Beverages
2211	1	Broadwoven Fabric Mills, Cotton
2252	1	Hosiery, Not Elsewhere Classified
2269	1	Finishers of Textiles, Not Elsewhere Classified
2611	1	Pulp Mills
2631	1	Paperboard Mills
2833	1	Medicinal Chemicals and Botanical Products
2834	1	Pharmaceutical Preparations
2865	1	Cyclic Organic Crudes and Intermediates, and Organic Dyes and Pigments
2874	1	Phosphatic Fertilizers
2879	1	Pesticides and Agricultural Chemicals, Not Elsewhere Classified
3089	1	Plastics Products, Not Elsewhere Classified
3229	1	Pressed and Blown Glass and Glassware, Not Elsewhere Classified
3334	1	Primary Production of Aluminum
3341	1	Secondary Smelting and Refining of Nonferrous Metals
3471	1	Electroplating, Plating, Polishing, Anodizing, and Coloring
5169	1	Chemicals and Allied Products, Not Elsewhere Classified
8731	1	Commercial Physical and Biological Research
Total	39	

Table 2. Summary of SIC Codes Associated with Potential PFAS SIUs

SIC Code	Count SIUs	SIC Description
4953	29	Refuse Systems
2834	25	Pharmaceutical Preparations
3479	15	Coating, Engraving, and Allied Services, Not Elsewhere Classified
2821	11	Industrial Inorganic Chemicals, Nec
3471	10	Electroplating, Plating, Polishing, Anodizing, and Coloring
7218	10	Industrial Launderers
2819	8	Industrial Inorganic Chemicals, Nec
2252	7	Hosiery, Not Elsewhere Classified
8731	7	Commercial Physical Research
2015	6	Poultry Slaughtering and Processing
2211	6	Broadwoven Fabric Mills, Cotton
2841	6	Soap and Other Detergents
2869	6	Industrial Organic Chemicals, Not Elsewhere Classified
3399	6	Primary Metal Products
3674	6	Semiconductors and Related Devices
4952	6	Sewerage Systems
2231	5	Broadwoven Fabric Mills, Wool
2297	5	Non-woven Fabrics
3089	5	Plastics Products, Not Elsewhere Classified
3714	5	Motor vehicle parts and accessories
2086	4	Bottled and canned soft drinks
2299	4	Textile Goods, Nec
3429	4	Hardware, Nec
3444	4	Sheet Metalwork
3531	4	Construction Machinery and Equipment
7213	4	Linen Supply
1711	3	Plumbing, Heating, Air-conditioning
2013	3	Sausages and Other Prepared Meats Products
2026	3	Dry, Condensed, Evaporated Products
2096	3	Potato chips and similar snacks
2099	3	Food Preparations, Not Elsewhere Classified
2281	3	Yarn Spinning Mills
2282	3	Yarn Texturizing, Throwing, Twisting, and Winding Mills
2323	3	Men's and Boy's Neckwear
2836	3	Biological Products, Except Diagnostic Substances
3011	3	Tires and Inner Tubes
3231	3	Glass Products, Made of Purchased Glass
3356	3	Rolling, Drawing, and Extruding of Nonferrous Metals, Except Copper and Aluminum
3491	3	Industrial Valves
3599	3	Industrial Machinery, Nec
4911	3	Electric Services
5122	3	Drugs, Drug Proprietaries, and Druggists' Sundries
7211	3	Power Laundries, Family and Commercial
7359	3	Equipment Rental and Leasing, Nec

SIC Code	Count SIUs	SIC Description
8062	3	General Medical and Surgical Hospitals
0254	2	Poultry Hatcheries
2023	2	Dry, Condensed, Evaporated Products
2082	2	Malt Beverages
2111	2	Cigarettes
2251	2	Women's Full-Length and Knee-Length Hosiery, Except Socks
2258	2	Lace and Warp Knit Fabric Mills
2273	2	Carpets and Rugs
2284	2	Thread Mills
2499	2	Wood Products, Nec
2599	2	Public Building and Related Furniture
2611	2	Pulp Mills
2621	2	Paper Mills
2653	2	Corrugated and Solid Fiber Boxes
2671	2	Paper; Coated and Laminated Packaging
2675	2	Die-Cut Paper and Paperboard and Cardboard
2843	2	Surface Active Agents
2844	2	Toilet Preparations
2851	2	Paints and Allied Products
2899	2	Chemicals and Chemical Preparations, Not Elsewhere Classified
3087	2	Custom Compound Purchased Resins
3321	2	Foundries-gray and ductile iron
3341	2	Secondary Smelting and Refining of Nonferrous Metals
3363	2	Aluminum Die Casting
3443	2	Fabricated Plate Work (Boiler Shops)
3466	2	Crowns and Closures
3499	2	Fabricated Metal Products, Not Elsewhere Classified
3519	2	Internal Combustion Engines, Nec
3523	2	Farm Machinery and Equipment
3556	2	Food Products Machinery
3562	2	Ball and Roller Bearings
3569	2	General Industrial Machinery and Equipment, Not Elsewhere
4213	2	Trucking, Except Local
4225	2	General Warehousing and Storage
5064	2	Electrical Appliances, Television and Radio
5085	2	Industrial Supplies
5093	2	Scrap and Waste Materials
5113	2	Industrial and Personal Service Paper
5199	2	Nondurable Goods, Nec
5461	2	Retail Bakeries
7215	2	Coin-Operated Laundries and Drycleaning
7389	2	Business Services, Not Elsewhere Classified
8011	2	Offices and Clinics of Medical Doctors
0213	1	Hogs
0253	1	Turkeys and Turkey Eggs
0259	1	Poultry and Eggs, Nec
0751	1	Livestock Services, Except Veterinary

SIC Code	Count SIUs	SIC Description
0781	1	Landscape Counseling and Planning
1081	1	Metal Mining Services
1522	1	Residential Construction, Nec
1541	1	Industrial Buildings and Warehouses
1721	1	Painting and Paper Hanging
1771	1	Concrete Work
1796	1	Installing Building Equipment
2011	1	Meat Packing Plants
2034	1	Dehydrated Fruits, Vegetables, Soups
2035	1	Pickles, Sauces, and Salad Dressings
2038	1	Frozen Specialties, Not elsewhere classified
2043	1	Cereal Breakfast Foods
2046	1	Wet Corn Milling
2047	1	Dog and Cat Food
2051	1	Bread, Cake, and Related Products
2053	1	Frozen bakery products, except bread
2077	1	Animal and Marine Fats and Oils
2079	1	Fats and oils-edible
2084	1	Wines, Brandy, and Brandy Spirits
2221	1	Broadwoven Fabric Mills, Manmade Fiber and Silk
2253	1	Knit Outerwear Mills
2254	1	Knit Underwear and Nightwear Mills
2257	1	Weft Knit Fabric Mills
2259	1	Knitting Mills, Not Elsewhere Classified
2261	1	Finishing plants, cotton
2269	1	Finishers of Textiles, Not Elsewhere Classified
2283	1	Textile Mill Products
2296	1	Tire Cord and Fabrics
2389	1	Apparel and Accessories, Not Elsewhere Classified
2399	1	Fabricated Textile Products
2541	1	Wood Office and Store Fixtures, Partitions, Shelving, and Lockers
2672	1	Coated and Laminated Paper, Not Elsewhere Classified
2676	1	Sanitary Paper Products
2759	1	Commercial Printing, Not Elsewhere Classified
2822	1	Synthetic Rubber (Vulcanizable Elastomers)
2842	1	Specialty Cleaning, Polishing, and Sanitation Preparations
2865	1	Cyclic crudes and intermediates
2879	1	Agricultural Chemicals, Nec
2911	1	Pulp Mills
2952	1	Asphalt Felts and Coatings
3052	1	Rubber and Plastics Hose and Beltings
3061	1	Mechanical Rubber Goods
3069	1	Fabricated Rubber Products, Not Elsewhere Classified
3084	1	Plastics Pipe
3272	1	Concrete Products, Nec
3291	1	Abrasive Products
3292	1	Asbestos Products

SIC Code	Count SIUs	SIC Description
3365	1	Aluminum Foundry, Electroplating, Plating...
3398	1	Metal Heat Treating
3411	1	Metal Cans
3431	1	Enameled Iron and Metal Sanitary Ware
3432	1	Plumbing Fixture Fittings and Trim
3433	1	Heating Equipment, Except Electric and Warm Air Furnaces
3449	1	Miscellaneous Structural Metal Work
3451	1	Screw Machine Products
3493	1	Steel Springs, Except Wire
3494	1	Valves and Pipe Fittings, Not Elsewhere Classified
3496	1	Miscellaneous Fabricated Wire Products
3537	1	Industrial trucks, tractors, trailers, stackers
3541	1	Machine Tools, Metal Cutting Type
3544	1	Special Dies and Tools, Die Sets, Jigs and Fixtures, and Industrial Molds
3545	1	Cutting Tools, Machine Tool Accessories, and Machinists' Precision Measuring Devices
3546	1	Power-driven Handtools
3561	1	Pumps and Pumping Equipment
3564	1	Industrial and Commercial Fans and Blowers and Air Purification Equipment
3585	1	Refrigeration and heating equipment
3594	1	Fluid Power Pumps and Motors
3625	1	Relays and Industrial Controls
3639	1	Appliances-household
3646	1	Lighting fixtures-commercial
3663	1	Radio and T.v. Communications Equipment
3692	1	Primary Batteries, Dry and Wet
3711	1	Motor Vehicles and Passenger Car Bodies
3715	1	Truck Trailers
3728	1	Aircraft Parts and Equipment, Nec
3743	1	Railroad Equipment
3812	1	Search and Navigation Equipment
3829	1	Measuring and Controlling Devices, Nec
3841	1	Surgical and Medical Instruments and Apparatus
3842	1	Surgical appliances and supplies
3861	1	Photographic Equipment and Supplies
3999	1	Textile Mill Products
4221	1	Farm Product Warehousing and Storage
4499	1	Water Transportation Services, Nec
4935	1	Refuse Systems
4941	1	Water Supply
4959	1	Sanitary Services, Nec
5031	1	Building Materials, Interior
5049	1	Professional Equipment and Supplies, Not Elsewhere Classified
5051	1	Metals Service Centers and Offices
5063	1	Electrical Apparatus and Equipment
5131	1	Piece Goods and Notions

SIC Code	Count SIUs	SIC Description
5136	1	Men's and Boy's Clothing
5137	1	Clothing and Accessories
5153	1	Grain and Field Beans
5169	1	Chemicals and Allied Products, nec
5198	1	Paints, Varnishes, and Supplies
5331	1	Variety Stores
5511	1	New and Used Car Dealers
5719	1	Miscellaneous Home Furnishings Stores
5812	1	Eating Places
5999	1	Miscellaneous Retail Stores
6411	1	Insurance Agents, Brokers, and Service
7219	1	Laundry and Garment Services, Not Elsewhere Classified
7371	1	Custom Computer Programming Services
7532	1	Top and Body Repair and Paint Shops
8049	1	Offices and Clinics of Health Practitioners, Not Elsewhere Classified
8071	1	Medical Laboratories
8711	1	Engineering Services
8721	1	Accounting, Auditing, and Bookkeeping
8742	1	Management Consulting Services
Total	464	

Appendix E: Summary of Projected Costs for the Proposed Rules

Summary of Cost Projections by Year from 2024 to 2060 for the Proposed Rules

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Cost Impacts to Industrial Dischargers and Significant Industrial Users						
Monitoring (Industrial Dischargers)	$0	$0	$390,568	$744,570	$377,093	$359,547
Monitoring (Significant Industrial Users)	$0	$0	$3,940,549	$5,650,757	$5,120,855	$4,254,134
Treatment and Operation (Industrial Dischargers)	$0	$0	$0	$0	$11,816,061	$11,043,047
Treatment and Operation (Significant Industrial Users)	$0	$0	$32,516,533	$51,001,294	$59,005,109	$63,351,070
Total Impacts to Private Sector	**$0**	**$0**	**$36,847,650**	**$57,396,622**	**$76,319,118**	**$79,007,797**
Cost Impacts to North Carolina Local Governments						
Monitoring (POTWs)	$0	$0	$878,777	$1,675,283	$1,597,098	$1,522,786
Treatment and Operation (POTWs)	$0	$0	$0	$0	$52,766,870	$62,467,224
Total Impacts to NC Local Governments	**$0**	**$0**	**$878,777**	**$1,675,283**	**$54,363,969**	**$63,990,011**
Cost Impacts to North Carolina State Government						
Engineer II	$111,435	$106,228	$101,264	$96,532	$92,021	$87,721
Environmental Program Consultant	$111,435	$106,228	$101,264	$96,532	$92,021	$87,721
Total Impacts to NC State Governments	**$222,870**	**$212,456**	**$202,528**	**$193,064**	**$184,042**	**$175,442**
Total Direct Cost Impacts						
Total Direct Costs (7% Discount Rate)	**$222,870**	**$212,456**	**$37,928,955**	**$59,264,969**	**$130,867,129**	**$143,173,250**

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Cost Impacts to Industrial Dischargers and Significant Industrial Users						
Monitoring (Industrial Dischargers)	$365,918	$623,793	$290,962	$297,593	$255,320	$280,088
Monitoring (Significant Industrial Users)	$4,148,987	$3,990,076	$4,791,695	$2,530,787	$1,803,941	$1,903,686
Treatment and Operation (Industrial Dischargers)	$10,607,635	$10,081,497	$32,008,824	$42,659,962	$40,470,704	$38,842,431
Treatment and Operation (Significant Industrial Users)	$74,922,389	$84,311,310	$91,032,660	$121,281,991	$126,721,929	$128,483,978
Total Impacts to Private Sector	**$90,044,928**	**$99,006,676**	**$128,124,141**	**$166,770,332**	**$169,251,893**	**$169,510,182**
Cost Impacts to North Carolina Local Governments						
Monitoring (POTWs)	$1,452,146	$1,472,920	$1,363,064	$1,240,386	$1,154,904	$1,074,808
Treatment and Operation (POTWs)	$75,098,555	$86,748,436	$164,692,546	$193,430,451	$245,749,918	$270,849,277
Total Impacts to NC Local Governments	**$76,550,700**	**$88,221,356**	**$166,055,610**	**$194,670,837**	**$246,904,821**	**$271,924,086**
Cost Impacts to North Carolina State Government						
Engineer II	$83,622	$79,714	$75,989	$72,439	$69,054	$65,827
Environmental Program Consultant	$83,622	$79,714	$75,989	$72,439	$69,054	$65,827
Total Impacts to NC State Governments	**$167,244**	**$159,429**	**$151,979**	**$144,877**	**$138,107**	**$131,654**
Total Direct Cost Impacts						
Total Direct Costs (7% Discount Rate)	**$166,762,872**	**$187,387,460**	**$294,331,730**	**$361,586,046**	**$416,294,821**	**$441,565,921**

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**
Cost Impacts to Industrial Dischargers and Significant Industrial Users						
Monitoring (Industrial Dischargers)	$232,554	$197,096	$188,172	$179,678	$316,090	$136,290
Monitoring (Significant Industrial Users)	$1,130,170	$871,373	$411,998	$431,227	$0	$0
Treatment and Operation (Industrial Dischargers)	$36,856,343	$48,323,154	$47,156,099	$44,551,901	$42,591,535	$40,519,119
Treatment and Operation (Significant Industrial Users)	$139,974,089	$142,896,203	$142,699,626	$140,514,328	$137,780,319	$129,493,013
Total Impacts to Private Sector	**$178,193,157**	**$192,287,827**	**$190,455,896**	**$185,677,134**	**$180,687,945**	**$170,148,421**
Cost Impacts to North Carolina Local Governments						
Monitoring (POTWs)	$1,069,315	$1,128,636	$847,766	$635,493	$816,416	$476,152
Treatment and Operation (POTWs)	$276,707,661	$313,907,796	$352,087,856	$368,809,045	$362,055,105	$378,485,460
Total Impacts to NC Local Governments	**$277,776,976**	**$315,036,432**	**$352,935,622**	**$369,444,538**	**$362,871,521**	**$378,961,611**
Cost Impacts to North Carolina State Government						
Engineer II	$62,751	$59,818	$57,023	$54,359	$51,818	$49,397
Environmental Program Consultant	$62,751	$59,818	$57,023	$54,359	$51,818	$49,397
Total Impacts to NC State Governments	**$125,501**	**$119,637**	**$114,046**	**$108,717**	**$103,637**	**$98,794**
Total Direct Cost Impacts						
Total Direct Costs (7% Discount Rate)	**$456,095,634**	**$507,443,896**	**$543,505,564**	**$555,230,389**	**$543,663,102**	**$549,208,827**

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**
Cost Impacts to Industrial Dischargers and Significant Industrial Users						
Monitoring (Industrial Dischargers)	$70,865	$80,300	$70,712	$50,323	$48,099	$45,980
Monitoring (Significant Industrial Users)	$0	$0	$0	$0	$0	$0
Treatment and Operation (Industrial Dischargers)	$38,284,817	$36,177,222	$34,188,956	$32,313,077	$30,543,061	$28,872,768
Treatment and Operation (Significant Industrial Users)	$121,713,925	$114,411,393	$107,555,753	$101,119,210	$89,589,065	$79,383,627
Total Impacts to Private Sector	**$160,069,606**	**$150,668,916**	**$141,815,421**	**$133,482,611**	**$120,180,225**	**$108,302,375**
Cost Impacts to North Carolina Local Governments						
Monitoring (POTWs)	$474,628	$188,942	$216,649	$0	$0	$0
Treatment and Operation (POTWs)	$364,472,962	$359,423,973	$345,785,431	$336,581,124	$318,509,655	$301,435,954
Total Impacts to NC Local Governments	**$364,947,590**	**$359,612,916**	**$346,002,080**	**$336,581,124**	**$318,509,655**	**$301,435,954**
Cost Impacts to North Carolina State Government						
Engineer II	$47,089	$44,888	$42,791	$40,791	$38,885	$37,068
Environmental Program Consultant	$47,089	$44,888	$42,791	$40,791	$38,885	$37,068
Total Impacts to NC State Governments	**$94,178**	**$89,777**	**$85,582**	**$81,582**	**$77,770**	**$74,136**
Total Direct Cost Impacts						
Total Direct Costs (7% Discount Rate)	**$525,111,374**	**$510,371,608**	**$487,903,082**	**$470,145,317**	**$438,767,651**	**$409,812,465**

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**
Cost Impacts to Industrial Dischargers and Significant Industrial Users						
Monitoring (Industrial Dischargers)	$43,960	$42,034	$40,198	$38,448	$36,778	$35,186
Monitoring (Significant Industrial Users)	$0	$0	$0	$0	$0	$0
Treatment and Operation (Industrial Dischargers)	$24,611,328	$23,299,168	$21,984,755	$20,817,235	$19,321,841	$18,200,404
Treatment and Operation (Significant Industrial Users)	$72,809,241	$67,142,600	$61,527,700	$55,247,397	$48,101,820	$37,939,938
Total Impacts to Private Sector	**$97,464,529**	**$90,483,802**	**$83,552,654**	**$76,103,079**	**$67,460,440**	**$56,175,529**
Cost Impacts to North Carolina Local Governments						
Monitoring (POTWs)	$0	$0	$0	$0	$0	$0
Treatment and Operation (POTWs)	$271,667,402	$253,915,819	$236,244,333	$219,616,667	$205,159,760	$188,596,431
Total Impacts to NC Local Governments	**$271,667,402**	**$253,915,819**	**$236,244,333**	**$219,616,667**	**$205,159,760**	**$188,596,431**
Cost Impacts to North Carolina State Government						
Engineer II	$35,336	$33,685	$32,111	$30,610	$29,180	$27,816
Environmental Program Consultant	$35,336	$33,685	$32,111	$30,610	$29,180	$27,816
Total Impacts to NC State Governments	**$70,672**	**$67,369**	**$64,221**	**$61,220**	**$58,359**	**$55,632**
Total Direct Cost Impacts						
Total Direct Costs (7% Discount Rate)	**$369,202,602**	**$344,466,990**	**$319,861,208**	**$295,780,967**	**$272,678,559**	**$244,827,592**

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2054**	**2055**	**2056**	**2057**	**2058**	**2059**
Cost Impacts to Industrial Dischargers and Significant Industrial Users						
Monitoring (Industrial Dischargers)	$0	$0	$0	$0	$0	$0
Monitoring (Significant Industrial Users)	$0	$0	$0	$0	$0	$0
Treatment and Operation (Industrial Dischargers)	$0	$0	$0	$0	$0	$0
Treatment and Operation (Significant Industrial Users)	$33,834,518	$30,622,417	$28,535,056	$23,523,860	$20,265,284	$17,977,537
Total Impacts to Private Sector	**$33,834,518**	**$30,622,417**	**$28,535,056**	**$23,523,860**	**$20,265,284**	**$17,977,537**
Cost Impacts to North Carolina Local Governments						
Monitoring (POTWs)	$0	$0	$0	$0	$0	$0
Treatment and Operation (POTWs)	$167,847,503	$154,435,869	$144,865,074	$130,921,291	$122,597,317	$112,670,894
Total Impacts to NC Local Governments	**$167,847,503**	**$154,435,869**	**$144,865,074**	**$130,921,291**	**$122,597,317**	**$112,670,894**
Cost Impacts to North Carolina State Government						
Engineer II	$26,516	$25,277	$24,096	$22,970	$21,897	$20,874
Environmental Program Consultant	$26,516	$25,277	$24,096	$22,970	$21,897	$20,874
Total Impacts to NC State Governments	**$53,033**	**$50,555**	**$48,192**	**$45,940**	**$43,793**	**$41,747**
Total Direct Cost Impacts						
Total Direct Costs (7% Discount Rate)	**$201,735,053**	**$185,108,840**	**$173,448,323**	**$154,491,091**	**$142,906,395**	**$130,690,178**

Summary of Costs (2024$), Converted to Present Value (PV) @ 7% Discount Rate		
Calendar Year	**2060**	**CY 2024-2060**
Cost Impacts to Industrial Dischargers and Significant Industrial Users		
Monitoring (Industrial Dischargers)	$0	$5,838,214
Monitoring (Significant Industrial Users)	$0	$40,980,236
Treatment and Operation (Industrial Dischargers)	$0	$786,142,944
Treatment and Operation (Significant Industrial Users)	$16,019,391	$2,793,305,575
Total Impacts to Private Sector	**$16,019,391**	**$3,626,266,969**
Cost Impacts to North Carolina Local Governments		
Monitoring (POTWs)	$0	$19,286,170
Treatment and Operation (POTWs)	$105,778,156	$7,544,381,814
Total Impacts to NC Local Governments	**$105,778,156**	**$7,563,667,984**
Cost Impacts to North Carolina State Government		
Engineer II	$19,898	$1,978,790
Environmental Program Consultant	$19,898	$1,978,790
Total Impacts to NC State Governments	**$39,796**	**$3,957,579**
Total Direct Cost Impacts		
Total Direct Costs (7% Discount Rate)	**$121,837,343**	
Total Present Value (7% Discount Rate)		**$11,193,892,532**
Total Average Annual (7% Discount Rate)		**$310,941,459**

Appendix F: Benefits Calculations and Summary of Projected Impacts

Benefits Calculations and Summary of Projected Impacts

I. Human Health Benefits Methodology and Example Calculations

The human health benefits were based on the references outlined in Table 1. All health impacts, except for small for gestational age and hypertension management, were determine using a unit value transfer. Using this method, the population and demographic breakdown was able to be used to estimate the number of cases associated with each impact.

Table 1. Summary of Health Benefits Quantified

Health Impacts	Source
Cardiovascular Diseases	
Non-Fatal Heart Attack Cases Avoided	EPA, (2024)
Non-Fatal Blood Flow Blockage Cases Avoided	EPA, (2024)
Hypertension Management	Nordic Council of Ministers, (2019)
Cardiovascular Disease Deaths Avoided	EPA, (2024)
Renal Cell Carcinoma	
Non-Fatal Renal Cell Carcinoma Cases Avoided	EPA, (2024)
Fatal Renal Cell Carcinoma Cases Avoided	EPA, (2024)
Neonatal Impacts	
Birth Weight-Related Deaths Avoided	EPA, (2024)
Small for Gestation Age	Malits et al. (2018)

Health benefits from the EPA PFAS MCL economic analysis reported the average number of cases per 100,000 people by four race/ethnicity groups. The NC population in 2020 was 10,439,388.

Table 2.

Health Endpoint	Non-Hispanic Black	Hispanic	Other	Non-Hispanic White
2020 NC Population	1,294,484	1,952,166	762,075	6,430,663
Non-Fatal Heart Attack Cases Avoided	2.34	3.78	3.52	2.91
Non-Fatal Blood Flow Blockage Cases Avoided	7.48	5.33	3.87	3.87
Cardiovascular Disease Deaths Avoided	3.90	1.57	1.29	1.26
Non-Fatal Renal Cell Carcinoma Cases Avoided	3.31	4.04	3.04	2.73
Fatal Renal Cell Carcinoma Cases Avoided	0.96	1.44	0.86	0.74
Birth Weight-Related Deaths Avoided	1.00	0.93	0.47	0.41

Table 3. Summary of Projected Number of Cases per Year in NC Exposed to Impacted Drinking Water

Health Endpoint	Non-Hispanic Black	Hispanic	Other	Non- Hispanic White	Total
2020 NC Population	1,294,484	1,952,166	762,075	6,430,663	10,439,388
Non-Fatal Heart Attack Cases Avoided	30	74	27	187	318
Non-Fatal Blood Flow Blockage Cases Avoided	97	104	29	249	479
Cardiovascular Disease Deaths Avoided	50	31	10	81	172
Non-Fatal Renal Cell Carcinoma Cases Avoided	43	79	23	176	320
Fatal Renal Cell Carcinoma Cases Avoided	12	28	7	48	95
Birth Weight-Related Deaths Avoided	13	18	4	26	61
Total Number of Affected Cases/People/Year*					**1,445**
Total Number of Affected Cases/People (2024-2060)**					**66,378**

* if PFAS levels are unchanged in surface water and proposed numeric criteria are not adopted.
** total includes an increase in population of 1.21% (2022-2030), 1.07% (2031-2040), and 1.0% (2041-2060). Increased based on NC OSBM County/State Population Projections

Table 4. Unit Value Transfer Values for Human Health Outcomes

Health Endpoint	Non-Fatal Heart Attack Cases Avoided	Non-Fatal Blood Flow Blockage Cases Avoided	Cardiovascular Disease Deaths Avoided	Non-Fatal Renal Cell Carcinoma Cases Avoided	Fatal Renal Cell Carcinoma Cases Avoided	Birth Weight-Related Deaths Avoided
$/case-year	$20,333	$20,333	$20,333	$22,911	$22,911	$102,967

Table 5. Example Calculation of Total Value of Health Benefits

Health Endpoint	Total	Total Costs/Case	Total Costs
Non-Fatal Heart Attack Cases Avoided	318	$20,333	$6,465,894
Non-Fatal Blood Flow Blockage Cases Avoided	479	$20,333	$9,739,507
Cardiovascular Disease Deaths Avoided	172	$20,333	$3,497,276
Non-Fatal Renal Cell Carcinoma Cases Avoided	320	$22,911	$7,331,520
Fatal Renal Cell Carcinoma Cases Avoided	95	$22,911	$2,176,545
Birth Weight-Related Deaths Avoided	61	$102,967	$6,280,987

Information in Table 4 was used along with the number of cases projected for NC in Table 3 (last column). These costs were then projects through 2060 by taking into account the increase in population[1] and inflation of 2%. These costs were already discounted at 7% and therefore were not discounted further in the analysis.

Table 6 shows how the direct value transfer was used for the studies that quantified the costs associated with small for gestational age and hypertension management. These costs were then projects through 2060 by taking into account the increase in population[2] and inflation of 2%. These costs were then discounted at 7%.

[1] https://www.osbm.nc.gov/facts-figures/population-demographics/state-demographer/countystate-population-projections
[2] https://www.osbm.nc.gov/facts-figures/population-demographics/state-demographer/countystate-population-projections

Table 6. Direct Value Transfer of Small for Gestational Age and Hypertension Management Costs

Health Outcome	Total Annual Costs	Population Basis	Percent NC Population Relative to Study	Total Cost for NC
Small for Gestational Age	$1,141,666,667	U.S.	3.0%	$34,250,000
Hypertension Management	$26,950,000,000	Europe	1.39%	$374,605,000

The information summarized above was then to continue the analysis of surface water impacts to food that is consumed that have been demonstrated to contain PFAS. The following assumptions were used:

- Exposure to PFOA/PFOS from diet is estimated to be 66-72%[3,4].
- Mass of PFOA/PFOS in drinking water and food items is not equal. Studies have shown PFAS to be up to 6 times higher in food intake vs. the intake from drinking water. As a conservative estimate a 3 to 1 ratio of PFAS in food to drinking water was used.
- Foods ingested by adults in the U.S. that can be impacted by surface water is about 43%. Examples include veggies, fruit, meat, and fish.
- GI absorption factor is the same was drinking water = 0.90
- Approximately 25% of the food North Carolinians ingest was projected to be food impacted by PFAS through surface water

The health values were directly used that were presented in Table 5 and 6 to project the total health benefits associated with reducing PFAS in surface water which translates to reduction in PFAS ingested through food. The calculation of health impacts related to the ingestion of impacted private well water followed the same approach expect the total projected population to be affected was 210,800. The breakdown of the four race/ethnicity groups for this population was assumed to be the same distribution across North Carolina.

[3] Haug LS, Huber S, Becher G, Thomsen C Characterisation of human exposure pathways to perfluorinated compounds—comparing exposure estimates with biomarkers of exposure. Environment International 2011; 37: 687–693. [PubMed: 21334069]

[4]

II. Private Well Avoided Treatment

This analysis relied on capturing the total number of residents and households that have a private well. This information is not well documented and represents the best estimate of the number of private wells.

Table 7. Summary of Calculations to Estimate the Number of Private Wells

Calculation of Number of Private Wells	Total
Total Population Served by GW or SW PWS	9,641,992
Total Population in NC (2022)	10,439,388
Remaining Residents Not Served	797,396
Average number of people per household (US Census)	2.48
Number of Households on Private Wells	321,531

Table 8. Extent of Private Wells Impacted by at least one PFAS above the Proposed MCLs

Wells tested through NCDEQ studies	20,415
Total Private Wells Tested that exceed MCLs	9,678
Percent of Private Wells Exceeding MCLs	47%
Percent of Groundwater PWS that Exceed MCLs	25%
Conservative estimate of the percent of wells that exceed MCLs across NC	25%

Table 9. Determination of the Remaining Numbers of Well that are Estimated to be Impacted by PFAS

Number of Private Wells not tested	301,290
Number of Private Wells not tested and estimated to be impacted	75,322
Total number of private wells estimated to be impacted (NCDEQ Study and Estimated Impacted Wells)	85,000
Total for Filtration ($4,500/house)	$382,501,851

Summary of Benefits Projections by Year from 2024 to 2060 for the Proposed Rules

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Human Health (Ingestion beyond Drinking Water)	$0	$0	$0	$0	$0	$0
Human Health (Impacted Private Wells)	$0	$0	$0	$0	$0	$0
Downstream Drinking Water Utilities Savings	$0	$0	$0	$325,570,000	$6,549,610	$6,243,553
Private Well Avoided Treatment	$382,500,000	$0	$0	$0	$0	$0
Retaining Property Value	$1,526,561,750	$0	$0	$0	$0	$0
Division of Water Infrastructure Grants	$131,963,131	$154,021,595	$154,621,595	$34,559,124	$34,559,124	$34,559,124
Total Direct Benefits (7% Discount Rate)	**$2,041,024,881**	**$154,021,595**	**$154,621,595**	**$360,129,124**	**$41,108,734**	**$40,802,677**

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Human Health (Ingestion beyond Drinking Water)	$397,678,234	$381,956,826	$367,027,298	$352,853,789	$339,402,140	$397,678,234
Human Health (Impacted Private Wells)	$2,529,264	$2,545,137	$2,562,948	$2,582,662	$2,604,245	$2,529,264
Downstream Drinking Water Utilities Savings	$5,673,677	$5,408,552	$5,155,816	$4,914,890	$4,685,222	$5,673,677
Private Well Avoided Treatment	$0	$0	$0	$0	$0	$0
Retaining Property Value	$0	$0	$0	$0	$0	$0
Division of Water Infrastructure Grants	$34,559,124	$35,559,124	$35,559,124	$35,559,124	$35,559,124	$34,559,124
Total Direct Benefits (7% Discount Rate)	**$440,440,299**	**$425,469,639**	**$410,305,186**	**$395,910,466**	**$382,250,731**	**$440,440,299**

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**
Human Health (Ingestion beyond Drinking Water)	$326,639,810	$314,535,802	$303,060,592	$292,186,062	$281,885,431	$272,096,990
Human Health (Impacted Private Wells)	$2,627,664	$2,652,892	$2,679,900	$2,708,666	$2,739,168	$2,769,690
Downstream Drinking Water Utilities Savings	$4,466,287	$4,257,582	$4,058,629	$3,868,974	$3,688,180	$3,515,836
Private Well Avoided Treatment	$0	$0	$0	$0	$0	$0
Retaining Property Value	$0	$0	$0	$0	$0	$0
Division of Water Infrastructure Grants	$35,559,124	$36,559,124	$36,559,124	$36,559,124	$36,559,124	$36,559,124
Total Direct Benefits (7% Discount Rate)	**$369,292,885**	**$358,005,399**	**$346,358,246**	**$335,322,826**	**$324,871,903**	**$314,941,639**

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**
Human Health (Ingestion beyond Drinking Water)	$262,868,142	$254,140,269	$245,891,353	$238,100,437	$230,747,570	$223,813,760
Human Health (Impacted Private Wells)	$2,803,573	$2,839,139	$2,876,374	$2,915,267	$2,955,809	$2,997,992
Downstream Drinking Water Utilities Savings	$3,351,544	$3,194,930	$3,045,634	$2,903,315	$2,767,646	$2,638,317
Private Well Avoided Treatment	$0	$0	$0	$0	$0	$0
Retaining Property Value	$0	$0	$0	$0	$0	$0
Division of Water Infrastructure Grants	$37,559,124	$37,559,124	$37,559,124	$37,559,124	$37,559,124	$38,559,124
Total Direct Benefits (7% Discount Rate)	**$306,582,383**	**$297,733,461**	**$289,372,486**	**$281,478,144**	**$274,030,149**	**$268,009,193**

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**
Human Health (Ingestion beyond Drinking Water)	$217,280,936	$211,131,900	$205,350,287	$199,920,530	$194,827,822	$190,058,077
Human Health (Impacted Private Wells)	$3,041,810	$3,087,259	$3,134,335	$3,183,039	$3,233,370	$3,285,330
Downstream Drinking Water Utilities Savings	$2,515,031	$2,397,506	$2,285,473	$2,178,675	$2,076,868	$1,979,818
Private Well Avoided Treatment	$0	$0	$0	$0	$0	$0
Retaining Property Value	$0	$0	$0	$0	$0	$0
Division of Water Infrastructure Grants	$38,559,124	$38,559,124	$38,559,124	$38,559,124	$39,559,124	$39,559,124
Total Direct Benefits (7% Discount Rate)	**$261,396,901**	**$255,175,789**	**$249,329,219**	**$243,841,368**	**$239,697,183**	**$234,882,350**

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate						
Calendar Year	**2054**	**2055**	**2056**	**2057**	**2058**	**2059**
Human Health (Ingestion beyond Drinking Water)	$185,597,906	$181,434,574	$177,555,980	$173,950,622	$170,607,571	$167,516,448
Human Health (Impacted Private Wells)	$3,338,924	$3,394,155	$3,451,031	$3,509,558	$3,569,747	$3,631,606
Downstream Drinking Water Utilities Savings	$1,887,303	$1,799,111	$1,715,041	$1,634,899	$1,558,502	$1,485,674
Private Well Avoided Treatment	$0	$0	$0	$0	$0	$0
Retaining Property Value	$0	$0	$0	$0	$0	$0
Division of Water Infrastructure Grants	$39,559,124	$39,559,124	$39,559,124	$40,559,124	$40,559,124	$40,559,124
Total Direct Benefits (7% Discount Rate)	**$230,383,257**	**$226,186,965**	**$222,281,176**	**$219,654,203**	**$216,294,944**	**$213,192,852**

Summary of Benefits (2024$), Converted to Present Value (PV) @ 7% Discount Rate		
Calendar Year	**2060**	**CY 2024-2060**
Human Health (Ingestion beyond Drinking Water)	$164,667,393	$7,524,784,551
Human Health (Impacted Private Wells)	$3,695,149	$89,945,706
Downstream Drinking Water Utilities Savings	$1,416,250	$436,840,143
Private Well Avoided Treatment	$0	$382,500,000
Retaining Property Value	$0	$1,526,561,750
Division of Water Infrastructure Grants	$40,559,124	$1,714,616,536
Total Direct Benefits (7% Discount Rate)	**$210,337,916**	
Total Present Value (7% Discount Rate)		**$11,675,248,686**
Total Average Annual (7% Discount Rate)		**$324,312,463**