Fiscal and Regulatory Impact Analysis
Amendment to 15A NCAC 02L .0202

Rule Citation Number 15A NCAC 02L .0202

Rule Topic: Groundwater Quality Standards – PFAS

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Agency: Environmental Management Commission
(Groundwater and Waste Management Committee)

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Impact Summary:

State government:	Potential (benefits only)
DOT:	Potential (benefits only)
Local government:	Potential (benefits only)
Federal government:	Potential (benefits only)
Private entities:	Potential (benefits only)
Substantial Impact:	Potential (benefits only)

Authority: G.S. 143-214.1

Necessity: This analysis represents a revision to the May 17, 2024, Fiscal and Regulatory Impact analysis that was certified on May 22, 2024. The rule is proposed for amendment to include groundwater quality standards for three of the eight PFAS originally proposed as to provide the benefits of regulatory certainty and clarification, and to attempt to reduce the fiscal burden on the regulated community, where possible, while still being protective of human health.

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Acronyms

Abbreviation	Term
$	Dollars
%	Percent
15A NCAC	Title 15A of the North Carolina Administrative Code – Environmental Quality
02B	15A NCAC Chapter 02 – Environmental Management, Subchapter B – Surface Water and Wetland Standards
02L	15A NCAC Chapter 02 – Environmental Management, Subchapter L - Groundwater Classification and Standards
AST	Above-Ground Storage Tank
BF	Brownfield
CDC	Centers for Disease Control and Prevention
DEQ	Department of Environmental Quality
DWM	Division of Waste Management
DWR	Division of Water Resources
EMC	Environmental Management Commission
EPA	U.S. Environmental Protection Agency
GS	NC General Statute
GWWMC	Groundwater and Waste Management Committee of the EMC
HW	Hazardous Waste
MCL	US EPA Maximum Contaminant Level for Drinking Water
MDL	Laboratory Method Detection Limit
NC	North Carolina
ng/L	Unit - nanograms per liter or parts per trillion (ppt)
NPDWR	National Primary Drinking Water Regulation
PFAS	Per- and poly-fluoroalkyl substances – the family of compounds
PFOA	Perfluorooctanoic Acid, CASRN 335-67-1
PFOS	Perfluorooctane Sulfonic Acid, CASRN 1763-23-1
HFPO-DA	Hexafluoropropylene Oxide Dimer Acid, CASRN 13252-13-6 (also known as GenX)
PFBA	Perfluorobutanoic Acid, CASRN 375-22-4
PFBS	Perfluorobutane Sulfonic Acid, CASRN 375-73-5
PFNA	Perfluorononanoic Acid, CASRN 375-95-1
PFHxA	Perfluorohexanoic Acid, CASRN 307-24-4
PFHxS	Perfluorohexane Sulfonic Acid, CASRN 355-46-4
PQL	Practical Quantitation Limit (as defined in 15A NCAC 02L .0102)
SF	Superfund
SW	Solid Waste Section (non-hazardous)
UST	Underground Storage Tank

I. Executive Summary

An agency must prepare a regulatory impact analysis for permanent rule changes as required by G.S. 150B-21.4. The purpose of conducting a regulatory impact analysis is to improve rule design, inform decision-makers, and communicate with the regulated community. These analyses identify, describe, and quantify the expected effects of the proposed rule changes to the extent possible. Following are some of the key points that are further described throughout the analysis:

- PFAS, or per- and polyfluoroalkyl substances, refers to a group of man-made chemicals. They are widely used in commercial and consumer products such as food packaging, water- and stain-repellent fabrics, nonstick products, and firefighting foams. They are also commonly used in industrial processes and manufacturing.

- PFAS can build up, or bioaccumulate, in humans and animals. Scientific studies have shown that exposure to certain levels of PFAS have been linked to reproductive effects such as decreased fertility or increased high blood pressure in pregnant women; developmental effects or delays in children, including low birth weight, accelerated puberty, bone variations, or behavioral changes; increased risk of some cancers; reduced ability of the body's immune system to fight infections, including reduced vaccine response; interference with the body's natural hormones; and increased cholesterol levels and/or risk of obesity.

- To ensure the protection of groundwater, it is necessary to identify sources of PFAS contamination in groundwater, prevent further contamination, and take steps to remediate any existing contamination. The existing regulatory framework provides DEQ with the authority to take these actions at levels representative of analytical capabilities of measurement instruments or the Practical Quantitation Limit (PQL). However, additional clarification is needed for North Carolina residents and the regulated community to provide numerical standards that are specific health-based levels as authorized under state rules.

- North Carolina's groundwater quality standards are not a federal requirement, so there is no State-level program that would need federal approval of these proposed standards to retain program approval. While there is no federal equivalent for groundwater quality standards, they are a critical component of State's compliance with federally delegated programs.

- There are federal standards for drinking water, and the State has delegated authority through the Clean Water Act to protect surface water. North Carolina is also working toward proposing surface water quality standards; however, these proposed standards will be addressed in a separate rulemaking action and a separate regulatory impact analysis, and therefore are not addressed in this document.

- North Carolina is proposing to adopt specific groundwater quality standards for a subset of PFAS. As directed by the GWWMC at the July 10, 2024, meeting, groundwater standards for three PFAS are proposed to be adopted to replace the existing regulatory level of the practical quantitation limit (PQL) for non-naturally occurring compounds in existing rule 15A NCAC 02L .0202. These three PFAS have available health effects data and toxicity information and have National Primary Drinking Water Regulations (NPDWR) or Maximum Contaminant Levels (MCLs) established by the EPA.

- Although the proposed standard for one compound (GenX) is higher than the existing regulatory limit at the current PQL, the proposed standard is a health-based value that takes into account lifetime risks to human health, and is consistent with the MCL for GenX at 10 ng/L. For this

compound, neither the PQL nor the proposed standard surpasses the risk management levels established in Rule 15A NCAC 02L .0202(d). Additional information can be found in the Toxicological Summary Information and Derivation of Groundwater Quality Numerical Standards for Per- and Poly- Fluoroalkyl Substances (PFAS) included in Appendix A. The additional toxicity information used in the derivation of the proposed standards provides a greater degree of confidence that the standards achieve the goal of preventing unacceptable health risks in NC waters without creating additional burdens.

- Although the standards as calculated and proposed for PFOA and PFOS are lower than the existing regulatory limit at the current PQL, for this circumstance the existing rule requires that the PQL continue to be used as the regulatory limit until or unless the PQL is below the proposed standard.

- The increased awareness of the presence and risks of PFAS means that multiple stakeholders in the regulated community, including multiple local governments, may concurrently be required to address PFAS contamination in groundwater under the existing rule requirements, and may also be required to address PFAS discharges to surface water if surface water standards for PFAS are adopted in a separate rulemaking.

- It is possible, but highly uncertain, that some regulated sites could realize future avoided costs for the regulated community from avoided assessment/remediation costs due to the relaxation of the value for GenX. For the 10-year period starting in 2026, we estimated the potential avoided costs for one hypothetical DWM-regulated site to be between $529,530 to $2,611,331 (in 2024$, 10-year NPV at 7% discount). Many variables will affect the likelihood that avoided costs will be realized such as driver contaminants, GenX concentrations as compared to the standard and the PQL, and site-specific circumstances and risk assessments including receptors and use of groundwater in and around the site.

- Incremental potential benefits may be provided to the regulated community (including local governments), state government, and residents/well users from improved clarity and consistency of standards and health risks when groundwater cleanup is required.

- It is possible, but highly uncertain, that benefits in the form of avoided costs could be a substantial economic impact (exceeding $1,000,000 in one year).

- The well-grounded and robust science behind PFAS is evolving. The existing requirement and process for triennial review of groundwater quality standards will be helpful in keeping these proposed standards updated with the latest developments in science and human health information every three years.

II. Background

In accordance with Rule 15A NCAC 02L .0103(a), the purpose of the rules established in Subchapter 15A NCAC 02L is to "maintain and preserve the quality of the groundwaters, prevent and abate pollution and contamination of the waters of the State, protect public health and permit management of the groundwaters for their best usage by the citizens of North Carolina." Historically, the North Carolina Environmental Management Commission (EMC) has considered the best usage of groundwaters of the State to be as a source of drinking water.

On April 10, 2024, the U.S. Environmental Protection Agency (EPA) finalized National Primary Drinking Water Regulations (NPDWRs) and established individual maximum contaminant levels (MCLs) for five PFAS, PFOA, PFOS, HFPO-DA (commonly known as GenX compounds), PFNA, and PFHxS. In addition, a hazard index (HI) MCL will be used for mixtures containing at least two or more of PFHxS, PFNA, HFPO-DA, and PFBS in drinking water (HI > 1.0 would be considered an exceedance).

To inform this final regulation, EPA evaluated toxicity assessments for each of these PFAS including peer reviewed scientific reports from EPA and CDC's Agency for Toxic Substances and Disease Registry (ATSDR). Because drinking water supplies are fed by surface water and groundwater sources, and groundwater is also a direct source of drinking water from private drinking water wells, it is important to ensure that these sources in North Carolina are protected so that drinking water sources are able to meet the MCLs. In North Carolina, 1,961 public water systems are affected by EPA's drinking water regulations. Over 90 percent of these systems (1,790) receive source water from groundwater supplies. As of April 10, 2024, based on single sample results, approximately 15 percent of the groundwater sourced systems measured greater than an MCL or HI. While the EPA regulates drinking water quality via the MCLs, they do not also regulate groundwater quality or establish groundwater quality standards. This rulemaking proposal is intended to clarify the levels necessary to protect the State's drinking water supplies and minimize treatment costs for drinking water systems.

The groundwater quality standards (hereafter referred to as "the standards" or "groundwater standards") for the protection of the groundwaters of the State are codified in subject Rule 15A NCAC 02L .0202. These standards represent the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the State that may be tolerated without creating a threat to human health or that would otherwise render the groundwater unsuitable for its intended best usage. The standards are used by various State regulatory programs to protect groundwater as a source of drinking water and other uses. The standards should not be confused with "maximum contaminant levels" (MCLs) which are established as part of the federal Safe Drinking Water Act and apply only to the treated drinking water supplied by public drinking water systems. These standards also do not apply directly to any other media such as air, surface water, wastewater, landfill leachate, or soil.

The groundwater standards are used to establish target cleanup levels primarily by the following NC Department of Environmental Quality (DEQ) regulatory programs under the Division of Waste Management (DWM) and the Division of Water Resources (DWR):

- Brownfields (DEQ-DWM)
  - safe redevelopment of abandoned or underutilized contaminated property in exchange for liability protections, developers utilize institutional and engineering controls to protect site occupants to be fully protective of public health from contaminants of concern in place of full remediation to unrestricted use standards.
  - utilizes the groundwater standards in 15A NCAC 02L .0202 and defines impacts as any exceedance of those standards.

- Underground Storage Tank (DEQ-DWM)
  - regulates the operation of petroleum and hazardous substance underground storage tank (UST) systems;
  - regulates closure activities and cleanup of petroleum spills, releases from petroleum and hazardous substance USTs, and petroleum aboveground storage tanks (ASTs);
  - administers the petroleum leaking UST trust fund; and
  - permits petroleum-contaminated soil remediation facilities.
- Superfund (DEQ-DWM)
  - monitoring and remediation of hazardous substance contamination sites;
  - includes the Inactive Hazardous Sites (IHS) program which addresses contamination at approximately 2,000 chemical spill or disposal sites, including the asphalt testing sites under the Roadside Environmental Unit of the NC Department of Transportation (NCDOT);
  - includes the Dry-Cleaning Solvent Cleanup program, which addresses solvent contamination at about 500 dry cleaner sites;
  - includes the Pre-Regulatory Landfill program, which addresses about 630 landfills that operated prior to 1983;
  - includes federal facilities;
- Solid Waste (DEQ-DWM)
  - permitting and compliance of solid waste facilities that include municipal solid waste landfills, industrial waste landfills, and construction/demolition waste landfills that conduct groundwater monitoring;
- Hazardous Waste (DEQ-DWM)
  - prevention of hazardous waste release;
  - permitting cleanup of sites with hazardous waste contamination;
  - groundwater monitoring to determine extent of contamination;
- Non-Discharge (DEQ-DWR)
  - permitting of wastewater treatment and disposal/reuse systems that avoid discharging to surface waters;
  - includes wastewater irrigation, high-rate infiltration, residuals management;
- Underground Injection Control (UIC) (DEQ-DWR)
  - permitting and monitoring of injection, remediation, and recovery wells.

DWM and DWR each enforce the requirements for groundwater quality protection under 15A NCAC 02L at sites that are regulated by their respective programs. In the drafting of this analysis, the Divisions met with and sought feedback from multiple stakeholders in the regulated community representing various state agencies, local government organizations, and private industry organizations including permittees and consultants in the fields of waste management, groundwater protection, and agriculture. DEQ has also been providing regular updates on the status of this rule drafting process and the calculations and methodology being used in the process as information items at meetings of either the EMC or the Groundwater and Waste Management Committee (GWWMC) of the EMC between November 2023 and May 2024.

DEQ also consulted the NC Secretaries' Science Advisory Board at their April 3, 2024, meeting to obtain their feedback on the consistency of the existing PFAS toxicological assessments, to ensure the proposed amendment is based on the most recent and adequate scientific information that was available at the time of the meeting. Further information on this meeting can be found on Page 3 of the Toxicological Summary Information and Derivation of Groundwater Quality Numerical Standards for Per- and Poly- Fluoroalkyl Substances (PFAS) included in Appendix A.

III. Reason for Rule Revision

PFAS, or per- and polyfluoroalkyl substances, refers to a group of man-made chemicals. They are widely used in commercial and consumer products such as food packaging, water- and stain-repellent fabrics, nonstick products, and firefighting foams. They are also commonly used in industrial processes and manufacturing. As a result, these compounds are present in household and industrial waste. In addition, industrial PFAS air emissions can deposit these compounds into surface water or soil and eventually reach groundwater. Regardless of how they enter the environment, the chemical structure of PFAS prevent them from breaking down easily, which is why they are known as "forever chemicals." They will continue to cycle through our environment indefinitely unless they are intercepted and removed through treatment.

PFAS can build up, or bioaccumulate, in humans and animals. Scientific studies have shown that exposure to certain levels of PFAS have been linked to reproductive effects such as decreased fertility or increased high blood pressure in pregnant women; developmental effects or delays in children, including low birth weight, accelerated puberty, bone variations, or behavioral changes; increased risk of some cancers; reduced ability of the body's immune system to fight infections, including reduced vaccine response; interference with the body's natural hormones; and increased cholesterol levels and/or risk of obesity.

Under the DEQ Action Strategy for PFAS, DEQ is taking a whole-of-department approach to protect communities by identifying, reducing, and remediating PFAS pollution. The action strategy can be reviewed at this link: https://www.deq.nc.gov/genx/nc-deq-action-strategy-pfas/open. DEQ continues to work with NCDHHS and academic partners to understand human exposures and health impacts. DEQ supports additional research in the public and private sector to better understand and reduce the risks from the impacts of PFAS contamination on the residents of North Carolina.

To ensure the protection of groundwater as a source of drinking water and to protect human health, it is necessary to identify sources of PFAS contamination, take steps to eliminate further introduction of PFAS to groundwater, and remediate existing PFAS contamination in groundwater. The existing regulatory framework provides DEQ with the authority to take action to address PFAS contamination for all PFAS. However, additional clarification is needed for NC residents and the regulated community to understand the levels of PFAS that are considered risks to human health and may require remedial action.

North Carolina is required by N.C. General Statute 143-214.1 and N.C. Administrative Code Subchapter 15A NCAC 02L to adopt groundwater quality standards to protect the use of groundwater as a source of drinking water. As research supporting our understanding of the human health effects of contaminants found in groundwater advances, updating the groundwater standards ensures that cleanup requirements are set at a level that minimizes the risk that private well water consumers (including sensitive subgroups) will experience adverse health effects over a lifetime of exposure without being unduly burdensome for site owners.

Rule 15A NCAC 02L .0202(g) also requires that these standards be evaluated and revised, as necessary, every three years. This process is known as the "triennial review." The last triennial review resulted in the identification of multiple contaminants for which standards were adopted. Rule 15A NCAC 02L .0202 was amended to adopt these standards, in addition to multiple other updates to the rule pertaining to the procedures for establishing Interim Maximum Allowable Concentrations (IMACs). The rule amendments became effective on April 1, 2022. The materials pertaining to the prior triennial review and subsequent rulemaking process can be found at the following link:

https://www.deq.nc.gov/about/divisions/water-resources/water-planning/classification-standards/groundwater-standards/groundwater-triennial-review-and-rulemaking.

During the prior triennial review, multiple PFAS were reviewed for the potential to establish groundwater standards. A groundwater standard of 70 ng/L for total PFOA and PFOS was proposed to the EMC based on the 2016 EPA Drinking Water Health Advisory for PFOA and PFOS, which was the most recent available EPA guidance at that time. After public notice and comment, the Hearing Officer and DWR recommended that the Commission not adopt the proposed total PFOA and PFOS standard due to the developing science on PFAS and the anticipated forthcoming studies and EPA scientific review and regulations. While standards were not established for any PFAS as a part of the triennial review, amendments to 15A NCAC 02L Rule .0202 effective April 1, 2022, DEQ committed to continue evaluating developing science and newly published data on PFAS. As a result of these efforts, the proposed rule amendment would establish groundwater standards to address the following three PFAS as a follow-up to the prior triennial review, and per the decision of the GWWMC at their July 10, 2024, meeting:

1. Perfluorooctanoic Acid (PFOA)
2. Perfluorooctane Sulfonic Acid (PFOS)
3. Hexafluoropropylene Oxide Dimer Acid (HFPO-DA; GenX)

This proposed amendment to add groundwater standards for these three PFAS is necessary because the EPA and other federal agencies have published toxicological data and established health-based risk levels for these compounds, in addition to five other PFAS: PFBA, PFBS, PFHxA, PFHxS, and PFNA. Each of these eight compounds have been detected in groundwater across North Carolina in varying occurrence levels and concentrations. Therefore, groundwater standards are necessary to ensure that these health-based levels are not exceeded for the protection of public health. While the EPA has established legally enforceable levels or individual MCLs for drinking water for five PFAS and a hazard index MCL for certain mixtures, they are not also developing groundwater standards since groundwater standards in NC are specific to and promulgated at the state level. DEQ is proposing PFAS standards as a separate or stand-alone rulemaking, separate from the next consecutive triennial review process, to simplify the process and associated documentation since PFAS are new chemicals being added to the rules and requires more detailed discourse with the Environmental Management Commission and the public.

Because PFAS are “forever compounds” due to their persistence in the environment and are likely to be found to be ubiquitous once widespread and periodic testing for these compounds occurs, it is important for NC residents to have some level of certainty to understand what levels of PFAS in groundwater are unacceptable for health-based purposes. It is also important for the regulated community to have some greater certainty regarding what levels of these compounds would be required for clean-up that is more reliable and/or consistent than the current/existing requirement of having the practical quantitation limit (PQL) as the regulatory limit, since PQLs may change over time with changes in technology in lab equipment.

IV. Proposed Rule Amendment

The current regulatory limit for non-naturally occurring compounds in groundwater in accordance with 15A NCAC 02L .0202 is the practical quantitation limit (PQL), and therefore DEQ already has existing authority under Subchapter 02L to require sampling, analysis, and corrective action for a release to groundwater of all PFAS, with the current required regulatory limit being the PQL. The proposed amendment to rule 15A NCAC 02L .0202(h) would add the numeric groundwater quality standards for three PFAS contaminants as listed in Table IV-1. No changes are proposed to the existing standards for other compounds already in Rule .0202(h).

The proposed standards are based on the most current available toxicological information and other relevant health risk assessment data in accordance with the criteria for establishing groundwater standards found in 15A NCAC 02L .0202(d), (e), and (f). Additional information can be found in the Toxicological Summary Information and Derivation of Groundwater Quality Numerical Standards for Per- and Poly- Fluoroalkyl Substances (PFAS) included in Appendix A. Information specific to the proposed standards for PFOS, PFOA, and GenX can be found in Sections 4.1 – 4.3 (pages 13 - 18) and Sections 6.3.1 – 6.3.3 (pages 42 – 44) of the document.

The goal of the cost and benefit analysis is to evaluate the expected impacts, both costs and benefits, of the proposed amendment to Rule .0202(h) as compared to the existing baseline as described in Section V. This analysis should not and does not address costs, benefits, or other impacts from PFAS-related actions required or taken by the EMC or DEQ based on other existing statute and rule requirements, consent orders, session laws, or permit requirements, where those impacts are not caused by this rule amendment. Discussions in this analysis regarding the analysis results and costs for site assessment and remediation for PFAS at sites regulated by DEQ have been included to demonstrate where and how the proposed amendment may provide a benefit to sites where PFAS have been or may be detected above the PQL. Further details on the scope of the analysis can be found in Section VI.

Table IV-1: Groundwater Standards Proposed for Adoption
All Values Reported in ng/L (ppt)

PFAS	Proposed 02L .0202(h) Standard	Existing 02L .0202(c) Limit – Current PQL*	Proposed Compliance Levels
PFOA	0.001	**4**	PQL **
PFOS	0.7	**4**	PQL **
HFPO-DA (GenX)	10	**5**	10

Notes:

*(*) PQLs based on national laboratory validation results as documented in U.S. EPA's Method 1633 – see additional information in Section V of this analysis.*

*(**) The applicable regulatory limit will be the PQL per 15A NCAC 02L .0202(c), unless or until the PQL decreases to a level that is at or below the proposed standard, if adopted. The PQL at the time of this rulemaking for PFOA and PFOS is 4 ng/L, as described in the note above and shown in the third column of the table. However, the PQL can vary based on laboratory capability or over time. Any changes or variability to the PQL could occur under either the existing rule language or the proposed rule language, and in both cases, the PQL would be the regulatory limit for PFOA and PFOS, at whatever level or value the PQL is when reported.*

V. Regulatory Baseline

As part of the permanent rulemaking process, G.S. 150B-19.1 requires agencies to quantify to the "greatest extent possible" the costs and benefits to affected parties of a proposed rule. To understand what the costs and benefits of the proposed rule changes would be to regulated parties, it is necessary to establish a regulatory baseline for comparison. For the purpose of this fiscal note, the baseline is comprised of the General Statutes in Chapters 130A, 143, and 143B, the existing rules in 15A NCAC Chapters 02 and 13 (which also incorporate by reference some federal regulations), any existing permit requirements, and the regulatory limit at the PQL for each contaminant as described below (see also Table IV-1).

> Practical Quantitation Limit - or "PQL" - is defined in 15A NCAC 02L .0102 as "lowest concentration of a given material that can be reliably achieved by a particular analytical technique operated within specified parameters of a given analytical method during routine laboratory analysis while following all applicable state or federal quality assurance and quality control requirements."

The following existing rule language establishes the PQL as the regulatory baseline for PFAS, which is consistent with prior impact analyses developed for the addition of groundwater standards in the past:

> Rule 15A NCAC 02L .0202(c) states in part: "substances which are not naturally occurring and for which no standard is specified shall not be permitted in concentrations at or above the practical quantitation limit…."

Also take note of the following rule language which is part of the regulatory baseline when reviewing impacts from the proposed standards for PFOA and PFOS:

> Rule 15A NCAC 02L .0202(b)(1) states in part: "Where the standard for a substance is less than the practical quantitation limit, the detection of that substance at or above the practical quantitation limit constitutes a violation of the standard."

The PQLs used as the baseline for PFOA, PFOS, and HFPO-DA (GenX) were calculated by the EPA following 1985 guidance to set the PQL at a level consistent with "five to ten times the method detection limit (MDL)" (50 FR 46906). The MDLs used in the calculation of the PQLs were reported in EPA Method 1633[1] and were based on the national Multi-Laboratory Validation Study of PFAS by Isotope Dilution LC-MS/MS Wastewater, Surface Water, and Groundwater (Willey et al., 2023).[2]

The regulatory limit which DEQ currently has the authority to enforce under the existing rules for non-naturally occurring constituents that do not otherwise have a standard established under 15A NCAC 02L .0202(h) is the PQL at the time that the laboratory conducts the analyses. If a laboratory were to report a detection of PFAS above the PQL in groundwater, the activity that caused that release is currently a violation of the regulatory limit. However, PQLs can vary over time or between laboratories based upon equipment used or other factors such as matrix effects and dilution. The reporting limits used by the DEQ Water Sciences Laboratory[3] and the average of the reporting limits at multiple commercial laboratories used by DWM sites in NC are similar to the PQLs determined using the methodology used by the EPA as

[1] EPA (2024) '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).

[2] 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).

[3] *For PQL values:* NCDEQ Chemistry Laboratory "QA/QC PQLs." *Available at:* https://www.deq.nc.gov/pqls/download?attachment.

described above. Therefore, selection of a different limit from a particular laboratory or source over another for the baseline would have very little effect on the impact of the proposed rule, especially as it pertains to determining whether the proposed standards are above or below the existing limit.

An IMAC of 2,000 ng/L had previously been established for PFOA per Rule 15A NCAC 02L .0202, effective December 6, 2006, at the request of a PFAS manufacturer in the regulated community to allow for some certainty in the clean-up goal, and to minimize the burden. DWR received a request to remove this IMAC on June 17, 2022, per procedures outlined in 15A NCAC 02L .0202(c). After review of this IMAC removal request through examination of supporting scientific basis, the Director of DWR removed the PFOA IMAC on November 4, 2022, and informed the Environmental Management Commission. The decision was based on health effects data published since 2006 and the anticipated forthcoming regulations from EPA at that time.[4] Because IMACs are established on a temporary basis by the Director of DWR - and not through the permanent rulemaking process - they are not considered the regulatory baseline.

Because the existing regulations provide authority to DEQ to require corrective action for activities that cause the release of any non-naturally occurring contaminants to groundwater above the PQL, any current or future enforcement of the existing rules, which includes requiring corrective action for releases of PFAS to groundwater, are also considered a part of the baseline for the proposed amendment. See Section VI of this analysis for further detail on the existing authority and enforcement for PFAS.

[4] *More information on the IMAC removal can be found at this link:* https://www.deq.nc.gov/about/divisions/water-resources/water-planning/classification-standards/groundwater-imacs.

VI. Scope of the Analysis

Addressing PFAS contamination in groundwater is an evolving and developing science with new information being gathered and published regularly, existing monitoring data for PFAS is limited, and remediation costs will vary widely between sites based on site-specific circumstances. The focus of this analysis is to estimate the scope of potential future impacts in general to existing and future sources to comply with groundwater requirements for PFAS by evaluating hypothetical examples of potential plausible future scenarios. While DEQ sought assistance from a third-party engineering consultant to estimate treatment costs, it is not possible to predict the site-specific costs that will be incurred at individual sites without the individual sites conducting an individual site assessment conducted by licensed professionals for that particular site that factors in all of the variables and factors applicable to that site such as, but not limited to, topography, groundwater hydrology including flow rate and direction, constituents detected and detection levels, any existing background and baseline data for groundwater quality, waste disposal options and proximity, other remediation goals at the site, applicable program-specific regulations and permitting requirements, etc.). This analysis also only addresses costs and impacts related to groundwater contamination as this rule amendment only revises the regulatory limits for groundwater. The analysis does not and cannot begin to address PFAS contamination of air, soil, or surface water, or any other media or types of impacts from PFAS contamination. An evaluation of a separate potential proposed amendment to 15A NCAC 02B to add numeric surface water standards for PFAS would be addressed in a separate regulatory impact analysis.

The proposed rule amendment for groundwater quality standards for PFAS for which this impact analysis has been drafted is one change of many being made concurrently to protect public health and to provide regulatory certainty and clarification to stakeholders for PFAS requirements. In addition to this proposed rule amendment, DEQ is currently implementing or planning to implement multiple changes in an attempt to ascertain the scope of and properly address PFAS contamination throughout DEQ programs and the regulated community, alongside concurrent efforts at the global, national, state, and local government levels. Many of the changes are being made under the authority of existing regulations at the federal, state, or local level, such as establishing MCLs for certain PFAS. Where applicable, adoptions or amendments to other State rules may be required in the future. In some cases, even if a rule change is not required to implement a change because existing regulations provide the necessary authority, DEQ or the EMC may elect to implement some changes via the rulemaking process to provide transparency and clarification for the regulated community.

However, it is important in reviewing this rule amendment and regulatory impact analysis to be aware that there are other activities and changes regarding PFAS happening concurrently with or subsequent to this rule amendment; however, this does not mean that this rule amendment is the cause of those concurrent or subsequent changes or activities. **The scope of this regulatory impact analysis is to identify, describe, and attempt to quantify, wherever possible, the impacts of the current proposed rule amendment to 15A NCAC 02L .0202(h).** If a change or activity can or does occur under other existing regulatory authority (i.e., even if this rule amendment was never proposed and/or does not become effective) in rule, statute, session law, or consent order, then the change or activity is not an impact of the rule amendment, but is an impact of the existing regulation(s) or order(s).

In Appendix B, DEQ has provided a Proposed Implementation Plan for Addressing PFAS Impacts to Groundwater at DWM-Regulated Sites Under Existing Rules in 15A NCAC 02L (with the PQL as the regulatory limit). In the proposed plan, DEQ has attempted to describe how they intend to implement future changes to groundwater monitoring and remediation of PFAS in the programs where DEQ administers and enforces groundwater quality standards. This plan would be implemented under the existing rules in 15A NCAC 02L, including remediation requirements in Section .0100, other program-specific rules for remediation, and the requirements in Chapters 130A, 143, and 143B of the General Statutes. The intent of the plan is to address known or potential major sources or contributors of PFAS contamination that are

under the purview of DEQ as a first step in the process to evaluate and address this issue. The attached plan is not intended at this time to address all statewide potential minor, individual, or unknown sources or affected parties.

The proposed amendment to modify the regulatory limit for PFAS in groundwater is not required to implement a plan to address PFAS contamination in groundwater because the existing regulations address assessment and remediation requirements. To be transparent with the regulated community, DEQ has provided this additional information on actions that they intend to take in the future regarding groundwater monitoring and remediation efforts, but the actions planned for implementation are not a result of this proposed rule amendment to groundwater quality standards and would be implemented under the existing rule regardless of whether the proposed amendment becomes effective.

VII. Estimating the Fiscal Impacts

A. Analysis Approach

This analysis will attempt to estimate the scope or potential range of costs that will be incurred by the regulated community to address PFAS under the existing regulations (i.e., the regulatory baseline), with the PQL as the existing regulatory limit for all PFAS, and compare them to the estimated scope of costs that would be incurred under the rule amendment (with numeric standards designated for three PFAS). No difference between the two cost estimates is expected in the majority of cases because the set of circumstances that a site would need to fall under in order to realize any avoided costs, while possible, are unlikely to occur. If a DWM-regulated site falls under this certain set of circumstances, that particular site may see significant avoided future costs as a result of the proposed amendment, but we do not expect many sites to fall under those specific circumstances, if any. The proposed standards for PFOA and PFOS are lower than the PQL at the time of this rulemaking; however, the existing rule language clarifies that the PQL would continue to be the regulatory limit that is implemented. The proposed standard for GenX is higher than the current PQL. The expected impacts in general for these two circumstances are described below, with specific costs provided in Item C. Item B provides an overview of each affected DEQ program and the respective regulated communities.

1. Standards less than (or equal to) the PQL

Rule 15A NCAC 02L .0202(b)(1) states: "**Where the standard for a substance is less than the practical quantitation limit, the detection of that substance at or above the practical quantitation limit constitutes a violation of the standard**." Of the three standards proposed in this rulemaking, only PFOA and PFOS are lower than the PQL. For these two contaminants, the PQL will remain the regulatory limit upon adoption of the standards, and the adoption of standards will neither increase nor decrease regulatory requirements. As discussed in Section VIII of this document, the adoption of these standards will not change the level of public health protection already in effect. For these reasons, the adoption of the standards for PFOA and PFOS should have no quantifiable impact on regulated persons, at least for the foreseeable future, and no impact on public health outcomes.

It is likely that environmental chemical testing methods and technologies will improve for some or all of these contaminants over time, thereby allowing laboratories to achieve lower PQLs. In the event that a PQL is achieved that is lower than the standard, the standard would replace the PQL as the regulatory baseline. At that point, the standard would provide regulatory relief which could result in avoided future costs for remediation, monitoring, and permitting. The standard would also provide regulatory certainty in comparison to the PQL, which may vary, and clarification of the limit for decision-making purposes. It is impossible, however, to predict how fast – or how much – testing technology might improve for a given contaminant, so we are not able to quantify this future benefit, which may or may not occur.

2. Standard greater than the PQL

Of the three standards proposed in this rulemaking, one is greater than the PQL: HFPO-DA (GenX). Unlike the standards for PFOA and PFOS that are less than the PQL, the proposed standard for GenX will replace the PQL as the regulatory limit upon adoption of the rule. For purposes of this analysis, the adoption of the proposed standard will reduce unnecessary regulatory burden. As a result, there should be some economic benefit and no economic cost to regulated parties.

The proposed standard is a health-based value that takes into account lifetime risks to human health from consumption of a contaminant. For GenX, neither the existing limit at the current PQL nor the proposed standard surpasses the risk management level established in Rule 15A NCAC 02L .0202(d). For additional information, see the Toxicological Summary Information and Derivation of Groundwater Quality Numerical Standards for Per- and Poly-Fluoroalkyl Substances (PFAS) included in Appendix A. The additional toxicity information used in the derivation of the proposed standard provides a greater degree of confidence that the standard achieves the goal of preventing unacceptable health risks in NC waters without creating additional burdens.

For GenX, there may be some economic benefit to regulated parties from having a higher value as the groundwater standard. This benefit would be realized by those regulated parties that meet the set of circumstances described for Table VII-8 in Section VII, including having GenX as the driver contaminant for remediation, if warranted. For the purpose of this analysis, driver contaminants are contaminants that are either potentially widespread or have the greatest economic cost in cleanup of sites. While analytical results for PFAS are currently limited, based on the analytical results for sanitary landfills and other DWM sites submitted as of August 2024, PFOA and PFOS are more likely to be the main drivers for site remediation, where warranted.

At sites where PFOA and PFOS are the main drivers for site remediation, the adoption of the standard for GenX should have no quantifiable impact, at least for the foreseeable future, and no impact on public health outcomes.

Many of the regulatory programs that are subject to the groundwater standards use the standards in similar ways. It makes sense, then, that those programs for which GenX is the driver contaminants might benefit in similar ways.

Monetizing costs and benefits is challenging for these programs, due to the degree of variability between sites, lack of available data for PFAS, unpredictability of future contaminant levels, and the complex nature of groundwater remediation. It is not possible for DEQ to conduct site-specific investigations at every site under the purview of DWM for the purpose of estimating costs for this analysis, which would likely require site-specific review by licensed professionals such as engineers and geologists for each individual site.

We have attempted to quantify impacts in Item C where possible, but due to this complexity, variability, and uncertainty, we focused on estimating the costs of addressing PFAS impacts under the existing rule using models based on hypothetical circumstances that we expect would be the most likely to occur (if at all) at sites under DWM programs. These models can be scaled up or down if warranted. The variables between models include existing infrastructure, number of assessment and monitoring wells, varying flow rates, types of treatment trains, and effluent and waste handling options. Then we compared potential estimated costs under the proposed rule amendment to the estimated costs under existing rule. We have also attempted to describe additional qualitative impacts that cannot be quantified in Item D, which is the benefit of regulatory certainty.

B. DEQ Program Information

1. Overview

During preparation of this document, it became evident through stakeholder meetings with the regulated community and discussions with DWM program staff that a number of DEQ's regulatory programs would potentially benefit in similar ways from the proposed standards. Benefits that can be generalized to multiple programs are listed below. Additional benefits

(or lack thereof) specific to each regulatory program may be discussed in greater detail under the programs' respective headings.

If a cleanup goal for a contaminant is relaxed (i.e., standard > PQL), and that contaminant is a driver for either monitoring or cleanup requirements, and no other PFAS are detected above the PQL (see additional circumstances described for Table VII-8), then the responsible party for a regulated site may benefit in one or more of the following ways where PFAS are present at levels above the PQL but below the proposed groundwater standard for GenX:

- Reduced assessment: avoided future costs could include the treatment system, operation and maintenance, labor, equipment, and analytical costs when contamination is delineated to the proposed groundwater standard rather than a lower PQL. It is difficult to quantify the savings on assessment activities as the subsurface transport properties and site characteristics are unique to each site.
- Reduced frequency of monitoring: avoided future costs could include the labor costs to sample monitoring wells, equipment, analytical costs, and the costs of mapping and reporting results to DEQ. Decisions to allow reduced frequency of monitoring will be made by regulatory staff on a case-by-case basis.
- When the proposed groundwater standard is met for PFAS, but other contamination exists at a site, there would be reduced number of contaminants being monitored: costs saved include the cost to analyze the samples. Analytical costs vary by laboratory.
- Reduced number of groundwater wells being monitored: costs saved include the cost to sample the well (labor costs). The avoided future costs realized by ceasing monitoring at a well will be somewhat reduced in the short term by the one-time costs associated with closing the well. Sites such as landfills, inactive hazardous sites, and USTs will incur these well closure costs at some point in time, regardless of the standard. But a numerically higher groundwater standard may result in those costs being incurred years earlier.
- Reduced cleanup time: avoided future costs from completing groundwater remediation in a shorter period of time would largely be from spending less on operation and maintenance of the cleanup technology. These costs would likely make up a large portion of avoided future costs realized from the proposed groundwater standards. It is difficult to quantify the savings on remediation costs as the technology used to reduce contaminant levels to the groundwater standard is site specific and depends on factors such as number and types of contaminants, contaminant properties, extent of contamination, hydrogeologic properties (soil and rock type), and cleanup goals. These factors will affect the time and cost to clean up groundwater.

The State agencies responsible for providing oversight of these regulatory programs could similarly realize potential benefits where state funding pays for assessment and remedial action and by freeing up staff capacity or funding resources that will be reinvested to address currently unmet needs:

- Regulated sites that may not have to conduct assessment and remediation, or that achieve compliance with groundwater standards earlier - perhaps years earlier - will require less staff time in terms of oversight over the long term. This will reduce staff time spent on reviewing reports, analyzing data, and preparing correspondence per site. It will also result in the need for less travel to perform each site visit, which will save on fuel and vehicle maintenance costs. However, any savings to staff time and resources due to one project's early completion will be immediately reinvested to

address the large backlog of other sites in need of staff attention across the state due to already limited resources. For this reason, we did not expect any direct budgetary savings.

2. Brownfields Redevelopment (DWM)

The Brownfields Redevelopment Section (BRS) administers the Brownfields Property Reuse Act under Part 5 of Article 9 of Chapter 130A of the General Statutes. The BRS cooperates with developers seeking to redevelop properties with real or perceived contamination that prevents or hinders redevelopment. The types of properties that are evaluated range from vacant land impacted by off-site releases to former heavy industrial manufacturing facilities. Brownfields provides liability protection from known contaminants of concern (COCs) to non-causative parties in exchange for implementing land use restrictions to fully protect public health from site contaminants of concern.

To understand PFAS regulatory effects on Brownfields, it is important to understand the risk management schema and liability issues associated with brownfields agreements. Virtually all brownfields agreements have a land use restriction which prohibits use of the groundwater. Therefore, unless there was the risk of migration to offsite receptors, the decision to include or not include PFAS as a general analyte may have little practical effect on the risk management actions at brownfields properties. Typically, a prospective developer gains liability protection for the existing contaminants of concern found during their site assessments. Hence, finding and cataloging the COCs through the brownfields agreement is both a risk management tool and a liability control mechanism. Furthermore, brownfields agreements generally prohibit the use of site COCs to prevent complicating potential enforcement of responsible parties by cleanup programs for the existing COC contamination.

While major PFAS sources are fairly well-characterized, information on the uses and fate of some lesser known PFAS sources continues to expand. Therefore, all of the potential sources or processes that use or contain PFAS and the extent to which they can contaminate environmental media at measurable levels remains to be fully understood. Hence, such activities may or may not complicate the separation of old from new PFAS contamination in future brownfields agreements.

At present, if PFAS are known/suspected to have been utilized in former site operations and are a concern for receptors that are on or adjacent to the brownfields property, BRS would require groundwater sampling for such, in addition to typical assessment requirements. Sampling for PFAS would determine baseline concentrations for liability protections for the developer/future property owners. Additionally, the data would determine if additional land use restrictions (LURs) related to groundwater (beyond non-consumption) were required. To date, two Brownfields properties have been sampled for and found to contain PFAS impacts.

By sampling for PFAS, when appropriate based on site/adjacent property history, Prospective Developers would provide themselves with liability protections in the event such impacts are found. This would serve to increase the economic value of properties to future site owners by taking away an unknown risk of contamination. Additionally, if PFAS are found, Brownfields can notify the applicable regulating DWM Section for initiating work with responsible parties. DEQ does not provide liability protections to responsible parties but does require that property owners provide access to accommodate regulatory requirements from other DEQ programs.

For BRS-guided assessments, the prospective developer typically samples groundwater one time to establish a baseline. The number of groundwater samples collected on a Brownfields property varies depending on the use history of the site, areas of concern from on/off-site impacts, size of a property, presence of surface water, etc. If, based on the site/adjacent property history, a prospective developer needed to add PFAS to the list of compounds that they sample and analyze per the existing rules, the cost range to that prospective developer (private sector) to add sampling and analysis for PFAS for one Brownfields Agreement Application is estimated in Table VII-1. The cost range is based on a range of between three and fourteen sampling locations using the same cost estimates and assumptions that were used to populate Table VII-5 of this analysis. The estimated range for the number of samples is based on the history of existing Brownfields agreements. In general, between 3 and 10 samples were collected for past agreements. To be conservative due to uncertainty of the dependent variables at future sites, this analysis is using 14 samples as the upper limit.

Table VII-1: Potential Cost Estimate to Add Sampling and Analysis of PFAS to Existing Sampling Protocols, if Warranted, Under Existing Rule vs. Proposed Amendment for One Brownfields Agreement

Cost Category	Cost Range Under Existing Rule (Limit is PQL)	Cost Range Under Proposed Amendment (New Standards)	Difference Between Existing Rule and Proposed Amendment
Adding PFAS Sampling and Analysis for 3 - 14 Sampling Locations	$2,170 - $8,545	$2,170 - $8,545	$0

Note: Costs are in November 2023 dollars.
See Table VII-5 of this analysis and the associated explanation for further detail on the cost estimates and assumptions used in this table.

Based on the last ten years of applications received, the BRS receives between 60 and 100 applications per year, with an average of 80 applications. As previously mentioned, to date only two Brownfields properties have been sampled for and found to have PFAS impacts. We cannot predict how many of the future applications will be for sites that are expected to have PFAS contamination (application to the program is voluntary), and therefore might need to analyze groundwater for PFAS.

The main impact from the rule amendment would be in the decision-making process and the likelihood that remediation would be required for PFAS at a site. Where the proposed standard is higher than the PQL for GenX, it would reduce the chances of the site having an exceedance of groundwater standard for GenX. Remediation of PFAS at a site included in a Brownfields Program Application would be managed under the Superfund Section's Inactive Hazardous Site Program. Therefore, the costs or benefits for a site conducting remediation are included in the discussion for the IHS program in Item 4.3 below.

A potential indirect impact of the rule amendment would be to cause the prospective developer, their consultants/subcontractors, or financial institutions involved with the project to *elect to* sample and analyze for PFAS, even if it is not required by DEQ and/or there is no reason to believe prior activities at the site caused PFAS contamination, in order to include liability coverage for those compounds in the brownfields agreement in an abundance of caution. However, in this case, the added cost for PFAS sampling and analysis would not be a direct impact of the regulation change. Presumably, an entity would choose to take on this added cost only if they believe the benefits to doing so will outweigh the costs for sampling and analysis.

Because the need to analyze for PFAS at sites where PFAS is likely to be present does not change because of the rule amendment, there is no change in costs from the cost estimate under the existing rules (with PQL as the regulatory limit).

3. Hazardous Waste (DWM)

The primary purpose of the Hazardous Waste Section is to prevent releases of hazardous waste and when hazardous waste releases that cannot be immediately cleaned up and/or lead to groundwater contamination do occur, to provide regulatory oversight for the investigation and remediation of the site through a hazardous waste permit.

The Facility Management Branch of the Hazardous Waste Section administers hazardous waste permitting and corrective action under the authority of G.S. 130A-294(c). Requirements are codified in the North Carolina Hazardous Waste Management Rules (15A NCAC 13A) which also incorporate by reference federal hazardous waste regulations. Specifically, 15A NCAC 13A .0109, .0110, and .0112 are the portions of the State rules that pertain to facilities seeking an operating or post-closure permit and to those facilities who must investigate and remediate releases of hazardous waste and/or hazardous waste constituents to the environment via their permit or other legal mechanism in lieu of a permit (e.g., Administrative Order on Consent).

In North Carolina, sites with groundwater contaminated by hazardous waste or hazardous waste constituents that have a hazardous waste permit are required to cleanup to the state groundwater standard or, in the absence of a standard, to the PQL. The Hazardous Waste Section uses the 15A NCAC 02L standards (or PQLs in the absence of a groundwater standard) as a performance measure or goal for remediation. 40 CFR 264.101, adopted by reference at 15A NCAC 13A .0109(g), directs the owner or operator of a facility with a hazardous waste permit to institute corrective action as necessary to protect human health and the environment for all releases of hazardous waste or constituents and that corrective action will be specified in the permit. Standard hazardous waste permit language states: "[Site Name] shall follow the requirements of 15A NCAC 02L .0106 and 40 CFR 264 as adopted in 15A NCAC 13A .0109 and guidance associated those rules and regulations."; "Goal of any required corrective action shall be restoration to level of standard 15A NCAC 02L .0101, *et seq*"; and "For any exceedance of the groundwater quality standards found in 15A NCAC 02L .0202, [Site Name] shall be required to do the following…" (specific requirements are listed in the permit to comply with 15A NCAC 02L .0106(f)(3), (f)(4) and (h).

PFAS are not, at this time, designated as a hazardous waste or a hazardous waste constituent. However, since these compounds are not naturally occurring, a site with a hazardous waste permit that has an exceedance of a state groundwater standard (or PQL, in the absence of a standard) for PFAS is required to further assess and remediate as necessary.

In February 2024, the US EPA proposed federal regulations (89 FR 8606)[5] that would add nine PFAS (PFOA, PFOS, PFBS, HFPO-DA/GenX, PFNA, PFHxS, PFHxA, PFBA, and PFDA (perfluorodecanoic acid, CASRN 335–76–2)) as "hazardous constituents" in 40 CFR 261 Appendix VIII, adopted by reference at 15A NCAC 13A .0106(m). EPA places a substance on the list of hazardous constituents in 40 CFR 261 Appendix VIII when scientific studies show the substance has toxic effects on humans or other life forms. The addition to Appendix VIII in 40 CFR 261 does not set a numerical value or standard/limit for this substance. Addition to Appendix VIII makes the substance subject to RCRA corrective

[5] EPA (2024) "Listing of Specific PFAS as Hazardous Constituents." Available at: https://www.federalregister.gov/documents/2024/02/08/2024-02324/listing-of-specific-pfas-as-hazardous-constituents (Accessed: 16 May 2024).

action requirements at permitted hazardous waste sites (hazardous waste treatment, storage, and disposal facilities (TSDFs)) and the site must perform assessment for that substance when there is a reasonable likelihood the substance is present at the site. The addition of PFAS as a hazardous constituent will cause these compounds to be included in the hazardous waste regulatory jurisdiction, and a site with a hazardous waste permit will be required to assess for the PFAS that are added as a hazardous constituent if there is a reasonable expectation that these substances are present at the site.

While the addition of PFAS as a hazardous constituent will affect the number of Hazardous Waste Section sites that must be evaluated (likely causing more sites to have to assess for PFAS in the future), regardless of whether PFAS have a state groundwater standard or the regulatory limit is the PQL, the process performed by the Hazardous Waste Section is the same. In any case, the Hazardous Waste Section, Facility Management Branch guides the affected facilities through the following regulatory processes: RCRA Facility Assessment to identify potential release sources on the facility's property; implementation of a groundwater monitoring/assessment program to determine the extent of hazardous constituent contamination; closure of the hazardous waste management unit; post-closure activities, including review of the post-closure plan and the post-closure permit application; design and implementation of a corrective action system to control and abate releases to soil, groundwater, surface water and air; and application of land use restrictions when releases of hazardous waste cannot be completely and fully remediated.

The Hazardous Waste Section, Facility Management Branch currently has oversight of 76 facilities. Two of these sites are aqueous fire-fighting foam (AFFF) manufacturing facilities that have been impacted by releases of AFFF, and the other 74 of these sites have hazardous waste permits and are required to perform corrective action, if needed. Of the 76 sites, six are federal government sites (military bases and federal research site), two are state government sites (universities), three are local government sites (county/city owned and operated), one is owned by a private entity but operated by the state, and the other 64 sites are privately owned and operated (including the two AFFF manufacturing sites).

Table VII-2: Ownership of Hazardous Waste Management Facilities in North Carolina

Type of Sites	All Hazardous Waste Section Sites Subject to Corrective Action	Hazardous Waste Section Sites Subject to Corrective Action Due to PFAS	Hazardous Waste Section Sites Potentially Subject to Corrective Action Due to PFAS
Federal Government	6	0	5
State Government	2	0	0
Local Government	3	2	0
Private	62	7	4
Other*	1	0	0
TOTAL	**74**	**9**	**9**

Note:
*(*) Site is privately owned but operated by a state government entity.*

Sources of hazardous waste contamination that result in a hazardous waste permit commonly include, but are not limited to, solvents and metals from industrial or manufacturing processes such as wood preservation, chemicals manufacturing, petroleum refining, pesticides manufacturing, iron and steel production, and explosives manufacturing. Only some of these sites with hazardous waste contamination will also have contamination including PFAS.

The Hazardous Waste Section permitted sites that can have contamination from PFAS include, but are not limited to, industrial or manufacturing processes producing commonly used man-made chemicals and the manufacturing sites that use these chemicals in the production of products such as, but not limited to, food packaging, water- and stain-repellent fabrics, nonstick products, and firefighting foams. PFAS can also be found at sites that operate as electroplaters, in leachate from landfills located at hazardous waste permitted facilities, and at sites like military bases and fire training facilities, and airports that have used aqueous film-forming foam as a fire suppressant or as a chemical fume suppressant.

Of the 76 sites, there are currently ten sites that have confirmed groundwater contamination above the PQL for PFAS. One site is a privately-owned chemical manufacturer and one site is an AFFF manufacturer, at which PFAS are driving groundwater cleanup. The other eight sites are another privately-owned chemical manufacturer, a privately owned metal finisher, four former landfills at textile manufacturing facilities, a municipal-owned fire training facility, and a county-owned landfill. The source of PFAS at two facilities is currently unclear. Cleanup at these sites is not driven by the presence of PFAS, but there will be costs associated with the assessment and remediation of PFAS under existing rules.

Ten other sites may be required, in the future, to assess for PFAS including five federally owned facilities (military bases) and five privately-owned sites. These sites were identified for potentially needing to conduct assessment for PFAS based on the current or past operations at the site where PFAS are known or suspected to have been utilized at the site. If PFAS are added as a hazardous constituent in the hazardous waste regulations and are found at these sites, further assessment and corrective action will be required.

For purposes of this analysis - which relies on the PQL being the regulatory baseline in the absence of a standard - the proposed groundwater standard for PFAS could provide some economic relief to regulated parties for which one or more of these contaminants is the driver for cleanup. The Hazardous Waste Section does not expect an appreciable economic impact from adopting the proposed standards. Of course, any avoided future costs will depend on factors that will vary from site to site such as relative concentrations, the scale and complexity of the remediation, and the available remediation technology.

4. Superfund (DWM)

The potential impacts on parties regulated within the Superfund Section are as follows:

4.1 Dry Cleaning Solvent Cleanup

The Dry-Cleaning Solvent Cleanup Act (DSCA) (G.S. 143, Article 21A, Part 6) established a fund to assess and cleanup dry-cleaning solvent contamination at dry-cleaning and wholesale distribution facilities and authorized the program to develop and enforce rules to prevent dry-cleaning solvent releases at operating facilities. Requirements are codified in DSCA Rules (15A NCAC 02S). The DSCA program is wholly funded by receipts from taxes on dry-cleaning sales and dry-cleaning solvents. G.S. 143-215.104C(c) states that monies in the Dry-Cleaning Solvent Cleanup Fund may be used to abate imminent hazards by dry-cleaning solvent contamination at DSCA sites. The constituents that are analyzed at DSCA sites are related to chlorinated solvents or

petroleum solvents that are used at dry cleaners. Since PFAS is associated with the clothing being dry-cleaned and is not associated with a dry-cleaning solvent or the degradation product of a dry-cleaning solvent, DWM does not currently sample environmental media for PFAS and cannot utilize the Dry-Cleaning Solvent Cleanup Fund for this purpose per statute.

If DWM discovers a threat to any water supply wells in the vicinity of a dry-cleaning release overseen by the DSCA program, DWM Bernard Allen program staff would sample and address any impacts to water supply wells, including any impacts from PFAS. As such, the proposed standards would not have any direct impact on the DSCA program.

4.2 Pre-Regulatory Landfill Program

The Pre-Regulatory Landfill (PRLF) Program established under G.S. 130A-310.6(c) through (g) uses funds from the Inactive Hazardous Sites Cleanup Fund to assess pre-1983 (pre-regulation) landfills, to determine the priority for remediation of pre-1983 landfills, and to develop and implement a remedial action plan for each pre-1983 landfill that requires remediation. The program has the authority to use a risk-based approach for assessment and remediation under the statutes referenced above. Of the 630 landfills currently being addressed under this program, groundwater investigation or monitoring is currently being conducted at 88 sites. The initial list of constituents sampled for is in Appendix D of the Guidelines for Addressing Pre-Regulatory Landfills and Dumps (DEQ, 2022)[6]. The list of constituents for continued monitoring is limited to those found in the initial assessment of the site. This program currently does not conduct analysis of PFAS in groundwater samples. If PFAS were required to be sampled and analyzed at PRLFs, it would not be as a result of the proposed rule amendment.

4.3 Inactive Hazardous Sites

The Inactive Hazardous Sites Response Act of 1987 (G.S. 130A-310 *et seq.*) was established by the North Carolina General Assembly to address releases to the environment of hazardous substances, as defined in Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 U.S.C. § 9601 *et seq.*). Requirements are codified in the North Carolina Inactive Hazardous Substance or Waste Disposal Site Rules (15A NCAC 13C). The Inactive Hazardous Sites Branch (IHSB) implements the Inactive Hazardous Sites Response Act, 15A NCAC 13C, and the 15A NCAC 02L groundwater quality standards in the remediation of hazardous substance contaminated sites. On April 19, 2024, the EPA issued a final rule that designates two PFAS, PFOA and PFOS, as "hazardous substances" under CERCLA or Superfund (40 CFR 302).[7]

Parties responsible under law for the releases must assess and clean up these contaminated sites. The IHSB is responsible for oversight and approval of the assessment and remediation activities conducted by remediating parties and their environmental consultants. These sites include historical and recent accidental releases of hazardous substances and contamination in, or threatening, groundwater. These are referred to as "inactive" sites because the releases are mostly historic from industries that are generally no longer operating, yet some are the result of newer product spills. Because most of these sites have since gone out of business or reorganized, it is difficult or impossible to

[6] DEQ (2022) "Guidelines for Addressing Pre-Regulatory Landfills and Dumps" Available at: https://www.deq.nc.gov/waste-management/dwm/sf/guidelines-addressing-prlfs-dumps-march-2022/download?attachment (Accessed: 17 May 2024).
[7] EPA (2024) "Designation of Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS) as CERCLA Hazardous Substances." Available at: https://www.govinfo.gov/content/pkg/FR-2024-05-08/pdf/2024-08547.pdf (Accessed: 16 May 2024).

know how, where, and when the release or releases occurred or find financially viable owners, operators, or responsible parties to remediate the site. When no such party can be identified, IHSB staff must use limited state funding to assess and mitigate imminent hazards at the sites that pose a risk to human health.

The IHSB reported that, as of June 2023, there were 1,951 open inactive hazardous sites. Of these, only about 13% are being remediated using private funds. PFAS are known to be associated with industrial and manufacturing facilities, including textile mills, metal finishing, and the paper industry to name a few. Therefore, it is estimated that up to 90% of the IHSB sites could contain PFAS.

Remediating parties must sample site media for contaminants of concern based on known/suspected evidence or documentation of prior uses. Unfortunately, the potential for historic PFAS use is typically unknown because PFAS compounds are generally not listed on Safety Data Sheets or other product inserts. In addition, unlike the typical solvents that comprise most of the inactive industrial and manufacturing sites, many PFAS tend to be resistant to degradation, so PFAS may extend farther in groundwater than other contaminants, requiring additional assessment to delineate their extent beyond traditional solvent plumes. Assessment of PFAS would be required at inactive hazardous sites based on available evidence and/or past property use. Any assessment required would not be a result of the proposed rule amendment.

4.4 Federal Facilities

In addition to the State-funded and privately funded sites, there are 75 inactive hazardous sites for which the federal government (EPA and Department of Defense (DoD)) has responsibility under the Superfund Program. These are the sites on the National Priority List (NPL) which are considered the most hazardous waste sites.

PFAS investigation is underway at DoD and National Guard sites; PFAS releases have been confirmed at all current active bases and suspected National Guard sites where PFAS were used. DoD is funding these investigations and future remediation. At non-DoD NPL sites, PFAS investigation has not yet started. PFAS investigation will be required at many of these sites based upon the site history. Any investigation required would not be a result of the proposed rule amendment. EPA will initiate the investigation at these sites where PFAS were likely used.
Sites for which the federal government has responsibility will likely realize a lesser benefit than State-managed sites. The reason for this is that the federal government manages sites containing the most hazardous contaminants that typically drive a cleanup, none of which are part of this proposed rulemaking.

5. Solid Waste (DWM)

The Solid Waste Program regulates the safe management of non-hazardous solid waste through guidance, technical assistance, regulations, permitting, environmental monitoring, compliance evaluation and enforcement. The Solid Waste Section administers non-hazardous solid waste permitting and corrective action under the authority of G.S. 130A Article 9. Requirements are codified in the North Carolina Solid Waste Management Rules (15A NCAC 13B). Specifically, groundwater monitoring rules for sanitary landfills found in 15A NCAC 13B Sections .0500, .0600, and .1600 are the most relevant to this analysis.

PFAS are widely used in commercial and consumer products such as food packaging, water- and stain-repellent fabrics, nonstick products, and firefighting foams. Many of these products and by-products are commonly disposed in solid waste sanitary landfills.

In March 2023 the Section issued a notification memo to all active and closed sanitary landfills that required these facilities to analyze groundwater from existing monitoring wells for PFAS to ensure protection of human health and the environment due to the potential health hazards associated with PFAS. This requirement was implemented in conjunction with the NC DEQ's Action Strategy for PFAS to manage the risks of PFAS in the State. Landfills are one of several priority areas in the plan and sampling will help to identify possible PFAS associated with the regulated management of solid waste and to evaluate the presence of PFAS in the environment from these managed activities. Collection and evaluation of this information will also assist DEQ in developing sound policies with respect to PFAS in the environment.

Within the Solid Waste Program, the facilities that might be impacted are the following sanitary landfills that are required to monitor groundwater:

- **Municipal Solid Waste (MSW) landfills -** nonhazardous waste from household, commercial, and institutional sources;
- **Construction and Demolition Debris (C&D) landfills –** solid waste from the construction, remodeling, repair, or demolition operations on pavement and buildings or structures;
- **Industrial Waste (ISW) landfills** – solid waste from manufacturing or industrial processes that is not a hazardous waste regulated under Subtitle C of RCRA. Includes waste resulting from manufacturing processes such as electric power generation, fertilizer/agricultural chemicals, iron and steel manufacturing, organic chemicals, transportation equipment, etc. Does not include mining waste or oil and gas waste. Scrap tire monofills are also included under the definition of industrial solid waste landfills in 15A NCAC 13B .0101, even though scrap tires are not directly an industrial waste.

MSW and C&D landfills are required to perform groundwater monitoring for a suite of contaminants set by federal and state regulation. Which contaminants they monitor for depend primarily on the age of the landfill, the type of landfill, and the specific rules applicable to them. Older MSW landfills (closed prior to October 9, 1993) and older C&D landfills (closed prior to July 1, 2008) monitor groundwater for contaminants listed in 40 CFR Part 258 "Criteria for Municipal Solid Waste Landfills" Appendix I "Constituents for Detection Monitoring" (typically referred to as "Appendix I")[8]. Newer MSW landfills permitted on or after October 9, 1993, and newer C&D landfills permitted on or after July 1, 2008, also monitor groundwater for Appendix I contaminants; however, if they have exceedances, they are required to do additional monitoring of contaminants in the "List of Hazardous Inorganic and Organic Constituents" ("Appendix II"). If a contaminant is not listed on Appendix I or II, it is generally not required to be monitored at MSW or C&D landfills, although there are occasional exceptions based on waste stream.

ISW landfills operate under a somewhat different groundwater monitoring scheme. In addition to monitoring for Appendix I contaminants, ISW landfills also monitor for contaminants depending on the makeup of their specific waste stream. This results in greater

[8] *For determination of which contaminants are monitored at landfills:* Appendix I and II referenced from NC Solid Waste Section Environmental Monitoring List, October 15, 2018: https://edocs.deq.nc.gov/WasteManagement/0/edoc/1257181/SWS_EnviroMonitoring_Constituents_List.pdf

variability between individual ISW landfill facilities. Also, ISW landfills may have been able to eliminate analysis for multiple Appendix I constituents after confirmation that those constituents have not been detected in the groundwater and are not expected to be present based on the limited waste stream.

To comply with the March 2023 PFAS memo, sanitary landfills currently conducting a groundwater monitoring program have added PFAS to the list of required analyses for groundwater samples from their existing monitoring well network for at least the next two consecutive monitoring events.[9] The monitoring programs at these landfills typically require routine monitoring on either a semi-annual or annual basis and the additional PFAS samples will be collected during each individual landfill's routine monitoring program, which occurs on a variable schedule for all landfills. The Solid Waste Section expects to receive the initial PFAS sample results over the next two years. After the initial two sampling events are completed, the Section will make a determination on the need to continue monitoring for PFAS. In Table VII-7, groundwater sample results submitted through the end of March 2024 for 168 of the existing 301 sanitary landfills are compared to the PQL and the proposed standards. However, the analysis results are preliminary and have not been verified by DEQ.

A determination to continue PFAS monitoring will be site-specific and depend on several factors including the results reported, the need for further confirmation or source determination, potential offsite receptors (for protection of human health and the environment), and/or regulatory developments. It is anticipated that some level of PFAS monitoring will be required on an ongoing basis for most landfills based on existing regulations and requirements, but this would not be a result of the proposed rule amendment.

Changing waste streams and other variables at landfills make it difficult to identify when one contaminant over another is the main driver for assessment or cleanup of contaminated groundwater. This means that even if a proposed contaminant was detected at a level above the PQL, we cannot claim that the adoption of a standard that is numerically higher has or has not benefited these landfills.

Although PFAS will be sampled at landfills initially and possibly not detected, we cannot say with reasonable certainty that they will not be monitored in the future. Degradation of landfill materials over time or the development of a leak in a liner could result in the detection of a previously undetected PFAS. It is also common for the makeup of materials collected at a landfill (waste stream) to vary over time. This could result in the introduction of additional PFAS-containing materials that could contaminate groundwater and impose additional testing requirements.
Further compounding the difficulty in monetizing a fiscal impact is that it is impossible to predict if future analytical testing will detect higher levels or lower levels of a particular contaminant.

It is assumed that all regulated landfills could potentially benefit from a numerically higher groundwater standard for the reasons stated above. This benefit could be realized regardless of ownership. According to DWM, there were approximately 301 active and inactive MSW, C&D, and ISW landfill facilities in North Carolina as of August 30, 2023[10]. The majority of these types of landfills are owned either by private entities or local governments, although

[9] *Links to initial* March 2023 memo *and* July 2023 clarification memo.
[10] For data on numbers of NCDWM Solid Waste permitted facilities:https://deq.nc.gov/about/divisions/waste-management/sw/data/facility-lists
You may also view these sites on the DWM Site Locator Tool, which can be accessed at this link:
https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=7dd59be2750b40bebebfa49fc383f688

there is a total of six landfills owned by state and federal governments (Table VII-3). We do not anticipate one type of landfill or one subgroup of owner to benefit more than another.

Table VII-3: Ownership of C&D, ISW, and MSW Landfills in North Carolina

Facility Type	Privately-owned	Local Govt-owned	State-owned	Federal-owned	Total
C&D	24	54	0	1	79
Industrial	43	1	0	0	44
MSW	30	143	2	3	178
TOTAL	**97**	**198**	**2**	**4**	**301**

6. Underground Storage Tanks (DWM)

The Underground Storage Tank (UST) Section of DEQ manages the Underground Storage Tank (UST) program, the non-UST petroleum releases program (including petroleum aboveground storage tank (AST) releases and other petroleum releases), and the Ex-Situ Petroleum Contaminated Soil Remediation Permit program under the authority of G.S. 143, Articles 21 and 21A. Requirements are codified in UST rules (15A NCAC 02L .0400 and .0500, 02N, 02O, 02P, and 02T .1500). Specifically, the following rules may be relevant to this analysis:

- 15A NCAC 02N .0500 and 15A NCAC 02L .0106 and .0400 which govern programs related to the cleanup of contaminated soil and groundwater due to releases of contaminants from petroleum and hazardous substances[11] USTs;
- 15A NCAC 02L .0106 and .0500 which govern petroleum ASTs and petroleum spills; and
- 15A NCAC 02T .1500 which governs the permitting of petroleum-contaminated soil remediation facilities. Remediation of petroleum contaminated soil is conducted in dedicated land farms or containment and treatment facilities. In addition, the Section also issues certificates of approval for the temporary storage and for a one-time land application of petroleum contaminated soil.

The UST Section encounters AFFF when it is used to suppress a vehicle fire or petroleum vapors at a small number of vehicle accidents. As a result, petroleum fuel and AFFF can be released to soil and groundwater in the vicinity of the accident. In general, petroleum contaminated soil mixed with AFFF is excavated to remove the contaminated soil as part of initial abatement requirements in accordance with 15A NCAC 02L .0106 and to return the sites as close to previous conditions as possible. Until recently, the soil was likely disposed of at UST Section permitted soil remediation facilities. Currently, soil mixed with AFFF must be analyzed for PFAS prior to acceptance at a UST permitted soil remediation facility. If the soil is not analyzed, the contaminated soil must be disposed of at a Subtitle D landfill. Spill sites are closed out when the petroleum contaminants have been cleaned up to applicable standards and any soil with PFAS remains in place.

[11] Hazardous substances are defined in G.S. 143-215.77 and described in G.S. 143-215.77A.

The sites are flagged in the UST Section database when there are known or suspected PFAS contamination. To date, there are two UST and 21 non-UST incidents where AFFF was used and PFAS are known or suspected to be present in soil and/or groundwater. Of the 19 UST permitted soil remediation facilities, there are currently three land farm facilities with confirmed PFAS detected in groundwater and 15 facilities that are suspected to have PFAS groundwater contamination.

In accordance with 15A NCAC 02L 0202(b)(1), both the spill sites and the soil remediation facilities are required to clean up to the groundwater standard or, in the absence of a standard, to the PQL. Of the three contaminants for which standards are being proposed, only those associated with AFFF, PFOA and PFOS, were identified by the UST Section as potential contaminants of concern at petroleum spill sites and consequently soil remediation facilities.

Prior to 2002, the legacy first generation AFFF contained PFOS and PFHxS and various other compounds in smaller amounts including PFNA and PFOA. From the 1970s to 2016, legacy second generation AFFF, contained fluorinated precursors which are known to degrade to perfluoroalkyl carboxylic acids (PFCAs) including PFOA. The precursors include 8:2 and 6:2 fluorotelomer sulfonate (FTS)-based compounds in addition smaller amounts of various other PFAS including PFOA and PFOS. Modern AFFF contains predominately short chain fluorotelomer based fluorosurfactants 6:2 and 4:2 FTS with trace amounts of PFOA, PFBA, PFHxA, and PFBSA (perfluorobutylsulfonamide, CASRN 30334-69-1). Based on available information, GenX is not generally considered a component of AFFF.

There could be some economic benefit in future avoided costs to various parties if standards were to be adopted that are numerically higher than the associated PQLs. However, because the proposed standard is only higher for GenX, and GenX is not known to be a component of AFFF, avoided costs are unlikely from this rulemaking for sites where AFFF was the sole PFAS contaminant. Note however that GenX has been found above the PQL at some sites that have AFFF contamination (at non-UST sites), but the source of GenX has not been determined/confirmed at this time.

Groundwater cleanup at legacy spill sites where AFFF has remained in the soil after the excavation of petroleum-contaminated soil and at permitted soil remediation facilities where petroleum contaminated soil mixed with AFFF containing PFAS was accepted may be necessary. Depending on the type of facility, most soil remediation facilities have an existing monitoring well network. The facilities that are not expected to have a monitoring well network are within a structure and on a concrete floor and are not expected to contaminate groundwater. The cost to analyze, monitor and remediate groundwater at these sites will be borne by the responsible party (e.g., trucking companies and/or soil remediation facility owners). Any requirement to analyze for PFAS at these sites would not be a result of the proposed rule amendment. If there are no standards for PFAS that are typically found in AFFF that are higher than the PQL, cleanup would continue until PFAS concentrations are below the PQL.

7. Underground Injection Control Well Program (DWR)

The Underground Injection Control (UIC) Well Program issues permits for the construction and operation of underground injection wells, some of which are used for groundwater remediation purposes. The UIC only regulates the construction and operation of those wells at the request of a site owner/operator or responsible party. The program does not determine that remediation is necessary, that injection wells are the best option for remediation, which constituents are required to be remediated, or if or when remediation can be terminated. That determination would have been made between the owner/operator/responsible party, their

consultants, and/or the applicable regulating agency. Because Underground Injection Wells are not used for the remediation of PFAS, no impacts are expected from the proposed amendment.

8. Non-Discharge Sites (DWR)

DWR is authorized under Subchapters 15A NCAC 02L (Groundwater Classification and Standards) and 15A NCAC 02T (Waste Not Discharged to Surface Waters) to issue permits that allow the discharge of waste onto land or into the subsurface under conditions outlined in a "non-discharge" permit. Infrequently, cleanup activities from these discharges may be required. Staff reported that there are no cleanup activities underway on permitted sites for any of the contaminants for which standards are proposed, and none of the contaminants are part of permittees' required monitoring suite. While there is no data available to quantify how many non-discharge sites could potentially be affected, and investigative and source assessment sampling would first need to be performed, any impacts to permitting decisions would be limited to a small number of facilities (less than 20). Also, there is no established methodology to calculate permit limits for PFAS, and any changes to the program would not be able to be implemented until an appropriate method is established.

9. Groundwater Management Branch – CCPCUA Permits (DWR)

Issuance of water withdrawal permits for the Central Coastal Plain Capacity Use Area (CCPCUA) is based on the capacity of groundwater withdrawal and well construction standards, and do not include or address requirements for groundwater quality monitoring. Therefore, the proposed rule amendment to groundwater quality standards does not impact the existing requirements for issuance of these permits.

10. On-Site Water Protection (DHHS)

The On-Site Water Protection Branch programs within DHHS provide oversight of sub-surface on-site wastewater treatment systems. They also provide consultative services related to wastewater and private drinking water wells to local health departments. They use the groundwater standards for non-regulatory purposes only. DHHS staff confirmed that the proposal to add groundwater standards for multiple PFAS in lieu of using the PQL as the regulatory limit should not impact their programs.

11. Private Wells (DHHS)

None of the PFAS for which standards are being proposed are currently required to be analyzed for under 15A NCAC 18A Section .3800 Private Drinking Water Well Sampling. Nor do these rules require that well water comply with State groundwater quality standards under 15A NCAC 02L. The State does not use the groundwater standards to regulate the water quality of private well water. The burden to monitor water quality of private well water is on the well owners. Information relating to the groundwater standards may be provided by NC DHHS to a well owner if there is a concern about possible contamination, but the well owner would not be required to take action. For these reasons, the proposal to add groundwater standards for multiple PFAS in lieu of using the PQL as the regulatory limit should not have a regulatory impact on private well owners.

C. Quantified Costs and Benefits

Because the costs for certain tasks or activities are likely to be similar across DWM programs, we have included here the calculations that were used to estimate the expenses across programs. These estimates are utilized in the cost summary in Table VIII-2 when estimating potential avoided costs.

Installation of Additional Monitoring Wells, if warranted under the existing rules or proposed amendment

The cost to construct/install a new permanent groundwater monitoring well varies based on the well depth and diameter, and between subcontractors. Groundwater monitoring wells at DWM remediation sites are generally two to four inches in diameter and range between 25 and 50 feet deep. Monitoring well construction must comply with 15A NCAC 02C "Well Construction Standards."

The majority of sites regulated by DWM are likely to have an existing groundwater monitoring well network for routine monitoring, and may also have had additional wells installed for assessment monitoring under the existing rules or for other compounds under remediation. These sites are not likely to need to install additional monitoring wells solely to monitor for PFAS. However, if additional wells were necessary (under existing rules), Table VII-4 provides estimates for installing one additional well at a depth of either 25 feet or 50 feet. Brown and Caldwell provided estimates for groundwater well installation, operation, and maintenance for wells 25 and 50 feet deep that could be used for groundwater monitoring or extraction for a pump and treat system. These estimates are provided in greater detail in the Brown and Caldwell technical memo included in Appendix C.

Table VII-4: Range of Cost Estimates for Installation and Operation and Maintenance of One Groundwater Well, if Needed

Cost Category	Cost for one 25-foot Well	Cost for one 50-foot well
Capital Expenditure – Well Installation	$12,150	$18,225
Annual O&M	$2,350	$2,350

Notes:
- *Costs are in November 2023 dollars.*
- *Costs may be for a well for assessment monitoring or for extraction for treatment, at 2 – 4 inches in diameter.*

PFAS Groundwater Sampling and Laboratory Analysis, if warranted under the existing rules or proposed amendment

A site may be required to conduct sampling and analysis of groundwater as routine detection monitoring, or during site assessment if contamination is suspected/identified, and during remediation/corrective action to assess effectiveness of the remedy. Because a DWM site is unlikely to be conducting sampling and analysis just for PFAS alone, the cost range below to sample and analyze groundwater for PFAS is estimated as costs added to an existing/already scheduled sampling event for constituents other than PFAS, such as metals, volatile organic compounds, etc. The estimated cost range for a laboratory to analyze PFAS assumes that the laboratory analyzes all PFAS as one analysis cost (i.e., a laboratory cost to analyze the family of PFAS is not based on how many different PFAS are requested to be analyzed and reported).

- Number of monitoring locations per DWM site: **3 - 25**
- Number of quality assurance/quality control samples per monitoring event: **3 – 5**
- Cost of additional equipment needed for PFAS protocols per event: **$50 - $100**
- Laboratory cost to analyze one sample for PFAS (depending on method and laboratory used): **$300 - $530**

- Number of staff added to conduct PFAS protocols: **1 additional staff**
- Time for 2 staff to sample 3 – 25 monitoring locations per site: **4 - 16 hours**
- Total hourly compensation (includes salary and fringe) for staff: **$80 - $120**

Cost range to add PFAS sampling and analysis in groundwater to **one** existing sampling event for other constituents, per routine monitoring event for an existing groundwater monitoring well network at a DWM site:

- Lower Estimate: ((3+3)*$300) + $50 + ($80*4) = **$2,170**
- Mid-Range Estimate: ((14+4)*$415) + $75 + ($100*10) = **$8,545**
- Upper Estimate: ((25+5)*$530) + $100 + ($120*16) = **$17,920**

Table VII-5: Range of Cost Estimates to Add PFAS Sampling and Analysis to Routine Monitoring of an Existing Groundwater Monitoring Well Network at DWM Sites

Routine Monitoring Event Frequency	Number of Wells Sampled	Annual Cost Range Under Existing Rule (Limit is PQL)	Annual Cost Range Under Proposed Amendment (New Standards)	Difference Between Existing Rule and Proposed Amendment
Annual	3	$2,170	$2,170	**$0**
	14	$8,545	$8,545	**$0**
	25	$17,920	$17,920	**$0**
Semi-Annual	3	$4,340	$4,340	**$0**
	14	$17,090	$17,090	**$0**
	25	$35,840	$35,840	**$0**

Note: Costs are in November 2023 dollars.

In consideration of all statewide costs and benefits to all parties, we must acknowledge that something that is a cost to the regulated community such as laboratory or consulting costs, could conversely be considered a benefit to the laboratory or consultant. However, for the purpose of the impacts of this analysis, these costs and benefits are expected to be the same under the existing rule and the proposed rule, and therefore would be a net zero cost/benefit to both the regulated community, their consultants, and laboratories.

Selection of Remedy, if warranted under the existing rules or proposed amendment

In general, DWM Program sites that are required to undergo assessment and remediation have multiple remedies to select from, at varying potential costs to the owner/operator or responsible party. The appropriate remedy depends on the site conditions and geology, site use and history, nearby receptors, and the type and nature of the identified contamination. All options are not available at all sites and a site may also use a combination of remedies.

Below is a list of potential methods of site remediation that waste management facilities may already be utilizing to address exceedances of regulatory limits for groundwater **for compounds other than PFAS** (*not comprehensive, and some may not be recommended for PFAS*):

- Treatment options:
  - Groundwater Extraction (i.e., pump and treat)
  - Phytoremediation
  - In-situ bioremediation
  - In-situ chemical reduction/oxidation
- Risk-based or passive remediation options for on-site contamination:
  - Institutional controls/land-use restrictions (risk-based)
  - Monitored natural attenuation (MNA) (passive, for certain circumstances)
- Landfill-specific options:
  - Landfill capping to prevent further leachate generation
  - Landfill gas (LFG) control, where landfill gas is suspected as the cause of the contamination

It is possible with some of the options listed above to have little to no additional costs for the selected remedy to address PFAS remediation because the site is already required to conduct those activities under existing regulations for compounds other than PFAS. For example, sanitary landfills are already required by rule to continue groundwater monitoring annually or semi-annually, provide landfill gas controls and monitoring, and cap the landfill upon closure regardless of their corrective action status. The remedy may just require that they adjust, improve, or upgrade their existing equipment or operations to meet existing requirements to prevent further contamination. Institutional controls may also have little to no immediate cost aside from the loss of potential future uses that would be difficult to predict or quantify and/or minor additional analysis costs if constituents are added to the routine monitoring list. A site-specific determination must be made to determine whether treatment of the groundwater and the associated costs are warranted, and which treatment method is appropriate.

Costs of Extraction and Treatment of PFAS in Groundwater, if warranted under the existing rules or proposed amendment

If the determination is made that treatment of PFAS in groundwater is warranted at a particular site, the most effective known treatment option for PFAS contamination in groundwater at this time is groundwater extraction and treatment via shelf-ready methods including granular activated carbon (GAC) and ion exchange (IX). Reverse osmosis (RO) is also an option for PFAS treatment; however, this method produces a higher volume of waste that would require disposal compared to GAC and IX. DEQ enlisted the assistance of an outside consultant, Brown and Caldwell, to provide cost curve estimates for the treatment of PFAS using either GAC, IX, or a combination of the two, with pretreatment (filtration). Determination of the best treatment option may depend on whether the driver for remediation is long-chain or short-chain PFAS, or a combination of both, and their concentrations. The choice of treatment type and other options would depend on site-specific factors, concentrations, treatment goals for the site, other constituents that are concurrently under remediation, and owner preferences.

This analysis is not intended to recommend one treatment technology over another. Where estimates are provided for particular treatment technology or train, it is solely to make assumptions that reduce the complexity of trying to consider multiple variables in cost calculations, which would be unlikely to add value to a discussion of hypothetical

scenarios with high levels of uncertainty. As existing technologies improve and new technologies are developed in the future, treatment costs may change. Neither the existing rules nor the rule amendment require that a certain type of treatment system or process be selected over another.

Costs also depend on the predicted/expected flow rate of the treatment system, how the treated effluent is handled, and how the waste or materials generated that contain PFAS are able to be handled. Costs were estimated for both the capital expenditure of installing a new treatment system, and also for the continued operation and maintenance (O&M) of the system. Brown and Caldwell generated tables and a technical memorandum, included in Appendix C, that estimate and describe the range of cost estimates for capital expenditures, operation and maintenance, and the variability depending on the treatment method(s) and the flow rates of the system, and also the assumptions made. The memo also provides cost estimates to install extraction wells to pump groundwater at a site, if needed (as summarized in Table VII-5).

Pre-treatment of the groundwater to reduce iron, magnesium, and total suspended solids (TSS) to improve treatment outcomes is also expected to be necessary for NC groundwater, and has been included in the cost estimates. Another factor that may increase treatment costs is the concentration of PFAS in groundwater. Higher concentrations mean that the system's filter media may need to be changed more often, which is likely to increase the cost of ongoing operation and maintenance of the system. Consideration of this added cost was included in the cost curves in the Brown and Caldwell technical memo in Appendix C.

Also, a treatment system installed to reduce PFAS concentrations (as required under existing rules) is likely to reduce concentrations for any PFAS of a similar carbon chain length that may be present in groundwater at the site. The treatment system is **not** limited to reducing the concentrations of PFAS that have been targeted because they exceed regulatory limits for groundwater.

A particular site may also be conducting remediation activities for groundwater standard exceedances for non-PFAS compounds, such as metals or volatile organic compounds, or may need to remove other compounds in order to meet effluent requirements. In this case, the site owner/operator may select to use a treatment system (such as RO) that is better suited to remove all types of compounds that are in exceedance of the standards, in addition to PFAS.

Note also that if the source of the PFAS contamination is eliminated or minimized, costs for O&M of the treatment system may eventually be reduced or eliminated. Because this circumstance would be difficult to predict or quantify, the costs below assume that the source would not be eliminated or minimized, to provide a conservative estimate.

Extraction

If a site needed to install a groundwater extraction well as a part of the pump and treat system for groundwater remediation, the costs to install, operate, and maintain the well are likely to vary depending on treatment needs, use, and site-specific factors for well construction. As previously noted, Table VII-4 provides an estimate for the installation of one hypothetical extraction well, either 25 or 50 feet deep.

Treatment

Table VII-6 includes potential cost estimates for treatment at one DWM facility under the existing and proposed rules where the following circumstances and assumptions are met:

- one or more of the three PFAS for which standards are proposed are detected above both the PQL and the proposed standards in groundwater,
- one or more of those three PFAS are the drivers for remediation,
- activities at the facility are the source of the PFAS exceedances,
- remediation is warranted,
- groundwater extraction and treatment is the selected remedy,
- no pump and treat system is currently on site,
- pretreatment filtration system is necessary to reduce solids, and
- the treatment system flow rate is 0.015 MGD.

Costs will vary based on higher or lower pumping flow rates for groundwater, as shown in the Brown and Caldwell technical memo included in Appendix C, and flow rates will vary based on site-specific circumstances. The average flow rate of 0.015 MGD used to estimate the costs in Tables VII-6 and VII-9 is similar to average flow rates found in practice at existing DWM sites currently conducting pump and treat for remediation for other contaminants.

Table VII-6: Potential Cost Estimates for PFAS Treatment, if Warranted, Under Existing Rule vs. Proposed Amendment at One DWM Facility

Treatment Technology	Recommended Use	Cost Sub-Category	Cost Range Under Existing Rule (Limit is PQL)	Cost Range Under Proposed Amendment (New Standards)	Difference Between Existing Rule and Proposed Amendment
GAC	Long-chain PFAS	Capital Expenditure	$169,000 - $674,000	$169,000 - $674,000	**$0**
		Annual O&M	$46,000 - $182,000	$46,000 - $182,000	**$0**
IX	Preferred (but not required) for combination of long- and short-chain PFAS	Capital Expenditure	$146,000 - $582,000	$146,000 - $582,000	**$0**
		Annual O&M	$52,000 - $208,000	$52,000 - $208,000	**$0**
GAC – IX Treatment Train	Preferred (but not required) for high concentration of long-chain PFAS combined with short-chain PFAS	Capital Expenditure	$206,000 - $822,000	$206,000 - $822,000	**$0**
		Annual O&M	$54,000 - $216,000	$54,000 - $216,000	**$0**

Note: Costs are in November 2023 dollars.

Potential Avoided Costs

Because one of the three PFAS has a proposed standard that is higher than the PQL, the proposed groundwater standard could reduce the chances that GenX is in violation of the regulatory limit. Where GenX would have been the drivers for remediation, this could potentially eliminate the need to conduct assessment and continued monitoring and remediation of GenX at that site. However, the chances that GenX are detected above the PQL but below the proposed standard and GenX is the driver for site remediation are very

low. At many of the DWM sites where PFAS has been detected, the drivers for remediation are either other constituents that are not PFAS (such as metals or volatile organic compounds), or for PFAS, would be more likely to be PFOA or PFOS (if the site was the cause of PFOA and PFOS contamination), in which case this benefit would not be realized.

The Department has received some initial analysis results for PFAS at sanitary landfills. Table VII-7 summarizes the currently available results compared to the PQL and the proposed standards. These tables compare the number of sites that may have exceedances of PFOA, PFOS, and GenX under the existing PQL vs. the proposed standards and show potential for some regulatory relief as a result of the proposed standard for GenX, if a site meets the criteria.

Table VII-7: Comparison of Groundwater Cleanup Requirements at 168 of 301 Sanitary Landfills Using the PQL as the Regulatory Limit vs Proposed Standards

PFAS	PQL	No. of Landfills w/ Exceedances of PQL (out of 168)	Proposed State GW Standard	No. of Landfills w/ Exceedances of Proposed GW Std (out of 168)
PFOS	4	144	0.7	164*
PFOA	4	157	0.001	166*
HFPO-DA (GenX)	5	29	10	17

Notes:
- All values are reported in nanograms per liter (ng/L).
- 168 of the 301 existing landfills had submitted analysis results as of 8/1/24, for a total of 2030 individual samples analyzed.
- This comparison is based on draft/preliminary data that has not yet been confirmed or validated by DEQ.
*(*) Only the exceedances of the PQL would be violations of 02L unless/until the PQL decreases to a level that is at or below the standard.*

Table VII-8 includes potential estimates for avoided costs of assessment and remediation at one hypothetical DWM-regulated facility under the existing and proposed rules where the circumstances are the same as the estimate in Table VII-6, with the following exceptions and additions:

- GenX is detected above the PQL in groundwater, but below the new/proposed standard,
- GenX is the driver for remediation (meaning the driver is not a different type of contaminant such as metals, volatile organic compounds, etc.), and
- no other PFAS are detected above the PQL.

Both treatment technologies evaluated in this analysis, GAC and IX, are viable options for treating GenX, so both technologies were included in Table VII-8. A treatment train using a combination of GAC and IX would not be necessary for GenX alone, since a site under this set of circumstances would not have high concentrations of long-chain PFAS or high concentrations of GenX. It would still be an option for the site, but is unlikely to be selected because of the higher costs, so it was not included in Table VII-8.

Table VII-8: Potential Avoided Assessment and Remediation Costs Under Proposed Amendment at One Hypothetical DWM-Regulated Facility

Treatment Technology	Cost Sub-Category	Cost Range Under Existing Rule (Limit is PQL)	Cost Under Proposed Amendment (New Standards)	Range of Potential Avoided Costs Due to Proposed Amendment
GAC	Capital Expenditure	$169,000 - $674,000	**$0**	$169,000 - $674,000
	Annual O&M	$46,000 - $182,000	**$0**	$46,000 - $182,000
IX	Capital Expenditure	$146,000 - $582,000	**$0**	$146,000 - $582,000
	Annual O&M	$52,000 - $208,000	**$0**	$52,000 - $208,000

Note: Costs are in November 2023 dollars.

Unquantified Impacts

Another potential for avoided future costs is if a higher regulatory limit results in the site being able to bring the concentrations in groundwater below the limit for GenX years earlier, and GenX is the driver for remediation, in which case they would avoid the cost of annual operation and maintenance for the remaining years that they did not need to continue remediation. We cannot determine whether this would actually occur at any sites or how many years earlier a site would be able to cease remediation efforts due to lack of remediation data over time for PFAS and wide variability between sites.

A potential future impact could be a change in behavior with real estate transactions, although it would not be a direct impact of the existing or proposed rule. A financial institution, a property buyer, or a consultant hired to conduct routine environmental site assessments for real estate transactions and lending may elect to conduct analysis for PFAS for their own purposes in making a determination whether to approve financing or purchase the property. Neither the existing rule nor the proposed rule include requirements for buyers or financial institutions in real estate lending. We cannot say whether they will elect to analyze for PFAS solely because a groundwater standard has been established for PFAS, or if they would have elected to require it under the existing rule and established MCLs, even if the proposed rule does not become effective. DWM is often contacted during such real estate transactions with questions about a property and existing contamination during the process.

D. Qualitative Benefit – Regulatory Certainty

An additional benefit to adding specific numeric groundwater standards for PFAS in general, and specifically for GenX in the case of this rulemaking, that could not be monetized but which is also an important benefit of this proposed amendment, is regulatory certainty for environmental and economic purposes.

Because the PQL is based on laboratory capability and may vary over time, establishing a specific, numeric, and consistent standard statewide will assist state and local governments and the private sector with decision-making and planning when all parties are clear on the limit that determines an exceedance and/or is used as the clean-up goal or regulatory limit now and in the future. The standards will assist all parties with decision-making and planning for the type of

remediation (which may include risk-based procedures), and how long remediation may need to be conducted, because it will provide confidence that any future change to the numeric standard that might impact their plans for ongoing remediation would be subjected to the rulemaking process.

VIII. Cost and Benefit Summary

The agency anticipates that if the groundwater standards are adopted as proposed, there could be net benefit to regulated parties from having a standard that is numerically higher than the regulatory baseline for GenX (PQL). The benefit would only be realized at sites that meet the set of specific circumstances described in Section VII, so the number of sites that would benefit is uncertain and likely to be very small, but the possibility cannot be ruled out without conducting individual site evaluations. For purposes of this analysis, the regulatory baseline limit is the PQL. For PFOA, the previous existing Interim Maximum Allowable Concentration (IMAC) was not used as the baseline since it was not included in the existing rule, and the IMAC was removed on November 4, 2022.

For PFOA and PFOS, the adoption of standards at values less than the PQL used as the baseline will neither increase nor decrease regulatory requirements because the PQL will remain the baseline, per the existing rule language (at whatever level the PQL is at that point in time, for both the existing and proposed regulations). For this reason, the adoption of the standards for PFOA and PFOS should have no quantifiable impact on regulated persons, at least for the foreseeable future until such time that the PQL might decrease below the proposed standards, which may or may not occur. At that time, the proposed standard could provide regulatory relief, because the standards for these two compounds would also be higher than the PQL.

Any potential benefits associated with this rulemaking, if realized, would be realized by parties regulated primarily under the agency's Hazardous Waste, Inactive Hazardous Sites, Solid Waste Landfill, and UST programs. PFAS groundwater remediation would be similar across programs, so we attempted to provide a plausible hypothetical scenario for assessment and remediation under existing rules to estimate the potential benefits. We provided quantitative data when available and made assumptions based on the limited existing data and trends when appropriate.

The high degree of variability among sites in terms of which contaminants are present, which contaminants are the drivers for cleanup, the degree of contamination, the scale and complexity of remediation required to meet the regulatory requirements, the protracted length of time required to remediate groundwater, and the lack of PFAS baseline and historical analysis data make it difficult to quantify costs and benefits statewide, and any quantification provided here is highly speculative. We also cannot reasonably predict future levels of groundwater contamination, how quickly the treatment systems will reduce PFAS concentrations in groundwater below the regulatory limit, nor the pace at which cleanup and testing technologies will advance.

A. Summary of Costs and Benefits by Sector

The potential costs and benefits of the proposed amendment have been described in detail in Section VII above as impacts to the regulated communities by programs under the purview of DWM and DWR. Below is a summary of the same information presented as impacts to different sectors, including the private sector (industrial/commercial) and federal, state, and local governments, and an evaluation for substantial economic impacts as required by G.S. 150B-21.4.

1. Regulated Community - Site Owner/Operators

Private Sector (Industrial/Commercial) and Local Governments

As described in further detail under each program in Section VII.B., the owners or operators (or both) of permitted facilities or sites regulated under the purview of the DWM are generally in the private sector (industrial/commercial) or are local governments. A small number of sites are also owned or operated by the State and the Federal Government. These

sites are required to comply with the existing requirements of 15A NCAC 02L .0100 and .0200, and include hazardous waste permitted facilities, solid waste management facilities, inactive hazardous sites, and petroleum spills and petroleum-contaminated soil remediation sites. Note also that a site responsible party may not be able to be identified for some inactive hazardous sites. The private sector may also analyze for PFAS under the existing rules where they are the prospective developer applying for a brownfields agreement to ensure liability protection for exceedances of the regulatory limit for groundwater (existing PQL or proposed standards).

Potential benefits to site owner/operators at sites that fall under the specific circumstances described under Section VII include eliminating the need to conduct site assessment, remediation, and groundwater extraction and treatment, which could eliminate both the capital expenses and the annual operation and maintenance for these particular sites. See Table VII-8 for estimates of a range of potential avoided future costs for any one site that falls under the narrow circumstances described for that table.

At other sites that are required to remediate and/or treat PFAS in groundwater, benefits may include reduced frequency of ongoing monitoring, reduced number of contaminants required for ongoing testing, reduced number of groundwater wells being monitored (labor costs), and reduced cleanup time. Avoided costs from completing groundwater remediation in a shorter period of time would largely be from spending less on operation, maintenance, and any effluent or waste handling costs for the cleanup/treatment technology.

Table VIII-1: Summary of Ownership of Potentially Affected Waste Management Sites in North Carolina

Facility Type	Private-owned	Local Govt-owned	State-owned*	Federal-owned	Total
HW - Permitted Facilities	65	3	2	6	76
SW - Sanitary Landfills	97	198	2	4	301
SF - IHSB Contaminated Sites	1951	--	--	--	1951
UST - Petroleum-Contaminated Soil Remediation	44	--	--	--	44
TOTAL:	**2,157**	**201**	**4**	**10**	**2,372**

Note:
*(*) Of the State-owned facilities, 3 are owned by State universities, and one is the NC State Fair Solid Waste Landfill.*

Local Government Site Owner/Operators

- ***While the requirement to address PFAS contamination in groundwater under the existing rules (with PQL as the regulatory limit) would require additional expenditures for a unit of local government now or in the future, these expenditures are not a result of the proposed amendment.***

  No increase or decrease to the expenditures or revenues of a unit of local government are expected as a result of the proposed rule change, and no budgetary changes would be necessary to comply with the proposed rule change. The impact of the proposed rule change to local government site owner/operators would be in potential avoided future costs only, if certain facilities fall under the specific circumstances described for Table VII-8.

2. North Carolina State Government

State Government Site Owner/Operators

As shown in Table VIII-1, State government owns four waste management facilities, two under the hazardous waste program, and two under the solid waste program. The impacts to state government for these four sites would be the same as the impacts to the private sector site owners/operators. While additional state funds may be necessary to address PFAS contamination under the existing rules, no additional state funds are expected to be expended or distributed as a result of the proposed rule change, and no budgetary changes would be necessary to comply with the proposed rule change. The impact of the proposed rule change to state government site owner/operators would be in potential avoided future costs only, if certain facilities fall under the specific circumstances described for Table VII-8.

State DEQ Staff Time and Resources

As described in detail in Section VII above, if any sites under the purview of DWM programs were able to avoid assessment or remediation for PFAS, or discontinue remediation sooner because of rule amendment, this would also result in savings of state staff time and resources spent on oversight of that DWM-regulated site. It is not possible to determine at this time how many sites might fall under the specific circumstances described for Table VII-8, or how much time might be saved on sites that fall under those circumstances, or when the savings would occur. This potential benefit would be limited to sites where one of the six PFAS where the proposed standard is higher than the PQL are the drivers for remediation, and the concentrations are between the PQL and the proposed standard.

However, any savings to staff time and resources due to any project's early completion will be immediately reinvested to address the large backlog of other sites in need of staff attention across the state due to already limited resources, most notably in the inactive hazardous sites branch. For this reason, we did not expect any direct budgetary savings for staff time and resources.

Inactive Hazardous Sites Cleanup Fund

Another benefit of this rulemaking would be the potentially avoided future costs to the Inactive Hazardous Sites Cleanup Fund that may provide funding for groundwater remediation projects. Savings to this fund in the near term would allow remediation to address the large backlog of other sites in the long term. This should result in improved compliance with the groundwater quality regulations, which would result in further protection of the groundwaters of the State as a resource and as a source of drinking water. This benefit would be realized by the environment and by those citizens who consume private well water.

- ***While additional state funds have been necessary to address PFAS contamination under the existing rules, no additional state funds are expected to be expended or distributed as a result of the proposed rule change, and no budgetary changes would be necessary to comply with the proposed rule change.***

- ***The proposed rule change will not result in increased cost to the Department of Transportation (DOT), but under specific circumstances descried for Table VII-8 (if they exist), the proposed rule change could potentially result in the benefit of avoided future PFAS assessment and remediation costs for DOT.***

B. NC Residents and Consumers of Groundwater

PFAS can build up, or bioaccumulate, in humans and animals. Scientific studies have shown that exposure to certain levels of PFAS have been linked to reproductive effects such as decreased fertility or increased high blood pressure in pregnant women; developmental effects or delays in children, including low birth weight, accelerated puberty, bone variations, or behavioral changes; increased risk of some cancers; reduced ability of the body's immune system to fight infections, including reduced vaccine response; interference with the body's natural hormones; and increased cholesterol levels and/or risk of obesity.

The current PQLs are based on laboratory technology and capability. The proposed standards are health-based values that take into account lifetime risks to human health from consumption of a contaminant. For additional information, see the Toxicological Summary Information and Derivation of Groundwater Quality Numerical Standards for Per- and Poly- Fluoroalkyl Substances (PFAS) included in Appendix A. The proposed standards do not surpass the risk management levels established under Rule 15A NCAC 02L .0202(d). The additional toxicity information used in the derivation of the proposed standards provides a greater degree of confidence that the standards achieve the goal of preventing unacceptable health risks in NC waters without creating additional burdens.

The proposed amendment may also provide clarification to residents and/or the regulated community in understanding the health risks for each PFAS when they are reviewing analysis results for these three PFAS, in their private well for example. Proposing standards for PFAS may provide greater understanding that seeing a PFAS detected above a PQL does not necessarily equate to a significant health risk in all cases. The proposed amendment may also instill more confidence into NC residents that the State's groundwater is being protected via a scientifically defensible groundwater quality standard. While important, these benefits and clarification to residents and consumers are unquantifiable.

C. Substantial Economic Impact Evaluation

It is reasonable to expect that there will be a zero to net-positive benefit to regulated entities, including local governments, the federal government, and the Department of Transportation, and to state government. The scope of savings is highly speculative and cannot be estimated accurately for individual sites because of the high degree of variability and unpredictability of contaminated sites and remediation strategies. Table VIII-2 attempts to provide a plausible potential range of avoided costs for a hypothetical individual site regulated under DWM, if any were to fall under the following specific set of circumstances:

- GenX is detected above the PQL in groundwater, but below the new/proposed standard;
- GenX is the driver for remediation;
- activities at the facility are the source of the PFAS exceedances;
- remediation is warranted;
- groundwater extraction and treatment is or would be the selected remedy; and
- no other PFAS are detected above the PQL.

❖ *Making a determination of substantial economic impact (aggregate costs + benefits in one year = over $1 million) would depend upon whether any DWM-regulated sites will fall under the narrow and specific set of circumstances outlined in the list above, which cannot be predicted at this time, but is unlikely to occur. Any substantial economic impact*

would be in potential avoided costs for assessment and remediation of PFAS at individual sites that fall under the specific circumstances and would not be required to assess or remediate PFAS, or may be able to discontinue remediation at an unknown earlier date. However, based on the limited results of PFAS analysis that have been submitted to DWM, DWM expects that most sites where PFAS is detected will still see detections above the PQL of PFOA, PFOS, or other PFAS for which no standard is being proposed (and therefore the PQL remains the regulatory limit for those compounds), so the sites may not be able to avoid treatment costs based on the relaxed regulatory limit, if treatment were warranted.

However, due to the extent of potential hypothetical benefits outlined in Table VIII-2 below, despite the high level of uncertainty and the limited chance that this particular circumstance would occur, we have written this analysis to attempt, wherever possible, to meet the requirements in G.S. 150B-21.4 on the assumption that the proposed amendment still has the potential to have a substantial economic impact in benefits (avoided costs) to the regulated community. Even if only one site is able to avoid assessment and remediation in one year due to the proposed amendment, their avoided costs for one year of capital expenses have the potential to exceed the $1,000,000 annual threshold for a substantial economic impact.

Table VIII-2: Potential Future Costs and Benefits from the Proposed Amendment (Escalated)

Category	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
ADDED COSTS FROM PROPOSED AMENDMENT										
Additional expenses to the regulated community to address PFAS as compared to baseline/existing rule	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CHANGES TO HUMAN HEALTH IMPACTS FROM PROPOSED AMENDMENT										
Changes to human health impacts as compared to baseline/existing rule	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
POTENTIAL FUTURE BENEFITS TO REGULATED COMMUNITY FROM PROPOSED AMENDMENT *										
Potential Avoided Future Capital Expenditures at One Hypothetical DWM-Regulated Site										
• Construction of additional 1 to 4 Groundwater Wells for either assessment monitoring or extraction, if needed	$13,054 to $78,322	--	--	--	--	--	--	--	--	--
• Treatment System Construction	$156,858 to $724,126	--	--	--	--	--	--	--	--	--
Potential Avoided Future Annual O&M and Monitoring Expenses at One Hypothetical DWM-Regulated Site										
• Adding PFAS Analysis to Routine Monitoring for 3-25 Wells, 1 or 2 Events	$2,303 to $38,034	$2,349 to $38,794	$2,396 to $39,570	$2,444 to $40,362	$2,493 to $41,169	$2,543 to $41,992	$2,593 to $42,832	$2,645 to $43,689	$2,698 to $44,563	$2,752 to $45,454
• Groundwater Well O&M (1 to 4 wells)	$2,494 to $9,975	$2,544 to $10,175	$2,595 to $10,378	$2,646 to $10,586	$2,699 to $10,798	$2,753 to $11,014	$2,808 to $11,234	$2,865 to $11,459	$2,922 to $11,688	$2,980 to $11,921
• Treatment System O&M	$48,816 to $220,731	$49,792 to $225,146	$50,788 to $229,649	$51,803 to $234,242	$52,840 to $238,927	$53,896 to $243,705	$54,974 to $248,579	$56,074 to $253,551	$57,195 to $258,622	$58,339 to $263,794
TOTAL QUANTIFIED BENEFITS TO REGULATED COMMUNITY IN POTENTIAL FUTURE AVOIDED COSTS AT ONE HYPOTHETICAL DWM-REGULATED SITE *	$223,524 to $1,071,188	$54,684 to $274,115	$55,778 to $279,597	$56,894 to $285,189	$58,032 to $290,893	$59,192 to $296,711	$60,376 to $302,645	$61,584 to $308,698	$62,815 to $314,872	$64,072 to $321,170
Ten-Year Net Present Value, 7% discount rate, 2024 dollars								**$529,530 to $2,611,331**		

Notes:
*(*) Range of potential avoided assessment and remediation costs over time for one hypothetical DWM-regulated site, if a site fell under the specific circumstances outlined in text.*
Original Costs obtained were in November 2023 dollars, but have been escalated at 2.42% for capital expenditures and 2% for operation and maintenance. This table assumes Year 1 is 2026 per the DWM planned implementation schedule. NPV is in 2024 dollars.
The year that remediation would have begun at a site is uncertain. Length of time required for remediation also uncertain, but annual avoided costs would continue until remediation would have been completed, if it had been required under existing rules.

D. Uncertainties and Limitations

1. Lack of Existing PFAS Groundwater Quality Monitoring Data, both Current and Background/Baseline Data

Because we do not have existing PFAS analysis data for groundwater quality monitoring at many waste management facilities, we cannot be certain which PFAS will be detected or at what concentrations it will be found in groundwater at all facilities under DWM's purview. This lack of data makes it difficult to predict which sites will have exceedances of the existing regulatory limit, and therefore would be required to comply with existing remediation requirements under 15A NCAC 02L .0100.

Most existing sites would not have had the opportunity to obtain baseline results for PFAS analysis prior to establishing a waste management facility and accepting waste. Additionally, some sites may not be able to monitor upgradient groundwater quality for comparison to downgradient groundwater quality at the site due to site-specific circumstances. These complications may mean that identifying the source of PFAS contamination could require further evaluation of the combinations and proportions of the various PFAS (i.e., the PFAS "signature" or "fingerprint"), and how those compounds might transform into other PFAS in groundwater under those site-specific circumstances.

If we cannot determine prior to this rulemaking whether PFAS contamination is present at all sites, which contaminants are present and at what levels, or whether remediation would be warranted at a site, we cannot say whether any site will realize any benefits from this rule amendment. We can only say with certainty that the regulated community will not realize any costs from this rule amendment, because any costs to remediate PFAS would be impacts of the existing rule, not the rule amendment.

We also cannot predict how many new sites will come under the purview of DWM in the future and whether they will be suspected of having PFAS contamination or will be found to have PFAS contamination.

2. Site Variability

Because there are so many site-specific variables that will impact selections for assessment and monitoring, remediation and treatment options, well installation, sampling and analysis methods and procedures, treated water effluent, and treatment waste generation and disposal, any cost estimates in this analysis are highly uncertain and generalized, and should not be used to predict costs at any individual sites. It is not possible for DEQ to conduct site-specific investigations at every site under the purview of DWM for the purpose of estimating costs for this analysis, which would likely also require site-specific preparation and evaluation by licensed professionals such as engineers and geologists for each site.

IX. Rule Alternatives

In accordance with G.S. 150B-21.4(b2)(5), the fiscal note for a proposed rulemaking with a substantial economic impact is required to contain a description of at least two alternatives to the proposed rules. As defined in G.S. 150B-21.4(b1), "substantial economic impact" means an aggregate financial impact on all persons affected of at least one million dollars ($1,000,000) in a 12-month period. As shown in Section VIII of this fiscal note, the proposed rules have the potential to have a substantial economic impact in benefits for sites/facilities that meet a set of specific criteria as described in Section VIII.C, which might not occur at any site/facility. Therefore, two alternatives have been evaluated in this section.

A. Alternative 1: Business-as-Usual

The first alternative to the proposed rules would be a business-as-usual or no action approach. Under the business-as-usual alternative, the applicable regulatory limit for groundwater for all PFAS would continue to be the PQL in existing rules. In this case, sites/facilities that detect any PFAS above the PQL, including GenX, would be in violation of the groundwater quality regulations and would be required to work with DEQ in complying with remediation requirements under 15A NCAC 02L .0100 and any program-specific rules for remediation. Under this business-as-usual scenario, facilities that meet the criteria where GenX is detected above the PQL but below the proposed standards (and the other criteria listed in this analysis) would forego the potential benefits (in the form of avoided costs) while providing no additional protection to consumers of groundwater above the acceptable risk level. For these reasons, this alternative was rejected.

B. Alternative 2: Establish Groundwater Standards for Other PFAS or for PFAS Mixtures, in Addition to the Three PFAS Proposed

The second alternative to the proposed rules would be to propose groundwater standards for more PFAS than the three that are included in the proposed amendment, or establish standards for mixtures of PFAS. The science and human health toxicity information is currently available for five additional PFAS: PFBA, PFBS, PFNA, PFHxA, and PFHxS. DEQ has derived potential groundwater standards for these five compounds and presented those proposed standards to the GWWMC at their July 2024 meeting. Establishing the standards as derived for these five compounds also has the potential to reduce the burden on the regulated community through avoided future costs, consistent with G.S. 150B-19.1(a)(2) and (6). The GWWMC made the decision not to move the proposed standards for these five compounds forward for consideration by the full EMC for public comment.

The option to propose standards for PFAS other than the eight PFAS listed above was rejected at this time because the science and human health toxicity information for those other compounds or for mixtures is either not yet available and/or finalized. Also, other PFAS were not selected where they have not yet been found to be prevalent in NC. This option may be considered at a later date when the science and data become available and/or as a part of a later triennial review process.

Appendix A: Toxicological Summary Information and Derivation of Groundwater Quality Numerical Standards for Per- and Poly- Fluoroalkyl Substances (PFAS)

Toxicological Summary Information
and
Derivation of
Groundwater Quality Numerical Standards
For
Per- and Poly- Fluoroalkyl Substances (PFAS)

All information is current as of July 29, 2024

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Table of Contents

List of Tables

1. Overview

The intended purpose of this document is to provide a summary of the toxicological information that meets the required criteria specified in Rule 15A NCAC 02L .0202 - Groundwater Quality Standards for the development and derivation of the PFAS water quality standards for the state of North Carolina. This document highlights the principal studies and health effects used in the determination of the toxicological values that are required in Rule .0202. A complete description of the toxicological values and the derivation of groundwater quality standards in accordance with Rule .0202 are described in subsequent sections.

There are eight PFAS compounds that are included in this toxicological summary. These eight PFAS compounds were selected 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 compound that are included in the toxicological summary are:

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

(*) Selected by the Groundwater and Waste Management Committee on July 10, 2024, for rulemaking under Rule .0202(h).

Six of the eight PFAS compounds that are included in the toxicological summary 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 toxicological summary are PFBA and PFHxA which have been comprehensively evaluated by the EPA and have not been included in the NPDWR, likely due to their toxicological assessments being finalized after 2021 when the NPDWR activities began (EPA, 2022b, 2023).

During the Environmental Management Commission Groundwater and Waste Management Committee Meeting on July 10, 2024, the Committee voted to proceed with three of the eight proposed PFAS Standards. The three PFAS chemicals the Committee approved are PFOS, PFOA, and HFPO-DA (GenX).

This Appendix includes scientific information for all eight PFAS compounds for which 02L groundwater standards can be derived from the existing toxicological information. The supporting toxicological information and groundwater quality standards for PFOS, PFOA, and HFPO-DA (GenX) are incorporated into the Regulatory Impact Analysis to reflect the Committee's decision to move forward with rulemaking for three of the eight PFAS chemicals summarized here.

2. Toxicological Information

The toxicological information 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 this toxicological summary-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 toxicological summary 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, also providing a high level of confidence in that toxicological information.

EPA National Primary Drinking Water Regulation (NPDWR) PFAS Compounds

The six PFAS compounds included in the NPDWR that was proposed by EPA on March 14, 2023 and finalized on April 26, 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 a 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 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, CDC, 2021; 88 FR 18667, 2023). 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, 2022c).

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 Secretaries Science Advisory Board (SAB). The SAB 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 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 occurred can be found at this link: April 3, 2024 NCSSAB Meeting Recording (See 40 minute through 2-hour time stamp).

2.1. Types of Toxicological Values

There are two types of toxicological values that are relevant to the rulemaking process for Rule .0202. They are the Reference Dose (RfD), and the Cancer Slope Factor (CSF). The RfD and the CSF come from the federal toxicity assessments. 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 was 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 (i.e., intraspecies variability);
- UF_A = the uncertainty in extrapolating animal data to humans (i.e., interspecies variability);
- UF_S = the uncertainty in extrapolating from data obtained in a study with less-than-lifetime exposure to lifetime exposure (i.e., extrapolating from subchronic to chronic exposure);
- UF_L = the uncertainty in extrapolating from a LOAEL rather than from a NOAEL; and
- 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 was evaluated for derivation of a CSF, in the same method that is used to evaluate literate 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 No Observed Adverse Effect Level (NOAEL) or Lowest Observed Adverse Effect Level (LOAEL) approach). 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, 2022a). 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 describe in their respective sections, when applicable, and presented in Table 4 as an Overall Dosimetric Adjustment Factor (oDAF) for ease of reference and interpretation of the values in Table 4.

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 that 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 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 as a 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 and 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).

3. North Carolina Water Quality Standards Development Information

Title 15A of the North Carolina Administrative Code (NCAC) provides for the derivation of groundwater quality standards in Rule 15A NCAC 02L .0202 - Groundwater Quality Standards. The Rule details specific requirements and procedures for the application of relevant toxicological values to derive water quality criteria to protect designated uses. These requirements and procedures are discussed below.

3.1. Groundwater Standards Derivation

Rule .0202 defines the criteria for preserving North Carolina's groundwaters. The groundwater quality standards represent the maximum permissible concentrations of contaminants released into the land or waters, ensuring they won't pose a risk to human health or compromise the groundwater's intended best use as a source of drinking water.

3.1.1. Toxicological Requirements

Rule .0202(d) states that groundwater quality standards are established as the least of:

(1) Systemic threshold (non-cancer) concentration
(2) Concentration that corresponds to an incremental lifetime cancer risk of $1x10^{-6}$
(3) Taste threshold limit value
(4) Odor threshold limit value
(5) Maximum contaminant level
(6) National secondary drinking water standard

The first two options in the list require toxicological values, these are the RfD (1; Systemic threshold (non-cancer) concentration), and the CSF (2; Concentration that corresponds to an incremental lifetime cancer risk of $1x10^{-6}$). Since the rule text states that a groundwater quality standard shall be the least of the listed values, all calculated values should be compared to determine which is the lowest and therefore the most protective value.

The rule text also provides a list of references that shall be used in establishing groundwater standards, they are:

(1) Integrated Risk Information System (U.S. EPA),
(2) Health Advisories (U.S. EPA Office of Drinking Water),
(3) Other health risk assessment data published by the U.S. EPA, or
(4) Other relevant, published health risk assessment data, and scientifically valid peer-reviewed published toxicological data.

The eight PFAS compounds that are included in the toxicological summary all meet these requirements, as the toxicological values were provided by the appropriate EPA programs and in some cases were evaluated by a second federal agency (CDC).

3.1.2. Groundwater Standards Equations

The equation to calculate the systemic threshold or non-cancer concentration and the equation to calculate the concentration that corresponds to an incremental lifetime cancer risk of $1x10^{-6}$ are below. These equations include exposure factors that are defined in the rule.

For non-carcinogens,

Groundwater Quality Standard (GWQS) equation:
GWQS = [(RfD x WT x RSC) / WI] * 1000

For carcinogens, the equation is provided by the EPA (EPA, 2000)*,*

Groundwater Quality Standard (GWQS) equation:
GWQS = [(RL x WT) / (q1* x WI)] * 1000

Acronyms

RfD = reference dose
RL = Risk Level
WT = adult human body weight
RSC = relative source contribution
q1* = carcinogenic potency (slope) factor
WI = adult water intake

Groundwater exposure factors

WT = 70kg
WI = 2.0L / day
RSC = 0.2 for organics
RL = 1 in 10^6

3.2. Exposure Factors used in NC Water Quality Standards 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) (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). Under Rule .0202 (d)(1), criteria for Ground Water Quality Standards must use an RSC of 0.2 for organic substances and an RSC 0f 0.1 for inorganic substances. Since PFAS are organic substances, the RSC of 0.2 will be used to derive criteria for Groundwater Standards.

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 criteria at a 10^{-6} risk level, which EPA considers appropriate for the general population (EPA, 2000). NC has adopted an RL of 10^{-6} in the groundwater rules, Rule .0202, for use in the derivation of water quality criteria for chemicals that are classified as carcinogenic.

3.3. EPA Analytical Method 1633

The EPA Analytical Method that will be used to detect and report the eight PFAS compounds included in this document is Method 1633. Method 1633 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 quantification (LOQ) for each PFAS included in the analytical method were determined. Method 1633's quality control requirements are meeting the acceptable precent 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). As with any analytical method, there is inherent uncertainty in the measurements reported, and very small detections can be difficult to achieve. The range of LOQs span 1 – 16 ng/L, with %RSDs ranging from 21 – 29%, and average precent recoveries ranging from 65 – 155% (Table A-2). Since Method 1633 will be used to report PFAS concentrations based on the numeric NC WQS, the uncertainty or %RSD that is permissible in the analytical method will be considered with setting the regulatory WQS numerical values.

4. Derived 02L .0202 Groundwater Quality Standards

The Rule .0202(d) derived water quality standards for the eight PFAS chemicals and outlined above 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 derived NC Water Quality Standards based on the toxicological values (RfD, CSF) taken from the relevant federal guidance document. 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 1: The-derived NC Groundwater Quality Standards for the eight PFAS compounds in the toxicological summary.

PFAS	Federal Guidance Document	Derived Groundwater Quality Standards [a] (ng/L)
		02L GW
PFOS*	EPA Office of Water Human Health Toxicity Assessment (draft until 03/24)	0.7 (RfD)
		0.9 (CSF)
PFOA*		0.21 (RfD)
		0.001 (CSF)
HPFO-DA*	EPA OW Human Health Toxicity Assessment (2021)	10[b]
PFBS	EPA OW Human Health Toxicity Assessment (2021)	2,000
PFNA	ATSDR Minimal Risk Level (2021); EPA MCLG Summary (2023)	10[b]
PFHxS		10
PFBA	EPA IRIS Assessment (2022)	7,000
PFHxA	EPA IRIS Assessment (2023)	4,000

[a] Rounded using the EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (EPA, 2000).
[b] Value based on EPA established a maximum contaminant level (MCL) in April 2024 (EPA, 2024a).
* Selected by the Groundwater and Waste Management Committee on July 10, 2024, for rulemaking under Rule .0202(h).

Table 2: The toxicological information used to derive the RfD (and CSF if appropriate) for each of the PFAS compounds included in the toxicological summary.

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 Office of Water Human Health Toxicity Assessment (draft until March 2024)
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)	
HFPO-DA*	**Hepatic:** Liver constellation of lesions in parental female mice (Dupont, 2010)	0.09 [a1]	0.14	0.01	3000 [b-e]	0.000003	EPA OW Human Health Toxicity Assessment (2021)
PFBS	**Developmental:** Decreased serum total T4 in newborn (PND1) mice (Feng *et al.*, 2017)	22 [a1]	0.0043	0.095	300 [b-d]	0.0003	EPA OW Human Health Toxicity Assessment (2021)
PFNA	**Developmental:** Decreased body weight and developmental delays in mice (Das *et al.*, 2015)	6.8 [a2]	0.0001518	0.001	300 [c]	0.000003	ATSDR Minimal Risk Level (2021); EPA MCLG Summary (2023)
PFHxS	**Thyroid:** Thyroid follicular epithelial hypertrophy/hyperplasia in rats (Butenhoff *et al.*, 2009)	73.2 [a2]	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 [a1]	0.229	1.27	1000	0.001	EPA IRIS Assessment (2022)
PFHxA	**Developmental:** Decreased F1 body weight at PND 0 in rats (Loveless *et al.*, 2009)	10.6 [a1]	0.0045	0.048	100	0.0005	EPA IRIS Assessment (2023)

[a1] Dose concentration (mg/kg/day); [^a2] 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. *Selected by the Groundwater and Waste Management Committee on July 10, 2024, for rulemaking under Rule .0202(h).

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

NC Water Quality Standards Calculated Value

The derived value for the-groundwater standard calculated in accordance with Rule .0202 would be 0.9 ng/L (Table 1).

The calculated standard values are derived from the Cancer Slope Factor (CSF) of 39.5 mg/kg/day published by the EPA 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 was used to calculate the WQS, rather than the RfD that was derived from two human epidemiology studies, because 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 (EPA, 2024b)(Table 4). When the surface water and groundwater standards calculations are calculated using each the CSF and the RfD, the non-cancer RFD-based equation provides a slightly smaller value that is two one-hundredths of a ng/L less than the CSF-based value (Table 3; Appendix Section 6.3.1).

Either of the resulting health-based standards (CSF-based or RfD-based) are below the lowest quantifiable concentration or practical limit of analytical quantification (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 quantification (LOQ) for PFOS by Method 1633 ranges from 1 – 4 ng/L and has a percent recovery that ranges from 70% - 140%, which equates to approximately ± 29 % uncertainty or relative standard deviation (RSD) (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 a 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 MCL for PFOS of 4 ng/L (EPA, 2024a). This MCL value is greater than the calculated numerical standard would be using the RfD, and so the value derived from the RfD is provided in accordance with Rule .0202(d) (0.7 ng/L, Table 1).

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

NC Water Quality Standards Calculated Value

The derived value for the-groundwater standard calculated in accordance with Rule .0202 would be 0.001 ng/L (Table 1).

The calculated WQ standard values are derived from the Cancer Slope Factor (CSF) of 0.0000000293 mg/kg/day published by the EPA 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). The CSF-based water quality standards were selected because 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 (EPA, 2024b).

When the surface water and groundwater standards calculations are calculated using each the CSF and the RfD, the cancer CSF-based equation provides a value that is at least 2 orders of magnitude lower than the non-cancer RfD-based equation (Table 3, Appendix Section 6.3.2).

Either of the resulting health-based standards (CSF-based or RfD-based) are below the lowest quantifiable concentration or practical limit of analytical quantification (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 quantification (LOQ) for PFOA by Method 1633 ranges from 1 – 4 ng/L and has a percent recovery that ranges from 65% - 155%, which equates to approximately ± 27% uncertainty or relative standard deviation (RSD) (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 3.0×10^{-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 3.05×10^{-7} mg/kg/day and 2.92×10^{-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 3.0×10^{-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 (3.0×10^{-8} mg/kg/day) so 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 3.52×10^{-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 MCL for PFOA of 4 ng/L (EPA, 2024a). This MCL value is greater than the calculated numerical standard would be using the CSF, and so the value derived from the CSF is provided in accordance with Rule .0202(d) (0.001 ng/L, Table 1).

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

NC Water Quality Standards Calculated Value

The derived value for the-groundwater standard calculated in accordance with Rule .0202 would be 10 ng/L (Table 1).

The calculated standard values are derived from the Reference Dose (RfD) of 0.000003 mg/kg/day published by the EPA 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 selected 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 calculations that were used in the standards development equations are presented in Appendix 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 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 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 3×10^{-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.

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) with an MCL for HFPO-DA of 10 ng/L (EPA, 2024a). This MCL value is lesser than the calculated numerical standard would be using the RfD, and so the value derived from the MCL is provided in accordance with Rule .0202(d) (10ng/L; Table 1).

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

NC Water Quality Standards-Calculated Value

The derived value for the groundwater standard calculated in accordance with Rule .0202 would be 2,000 ng/L (Table 1).

The calculated standard values are derived from the Reference Dose (RfD) of 0.0003 mg/kg/day published by the EPA 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 selected 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 calculations that were used in the standards development equations are presented in Appendix A 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 3×10^{-4} mg/kg/day PFBS.

Cancer Slope Factor (CSF) Development

The EPA has not classified PFBS for carcinogenicity. The 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.

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 (EPA, 2024a). No individual maximum contaminant level has been established for PFBS, so the value derived from the RfD is provided in accordance with Rule .0202(d) (2,000 ng/L; Table 1).

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

NC Water Quality Standards Calculated Value

The derived value for the-groundwater standard calculated in accordance with Rule .0202 would be 20 ng/L (Table 1).

The calculated standard values are derived from the Reference Dose (RfD) of 0.000003 mg/kg/day published by the EPA in the Federal Register and in the ATSDR Toxicological Profile for Perfluoroalkyls as an intermediate Minimal Risk Level (MRL) (ATSDR, CDC, 2021; 88 FR 18667, 2023). This RfD was selected based on decreased body weight and developmental delays in mice (Das *et al.*, 2015) (Table 4). The calculations that were used in the standards development equations are presented in Appendix 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, CDC, 2021; 88 FR 18667, 2023). 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 x 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, CDC, 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.

$$MRL = NOAELHED \div (UFs \times MF)$$

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. The 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 Rule .0202(a)(2)(B).

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) with an MCL for PFNA of 10ng/L (EPA, 2024a). Since the MCL value is equal to the value derived from the RfD, value derived from the RfD is provided in accordance with Rule .0202(d) (10 ng/L; Table 1).

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

NC Water Quality Standards Calculated Value

The derived value for the-groundwater standard calculated in accordance with Rule .0202 would be 10 ng/L (Table 1).

The calculated standard values are derived from the Reference Dose (RfD) of 0.000002 mg/kg/day published by the EPA in the Federal Register and in the ATSDR Toxicological Profile for Perfluoroalkyls as an intermediate Minimal Risk Level (MRL) of 0.00002 mg/kg/day (ATSDR, CDC, 2021; 88 FR 18667, 2023). There is an order of magnitude difference between the ATSDR MRL and the EPA RfD, which is described in detail below. Both values were based on the same critical thyroid effects observed in rats (Butenhoff et al 2009a, Table 4). The calculations that were used in the standards development equations are presented in the Appendix 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, CDC, 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, CDC, 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, CDC, 2021; 88 FR 18667, 2023). 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 (88 FR 18667, 2023)(Table A-10).

Cancer Slope Factor (CSF) Development

The EPA and ATSDR have not classified PFHxS for carcinogenicity. The 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.

Maximum Contaminant Level (MCL) Information

In April 2024, the EPA established a National Primary Drinking Water Regulation (NPDWR) with an MCL for PFHxS of 10ng/L (EPA, 2024a). The MCL value is lesser than the value derived from the RfD, so the MCL value is provided in accordance with Rule .0202(d) (10 ng/L; Table 1).

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

NC Water Quality Standards Calculated Value

The derived value for the groundwater standard calculated in accordance with Rule .0202 would be 7,000 ng/L (Table 1).

The calculated standard values are derived from the Reference Dose (RfD) of 0.001 mg/kg/day published by the EPA in the *IRIS Toxicological Review of Perfluorobutanoic Acid (PFBA, CASRN 375-22-4) and Related Salts* (EPA, 2022b). This RfD was selected based on decreased thyroid hormones and increased liver weight and hypertrophy (Butenhoff *et al.*, 2012)(Table 4). The calculations that were used in the standards development equations are presented in Appendix 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, 2022b). 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, 2022b), 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. The 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.

Maximum Contaminant Level (MCL) Information

There is currently no MCL for PFBA in the NPDWR (EPA, 2024a), so the value derived from the RfD is provided in accordance with Rule .0202(d) (7,000 ng/L; Table 1).

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

NC Water Quality Standards Calculated Value

The derived value for the-groundwater standard calculated in accordance with Rule .0202 would be 4,000 ng/L (Table 1).

The calculated standard values are derived from the Reference Dose (RfD) of 0.0005 mg/kg/day published by the EPA in the *IRIS Toxicological Review of Perfluorohexanoic Acid [PFHxA, CASRN 307-24-4] and Related Salts* (EPA, 2023). This RfD was selected based developmental effects, specifically decreased postnatal weight, observed in a gestational 12/day oral exposure study in rodents (Loveless *et al.*, 2009) (Table 4). The calculations that were used in the standards development equations are presented in Appendix 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.

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

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.

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

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. The 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.

Maximum Contaminant Level (MCL) Information

There is currently no MCL for PFHxA in the NPDWR (EPA, 2024a), so the value derived from the RfD is provided in accordance with 15A NCAC 02L .0202(d) (4,000 ng/L; Table 1).

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6. Appendix

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). *Selected by the Groundwater and Waste Management Committee on July 10, 2024, for rulemaking under Rule .0202(h).

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: 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; 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.

[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; 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 - 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; 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 - 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, CDC, 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; 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.

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, CDC, 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, 2022b).

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-Resoponse 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 simlilar 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. Ground Water Quality Standards 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 Groundwater Standards.

6.3.1. PFOS 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorooctanesulfonic acid (PFOS)			CASRN 1763-23-1
North Carolina Ground Water (GW) Standard =	**0.7 ng/L***		
GW standard based on noncancer endpoint			
GWQS = [(RfD x WT x RSC) / WI] * 1000			
RfD = reference dose[1]	1.0E-07	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	**0.00070**	**µg/L (ppb)**	**0.7 ng/L (ppt)**
GW Standard based on cancer endpoint			
GWQS = [(RL x WT) / (q1* x WI)] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	70	kg	
q1* = carcinogenic potency factor (slope factor)[1]	39.5	$(mg/kg/day)^{-1}$	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using cancer endpoint	**0.0008861**	**µg/L (ppb)**	**0.89 ng/L (ppt)**
GW Standards based on published values			
Taste Threshold	**NA**	**µg/L**	
Odor Threshold	**NA**	**µg/L**	
Maximum Contaminant Level (MCL)[4]	**0.004**	**µg/L**	**4 ng/L (ppt)**
Secondary Drinking Water Standard (SMCL)	**NA**	**µg/L**	

References

[1] U.S. EPA. (2024). Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts. Office of Water. EPA Document Number: 815R24007. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfos_2024-04-09-refs-formatted_508c.pdf
[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).
[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).
[4] U.S. EPA. (2024). Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

*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
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.2. PFOA 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorooctanoic acid (PFOA) **CASRN 335-67-1**

North Carolina Ground Water (GW) Standard = 0.001 ng/L*

GW standard based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	3.0E-08	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	**0.00021**	**µg/L (ppb)**	**0.21 ng/L (ppt)**

GW Standard based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06		
WT = average adult human body weight[2]	70	kg	
q1* = carcinogenic potency factor (slope factor)[1]	0.0293	(ng/kg/day) $^{-1}$	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	0.001	µg/ng	
Calculated GW Standard using cancer endpoint	**0.0000012**	**µg/L (ppb)**	**0.0012 ng/L (ppt)**

GW Standards based on published values

Taste Threshold	NA	µg/L	
Odor Threshold	NA	µg/L	
Maximum Contaminant Level (MCL)[4]	0.004	µg/L	4 ng/L (ppt)
Secondary Drinking Water Standard (SMCL)	NA	µg/L	

References

[1] U.S. EPA. (2024). Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts, U.S. Environmental Protection Agency. Office of Water. EPA Document Number: 815R24006. https://www.epa.gov/system/files/documents/2024-04/main_final-toxicity-assessment-for-pfoa_2024-04-09-refs-formatted.pdf

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).

[4] U.S. EPA. (2024). Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

*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
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.3. HFPO-DA 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Hexafluoropropylene oxide dimer acid (HFPO-DA)	CASRN 13252-13-6
North Carolina Ground Water (GW) Standard =	**0.01 µg/L**

GW standard based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	3.0E-06	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard with noncancer endpoint	**0.021**	**µg/L (ppb)**	**21 ng/L (ppt)**

GW Standard based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06		
WT = average adult human body weight[2]	70	kg	
q1* = carcinogenic potency factor (slope factor)	NA	$(mg/kg/day)^{-1}$	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using cancer endpoint	**NA**	**µg/L (ppb)**	

GW Standards based on published values

Taste Threshold	**NA**	**µg/L**	
Odor Threshold	**NA**	**µg/L**	
Maximum Contaminant Level (MCL)[4]	**0.01**	**µg/L**	**10 ng/L (ppt)**
Secondary Drinking Water Standard (SMCL)	**NA**	**µg/L**	

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] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).
[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).
[4] U.S. EPA. (2024). Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

ppb= parts per billion
ppt= parts per trillion
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.4. PFBS 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorobutane sulfonic acid (PFBS) — **CASRN 375-73-5**

North Carolina Ground Water (GW) Standard = 2 µg/L*

GW standard based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	3.0E-04	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	**2.1**	**µg/L (ppb)**	**2100 ng/L (ppt)**

GW Standard based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)	NA	$(mg/kg/day)^{-1}$
WI = average daily adult human water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW Standard using cancer endpoint	**NA**	**µg/L (ppb)**

GW Standards based on published values

Taste Threshold	NA	µg/L
Odor Threshold	NA	µg/L
Maximum Contaminant Level (MCL)[4]	NA	µg/L
Secondary Drinking Water Standard (SMCL)	NA	µg/L

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 Research and Development (ORD) Center for Public Health and Environmental Assessment (CPHEA).

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).

[4] U.S. EPA established a unitless Hazard Index approach to regulate for mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS. No individual MCL has been established for PFBS; U.S. EPA. (2024). Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

*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
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.5. PFNA 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorononanoic acid (PFNA)			CASRN 375-95-1
North Carolina Ground Water (GW) Standard =	**0.01 µg/L**		
GW standard based on noncancer endpoint			
GWQS = [(RfD x WT x RSC) / WI] * 1000			
RfD = reference dose[1]	3.0E-06	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	**0.021**	**µg/L (ppb)**	**21 ng/L (ppt)**
GW Standard based on cancer endpoint			
GWQS = [(RL x WT) / (q1* x WI)] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	70	kg	
q1* = carcinogenic potency factor (slope factor)	NA	$(mg/kg/day)^{-1}$	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using cancer endpoint	**NA**	**µg/L (ppb)**	
GW Standards based on published values			
Taste Threshold	NA	µg/L	
Odor Threshold	NA	µg/L	
Maximum Contaminant Level (MCL)[4]	0.01	µg/L	10 ng/L (ppt)
Secondary Drinking Water Standard (SMCL)	NA	µg/L	

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] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).
[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).
[4] U.S. EPA. (2024). Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

ppb= parts per billion
ppt= parts per trillion
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.6. PFHxS 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorohexane sulfonate (PFHxS)			CASRN 355-46-4
North Carolina Ground Water (GW) Standard =	**0.01 µg/L***		
GW standard based on noncancer endpoint			
GWQS = [(RfD x WT x RSC) / WI] * 1000			
RfD = reference dose[1]	2.0E-06	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	0.01	µg/L (ppb)	14 ng/L (ppt)
GW Standard based on cancer endpoint			
GWQS = [(RL x WT) / (q1* x WI)] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	70	kg	
q1* = carcinogenic potency factor (slope factor)	NA	$(mg/kg/day)^{-1}$	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using cancer endpoint	NA	µg/L (ppb)	
GW Standards based on published values			
Taste Threshold	NA	µg/L	
Odor Threshold	NA	µg/L	
Maximum Contaminant Level (MCL)[4]	0.01	µg/L	10 ng/L (ppt)
Secondary Drinking Water Standard (SMCL)	NA	µg/L	

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] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).

[4] U.S. EPA. (2024). Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation. https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

*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
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.7. PFBA 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorobutanoic Acid (PFBA)			CASRN 375-22-4
North Carolina Ground Water (GW) Standard =	**7 µg/L***		
GW standard based on noncancer endpoint			
GWQS = [(RfD x WT x RSC) / WI] * 1000			
RfD = reference dose[1]	1.0E-03	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	7	µg/L (ppb)	7000 ng/L (ppt)
GW Standard based on cancer endpoint			
GWQS = [(RL x WT) / (q1* x WI)] * 1000			
RL = risk level	1.0E-06		
WT = average adult human body weight[2]	70	kg	
q1* = carcinogenic potency factor (slope factor)	NA	$(mg/kg/day)^{-1}$	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using cancer endpoint	NA	µg/L (ppb)	
GW Standards based on published values			
Taste Threshold	NA	µg/L	
Odor Threshold	NA	µg/L	
Maximum Contaminant Level (MCL)	NA	µg/L	
Secondary Drinking Water Standard (SMCL)	NA	µg/L	

References

[1] U.S. EPA. (2022). Integrated Risk Information System (IRIS) Toxicological Review of Perfluorobutanoic Acid (PFBA, CASRN 37522-4) and Related Salts. Office of Research and Development. EPA/635/R-22/277Fa. https://iris.epa.gov/static/pdfs/0701tr.pdf
[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).
[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).

*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
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

6.3.8 PFHxA 02L Numerical Standard Calculations

North Carolina Groundwater Standard

Perfluorohexanoic Acid (PFHxA) CASRN 307-24-4

North Carolina Ground Water (GW) Standard = 4 µg/L*

GW standard based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	5.0E-04	mg/kg/day	
WT = average adult human body weight[2]	70	kg	
RSC= relative source contribution	0.2	unitless value	
WI = average daily adult human water intake[3]	2	L/day	
1000 = conversion factor	1000	µg/mg	
Calculated GW Standard using noncancer endpoint	**3.5**	**µg/L (ppb)**	**3500 ng/L (ppt)**

GW Standard based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)	NA	$(mg/kg/day)^{-1}$
WI = average daily adult human water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW Standard using cancer endpoint	**NA**	**µg/L (ppb)**

GW Standards based on published values

Taste Threshold	NA	µg/L
Odor Threshold	NA	µg/L
Maximum Contaminant Level (MCL)	NA	µg/L
Secondary Drinking Water Standard (SMCL)	NA	µg/L

References

[1] U.S. EPA. (2023). Integrated Risk Information System (IRIS) Toxicological Review of Perfluorohexanoic Acid (PFHxA) and Related Salts. National Center for Environmental Assessment, Office of Research and Development. https://iris.epa.gov/static/pdfs/0704tr.pdf
[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2022).
[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2022).

*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
NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

Appendix B: Proposed Plan for Addressing PFAS Impacts to Groundwater at DWM-Regulated Sites Under Existing Regulations

Proposed Plan for Addressing PFAS Impacts to Groundwater at DWM-Regulated Sites Under Existing Regulations
August 14, 2024

The NC Department of Environmental Quality's (DEQ) Division of Waste Management (DWM) regulates both permitted facilities that have the potential to release per- and polyfluoroalkyl substances (PFAS) directly or indirectly to groundwater in NC, and also contaminated sites where PFAS contamination of groundwater may have occurred (e.g., inactive hazardous sites, pre-regulation sites, or illegal dumping sites). To what degree waste management facilities contribute to PFAS contamination of groundwater is not well understood since PFAS have not been required to be monitored in groundwater, either before the waste management facility was constructed to establish baseline groundwater quality, or historically after a facility has initiated management of waste. Also, initial site evaluations at contaminated sites to determine the types and extent of contamination had not historically included sampling and analysis for PFAS in those evaluations. Initial investigations and monitoring are necessary to understand the sources and levels of PFAS contamination in groundwater, including DWR's ambient monitoring well network. DWM intends to require these investigations to understand the impacts of PFAS on groundwater under the existing rules, even in the absence of the proposed amendment to regulatory limits for PFAS.

The existing requirements in 15A NCAC 02L .0202 state that "substances which are not naturally occurring and for which no standard is specified shall not be permitted in concentrations at or above the practical quantitation limit…." Therefore, PFAS have an existing regulatory limit in groundwater, the PQL, which allows DEQ to require monitoring and remediation for PFAS detected above the PQL in groundwater under existing regulations. The proposed rule amendment to add groundwater quality standards for PFAS to Rule .0202(h) would only change the regulatory limit at which three PFAS, PFOA, PFOS, and GenX are considered a violation of the standards, and the target cleanup level where any of those three PFAS are the driver for remediation. While developing proposed PFAS groundwater standards and the subsequent effects on waste management facilities and sites under remediation, an implementation plan was developed to better understand the steps that will be taken in compliance with the existing rules in 15A NCAC 02L .0100 and .0200 to address potential PFAS contamination in groundwater.

For PFOA and PFOS, the proposed standards are lower than the existing PQL. Rule .0202 states that, where the standard is lower than the PQL, the PQL is implemented as the regulatory limit. Throughout this plan, wherever implementation of the proposed standard is mentioned, for PFOA and PFOS the effective regulatory limit that will be implemented will continue to be the PQL, until or unless the PQL falls below the proposed standard.

1. Potential DWM Source Evaluation

DWM's programs outlined below will be evaluated in the implementation plan to determine potential sources of PFAS groundwater contamination:

(i) Hazardous Waste Contaminated Sites
(ii) Superfund Remediation of Contaminated Sites
(iii) UST Petroleum Spill and Contaminated Soil Remediation Sites
(iv) Brownfields Agreements
(v) Solid Waste Sanitary Landfill Routine Monitoring (per rule) and Remediation

2. Implementation Strategy Under Existing Rules

The implementation steps outlined below will generally be followed at most remediation sites regulated by DWM in compliance with the existing rules in 15A NCAC 02L .0100 and .0200 to address potential PFAS contamination in groundwater. Further program-specific details for each DWM program can be found in Item 4 of this plan below. The intended outcome of this plan will be to remediate PFAS at the sites regulated by DWM that are the most likely to be sources contributing to PFAS contamination of groundwater to minimize the presence of PFAS in groundwater, which will reduce the exposure to private drinking water wells and ecological receptors, and limit potential exposure through recreational activities for all North Carolinians.

a. DEQ will identify existing sites where PFAS contamination is likely to have occurred by reviewing and utilizing existing site history and status information and monitoring data in comparison with the list of priority industry types for PFAS impacts published by the EPA.
b. DEQ will require initial monitoring (e.g., one or two events) for PFAS at the sites identified in the review to determine if PFAS contamination has occurred. Written notice of the required sampling will be sent to these sites, with a deadline for submittal of analysis results (e.g., within a year of receipt of the notice).
c. If PFAS is found in exceedance of the 02L regulatory limit (either the PQL or the proposed standard, if adopted), DEQ will follow the existing requirements for the protection of groundwater under existing 15A NCAC 02L Sections .0100 and .0200 and other existing applicable waste management regulations under 15A NCAC Chapters 02 and 13 as follows:
    i. DEQ will require the site representatives for permitted facilities to update the receptor survey that would have initially been done during the permitting process to identify risks to off-site receptors (e.g., review nearby private wells, surface water). A similar receptor survey will be required for other DWM-regulated sites where it has not previously been conducted. DEQ will conduct this step directly if there are no site representatives or site responsible party (e.g., some inactive hazardous sites).
    ii. DEQ will require the site representatives to sample and analyze receptors for PFAS if warranted. DEQ may conduct this step directly if there are no site representatives or site responsible party.
    iii. DEQ will review receptor analysis results and determine whether any immediate actions are necessary for the protection of public health or the environment.
    iv. DEQ will work with the site representatives to attempt to determine whether the site activity was the source of the PFAS exceedance.
    v. Where an activity can be identified as the source at a permitted waste management facility, DEQ may require changes to allowed activities or accepted waste types or sources in the permit to prevent further contamination.
    vi. If warranted, DEQ may require the site representatives to conduct assessment monitoring to determine the extent of contamination, prioritizing off-site contamination. DEQ may conduct this step directly if there are no site representatives or site responsible party.
    vii. If warranted, DEQ may require site representatives to conduct remediation of PFAS until remediation requirements have been met, which could be the requirements outlined in:

- 15A NCAC 02L existing Section .0100 and existing (or proposed, if adopted) regulatory limits in .0200;
- the existing risk-based remediation requirements under Chapter 130A or 143 of the General Statutes, where applicable as outlined in those statutes;[1]
- other existing program-specific remediation requirements adopted thereunder in 15A NCAC Chapters 02 or 13, and/or
- other requirements in site-specific permits, agreements, or orders in accordance with the applicable regulations.

DEQ may conduct this step directly if there are no site representatives or site responsible party.

3. Implementation Timeline

- In 2023, all programs under DWM initiated the review of existing sites in comparison with the list of priority industry types for PFAS impacts published by the EPA, and notifying sites that are required to conduct initial monitoring of PFAS. This review is expected to be complete by the end of 2024. For example, a memo was sent to solid waste sanitary landfills in March 2023 (updated July 2023) requiring initial PFAS monitoring for two monitoring events (see Item 4.3 below for further details).
- DWM expects to have completed Steps a and b in Item 2 above by the end of 2026 (identification of existing sites where PFAS contamination is likely and any initial monitoring of those sites to determine if PFAS contamination has occurred).
- Step c of Item 2 above, where PFAS contamination will have been identified, is expected to begin in 2026 or 2027, with the exception that any immediate actions needed under Step c(iii) will be required immediately upon identifying the need.
- The timeline for completion of Step c at each PFAS-contaminated site will vary by site and will depend on site-specific factors, and therefore cannot be predicted at this time.

4. Program-Specific Implementation

4.1. Contaminated Site Remediation Regulated by the Hazardous Waste, Superfund, and Underground Storage Tank Sections

Contaminated sites, once identified, must be remediated for any substance that occurs in groundwater as a result of the anthropogenic activity that caused the contamination according to 15A NCAC 02L .0106. Substances that are not naturally occurring and for which no numeric standard is specified in 15A NCAC 02L .0202(h) are a violation of the standards at concentrations at or above the practical quantitation limit according to 15A NCAC 02L .0202(c). At contaminated sites regulated by the DWM Hazardous Waste (Facility Management Branch), Superfund (Federal Remediation and Inactive Hazardous Sites (IHS) Branch), and Underground Storage Tank (Corrective Action Branch - Soil Remediation) Sections, monitoring and remediation is required for groundwater contamination caused by activities at the site. Monitoring and remediation are conducted by either the site representatives or by DEQ, depending on the program, circumstances, and funding.

[1] An example of existing statutes governing risk-based remediation procedures for some DWM programs can be found in G.S. 130A Article 9, Part 8. Other statutes in Chapters 130 and 143 may contain similar risk-based remediation procedures applicable to other DWM programs.

The goal for clean-up may be a groundwater quality standard or the regulatory limit at the PQL established under 15A NCAC 02L .0202 as applicable. Another option is to clean up the site to meet requirements for risk-based remediation in the General Statutes. The determination regarding which compounds to monitor and remediate at the site is not determined by whether a compound has a groundwater quality standard established under 15A NCAC 02L .0202(h) under existing rule. 15A NCAC 02L .0106(b) – (e) outlines the requirements for remediation, depending on the circumstances. In general, the responsible party, or DEQ where no responsible party exists or can be identified, must monitor and/or conduct remediation for exceedances of the regulatory limit from a release or discharge caused by an activity conducted or controlled by the responsible party.

When DEQ is evaluating a newly-identified contaminated site to identify constituents for which remediation is required, the site use history and the cause of contamination would be reviewed to determine if a prior site use was a type of industry or incident where PFAS may have been used and/or released, using the EPA guidance outlining priority industries where PFAS was likely used in their process and/or may have generated waste containing PFAS. Monitoring and remediation for PFAS would be required if the waste management site is suspected to be the source of the PFAS contamination. DEQ also expects to revisit existing sites where remediation is currently being conducted to review the site use history and the cause of contamination to determine if PFAS may have been used or released at the site, similar to new sites. Note again that this is the existing plan for addressing PFAS contamination at the existing regulatory limit of the PQL. Therefore, the only impact to this plan that would be caused by the amendment to 15A NCAC 02L .0202 is to change the regulatory limit from the PQL to the new adopted standard, where applicable. It is not the intention of DEQ at this time to revisit sites where remediation has been completed, where this decision is at the discretion of DEQ. For information regarding Superfund/CERCLA sites that were closed under federal requirements, see EPA's PFAS Enforcement Discretion and Settlement Policy Under CERCLA issued April 19, 2024.[2]

4.2. Brownfields Redevelopment

Because site remediation for sites being considered under the Brownfields Redevelopment Section is handled by the Superfund Section IHS Branch, implementation of the regulatory limits for remediation would be as described for IHS contaminated sites in Item 4.1. From the standpoint of the prospective developer, this is a voluntary program, and it is in their best interests to sample and analyze for PFAS where it is suspected to be present as a contaminant as a part of negotiating the Brownfields agreement to ensure that they have liability protection for PFAS contamination in the future. Analysis for PFAS is already being conducted under existing rules for sites where it is suspected to be present. To make a determination for new applications as to whether analysis for PFAS would be required for each brownfields agreement application, the site use history would be reviewed to determine if a prior site use was a type of industry where PFAS may have been used or released, utilizing the EPA guidance outlining priority industries where PFAS was likely used in their process and/or may have generated waste containing PFAS.

[2] EPA (2024) "PFAS Enforcement Discretion and Settlement Policy Under CERCLA" Available at: https://www.epa.gov/system/files/documents/2024-04/pfas-enforcement-discretion-settlement-policy-cercla.pdf (Accessed: 16 May 2024).

Existing brownfields agreements are tracked by the Property Management Unit in the Section. Existing agreements have already been signed and are being implemented, and in many cases development of the site may be complete. The applicant has the right to request to amend an effective agreement to attempt to add PFAS as a constituent for which they could have liability protection. However, it would be difficult for the developer or DEQ to determine if any PFAS contamination found after development begins was caused by the prior responsible party, or the current development at the site. Therefore, it is unlikely that DEQ would be able to amend the existing agreement to include liability protection for PFAS.

4.3. Solid Waste Sanitary Landfills

Groundwater Monitoring for Landfills Under the Authority of 15A NCAC 13B .0531 - .0546 and Section .1600

Under the existing rules in 15A NCAC 13B Rules .0531 - .0546 and Section .1600, non-hazardous solid waste sanitary landfills are required to monitor groundwater for a list of constituents established in 15A NCAC 13B Rules .0531 - .0546 and Section .1600 on a routine basis, generally either annually or semi-annually. The purpose of this routine monitoring is to determine whether a release of leachate has occurred at the facility that could cause contamination of groundwater or other media. The constituent list for routine monitoring is established under federal law for municipal solid waste (MSW) landfills and incorporated into the above-mentioned State rules by reference. The constituent list was selected at the federal level based on which constituents are known to be indicator parameters of a release of leachate to groundwater. In general, if the levels of indicator parameters are observed to be increasing above baseline or established background levels, this can indicate a potential release of leachate from the landfill. The presence of any contaminant is not necessarily direct evidence of a release from that facility, and the facility owner or operator has the ability to demonstrate that the source of a contaminant is not the landfill facility.

If a release of leachate from the facility is suspected, DEQ requires that a facility conduct assessment monitoring to further support or refute that suspicion, and, if confirmed, to determine what constituents may have been released to groundwater and the extent of contamination. The list of constituents required to be monitored for assessment purposes contains more constituents than the routine list, and it is also established in federal law for MSW landfills and incorporated into the above-mentioned State rules by reference. If a leachate release is determined to have caused an exceedance of the regulatory limit in groundwater, a landfill facility would be required to take corrective action to remediate the contaminant plume, with continued monitoring to assess performance of the remediation method selected.

The current proposed amendment to change the regulatory limit in groundwater for three PFAS from the PQL to specific groundwater quality standards does not automatically require analysis for PFAS at existing sanitary landfills that are regulated by 15A NCAC 13B Rules .0531 - .0546 and Section .1600 during routine monitoring at sites where PFAS is not detected above the PQL in groundwater. If PFAS were to be added to the routine detection monitoring list at sites where PFAS is not detected, an amendment to the rules in 15A NCAC 13B Rules .0531 - .0546 and Section .1600 would make that change for the

purpose of clarification, and a fiscal analysis of that change would be done as a part of that rulemaking action. Note that DEQ has existing authority under G.S. 143-215.1(a) and 15A NCAC 02L .0100 to require analysis of additional constituents to determine compliance with 15A NCAC 02L .0100 and .0200 if a release of waste/leachate is suspected to have occurred or is found to have occurred. Under existing rule, the regulatory limit is the PQL for PFAS. DEQ would continue to have this authority if the proposed amendment does not become effective. However, DWM could also address PFAS monitoring requirements via rulemaking for transparency and clarification for the regulated community.

A determination as to how the landfill rules may be revised is expected to be made after the initial landfill monitoring results for PFAS have been evaluated by DWM. Any future rulemaking to add these PFAS to the monitoring list would provide the benefit of clarification of the requirements for the regulated community and may clarify steps that the owner/operator may take to determine the source of any PFAS detected, and any corrective actions necessary. The fact that there are no baseline groundwater sampling results for PFAS at existing landfills and some PFAS have been detected in ambient groundwater monitoring wells complicates the determination of whether a detection of PFAS was caused by the landfill or some other source.

For new solid waste sanitary landfill units that fall under the authority of 15A NCAC 13B Rules .0531 - .0546 and Section .1600, either at an existing facility or at a new facility, where initial waste placement has not yet occurred at a new phase or "cell", a future rulemaking may also be needed for analysis of PFAS during baseline sampling to determine what constituents were present in groundwater prior to waste placement (and therefore were not caused by the landfill). However, DWM recommends that initial baseline monitoring of groundwater for any new well installed for new landfills or expansions of existing landfills include analysis for PFAS. It is in the best interests of the owner or operator to do so, to be able to provide evidence as either background or baseline of any PFAS in the groundwater that may be present prior to waste placement. The results would provide a baseline level to compare future PFAS detections against for compliance once the landfill becomes operational. Again, this baseline sampling for PFAS is a recommendation that is being made under existing rules, regardless of whether the proposed groundwater quality standards for the three PFAS in the current rulemaking action become effective.

<u>Landfills Under the Authority of 15A NCAC 13B .0503 - .0505, .0510, and .0601 for Groundwater Monitoring</u>

For solid waste sanitary landfill units that fall under the authority of 15A NCAC 13B .0503 - .0505, .0510, and .0601 for groundwater monitoring, DWM requires groundwater monitoring for the same list of Appendix I constituents in federal CFR that are required for landfills that fall under 15A NCAC 13B Rules .0531 - .0546 and Section .1600. Because most of these landfills were constructed and/or accepted waste prior to the newer federal and state requirements becoming effective, the detection and assessment monitoring requirements in Rules .0531 - .0546 and Section .1600 are not directly applicable. Also, because industrial landfills are permitted to only accept a specific type of industrial waste from particular industrial facilities, their monitoring list can be

customized to be specific to that waste. Rule .0601 requires that landfills comply with the requirements of 15A NCAC 02L. The routine "detection" monitoring list for landfills under Rule .0601 is not based on the list of specific numeric groundwater quality standards established in 15A NCAC 02L Rule .0202(h). The monitoring list is meant to be consistent with the federal Appendix I monitoring list. If PFAS contamination in groundwater is suspected, analysis would be required under existing rules, with the regulatory limit being the PQL per 15A NCAC 02L .0202(c). The majority of these landfills are unlined. Closed landfills are capped to prevent additional leachate generation.

5. Changes to DWM's Plan for Addressing PFAS Impacts to Groundwater if the Proposed Amendment to 15A NCAC 02L .0202 Becomes Effective

If the proposed amendment to 15A NCAC 02L .0202 to include groundwater quality standards for three PFAS becomes effective according to the proposed rulemaking schedule, the proposed groundwater standards would become effective immediately upon the rule amendment becoming effective. Where the standard is higher than the PQL, the new standard would apply. Where the standard is at or below the PQL, the regulatory limit in groundwater would continue to be the PQL (no change). The proposed plan for DWM to address PFAS impacts to groundwater described above would not change as a result of the rule amendment. The only change may be in minor benefits to the outcomes for individual sites that fall under a specific set of circumstances described in the regulatory impact analysis for the proposed GenX groundwater quality standard.

Appendix C: Brown and Caldwell Technical Memorandum: General Methodology Used to Determine PFAS Treatment Cost for Groundwater

Technical Memorandum

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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 2L Standards)

Project No.: 195202

Technical Memorandum

Subject: Draft General Methodology Used to Estimate Potential PFAS Treatment Costs for Contaminated Groundwater (2L) - UPDATED

Date: May 16, 2024

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

This is a draft memorandum and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It should not be relied upon; consult the final report.

This document was prepared solely for North Carolina Department of Environmental Quality in accordance with professional standards at the time the services were performed and in accordance with the contract between North Carolina Department of Environmental Quality and Brown and Caldwell dated November 6, 2023. This document is governed by the specific scope of work authorized by North Carolina Department of Environmental Quality; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by North Carolina Department of Environmental Equality and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 1: Introduction

The North Carolina Department of Environmental Quality (NCDEQ) and North Carolina Office of Strategic Partnerships (OSP) are interested in identifying methods to minimize and treat per- and polyfluoroalkyl substances (PFAS) in groundwater and to estimate potential costs for PFAS management. Results of the evaluation would be used to determine potential economic impacts of proposed rules implementing groundwater quality standards (Title 15A of the North Carolina Administrative Code, Subchapter 2L) that could regulate certain PFAS compounds.

PFAS comprise of a large group of synthetic chemicals that can be present in multiple media including water, soil, air, and consumer products. PFAS can be present in groundwater due to releases from fire-fighting activities, spills or other waste disposal activities. Both long-chain (e.g., C7 (7 carbon atoms) and higher and short-chain (e.g., C6 and lower) compounds may be present in groundwater based on NCDEQ information. Long-chain PFAS such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), commonly referred to as legacy PFAS, are the most studied PFAS compounds. Fate and reactivity of short-chain PFAS compounds such as perfluorohexane sulfonic acid (PFHxS), GenX and other degradation products from more complex PFAS are less known. PFAS compounds are a concern to NCDEQ due to potential adverse health impacts. For this evaluation, different treatment technologies were evaluated to remove PFAS from various contaminated water streams. 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 requires 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 water streams that contain short-chain PFAS, treatment technologies, such as IX and RO, are known to be more effective compared to the others. Note that these technologies primarily separate PFAS from the bulk water stream but do not degrade or transform the concentrated compounds. 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 groundwater may be informed by estimating associated cost for different treatment options or categories that are applicable to multiple sites with similar characteristics. Employing these treatment options for a general scenario described in the next section, were used to establish the basis needed to develop the cost estimates. The capital expenditure (CAPEX) required to build the necessary treatment system and the operation expenditure (OPEX) needed to operate and maintain the system were estimated for each given case. This technical memorandum describes the general methodology used by Brown and Caldwell (BC) to develop the cost estimates and presents the resulting cost curves that can be used to predict potential costs for PFAS treatment in contaminated groundwater. 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 Treatment Cost Estimate

Based on a series of discussions with NCDEQ staff, different treatment options were evaluated for a given Division of Waste Management (DWM) facility with the following assumptions:

- at least one of the regulated PFAS compounds is detected above the proposed standards in groundwater and is the cause for the need to remediate
- groundwater extraction and treatment is the selected treatment approach
- there is no pump and treat system currently on site
- pretreatment filtration system is necessary to reduce solids and metals
- treated effluent would be directly discharge (i.e., via NPDES)
- the treatment system flow rate is assumed to be between 2,000 gallons per day (GPD) up to 30,000 GPD.

The PFAS treatment options evaluated for cost estimating were GAC, IX and GAC followed by IX (GAC-IX) (Table 1). As previously mentioned, these 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. In general, these treatment technologies are able to treat up to non-detect levels (< 1 nanogram per Liter [ng/L]) for most common long chain and short chain PFAS at optimal operating conditions.

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 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.

Typical schematics of these different treatment trains are shown in Figures 1 through 3. Dual (lead-lag) system was employed and recommended for effective PFAS removal. Note that because groundwater quality may vary from site to site, pretreatment steps via filtration (cartridge and green sand filtration) were included as part of each treatment train based on the potential need to remove solids and metals prior to PFAS removal.

PFAS removed from the groundwater are concentrated in media are then destroyed using high-temperature incineration of the spent media as part of residuals management. Disposal of spent media via landfilling was not considered given recent information that suggests a significant fraction of adsorbed PFAS may desorb from the media in a landfill environment.

Additional storage and pumping equipment were added to each system to account for a new pump and treat system. Costs for well installation and well maintenance were excluded from the CAPEX and OPEX estimates since extraction well requirements (and associated costs) for pump and treat systems are often site-specific. Examples of potential order-of-magnitude add-on costs for well installation and well maintenance are provided in Attachments A and B.

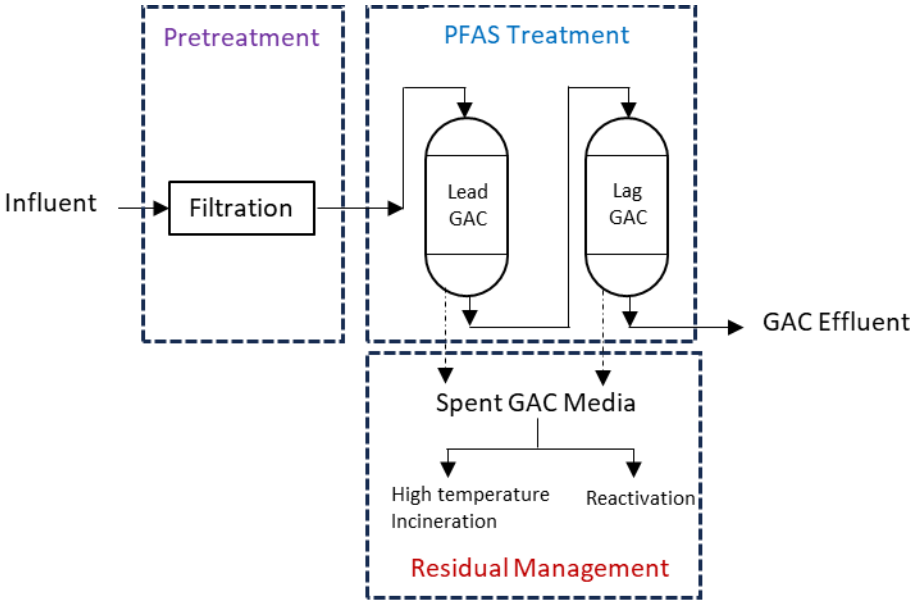


Figure 1. Filtration and Granular Activated Carbon (GAC) Treatment for PFAS Removal

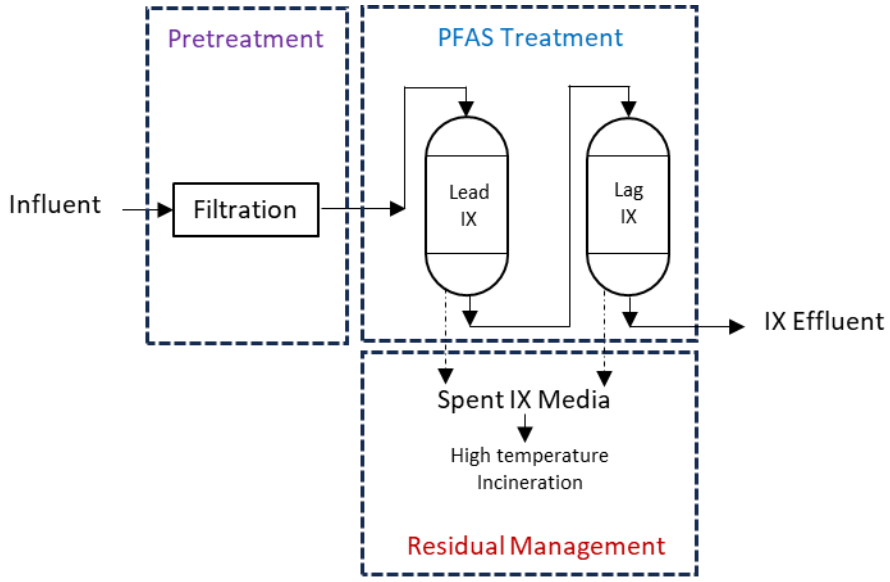


Figure 2. Filtration and Ion Exchange (IX) Treatment for PFAS Removal

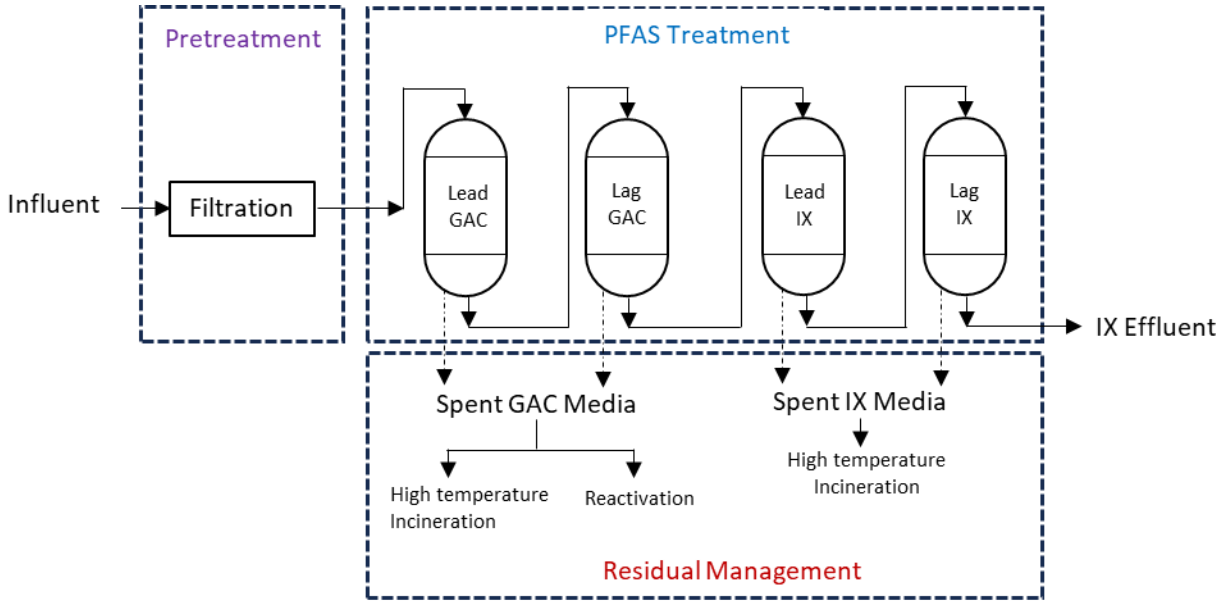


Figure 3. Filtration followed by Granular Activated Carbon and Ion Exchange for PFAS Removal

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 Association for the Advancement of Cost Engineering International (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 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 six-tenths 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 specific scaling index for the particular process

(Remer (1990) and Chilton (1950)). When necessary, an n+1 redundancy was included in the equipment costing to provide backup to on-duty equipment (i.e., pumps).

The recommended treatment train is assumed to be solely for PFAS treatment at the management site. It was assumed that there is enough electrical power for new equipment and that there is sufficient land onsite to accommodate added footprint for new treatment system installation. Further, onsite soil was presumed to be of adequate nature and not require remediation due to soil contamination to 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 generally within recommended ranges based on Peters et al. (2002) but some have been adjusted based on current industry practice or modified 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 30 percent was applied to these costs to cover unknowns.

Table 2. Cost Markups 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	15	Installation of all equipment listed on complete flow sheet, structural supports, insulation, paint
Instrumentation and Controls (Installed)	8	Purchase, installation, calibration, computer tie-ins
Piping (Installed)	10	Process piping, pipe hangers, fittings, valves, insulation, equipment
Electrical systems (installed)	10	Electrical equipment, switches, conduit, wire, fittings, feeders, grounding, lighting, panels, etc.
Yard Improvements	5	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	15	Engineering cost-administrative, process, design and general engineer, drafting, cost engineering, procuring, expediting, reproduction, communications, scale models, consultant fees, travel.
Legal Expenses, Permits	1	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	10	Costs associated with general contractor's overhead (tools, resources, equipment) pertaining to site management, material handling, project management, etc.
Contingency	30	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 Maintenace Cost Estimating Cost Assumptions

Cost Item	Value	Unit
Equipment Maintenance	3%	% of Equipment Cost
Building Maintenance	$2.50	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 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. Because representative groundwater water quality data were unavailable for all of the scenarios evaluated above, design criteria and treatment performance 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	15,700[1]
IX media empty bed contact time (EBCT) requirement	4 mins
Number of IX bed volumes prior to PFAS contaminant breakthrough	20,000[1]

Note:

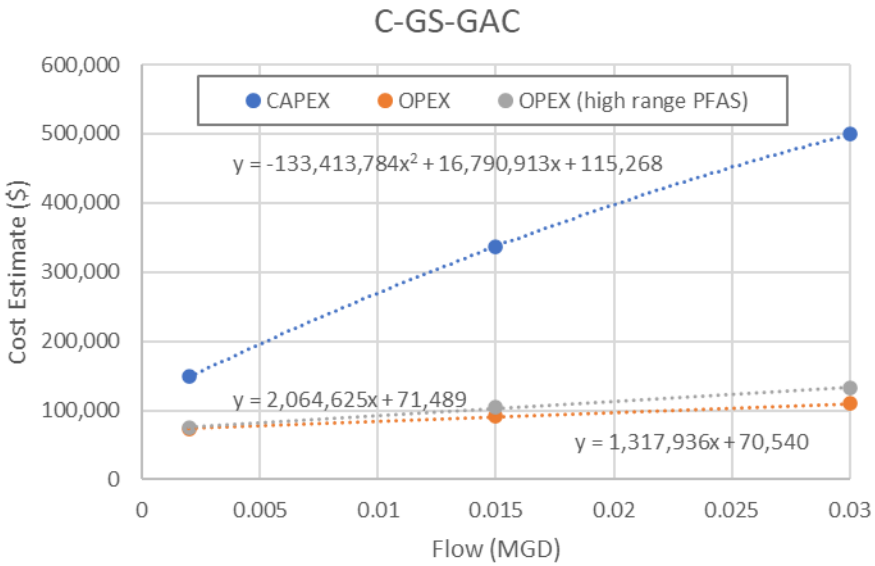
1. *In determining media replacement frequency for highly contaminated-PFAS groundwater, the bed volumes prior to media breakthrough are hypothetically assumed to be half of the specified literature value.*

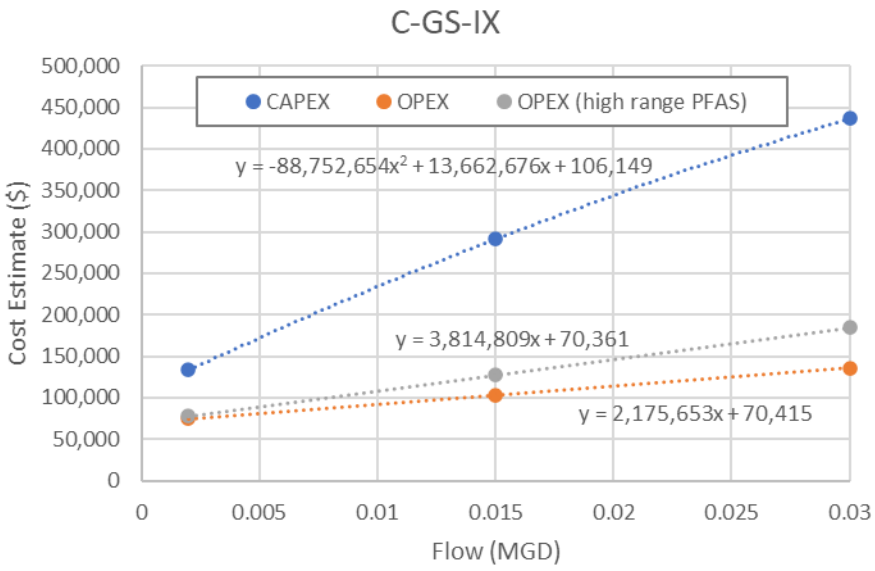
Section 3: Cost Curves for Estimating Cost Impacts

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 values. A summary of the cost estimates is presented in Table 4 and the resulting cost curves are presented in Figure 4.

Table 5. Summary of PFAS Treatment Cost for Groundwater													
PFAS Treatment	Recommended for:	Flow, MGD	CAPEX, $	CAPEX $ per gallon	OPEX, $	OPEX Unit cost (daily) $ per 1000 gallon	CAPEX Cost Curve			OPEX Cost Curve		OPEX Cost Curve (High PFAS concentration)**	
							A	B	C	D	E	F	G
Cartridge (C) and Green sand (GS) Filtration-GAC	Long-chain PFAS with typical groundwater contaminants, if present	0.002	$148,000	$74	$73,000	$100	-133,413,784	16,790,913	115,268	1,317,936	70,540	2,064,625	71,489
		0.015	$337,000	$22	$91,000	$17							
		0.03	$499,000	$17	$110,000	$10							
C and GS Filtration-IX	Preferred (but not required) for combination of long- and short-chain PFAS and PFAS is the only contaminant	0.002	$133,000	$67	$75,000	$103	-88,752,654	13,662,676	106,149	2,175,653	70,415	3,814,809	70,361
		0.015	$291,000	$19	$103,000	$19							
		0.03	$436,000	$15	$136,000	$12							
C and GS Filtration-GAC-IX	Preferred (but not required) for high concentration of long-chain PFAS combined with short-chain PFAS, and with typical groundwater contaminants, if present	0.002	$184,000	$92	$78,000	$107	-240,287,039	21,506,758	142,005	2,281,597	73,415	4,026,696	74,363
		0.015	$411,000	$27	$108,000	$20							
		0.03	$571,000	$19	$142,000	$13							
Note:							*CAPEX = A*(MGD Flow^2)+B*(MGD Flow)+C*			*OPEX = D*(MGD Flow)+E*		*OPEX = F*(MGD Flow) +G*	

***The estimated bed volume prior to breakthrough is assumed to decrease by 50% due to higher PFAS concentration.*





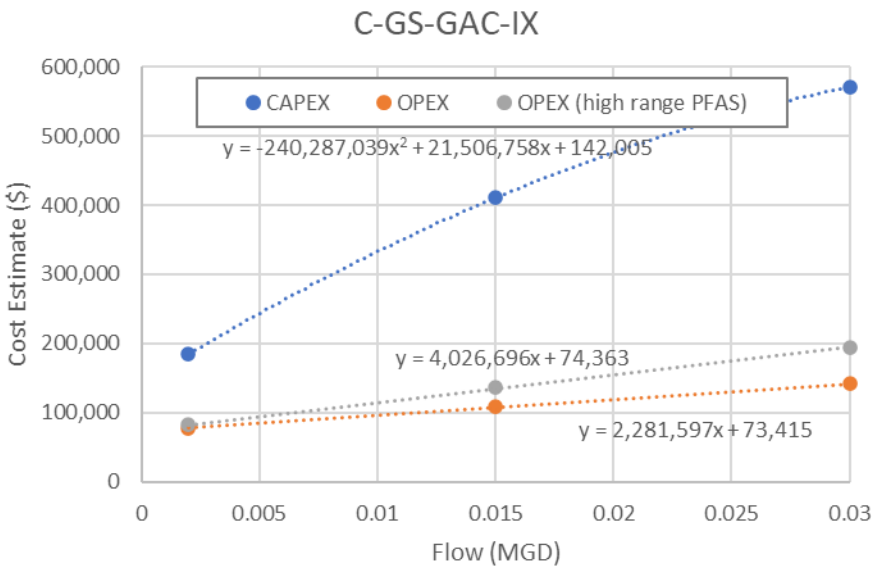


Figure 4. CAPEX and OPEX Cost Curves for granular activated carbon (GAC), ion exchange (IX) and granular activated carbon followed by ion exchange (GAC-IX) treatment trains with pretreatment (cartridge (C) and green sand (GS) filtration).

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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-ip engineering equipment”, *Chemical Engineering Progress*. 77.

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Attachment A: Example of Well Installation and Maintenance Costs (25-foot well)

Well Installation/Drilling Cost (25-foot well)			
Cost Items	Cost ($)	# of Units	Total Cost ($)
Concrete saw cut/hole	100	1	100
Sonic/mobe	1,500	1	1,500
Sonic/day	4,000	0.5	2,000
4" Schedule 80 PVC	20	25	500
Well box	250	1	250
55-gallon drums	50	3	150
Drill rig dev/hr	150	6	900
Waste Disposal	200	3	600
Technical Oversight/hr	250	12	3,000
Subtotal			9,000
Contingency (35%)			3,150
Total			12,150

Assumptions:

1. Scope is to install one 2- or 4-inch diameter schedule 80 PVC well to 25' bgs using a sonic rig
2. Permit fees (well, encroachment, etc.) not included
3. Underground utility clearance consists of calling North Carolina 811
4. Well sampling not included
5. Investigation-derived waste (IDW) material (2 drums for drill cuttings, 1 drum for well development) is non-hazardous under existing profile and drums picked up on a milk run
6. Labor rate all-inclusive includes onsite oversight, office oversight, vehicle, monitoring equipment
7. Reporting not included
8. Well installed in one 5-hr day
9. 1 hour mobilization/demobilization to the site.
10. 35% markup for contingency

Annual Well O&M Cost (25-foot well)			
Cost Items	Cost ($)	# of Units	Total Cost ($)
55-gallon drums	50	1	50
Drill rig dev/hr	150	4	600
Waste Disposal	200	1	200
Technical Oversight/hr	250	6	1,500
Total			2,350

Assumptions:

1. Operation and Maintenance (O&M) consists of well redevelopment/biofouling removal
2. Scope is to redevelop one well annually
3. IDW is non-hazardous under existing profile and drums picked up on a milk run
4. Labor rate all-inclusive includes onsite oversight, office oversight, vehicle, monitoring equipment
5. Reporting not included
6. Well sampling not included

Attachment B: Example of Well Installation and Maintenance Costs (50-foot well)

Well Installation/Drilling Cost (50-foot well)			
Cost Items	Cost ($)	# of Units	Total Cost ($)
Concrete saw cut/hole	100	1	100
Sonic/mobe	1,500	1	1,500
Sonic/day	4,000	1	4,000
4" Schedule 80 PVC	20	50	1,000
Well box	250	1	250
55-gallon drums	50	5	250
Drill rig dev/hr	150	6	900
Waste Disposal	200	5	1,000
Technical Oversight/hr	250	18	4,500
Subtotal			13,500
Contingency (35%)			4,725
Total			18,225

Assumptions:

1. Scope is to install one 2- or 4-inch diameter schedule 80 PVC well to 50' bgs using a sonic rig
2. Permit fees (well, encroachment, etc.) not included
3. Underground utility clearance consists of calling North Carolina 811
4. Well sampling not included
5. Investigation-derived waste (IDW) material (4 drums for drill cuttings, 1 drum for well development) is non-hazardous under existing profile and drums picked up on a milk run
6. Labor rate all-inclusive includes onsite oversight, office oversight, vehicle, monitoring equipment
7. Reporting not included
8. Well installed in one 10-hr day
9. 1 hour mobilization/demobilization to the site.
10. 35% markup for contingency

Annual Well O&M Cost (50-foot well)			
Cost Items	Cost ($)	# of Units	Total Cost ($)
55-gallon drums	50	1	50
Drill rig dev/hr	150	4	600
Waste Disposal	200	1	200
Technical Oversight/hr	250	6	1,500
Total			2,350

Assumptions:

1. Operation and Maintenance (O&M) consists of well redevelopment/biofouling removal
2. Scope is to redevelop one well annually
3. IDW is non-hazardous under existing profile and drums picked up on a milk run
4. Labor rate all-inclusive includes onsite oversight, office oversight, vehicle, monitoring equipment
5. Reporting not included
6. Well sampling not included

Proposed Rule Text

15A NCAC 02L .0202

August 14, 2024

15A NCAC 02L .0202 is proposed for amendment as follows:

15A NCAC 02L .0202 GROUNDWATER QUALITY STANDARDS

(a) The groundwater quality standards for the protection of the groundwaters of the State are those specified in this Rule. They are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the State, which may be tolerated without creating a threat to human health or which would otherwise render the groundwater unsuitable for its intended best usage.

(b) The groundwater quality standards for contaminants specified in Paragraphs (h) and (i) of this Rule are as listed, except that:

(1) Where the standard for a substance is less than the practical quantitation limit, the detection of that substance at or above the practical quantitation limit constitutes a violation of the standard. The practical quantitation limit, defined in Rule .0102 of this Subchapter, is a scientific standard pursuant to G.S. 150B-2(8a)(h).

(2) Where two or more substances exist in combination, the Director shall consider the effects of chemical interactions after consulting with the Division of Public Health and may establish maximum concentrations at values less than those established in accordance with Paragraphs (c), (h), or (i) of this Rule, based on additive toxic effects. In the absence of information to the contrary, in accordance with Paragraph (d) of this Rule, the carcinogenic risks associated with carcinogens present shall be considered additive and the toxic effects associated with non-carcinogens present shall also be considered additive.

(3) Where naturally occurring substances exceed the established standard, the standard shall be the naturally occurring concentration as established by the Director based upon site-specific conditions.

(4) Where the groundwater standard for a substance is greater than the Maximum Contaminant Level (MCL), the Director shall apply the MCL as the groundwater standard at any private drinking water well or public water system well that may be impacted.

(c) Except for tracers, the use of which has been permitted by the Division in 15A NCAC 02C .0200, substances that are not naturally occurring and for which no standard is specified in Paragraphs (h) or (i) of this Rule shall not be permitted in concentrations at or above the practical quantitation limit in Class GA or Class GSA groundwaters. Any person may request the Director of the Division of Water Resources modify this requirement by establishing an Interim Maximum Allowable Concentration (IMAC) in accordance with the specific guidelines listed in Subparagraphs (1)-(9) of this Paragraph. In addition, any person may request the Director of the Division of Water Resources to update or remove an existing IMAC in accordance with the specific guidelines listed in Subparagraphs (1)-(9) of this Paragraph. The requestor shall submit relevant toxicological and epidemiological data, study results, and calculations in accordance with Paragraphs (d) and (e) of this Rule. The specific guidelines are as follows:

(1) The Division shall review the request to determine whether the information submitted is in accordance with Paragraphs (d) and (e) of this Rule.

(2) If the information submitted is not in accordance with Paragraphs (d) and (e) of this Rule, the Director of the Division of Water Resources shall request additional information from the requester. If the requester does not provide the additional information necessary to be in accordance with Paragraphs (d) and (e) of this Rule, the Director of the Division of Water Resources shall return the request.

(3) If the information submitted is in accordance with Paragraphs (d) and (e) of this Rule, at least 30 days prior to establishing, updating, or removing an IMAC for any substance, the Division of Water Resources shall provide public notice and opportunity for comment that an IMAC has been requested to be established, updated, or removed. The public notice shall include:

(A) the request for the establishment, update, or removal of the IMAC for a substance,

(B) the level of the proposed IMAC, which is calculated by the Division of Water Resources in accordance with Paragraphs (d) and (e) of this Rule,

(C) if applicable the level of the existing IMAC, and

(D) the basis upon which the Division of Water Resources has relied in development of the proposed IMAC establishment, update, or removal.

This notice shall be emailed to interested parties and posted on the Division of Water Resources' website: https://deq.nc.gov/about/divisions/water-resources/water-planning/classification-standards/groundwater-imacs.

(4) If the Director of the Division of Water Resources finds the establishment, update or removal will not degrade the quality of the groundwaters, will not likely cause or contribute to pollution of the waters of the state, and will be protective of public health, then the Director shall establish, update or remove the IMAC. If the request does not meet the requirements listed in this Subparagraph, the Director of the Division of Water Resources shall return the request. The Director shall establish, update, or remove the IMAC or return the request within 180 calendar days of receipt of a request submitted in accordance with Paragraphs (d) and (e) of this Rule unless the requester agrees, in writing, to a longer period. Failure by the Director to establish, update or remove an IMAC or return the request within 180 days of receipt of a request submitted in accordance with Paragraphs (d) and (e) of this Rule shall be considered a return of the request.

(5) If the Director of the Division of Water Resources establishes or updates an IMAC, the IMAC shall be posted on the Division of Water Resource's website and the Commission shall be notified in writing within 30 calendar days and at the next regularly scheduled Commission meeting that a new IMAC has been established or an existing IMAC has been updated or removed.

(6) (A) Within 12 months of establishing an IMAC pursuant to this Paragraph, the Director of the Division of Water Resources shall make a recommendation to the Commission whether:

(i) a new groundwater standard in place of the IMAC should be established pursuant to this Rule; or

(ii) the IMAC should expire.

(B) After a recommendation is presented by the Director under Part (A) of this Subparagraph, the Commission shall decide whether rulemaking shall be initiated to adopt a new groundwater standard in place of the IMAC.

(C) If the Commission initiates rulemaking to adopt a new groundwater standard in place of the IMAC, then the IMAC shall remain in effect unless it expires under Subparagraph (7) of this Paragraph.

(7) An IMAC shall expire upon the earliest of:

(A) the date the Commission declines to initiate rulemaking to adopt a new groundwater standard in place of the IMAC under Part (B) of Subparagraph (c)(6);

(B) the effective date of a Rule adopted by the Commission establishing a new groundwater standard in place of the IMAC; or

(C) after initiating rulemaking pursuant to Part (C) of Subparagraph (c)(6), the date the Commission declines to adopt a new groundwater standard in place of the IMAC.

(8) For any IMAC that expires prior to the adoption by the Commission of a new groundwater standard in place of the IMAC, any person may request an IMAC be established again under this Paragraph based on new information in accordance with Paragraphs (d) and (e) of this Rule that was not included in the original IMAC request to the Director or new site information that was not included in the original IMAC request to the Director.

(9) The Director of the Division of Water Resources shall provide an annual update to the Commission on the status of pending IMAC requests and any IMACs that have been established, updated or removed during the previous calendar year.

(d) Except as provided in Paragraph (f) of this Rule, groundwater quality standards for substances in Class GA and Class GSA groundwaters are established as the least of:

(1) Systemic threshold concentration calculated as follows: [Reference Dose (mg/kg/day) x 70 kg (adult body weight) x Relative Source Contribution (0.10 for inorganics; 0.20 for organics)] / [2 liters/day (avg. water consumption)];

(2) Concentration that corresponds to an incremental lifetime cancer risk of 1x10-6;

(3) Taste threshold limit value;

(4) Odor threshold limit value;

(5) Maximum contaminant level; or

(6) National secondary drinking water standard.

(e) The following references, in order of preference, shall be used in establishing concentrations of substances which correspond to levels described in Paragraph (d) of this Rule:

(1) Integrated Risk Information System (U.S. EPA);

(2) Health Advisories (U.S. EPA Office of Drinking Water);

(3) Other health risk assessment data published by the U.S. EPA; or

(4) Other relevant, published health risk assessment data, and scientifically valid peer-reviewed published toxicological data.

(f) The Commission may establish groundwater standards less stringent than existing maximum contaminant levels or national secondary drinking water standards if it finds, after public notice and opportunity for hearing in accordance with G.S. 150B, that:

(1) more recent data published in the EPA health references listed in Paragraph (e) of this Rule results in a standard that is protective of public health, taste threshold, or odor threshold;

(2) the standard will not endanger the public health and safety, including health and environmental effects from exposure to groundwater contaminants; and

(3) compliance with a standard based on the maximum contaminant level or national secondary drinking water standard would produce substantial hardship without equal or greater public benefit.

(g) Groundwater quality standards specified in Paragraphs (h) and (i) of this Rule shall be reviewed by the Division of Water Resources on a triennial basis to consider whether to recommend to the Commission that new or revised groundwater quality standards be adopted in accordance with Paragraphs (d) and (e) of this Rule.

(h) Class GA Standards. Unless otherwise indicated, the standard refers to the total concentration in micrograms per liter (µg/L) of any constituent in a dissolved, colloidal, or particulate form that is mobile in groundwater. These standards do not apply to sediment or other particulate matter that is preserved in a groundwater sample as a result of well construction or sampling procedures. The Class GA standards are:

Substance	Chemical Abstracts Service (CAS) Registry Number	Standard ~~(µg/L)~~ (µg/L unless otherwise indicated)
Acenaphthene	83-32-9	80
Acenaphthylene	208-96-8	200
Acetic acid	64-19-7	5,000
Acetochlor	34256-82-1	100
Acetochlor ESA	187022-11-3	500
Acetochlor OXA	184992-44-4	500
Acetone	67-64-1	6,000
Acetophenone	98-86-2	700
Acrolein	107-02-8	4
Acrylamide	79-06-1	0.008
Alachlor	15972-60-8	2
Aldrin	309-00-2	0.002
Anthracene	120-12-7	2,000
Antimony	7440-36-0	1

Arsenic	7440-38-2	10
Atrazine and chlorotriazine metabolites	1912-24-9	3
Barium	7440-39-3	700
Benzene	71-43-2	1
Benzo(a)anthracene	56-55-3	0.05
Benzo(a)pyrene	50-32-8	0.005
Benzo(b)fluoranthene	205-99-2	0.05
Benzo(g,h,i)perylene	191-24-2	200
Benzo(k)fluoranthene	207-08-9	0.5
Benzoic acid	65-85-0	30,000
Benzyl alcohol	100-51-6	700
Beryllium	7440-41-7	4
Bis(chloroethyl)ether	111-44-4	0.03
Bis(2-ethylhexyl) phthalate	117-81-7	3
Boron	7440-42-8	700
Bromodichloromethane	75-27-4	0.6
Bromoform	75-25-2	4
Bromomethane	74-83-9	10
n-Butanol	71-36-3	590
sec-Butanol	78-92-2	10,000
n-Butylbenzene	104-51-8	70
sec-Butylbenzene	135-98-8	70
tert-Butylbenzene	98-06-6	70
Butylbenzyl phthalate	85-68-7	1,000
Cadmium	7440-43-9	2
Caprolactam	105-60-2	4,000
Carbofuran	1563-66-2	40
Carbon disulfide	75-15-0	700
Carbon tetrachloride	56-23-5	0.3
Chlordane	12789-03-6	0.1
Chloride	16887-00-6	250,000
Chlorobenzene	108-90-7	50
Chloroethane	75-00-3	3,000
Chloroform	67-66-3	70
Chloromethane	74-87-3	3

2-Chlorophenol	95-57-8	0.4
2-Chlorotoluene	95-49-8	100
4-Chlorotoluene	106-43-4	24
Chromium	7440-47-3	10
Chrysene	218-01-9	5
Cobalt	7440-48-4	1
Coliform organisms (total)	No CAS Registry Number	1 per 100 mL
Color	No CAS Registry Number	15 color units
Copper	7440-50-8	1,000
Cyanide (free cyanide)	57-12-5	70
2,4-D (2,4-dichlorophenoxy acetic acid)	94-75-7	70
Dalapon	75-99-0	200
DDD	72-54-8	0.1
DDE	72-55-9	0.1
DDT	50-29-3	0.1
Dibenz(a,h)anthracene	53-70-3	0.005
1,4-Dibromobenzene	106-37-6	70
Dibromochloromethane	124-48-1	0.4
1,2-Dibromo-3-chloropropane	96-12-8	0.04
Dibutyl phthalate	84-74-2	700
Dichloroacetic acid	79-43-6	0.7
1,2-Dichlorobenzene	95-50-1	20
1,3-Dichlorobenzene	541-73-1	200
1,4-Dichlorobenzene	106-46-7	6
Dichlorodifluoromethane	75-71-8	1,000
1,1-Dichloroethane	75-34-3	6
1,2-Dichloroethane	107-06-2	0.4
1,2-Dichloroethene (cis)	156-59-2	70
1,2-Dichloroethene (trans)	156-60-5	100
1,1-Dichloroethylene	75-35-4	350
2,4-Dichlorophenol	120-83-2	0.98
1,2-Dichloropropane	78-87-5	0.6
1,3-Dichloropropene (cis and trans isomers)	542-75-6	0.4
Dieldrin	60-57-1	0.002
Diethylphthalate	84-66-2	6,000

2,4-Dimethylphenol	105-67-9	100
2,4-Dinitrotoluene	121-14-2	0.05
2,6-Dinitrotoluene	606-20-2	0.05
Di-n-octyl phthalate	117-84-0	100
Dinoseb	88-85-7	7
1,4-Dioxane	123-91-1	3
Dioxin (2,3,7,8-TCDD)	1746-01-6	0.0002 ng/L
1,1-Diphenyl	92-52-4	400
Diphenyl ether	101-84-8	180
Diquat	85-00-7	20
Dissolved solids (total)	No CAS Registry Number	500,000
Disulfoton	298-04-4	0.3
Diundecyl phthalate (Santicizer 711)	3648-20-2	100
Endosulfan	115-29-7	40
Endosulfan sulfate	1031-07-8	40
Endothall	145-73-3	100
Endrin, total (includes endrin, endrin aldehyde, and endrin ketone)	72-20-8	2
Epichlorohydrin	106-89-8	4
Ethyl acetate	141-78-6	3,000
Ethylbenzene	100-41-4	600
Ethylene dibromide	106-93-4	0.02
Ethylene glycol	107-21-1	10,000
Fluoranthene	206-44-0	300
Fluorene	86-73-7	300
Fluoride	16984-48-8	2,000
Foaming agents	No CAS Registry Number	500
Formaldehyde	50-00-0	600
Gross alpha (adjusted) particle activity (excludes radium-226 and uranium)	12587-46-1	15 pCi/L
Heptachlor	76-44-8	0.008
Heptachlor epoxide	1024-57-3	0.004
Heptane	142-82-5	400
Hexachlorobenzene	118-74-1	0.02
Hexachlorobutadiene	87-68-3	0.4
Hexachlorocyclohexane isomers (technical grade)	608-73-1	0.02
alpha-Hexachlorocyclohexane	319-84-6	0.006

beta-Hexachlorocyclohexane	319-85-7	0.02
gamma-Hexachlorocyclohexane (Lindane)	58-89-9	0.03
Hexafluoropropylene oxide dimer acid (HFPO-DA)	13252-13-6	10 ng/L
n-Hexane	110-54-3	400
Indeno(1,2,3-cd)pyrene	193-39-5	0.05
Iron	7439-89-6	300
Isophorone	78-59-1	40
Isopropyl ether	108-20-3	70
Isopropylbenzene	98-82-8	70
4-Isopropyltoluene	99-87-6	25
Lead	7439-92-1	15
Manganese	7439-96-5	50
Mercury	7439-97-6	1
Methanol	67-56-1	4,000
Methoxychlor	72-43-5	40
Methylene chloride	75-09-2	5
Methyl butyl ketone	591-78-6	40
Methyl ethyl ketone	78-93-3	4,000
Methyl isobutyl ketone	108-10-1	100
Methyl methacrylate	80-62-6	25
1-Methylnapthalene	90-12-0	1
2-Methylnaphthalene	91-57-6	30
2-Methylphenol	95-48-7	400
3-Methylphenol	108-39-4	400
4-Methylphenol	106-44-5	40
Methyl tert-butyl ether (MTBE)	1634-04-4	20
Naphthalene	91-20-3	6
Nickel	7440-02-0	100
Nitrate (as N)	14797-55-8	10,000
Nitrite (as N)	14797-65-0	1,000
N-nitrosodimethylamine	62-75-9	0.0007
Oxamyl	23135-22-0	200
Pentachlorophenol	87-86-5	0.3
Petroleum aliphatic carbon fraction class (C5 – C8)	No CAS Registry Number	400
Perfluorooctanoic acid (PFOA)	335-67-1	0.001 ng/L

Perfluorooctane sulfonic acid (PFOS)	1763-23-1	0.7 ng/L
Petroleum aliphatic carbon fraction class (C9 – C18)	No CAS Registry Number	700
Petroleum aliphatic carbon fraction class (C19 – C36)	No CAS Registry Number	10,000
Petroleum aromatics carbon fraction class (C9 – C22)	No CAS Registry Number	200
pH	No CAS Registry Number	6.5 - 8.5 (no unit)
Phenanthrene	85-01-8	200
Phenol	108-95-2	30
Phorate	298-02-2	1
n-Propylbenzene	103-65-1	70
Propylene glycol	57-55-6	100,000
Pyrene	129-00-0	200
Selenium	7782-49-2	20
Silver	7440-22-4	20
Simazine	122-34-9	4
Strontium	7440-24-6	2,000
Styrene	100-42-5	70
Sulfate	14808-79-8	250,000
1,2,4,5-Tetrachlorobenzene	95-94-3	2
1,1,2,2-Tetrachloroethane	79-34-5	0.2
1,1,1,2-Tetrachloroethane	630-20-6	1
Tetrachloroethylene (PCE)	127-18-4	0.7
2,3,4,6-Tetrachlorophenol	58-90-2	200
Thallium	7440-28-0	2
Tin (inorganic forms)	7440-31-5	2,000
Toluene	108-88-3	600
Toxaphene	8001-35-2	0.03
2,4,5-TP (Silvex)	93-72-1	50
1,2,4-Trichlorobenzene	120-82-1	70
1,1,1-Trichloroethane	71-55-6	200
1,1,2-Trichloroethane	79-00-5	0.6
Trichloroethylene (TCE)	79-01-6	3
Trichlorofluoromethane	75-69-4	2,000
2,4,5-Trichlorophenol	95-95-4	63
2,4,6-Trichlorophenol	88-06-2	4
1,2,3-Trichloropropane	96-18-4	0.005

1,2,4-Trimethylbenzene	95-63-6	400
1,3,5-Trimethylbenzene	108-67-8	400
Vanadium	7440-62-2	7
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	200,000
Vinyl chloride	75-01-4	0.03
Xylenes	1330-20-7	500
Zinc	7440-66-6	1,000

(i) Class GSA Standards. The standards for this class are the same as those for Class GA except as follows:

(1) chloride: allowable increase not to exceed 100 percent of the natural quality concentration; and

(2) dissolved solids (total): 1,000,000 µg/L.

(j) Class GC Standards.

(1) The concentrations of substances that, at the time of classification, exceed the standards applicable to Class GA or GSA groundwaters shall not be caused to increase, nor shall the concentrations of other substances be caused to exceed the GA or GSA standards as a result of further disposal of contaminants to or beneath the surface of the land within the boundary of the area classified GC.

(2) The concentrations of substances that, at the time of classification, exceed the standards applicable to GA or GSA groundwaters shall not be caused to migrate as a result of activities within the boundary of the GC classification, so as to violate the groundwater or surface water quality standards in adjoining waters of a different class.

(3) Concentrations of specific substances, that exceed the established standard at the time of classification, are listed in Section .0300 of this Subchapter.

History Note: *Authority G.S. 143-214.1; 143-214.2; 143-215.3(a)(1); 143-215.3(a)(4); 143B-282(a)(2); 150B-2(8a)(h); 150B-19(6);*
Eff. June 10, 1979;
Amended Eff. November 1, 1994; October 1, 1993; September 1, 1992; August 1, 1989;
Temporary Amendment Eff. June 30, 2002;
Amended Eff. August 1, 2002;
Temporary Amendment Expired February 9, 2003;
Amended Eff. April 1, 2013; January 1, 2010; April 1, 2005;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. March 6, 2018;
Amended Eff. April 1, ~~2022.~~2022;
Amended Eff. [Date TBD].