Cape Fear
Public Utility Authority
Stewardship. Sustainability. Service.

James R. Flechtner, PE
Executive Director
235 Government Center Drive
Wilmington, NC 28403
910-332-6625
jim.flechtner@cfpua.org

April 3, 2020

Sheila Holman
N.C. Department of Environmental Quality
1601 Mail Service Center
Raleigh, North Carolina 27699

Re: Chemours Corrective Action Plan

Dear Ms. Holman,

Cape Fear Public Utility Authority remains concerned about discharges of PFAS to the Cape Fear River from the Chemours site. We and our consultants have reviewed the Corrective Action Plan Chemours submitted on December 31, 2019 under terms of the 2019 consent order.

More than a year has passed since the approval of the consent order meant to address Chemours' widespread PFAS contamination. At the time, CFPUA expressed concerns that measures outlined in the consent order seemed insufficient to effectively and consistently address PFAS levels in the Cape Fear River, source of 80 percent of our community's drinking water. We were assured by those who signed the consent order that these concerns were unfounded. Just wait, we were told, and PFAS concentrations in the Cape Fear would begin to decrease.

It's going on Year Two of the consent order, and we're still waiting. Our regular monitoring of raw and finished water has not shown this promised sustained decrease in PFAS. Instead, PFAS levels increased throughout most of 2019 – spiking as high as 377 parts per trillion and often remaining above concentrations that, when detected in wells in Bladen or Cumberland counties, trigger immediate, unambiguous remedies by Chemours.

CFPUA staff have spent the last several months evaluating the 1,835-page Corrective Action Plan (CAP) proposed by Chemours to address PFAS in surface water and groundwater resulting from a long history of releases at its chemical manufacturing plant on the Bladen-Cumberland county line. CFPUA's review was supplemented by analysis provided by expert contractors, whose reports are provided with these comments. Detailed comments are being submitted separately by CFPUA's attorneys.

What we find in the CAP are promises to attempt to reduce PFAS loading in the Cape Fear River sometime in the next five years or more from Chemours, a company that, along with its creator DuPont, spent almost four decades making a profit while quietly releasing these same PFAS. We find promises based on untested models and models built with inconsistent, incomplete data, confounding attempts at independent verification. We find several obvious, significant sources of contamination ignored or set aside because addressing them would cost too much or otherwise be too difficult for the company responsible for this contamination. We find gaps in calculations of the potential risks to human health posed by Chemours' pollution. Overall, for the hundreds of thousands of people who rely on CFPUA for drinking water, we find this plan falls far short of the actions needed to meaningfully correct the damages done by Chemours and DuPont.

Chemours promises to reduce PFAS loading in the Cape Fear River by 79 percent, yet the implementation schedule for these measures clearly shows that almost two-thirds of this promised reduction won't be realized for four to five years, at best. Chemours has made much of the $100 million-plus thermal oxidizer it says went online at the end of 2019 and features it prominently in the CAP. Yet, for all the fanfare, the thermal oxidizer apparently provides miniscule benefit to downstream water users, contributing less than 2 percent of the PFAS reduction in the Cape Fear River promised by Chemours, according to the CAP.

The CAP waves away or ignores a number of important pathways for PFAS loading to the Cape Fear River. No mitigation efforts are proposed to address PFAS in the more than 50 miles of river sediment between Chemours' outfall and CFPUA's raw water intakes at Kings Bluff. No mitigation efforts are proposed for Willis and Georgia creeks, which carry PFAS into the Cape Fear River. No remediation efforts are proposed for the 70-plus square miles of groundwater around the Fayetteville Works that Chemours estimates it has contaminated.

In the CAP, Chemours has applied a variety of analytical methods in its monitoring of PFAS contamination. In some instances, it used a "Table 3+ PFAS" method, which can analyze for 20 compounds specific to the site. In other cases, different methods were applied, including some where only GenX was analyzed. The consent order, however, states that sampling is to be conducted for all PFAS for which test methods and lab standards have been developed. The rationale behind Chemours' choice of methods is not entirely clear. This inconsistency makes any review of Chemours' data difficult, and narrowing the focus to a few or just one substance likely results in gross underestimations of the extent of Chemours' contamination.

High levels of PFAS have been detected just beyond the process water outfall from the operations of another tenant at the Fayetteville Works site, Kuraray ("Outfall 002 Assessment," Geosyntec, August 26, 2019). Chemours has suggested this might have been caused by sediment clogging sampling equipment. The CAP also theorizes that a terracotta pipe conveying wastewater may be leaking. We urge NCDEQ to scrutinize discharges from Kuraray and from DuPont, which also have operations at the site. After all, both companies continue to discharge their process wastewater into the Cape Fear River.

We also would urge NCDEQ to regularly confirm Chemours' PFAS analysis by requiring that samples be split, so that results can be validated at an independent laboratory.

The CAP often relies on an assessment, contained in Attachment F, that levels of PFAS at various points of exposure pose no risk to human health. Crucial gaps exist in the analysis that led to this assessment.

For example, it did not consider exposure in fetuses during pregnancy, infants, and lactating women. And, as is the case with other portions of the CAP, data related to specific PFAS and the extent of PFAS contamination are inconsistent and/or incomplete.

Since 2017, NCDEQ has initiated a number of important regulatory actions to force Chemours to address the damage caused by its and DuPont's PFAS releases. Nevertheless, relief outlined in Chemours' CAP for the almost 200,000 people who rely on water treated at Sweeney Water Treatment Plant consists largely of vague, difficult-to-assess promises of PFAS reductions to be realized years into future.

Enclosed are reports prepared by Tetra Tech and Dr. Jamie DeWitt regarding the latest CAP submittal.

We trust DEQ will continue to take this matter seriously and take steps to hold Chemours accountable for the damages they have caused to downstream communities.

Regards,

James R. Flechtner, PE
Executive Director

Enclosures

Technical Review of Cape Fear River PFAS Corrective Action Plan for Cape Fear Public Utility Authority (CFPUA)

February 28, 2020

PREPARED FOR

Cape Fear Public Utility Authority
235 Government Center Drive
Wilmington, NC 28403

PREPARED BY

Tetra Tech
One Park Drive, Suite 200
PO Box 14409
Research Triangle Park, NC 27709
Tel 919-485-8278
Fax 919-485-8280
www.tetratech.com

TETRA TECH

(This page was intentionally left blank.)

1.0 EXECUTIVE SUMMARY

This report is a technical review of the Corrective Action Plan (CAP; Geosyntec, 2019a) for remediation of per- and polyfluoroalkyl substances (PFAS) discharged by the Chemours Company Fayetteville Works facility. Comments regarding the technical soundness of the assessments presented in the CAP and critical gaps are discussed in Section 3.0. The main concerns relevant to the Cape Fear Public Utility Authority's (CFPUA) downstream raw water intake are summarized below. Based on the information provided and information lacking, the adequacy of the modeling and CAP cannot be judged.

- The CAP and past reports use an **inconsistent application of PFAS analyte groups** for monitoring, loading analyses, and remediation planning (Section 3.1 #1). It is stated that, except for HFPO-DA, Modified EPA 537 method PFAS do not originate from onsite manufacturing; however, this is inconsistent with some process water samples presented in Characterization of PFAS in Process and Non-process Wastewater and Stormwater Quarterly Report #1 (Table 4, Location ID 16). Loads from the Modified EPA 537 method PFAS are excluded from the mass balance model. As a result, the model may underestimate PFAS loading from the site that impacts downstream water quality.
- The CAP **does not clearly define a baseline period**. The PFAS Loading Reduction Plan and CAP are also missing important information; relative contributions are presented by transport pathway, however, flows, concentrations, and loads to the river (mass of total PFAS per time) are not specified. Without a clear definition of the baseline period and loads, results could be interpreted in a manner that misrepresents progress and the effectiveness of remediation strategies (Section 3.1 #2).
- Multiple **technical issues related to the numerical groundwater model** are discussed in Section 3.1 #7 and Section 3.2 #2 that raise questions about the validity of the model and simulated remediation strategies. The model lacks a validation period to establish the robustness of the calibration. The report does not provide a rationale for the selection of proposed remedies and, based on the limited information provided, it is uncertain if the strategies will effectively capture and treat the PFAS-contaminated groundwater plumes.
- The onsite treatment strategies described in the CAP **neglect components of onsite pathways that may continue to contribute PFAS to the river** (Section 3.2 #1). The strategy specified for Old Outfall 002, for example, targets dry weather flows for treatment and excludes the treatment of wet weather flows that have the potential to transport contaminated sediment to the river. No creek-specific controls are planned for Willis Creek and Georgia Creek and no treatment plans are described for the newly identified seeps (E to M) south of the site. The effectiveness of the proposed treatment measures is uncertain and cannot be evaluated from the material provided in the CAP.
- There is a gap regarding the extent, magnitude, and **loading of PFAS from offsite contaminated soils and groundwater** that could act as long-term sources of PFAS to the river, continuing to impact the quality of raw intake water for CFPUA (Section 3.2 #1 and #4). PFAS contamination from Chemours has been detected in an area of 70 square miles (or more) surrounding the facility. However, because of the extent of the contamination, lack of scalable remediation technologies, and because no groundwater standards have been issued, it is claimed in the CAP that restoring groundwater conditions to PQLs is not feasible, which does not seem to comply with 2L Rules as required by the CO (paragraph 16). PFAS contamination of sediment in the bed and riparian wetlands of the river also remains uncertain. A comparative PFAS loading assessment just downstream of the site and at the CFPUA raw water intake is needed to evaluate offsite loading contributions to the river.

2.0 BACKGROUND

Chemours Company submitted the Cape Fear River PFAS Corrective Action Plan (Geosyntec, 2019a) to the North Carolina Department of Environmental Quality (NCDEQ) and Cape Fear River Watch (CFRW) on December 31, 2019, in response to the Consent Order (CO) entered by the Bladen County Superior Court (paragraphs 11.1 and 12) on February 25, 2019. The CO was issued regarding emissions and discharges of PFAS, including HFPO-DA and the ammonium salt of HFPO-DA, which has the trade name of GenX®, from the Fayetteville Works facility. GenX is used to manufacture high-performance fluoropolymers. GenX replaces the ammonium salt of perfluorooctanoic acid (PFOA), which was phased out of production in 2009 because PFOA is persistent in the environment, bioaccumulates, and is toxic. At that time the Fayetteville Works facility was owned and operated by E.I. du Pont de Nemours and Company (DuPont). The Chemours Company was founded in July 2015 as a spin-off from DuPont.

In 2009 EPA authorized the manufacture of GenX; however, EPA also issued an order that required DuPont to capture new chemical substances from wastewater effluent and air emissions at an overall efficiency of 99 percent (premanufacture notice numbers P-08-508 and P-08-509). News broke regarding elevated levels of GenX and PFAS in the Cape Fear River in 2017 – spurring further environmental investigations and facility inspections. Shortly thereafter, NCDEQ filed a Complaint alleging violations of Title 15A of the North Carolina Administrative Code Subchapter 02L .0202 Groundwater Quality Standards due to evidence of PFAS discharges by Chemours and DuPont, ultimately leading to the CO.

The Fayetteville Works facility is in Bladen County, North Carolina, on the west side of the Cape Fear River just upstream of the William O. Huske Lock and Dam (Lock and Dam #3). The facility includes two Chemours manufacturing areas, the Monomers IXM area and the Polymer Processing Aid Area (PPA area), as well as an onsite process wastewater treatment plant (WWTP) and power area (Geosyntec, 2019b). Manufacturing areas on the facility grounds are leased to Kuraray America Inc. for Butacite® and SentryGlas® production and to DuPont for polyvinyl fluoride (PVF) resin manufacturing.

The Chemours Fayetteville Works facility is located about 55 miles upstream of the Kings Bluff water intake on the Cape Fear River where the Cape Fear Public Utility Authority (CFPUA) withdraws water for treatment and potable use distribution. Elevated levels of PFAS have been observed in both the raw source water from the Cape Fear River and finished water at the CFPUA's Water Treatment Plants (WTPs). Traditional water treatment processes do not successfully remove GenX and other PFAS (Hopkins et al., 2018). The effectiveness of currently implemented and proposed PFAS pollution control strategies adopted by Chemours directly impacts the quality of CFPUA's intake water and community exposure to these substances.

Chemours submitted the Cape Fear River PFAS Loading Reduction Plan (Geosyntec, 2019b) in August 2019 and CFPUA engaged Tetra Tech to conduct a technical review of the report (Tetra Tech, 2019). The review evaluated the technical soundness of the modeling, the reasonableness of the assumptions applied in the analyses, the reasonableness of the proposed strategies for reducing PFAS loads, identified critical gaps, and recommended additional studies related to reducing PFAS loads. Comments most pertinent to CFPUA's downstream water intake included the lack of groundwater data, insufficient extents and lack of information about the extent, magnitude, and impact of offsite groundwater and soil contamination, lack of information necessary to characterize PFAS contamination in the sediment of the riverbed and riparian wetlands, and lack of information regarding the effectiveness of the proposed treatment measures.

A technical review of the CAP is presented in this report. The CAP describes site information, recent receptor monitoring details, a numerical hydraulic groundwater model, PFAS signatures source assessment, recent corrective actions summary, human health and ecological exposure and hazard assessments, proposed remediation activities by source pathway, and performance monitoring plans. The appendices relevant to the fate and transport of PFAS in the environment were also reviewed. This includes Appendix A - On and Offsite Assessment Tables; Appendix B - Additional Corrective Action Plan Tables and Figures; Appendix C - K_{ow}, K_{oc} and Mass Distribution Calculations; Appendix D - Southwestern Offsite Seeps Assessment; Appendix E - PFAS Signatures Assessment; and Appendix H - Numerical Groundwater Modeling Report. CFPUA plans to collaborate with expert Dr. Jamie Dewitt for elements related to human exposure and toxicity, as described in Appendix F - Human Health Screening Level Exposure Assessment of Table 3+ PFAS. The ecological assessment, discussed in Appendix G – Ecological Screening Level Exposure Assessment of Table 3+ PFAS, and Appendix I – Detailed Costs were not reviewed as part of the technical assessment described in this report.

3.0 TECHNICAL REVIEW

Key comments from the technical review of the CAP and supporting appendices are discussed in the following sections. The adequacy of the modeling and CAP cannot be evaluated due to the reasons summarized below.

3.1 TECHNICAL SOUNDNESS

This section summarizes concerns regarding the technical soundness of data and analyses cited to support conclusions in the Cape Fear River PFAS CAP and supporting appendices.

1. Information provided in the quarterly reports indicate that monitoring conducted aligns with specifications in the approved monitoring plan. However, results from the PFAS monitoring tests are inconsistently applied in the assessments. On page xii of the CAP, it states “The PFAS that originate from the Site are referred to as Table 3+ PFAS. The Table 3+ analytical method was developed to analyze PFAS specific to the Site that were identified through non-targeted chemical analyses. Currently, the Table 3+ method can quantitate for 20 PFAS compounds including HFPO-DA, i.e., “GenX”. When examining PFAS at the Site, the sum of these compounds, i.e., total Table 3+ PFAS compounds, is often used to evaluate trends and distributions.” However, in some analysis components Table 3+ PFAS are applied, in other components the assessment is limited to HFPO-DA, and sometimes Modified EPA Method 537 compounds are evaluated. This inconsistency hinders comparison between sources and components of the study (i.e., not always apples-to-apples). Example instances and impacts of this are described below.
    - The CO specifies the PFAS to be monitored for public drinking water and private wells (paragraphs 19-21 and 24) in Attachment C. According to paragraph 11 in the CO, ongoing sampling for process and non-process wastewater and stormwater at the facility is to be conducted for “all” PFAS for which test methods and lab standards have been developed, although these are not explicitly listed. The results described in the quarterly reports seem to include the Table 3+ PFAS and Modified EPA 537 PFAS for most sites, which matches specifications in the monitoring plan. Chemours claims that the Modified EPA 537 PFAS (excluding HFPO-DA) did not originate from the site as these were

already present in the intake water. Modified EPA 537 PFAS other than HFPO-DA are assigned a concentration of zero for onsite transportation pathways in the PFAS mass loading model. However, based on analytical results from the April 2019 monitoring event described in Chemours' first quarterly report, other PFAS (e.g., Perfluoropentanoic Acid) were found in process water from the Chemours Monomers IXM Area (site 16, page 3 of Table 4) at much higher concentrations than found in the background/intake water (later monitoring reports do not include samples from process wastewater). This suggests that some of the other Modified EPA 537 PFAS may originate from manufacturing on the site, but Modified EPA 537 PFAS (except for HFPO-DA) are excluded from the mass loading model and assessments discussed in the CAP (e.g., PFAS signatures). Therefore, it is unclear if the approach abides by the CO requirements and if the approach characterizes PFAS loads from the site accurately. Monitoring results, such as those from onsite and offsite groundwater wells, indicate that the relative proportions of PFAS compounds vary spatially, thus, it cannot be assumed that evaluating HFPO-DA in isolation is representative of other/total PFAS as has been assumed for atmospheric deposition modeling.

- Table 3+ and Modified EPA 537 PFAS methods exclude two PFAS listed in Attachment C of the CO, PFMOPrA, and PFMOBA, which are isomers that have the same chemical formulae as PMPA and PEPA, respectively, but have different chemical structures and CASN numbers. PFHpA listed in Attachment C is not included in the Table 3+ method, although it is included in the Modified EPA 537 method. Monitoring and assessments that are limited to Table 3+ PFAS exclude PFMOPrA, PFMOBA, and PFHpA from Attachment C of the CO.

2. Throughout the report and appendices, reduction targets are expressed as a relative percent reduction compared to an undefined baseline period. Appropriate quantification of the reductions achieved with the implementation of treatment technologies requires a clear definition of the baseline period and associated baseline loads for each PFAS transport pathway. In both the CAP and PFAS Loading Reduction Plan, baseline loading rates have not been specified; instead, relative percent contributions from the various onsite transport pathways are described (e.g., 22 percent for onsite groundwater in May 2019 as listed in Table 7 in the CAP). Without a clear definition of the baseline period and loads, results could be interpreted in a manner that misrepresents progress. For example, monitoring data from a single day were extrapolated to generate an annual HFPO-DA load. The river flow that was applied to estimate the load for 2019 was less than one-third of the river flow applied for 2017. This caused an overestimation of the reported reduction in loading to the Cape Fear River that was described in the technical review report for the PFAS Loading Reduction Plan. It is recommended that a) a clear and consistent baseline period is defined and b) for past and future monitoring events, that the flow, PFAS concentration, and load associated with each transport pathway should be presented.
3. Reductions for aerial deposition were estimated for HFPO-DA and the report states there are "expected comparable reductions for other PFAS", although information to justify this important assumption is lacking (e.g., measured pollutant removal efficiencies for other PFAS through the application of air control technologies). Indeed, differences in adsorption and volatility characteristics among PFAS compounds suggests that rates will differ. Previous comments regarding the atmospheric deposition modeling described in the technical review of the PFAS Loading Reduction Plan do not appear to have been addressed and, thus, remain a concern.

4. Although the analysis time period is not specified in the CAP, historical process water releases are estimated to account for 76 to 86 percent of the Table 3+ PFAS detected in the Cape Fear River with the remainder coming almost entirely from historic air emissions (14 to 24 percent). This implies that no significant loading of Table 3+ PFAS to the river originates from other background sources, although information is not presented to justify this assumption. As described in other comments, only the relative percent contributions are listed and actual load estimates are not presented (i.e., in mass of PFAS per time interval). It is also important to determine how both the magnitude and relative contributions of PFAS loads have shifted over time in response to halting releases of process water in 2017 and subsequent implementation of other control measures.
5. Figure 3 in the CAP shows the total Table 3+ PFAS mass distribution in a normalized volume of the unsaturated and saturated soil zones (kg/m^3). For several of the assessed locations (11 of 18), a result is not shown for the unsaturated zone because no Table 3+ compounds were detected (Table C-3); however, the text does not specify the detection limit.
6. The PFAS signatures assessment component of the CAP evaluated the make-up and distribution of PFAS compounds in onsite and offsite groundwater. Two main categories identified included 1) aerial deposition PFAS signature from emissions to air and 2) combined process water PFAS signature from historic releases of process water to soil and groundwater. The latter signature is only detected onsite, affects approximately 1 square mile, exhibits Table 3+ PFAS concentrations of 2,900 to 18,000,000 ng/L onsite, and is estimated to contribute 76 to 86 percent of Table 3+ PFAS loading to the river. The former (aerial) signature is detected on and offsite, affects >70 square miles, exhibits lower Table 3+ PFAS concentrations (15 to 13,000 ng/L onsite and 10 to 4,500 ng/L offsite) and is estimated to contribute 14 to 24 percent of Table 3+ PFAS loading to the river. Comments related to the PFAS signatures assessment are summarized below:
    - Three PFAS signatures were established for aerially deposited PFAS from a hierarchical cluster analysis. These include 1) predominantly PMPA (perfluoromethoxypropyl carboxylic acid); 2) predominantly HFPO-DA (hexafluoropropylene oxide dimer acid); and 3) mixed PMPA and HFPO-DA. Another signature, predominately PFMOAA (perfluoro-1-methoxyacetic acid), is described to be the signature representative of process water contamination. A physical/chemical/geological explanation for the distribution of the signatures is missing and a discussion regarding the interactions and transformations of PFAS (precursors to degradation resistant PFAAs (perfluoroalkyl acids) via abiotic or biotic mechanisms) over time is lacking, although the report generically states that transformation of most PFAS substances in the environment is negligible. For example, why is PFMOAA primarily associated with process waste contamination? Are there atmospheric transport mechanisms that influence the distribution of the aerial signatures? The rate at which rainfall scours a substance from the air will vary according to the Henry's law constant, which varies across the PFOA/PFOS substances in Appendix G, however, the CAP does not describe this phenomenon (note that the Table 2-3 in Appendix G lists the Henry's law constants and includes a footnote stating the estimates originate from the CAP, but that does not appear to be correct). This contradicts previous statements that claim atmospheric deposition modeling of HFPO-DA is directly applicable to other PFAS. What other biogeochemical transformations in the environment influence the distribution of the aerial signatures?

- The thresholds used to differentiate the signatures (e.g., what constitutes an aerial mixture signature versus a predominately PMPA or HFPO-DA aerial signature) is vague and should be explicitly described.
- The signatures assessment did not attempt to distinguish the portion of the PFAS signatures attributed to background, or non-Chemours, sources (e.g., biosolids applications, fire response chemicals, atmospheric deposition from other regional or global sources).
- The report does not describe how the findings from the signature assessment will inform future studies and remediation efforts.
- We suggest that the analysis could be improved and clarified through the application of a fugacity analysis with a model such as QWASI (Mackay et al., 1983) to determine the likely theoretical distribution of compounds of interest between air, soil, and water (e.g., Kong et al., 2018).

7. To simulate groundwater hydraulics, an EVS geologic model (seven hydrostatic and heterogenous units) and a FEFLOW 3D finite element groundwater model were developed for the site. Comments regarding the development and calibration of the numerical groundwater model (Appendix H) include:
   - As noted in the numerical groundwater modeling report, the subsurface hydraulic conductivity (K) values listed in Table 2 for the Surficial and Black Creek aquifers are well outside of the typical range presented in Table 1. Anomalous K values would have implications for the estimation of groundwater discharge and pumping rates. Were calibrations attempted with lower K values and, if so, what were the outcomes? Also, the model sensitivity test ranges for K (±20 percent) appear low given the modeled versus typical range values presented in the report. Were the much higher K values derived from the groundwater model calibration subsequentially incorporated into the contaminant mass loading estimates that were generated separately? If not, the mass loading flux to the river due to groundwater discharge may be significantly underestimated.
   - The numerical groundwater modeling report describes the data source for specifying the upper layer boundary (site precipitation and evapotranspiration estimates for the Mid-Atlantic Coastal Plain from USGS) but does not present the initial rainfall recharge rates used in the model. It is inferred from the wording that these served as initial rates that were adjusted during the model calibration, however, the final calibrated rates are not provided. On page 12 it is stated that the final hydraulic parameters are provided in Table 3, although Table 3 instead lists the final calibration statistics for the three zones (Perched Zone, Surficial Aquifer, and Black Creek Aquifer), not the hydraulic parameters.
   - It is stated that localized anthropogenic stormwater recharge (a second upper layer boundary in addition to rainfall recharge described in the previous bullet) and historic infiltration from previously unlined sedimentation basins is included in the top boundary condition. The sedimentation basins have been lined so it is unclear why the basins are assumed to contribute infiltration water to the Perched Zone for the simulation period of October 2019. In addition, the rate is presented as 80,000 GPD and this should be correspondingly presented as a depth-based rate (e.g., inches per day/month).
   - Bluff seep discharge rates were evaluated but the report lacks presentation of performance metrics. Based on the information provided (Table 6.2), the model underpredicts Cape Fear River bluff seeps by about 88 percent and overestimates Old

Outfall 002 flow by 60 to 140 percent (range provided for measured/estimated flow). Therefore, the model seems to provide a weak correlation of these outflow features although the implications are not discussed.

- It is not clear from the numerical groundwater modeling report and CAP whether the onsite seeps originate from the perched zone, surficial aquifer, or both – this is important information for the development of a groundwater remediation strategy. It is also unclear what groundwater flow unit the offsite seeps described in Section 3.5 of the CAP discharge from.
- There is no quantification of the groundwater flux into the river from each of the groundwater flow units included in the model. Such fluxes should inform the basis for developing groundwater extraction and treatment scenarios.
- The daily median water elevation for the Cape Fear River measured at the W.O. Huske Dam is used to set the hydraulic head for the eastern boundary condition. It is not stated if this is the median water elevation for October 2019 or another period, although the former is preferable for the steady-state application described.
- On page 13 it is stated that an overall error of 10 percent or less is considered acceptable for the intended application (although no reference is provided) and that the groundwater model achieves this target (overall and for the Surficial and Black Creek Aquifers). Contradictorily, the calibration resulted in a Normalized Root Mean Square (NRMS) error of 12.5 percent for the final groundwater model (Table 5). Therefore, the calibration effort did not achieve the target performance metric. Additional information regarding model performance and justification that the calibrated model is acceptable is needed. For example, it would be preferable to report performance metrics (such as NRMS) for each borehole calibration site to assess spatial variability in model performance. NRMS errors are presented for the three vertical zones, and the error for the Perched Zone is quite high, 25.2 percent – it is noted that additional calibration efforts may be required to improve the representation of hydraulics in this zone. It is also stated that the calibrated FEFLOW model meets the requirements of the NCDEQ 2007 Groundwater Modeling Policy, however, these are not presented or discussed. The first step in the guidance (Define Study Objectives) is not addressed – specific and detailed objectives are called for in the guidance but not provided in the modeling report, although these are critical for producing a technically sound and appropriate model.
- The model was calibrated for steady-state conditions in October 2019. It would be preferable to complete a model validation using monitoring and conditions from an alternative period to demonstrate that the calibrated parameters are robust and the model responds correctly to different conditions. This is important because, as discussed in Section 7, the model was run for a forecast period of 1 year for the purpose of evaluating remedy scenarios given that conditions vary throughout the year (e.g., precipitation and recharge, boundary condition hydraulic heads including the Cape Fear River).
- The rationale and logic behind the selection of remedy simulations is missing. The scenario set should be identified based on clear objectives and technical/hydrogeologic analysis. In Section 5.4 of the CAP, it is stated that the hydraulic containment objectives are presented in Table 8, however, the table lists a summary of the six predictive simulations without describing the objectives. For example, no information is provided about:

        - The groundwater discharge rates to the river under ambient conditions from each hydrogeologic unit, which would be necessary to establish the minimum required pumping rates for plume capture.
        - The expected unit-specific maximum sustainable pumping rates for extraction wells based on hydrogeologic analyses and calculations.
        - The hydrogeologic units from which the extraction wells draw water. Is it just the Black Creek Aquifer or are the wells screened across the Surficial Aquifer too?
        - Capture zone calculations for wells in the initial well placement scheme.
        - The rationale behind groundwater extraction rates being selected for the different scenarios. For example, there is a scenario with 41 wells pumping at 20 gpm each (820 gpm total) and another with 31 wells pumping at 30 gpm (930 gpm total), although the Black Creek Aquifer groundwater discharge for each scenario is presented as 1551 gpm. If the pumping scheme extracts substantially less groundwater compared to the discharge rate, then the entire plume will not be captured.
    - There is no information provided regarding the locations of the extraction wells nor the constraints on the placement of the extraction wells in Appendix H or Section 5 of the CAP. Shifting the wells back from the river will alter capture processes and impact the assessment of feasibility. The groundwater units that the extraction wells will capture water from is not clear in the documentation. Comparisons are made for the Black Creek Aquifer. It is unclear if the perched and surficial aquifers are also targeted.
    - It is not clear what is represented in column 5 of Table 7, labeled “Black Creek Groundwater Capture Flow into the Cape Fear River – By Simulated Pumping (GPM)”. Manipulating the numbers in the other columns does not shed light on what the value is supposed to represent.
    - It is unclear where the flow diverted by the groundwater barrier will go (e.g., will groundwater reemerge downstream of the wall terminus?). This should be described. It remains uncertain if a groundwater barrier to limit interactions between onsite contaminated groundwater and the Cape Fear River would be feasible and effective.
8. Comments related to the measured and calculated partition and mass distribution coefficients (Appendix C and Section 3.7 of the CAP) include:
    - In Section 3.7 it is stated that detailed calculations for the mass estimates are provided in Appendix C, however, Appendix C describes the process but does not include sufficient data/spreadsheets to verify the calculations.
    - In this appendix, Log K_{ow} values were used to derive Log K_{oc} values for various PFAS compounds. Contradictorily, in the 2018 Interstate Regulatory Technology Council (IRTC) guidance document “Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances” it specifically states that “It should be noted that although the K_{ow} for some organic contaminants can be used for estimating K_{oc}, this cannot be performed for estimating values for PFAS”. This calls into question the technical approach used in Appendix C and the results obtained.
    - For HFPO-DA, the Table C-2 Log K_{oc} value is 1.1, while in Table 2 of the CAP it is 1.69. Which (if either) of these is correct and used for the calculations?
    - Throughout Table C-2, as the Log K_{ow} increases, the Log K_{oc} increases as well. This is true except when comparing PFBA and PFPeA – what is unique about these compounds? The specific calculations are not provided for review and evaluation.

9. In the monitoring well redevelopment and resampling section, it is stated that 17 wells were redeveloped onsite, and 45 wells were resampled onsite based on recommendations issued in the Onsite and Offsite Assessment Report. The CAP does not provide summary level statistics for the groundwater monitoring effort, which would be very informative (e.g., mean and range of concentrations observed).
10. As described in the updated PFAS characterization sampling plan for process and non-process wastewater and stormwater, the raw intake point onsite is used to characterize background PFAS levels. However, water from the Cape Fear River at the intake point may be influenced by legacy atmospheric emissions and contaminated groundwater attributable to the site. Samples collected further upstream are needed to better characterize background PFAS concentrations.

3.2 CRITICAL GAPS

1. Concerns regarding the planned strategies to meet the cleanup goals described in Table 10 in the CAP include:
    - **Old Outfall 002**. The cleanup goal and proposed capture and treat strategy are solely designed to handle dry weather flows, thus, wet weather flows that may facilitate erosion of contaminated sediment are excluded. Based on the three 2019 monitoring events (May, June, and September), the relative contribution of Old Outfall 002 is estimated to be 26 percent of the total onsite PFAS load to the Cape Fear River. In Table 14, 26 percent of the planned loading reduction to the Cape Fear River is attributed to the capture and treatment of Old Outfall 002. This implies that 100 percent of PFAS will be treated by 2020 for the outfall, which conflicts with only targeting groundwater with the process wastewater signature.
    - **Willis Creek and Georgia Creek**. Indirect air abatement controls and onsite groundwater remedies are listed as strategies, but no creek specific controls are planned (e.g., removal of PFAS elevated sediment, flow capture and treatment).
    - **Onsite Groundwater**. The cleanup goal for groundwater describes mitigation of PFAS with a process water signature, thus, inherently excluding remediation of onsite groundwater exhibiting an aerial deposition signature. As shown in Figure 2, some of the groundwater wells onsite exhibit the latter. Based on the three 2019 monitoring events (May, June, and September), the relative contribution of onsite groundwater is estimated to be 18 percent of the total onsite PFAS load to the Cape Fear River. In Table ES2, 18 percent of the planned loading reduction to the Cape Fear River is attributed to onsite groundwater treatment. This implies that 100 percent of PFAS in groundwater will be treated by 2024, which conflicts with only targeting groundwater with the process wastewater signature.
    - **Offsite Groundwater and Offsite Soils**. It is stated that PFAS contamination has been detected in an area of 70 square miles (or more) surrounding the facility. However, because of the extent of the contamination, lack of scalable remediation technologies, and because no groundwater standards have been issued, it is claimed in the CAP that restoring groundwater conditions to PQLs is not feasible. A lack of management of offsite pollution does not seem to comply with 2L Rules as required in the CO Paragraph 16. It is also stated that PFAS are not expected to degrade in a reasonable time period in the environment. This is a concern because contaminated soils and groundwater will contribute legacy PFAS to the Cape Fear River in the future, continuing to impact the

quality of raw intake water for CFPUA. PFAS loading just downstream of the site and at the CFPUA intake should be quantified and compared to better understand the potential for long-term contamination from offsite sediment erosion, resurfacing groundwater, and releases from sediment in the riverbed and riparian areas. The assessment should compare loading at the two locations under varied conditions (e.g., dry/low flow periods, storm events). Also, the CAP describes several newly identified seeps, labeled E to M, south of the site, although no treatment plans are prescribed.

- **Onsite Soils**. Contamination in onsite soils remains unclear and no remediation strategies have been suggested in the CAP.
- **Outfall 002**. The remediation strategies for Outfall 002 are too vague, stating that compliance with NPDES permit requirements will be completed. Information regarding the PFAS-related requirements that will be included in Chemours' NPDES permit should be requested from DEQ.

2. As discussed in Section 5.1 of the CAP, the groundwater numerical model is only intended to simulate subsurface hydraulic processes, not associated PFAS fate and transport, for the purpose of remedy costing and design. Therefore, in its current state, the model provides limited insight in terms of PFAS loading and potential remediation effectiveness. In addition, the groundwater model covers the limited domain of the site. Thus, groundwater hydraulics are not represented for the surrounding vicinity contaminated by PFAS due to legacy atmospheric deposition. Since offsite seep data is attributed to aerial PFAS deposition, it could be used to estimate groundwater PFAS discharges to the river throughout the area (including upstream and downstream of the site) by using a distance-versus-concentration gradient approach and including discharge from both sides of the river due to airborne transport processes. This analysis would be informative, although it is not discussed.
3. There is a very limited discussion of PFAS transformations in the environment and the implications for ongoing contamination, exposure risk, and remediation activity effectiveness (e.g., presence of precursors that can degrade to PFAS analytes over time). It is noted in Section 3.4, that total Table 3+ concentrations in wells are comparable to prior results (within ± 25 percent), however, temporal monitoring records have not been applied to explore transformations of PFAS, nor has available and relevant information from the literature been summarized.
4. As noted in the previous technical review, a critical gap is that the extent, magnitude, and impact (loading) of PFAS contamination in offsite groundwater and soils are poorly quantified. Releases of contaminated groundwater, diffusion from contaminated sediment, and erosion of contaminated soils may contribute PFAS to the CFPUA's intake water following the implementation of the proposed onsite control strategies. PFAS contamination of sediment in the Cape Fear River bed and riparian wetlands remains uncertain and diffusion from these stores could act as a long-term source of PFAS to the river. A river sediment sampling plan was issued in August 2019 and it is anticipated that monitoring will be conducted at several riverine locations, including near CFPUA's raw water intake site, and a report released in 2020.
5. At this time, a comprehensive flow mass balance that represents all inflow and outflows at the site has not been developed. It is stated in Section 3.4 of Appendix H that the numerical groundwater model will eventually be used to support the development of an initial water budget. However, this is a current information gap.
6. In the CAP, the onsite Willis Creek to the north and Georgia Branch Creek to the south are described as being erosional channels that empty to the Cape Fear River. PFAS accumulated in the creek beds that is eroded during storm events may contribute to ongoing PFAS loading to the

river, yet the report does not attempt to measure bed contamination and model sediment transport (net deposition and scour) for the purpose of characterizing particulate-associated PFAS transport. Note that deeper soil samples (depths of 8.5 to 11 feet) have been collected in the vicinity of Willis Creek at a single location (Figure A7-1). The results for the analytes reported were either flagged as "UJ" (defined as "Analyte not detected. Reporting limit may not be accurate or precise") or flagged as "<" (defined as "Analyte not detected above associated reporting limit").

7. It was noted in the technical review for the PFAS Loading Reduction Plan and the CAP (Section 3.3.3) that discharge of Chemours' process wastewater has been halted and the waste is injected into subsurface storage out-of-state. However, elevated HFPO-DA and PFMOAA concentrations were also observed in Kuraray process wastewater, which continues to be discharged from the onsite WWTP via Outfall 002, as discussed in the PFAS Loading Reduction Plan and previous technical review. Loading from Kuraray process wastewater remains unquantified and untreated.
8. Another gap, although perhaps minor, is related to process wastewater. Before June 21, 2017 process wastewater was discharged to the Cape Fear River and after November 29, 2017 process wastewater was captured, stored, and transported offsite for disposal. The report does not describe what was done with process wastewater in the interim, between June 22 and November 28, 2017.

3.3 OTHER COMMENTS

Other comments related to vulnerabilities pertaining to CFPUA's intake water include:

1. No manufacturing process changes have been required for Chemours to date. Spills or unknown leaks or emissions at the facility remain a risk to CFPUA's source water.
2. All monitoring applied in the assessment appears to have been conducted by Geosyntec and contracted labs for Chemours. DEQ can require split sampling (samples provided to DEQ for parallel testing) per the CO. Split sampling would be beneficial from the perspective of CFPUA for quality assurance and control checking, therefore, CFPUA should inquire about completed split sampling and the findings.

4.0 REFERENCES

Geosyntec. 2019a. Cape Fear River PFAS Corrective Action Plan, Chemours Fayetteville Works. Prepared for Chemours Company FC, LLC. by Geosyntec Consultants of NC, P.C., Raleigh, North Carolina.

Geosyntec. 2019b. Cape Fear River PFAS Loading Reduction Plan. Prepared for Chemours Company FC, LLC. by Geosyntec Consultants of NC, P.C., Raleigh, North Carolina.

Hopkins, Z. R., M. Sun, J.C. DeWitt, and D.R.U. Knappe. 2018. Recently detected drinking water contaminants: GenX and other per- and polyfluoroalkyl Ether Acids. *Journal of the American Water Works Association*, 110(7), https://doi.org/10.1002/awwa.1073.

IRTC. 2018. Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS). Interstate Regulatory Technology Council. https://pfas-1.itrcweb.org/wp-content/uploads/2017/10/pfas_fact_sheet_naming_conventions_11_13_17.pdf.

Kong, X., W. Liu, W. He, F. Xu, A.A. Koelmans, and W.M. Mooij. 2018. Multimedia fate modeling of perfluorooctanoic acid (PFOA) and perfluoroctane sulphonate (PFOS) in the shallow lake Chaohu, China. *Environmental Pollution*, 237: 339-347.

Mackay, D., M. Joy, and S. Paterson. 1983. A quantitative water, air, sediment interaction (QWASI) fugacity model for describing the fate of chemicals in lakes. *Chemosphere*, 12: 981-997.

Tetra Tech. 2019. Technical Review of Cape Fear River PFAS Loading Reduction Plan for Cape Fear River Public Utility Authority (CFPUA). Prepared for Cape Fear River Public Utility Authority by Tetra Tech, Research Triangle Park, North Carolina.

Limited Review of "APPENDIX F: Offsite Human Health Screening Level Exposure Assessment (SLEA) of Table 3+ PFAS" (authored by Geosyntec Consultants) for the Cape Fear Public Utility Authority.

February 21, 2020

Prepared for:
Cape Fear Public Utility Authority
235 Government Center Drive
Wilmington, NC 28403

Prepared by:
Jamie C. DeWitt, PhD, DABT
Independent Consultant
Greenville, NC 27834
Voice: 919-608-2373
Email: dewittj@ecu.edu

Brief Summary of Appendix F and Overview of Charge

"Appendix F" is a support document for the Corrective Action Plan (CAP) for the Chemours Fayetteville Works Facility in Bladen, County, North Carolina (referred to as "the Facility" in Appendix F). The "Screening Level Exposure Assessment" (SLEA) contains numerical estimates of human exposure to per- and polyfluoroalkyl substances (PFAS) originating from air emissions and/or past process water releases from the Facility. These numerical estimates of human exposure come from PFAS estimated or measured from a variety of environmental media – soil, well water, homegrown produce, offsite surface water and fish tissue, onsite surface water and fish tissue, and surface water from an offsite pond. Where possible, the consulting company hired by Chemours (Geosyntec Consultants of NC, P.C.) calculated "exposure point concentrations" (EPCs) for these environmental media using models from the U.S. Environmental Protection Agency (EPA).

EPCs were calculated from environmental media to estimate PFAS exposure to different groups of people through these environmental media. The groups of people included in Appendix F were adult and child residents, farmers, and gardeners. Some PFAS exposures also were calculated for adult and child recreational consumers of surface waters and fish tissues. Exposure was therefore based on how much PFAS these groups of people would take into their bodies through these various environmental media (defined as "intake"). As with EPCs, assumptions about intake were based on values available from the U.S. EPA (i.e., how much water an adult drinks per day or how much incidental ingestion of soil occurs for a child).

Once the total intake of PFAS was calculated for each group of people, the consulting company compared the values to the North Carolina Department of Health and Human Services (NC DHHS) 2017 draft oral reference dose (oral RfD) for "GenX," or hexafluoropropylene oxide dimer acid (HFPO-DA), which is 1×10^{-4} mg/kg/day. This comparison was made to determine if intake was greater or lesser than this RfD. The U.S. EPA (1993) defines a RfD as "an estimate (with uncertainty spanning perhaps an order of magnitude) 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." The U.S. EPA (1993) further clarifies the RfD by indicating that it should not be categorically concluded that all doses below the RfD are without risk and that all doses in excess of the RfD will result in adverse effects. In other words, the RfD can be used as a guide to determine if intake of PFAS is above or below an acceptable level but does clearly and unquestionably separate groups "with risk" from groups "without risk."

I have been asked to prepare a brief memorandum evaluating specific points in Appendix F that concern surface water consumption from offsite surface water. This evaluation will include a) components not considered or gaps in the assessment that have the potential to impact the results and b) additional studies that should be conducted to strengthen the assessment.

This memorandum reflects my professional opinion based on my extensive knowledge of toxicology and the risk assessment process and the toxicology of PFAS. It does not reflect the

opinion of the Department of Pharmacology and Toxicology, the Brody School of Medicine, East Carolina University, or any other organization or entity to which I belong.

Section 3: Conceptual Exposure Model (pp 10-14 in Appendix F)

PFAS evaluated in the SLEA are listed in Table 1 of Appendix F and are included here as a reference point.

TABLE 1
TABLE 3+PFAS EVALUATED IN THE SLEA
Chemours Fayetteville Works, North Carolina

Geosyntec Consultants of NC P.C.

Chemical Abbreviation	Chemical Name	Chemical Formula	Consent Order Constituent	Table 3+ Constituent
HFPO-DA	Hexafluoropropylene oxide dimer acid	C6HF11O3	X	X
PEPA	Perfluoroethoxypropyl carboxylic acid	C5HF9O3	X	X
PFECA-G	Perfluoro-4-isopropoxybutanoic acid	C12H9F9O3S	X	X
PFMOAA	Perfluoro-2-methoxyaceticacid	C3HF5O3	X	X
PFO2HxA	Perfluoro(3,5-dioxahexanoic) acid	C4HF7O4	X	X
PFO3OA	Perfluoro(3,5,7-trioxaoctanoic) acid	C5HF9O5	X	X
PFO4DA	Perfluoro(3,5,7,9-tetraoxadecanoic) acid	C6HF11O6	X	X
PMPA	Perfluoromethoxypropyl carboxylic acid	C4HF7O3	X	X
Hydro-EVE Acid	Perfluoroethoxsypropanoic acid	C8H2F14O4		X
EVE Acid	Perflouroethoxypropionic acid	C8HF13O4		X
PFECA B	Perfluoro-3,6-dioxaheptanoic acid	C5HF9O4		X
R-EVE	R-EVE	C8H2F12O5		X
PFO5DA	Perfluoro-3,5,7,9,11-pentaoxadodecanoic acid	C7HF13O7	X	X
Byproduct 4	Byproduct 4	C7H2F12O6S		X
Byproduct 6	Byproduct 6	C6H2F12O4S		X
Byproduct 5	Byproduct 5	C7H3F11O7S		X
NVHOS	Perflouroethoxysulfonic acid	C4H2F8O4S		X
PES	Perfluoroethoxyethanesulfonic acid	C4HF9O4S		X
PFESA-BP1	Byproduct 1	C7HF13O5S	X	X
PFESA-BP2	Byproduct 2	C7H2F14O5S	X	X

Notes:
CASN - Chemical Abstract Service Number
SLEA - Screening Level Exposure Assessment

This section defined the groups of people who were included in the "conceptual exposure model." This type of model draws the connections between levels of PFAS in environmental media with how much PFAS groups of people will take in from those environmental media. These connections were highlighted in Figure 2 of Appendix F. Connections that were considered incomplete were not evaluated. These were based on whether or not data were available on 1) a source of PFAS or release of PFAS from a source, 2) a mechanism of release and transport of PFAS, 3) a point of contact of the groups of people to the environmental media containing PFAS, 4) and exposure route (i.e., ingestion, inhalation, dermal), and 5) the presence of groups of people. Note that groups of people were referred to as "receptors" or "receptor populations" throughout Appendix F. This is standard terminology for conceptual exposure models.

Components not considered/gaps in the assessment/additional studies: Three groups of people were not considered in the SLEA: fetuses during pregnancy, infants, and lactating women. The U.S. EPA Health Advisory Level for two PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) were based on protection of fetuses during pregnancy and breastfed infants. The Health Advisory Level was calculated based on drinking water intake of

lactating women who drink a higher volume of water than other people and who can pass PFAS to their nursing infants through breastmilk (U.S. EPA, 2017). In addition, the NC DHHS drinking water exposure limit (DWEL) for HFPO-DA also was based on protection of bottle-fed infants. Therefore, the populations at the highest risk from adverse health effects arising from PFAS exposure, fetuses during pregnancy and infants, were not considered in the SLEA.

Section 4: Identification of Offsite Exposure Units (pp 15-16 in Appendix F)

The conceptual exposure model also included a description of the environmental media that contained PFAS as identified in environmental investigations in and around the Facility. Only surface waters are considered in this memorandum and they include all identified exposure units (EUs) of the Cape Fear River (EUs 13-17). These surface waters included upstream and Facility-adjacent locations as well as locations 4, 8, and 55 miles downstream from the Facility.

Components not considered/gaps in the assessment/additional studies: None identified.

Section 5: Environmental Datasets and EPCs; 5.3: Surface Water (pp 23-26 in Appendix F)

Information of PFAS detected in surface waters was collected from locations depicted in Figure 7, which included upstream, Facility-adjacent, and downstream (4, 8, and 55 miles from the Facility) and included nine discrete sampling events between September of 2017 and the Summer of 2019. These events included months in the spring, summer, fall, and winter seasons and also appear to have included weather events such as Hurricane Florence. The water samples were analyzed with Method 537, which is a method developed by the U.S. EPA for evaluation of up to 18 different PFAS in water samples (EPA, 2018a). Additional methods were employed for some samples to evaluate Table 3+ PFAS. The surface water data were then segregated to develop EPCs for recreational and drinking water uses.

Components not considered/gaps in the assessment/additional studies: Additional sampling locations between 8 and 55 miles from the Facility would provide more information about the spatial distribution of PFAS in surface waters of the Cape Fear River. Additional collection times would provide more details about the temporal fluctuations of PFAS in surface waters of the Cape Fear River.

Section 6: Intake Characterization; (pp 32-34 in Appendix F)

Intake of PFAS was expressed in milligrams of PFAS per kilogram of body weight per day as an average daily intake (ADI). Equations used to calculate intake were based on U.S. EPA guidance documents that provide intake rates. The following surface water ADIs were included in Appendix F:

- Facility-adjacent and near-downstream EUs for recreationalists = 7.3×10^{-8} to 3.1×10^{-6} mg/kg/day.
- Bladen and Kings Bluffs EUs for recreationalists = 1.1×10^{-7} to 2.1×10^{-6} mg/kg/day
- Bladen Bluffs EUs for residents, HFPO-DA only = 1.2×10^{-5} to 1.8×10^{-5} mg/kg/day
- Kings Bluffs EUs for residents, HFPO-DA only = 6.4×10^{-7} to 9.2×10^{-7} mg/kg/day
- Kings Bluffs EUs for residents, Table 3+ PFAS = 3.5×10^{-6} to 5.0×10^{-6} mg/kg/day

Components not considered/gaps in the assessment/additional studies: ADI calculations used in the SLEA do not consider biological half-life and body burden. The biological half-life is how much time it takes to reduce the concentration of a chemical in the body by one-half and body burden is how much of a chemical is in the body at any given time (Baynes et al., 2012). Failure to include half-life and body burden inherently flaws ADI calculations because it assumes complete elimination of a chemical from the body between exposures. PFAS such as PFOA and PFOS have biological half-lives of years, leading to increased body burdens over time with repeated exposures. Therefore, ADI calculations without a factor that includes biological half-life tend to underestimate intake. While the half-life of HPDO-DA and other Table 3+ PFAS are unknown, an assumption of complete elimination is flawed without empirical data on half-life.

Components not considered/gaps in the assessment/additional studies: Dermal intakes were not calculated due to the lack of dermal toxicity criteria (i.e., an RfD for dermal toxicity) developed at the state or federal level. There are a few studies of adverse health outcomes arising from dermal exposure to, for example, PFOA (Shane et al., 2020). Such values could have been used as a basis for comparing dermal intakes.

Section 7: Provisional Hazard Characterization (pp 35-38 in Appendix F)

Much of this section contained background definitions of toxicological values (section 7.1). Section 7.2 contained the basic methods used by Geosyntec Consultants to characterize the potential hazards of HFPO-DA and Table 3+ PFAS. The basic comparison was the ratio of the ADI to the RfD, often referred to as the "hazard quotient." Recall that the RfD was derived by NC DHHS in 2017 and was a draft oral RfD (1×10^{-4} mg/kg/day) for HFPO-DA. If the ADI exceeded the RfD (hazard quotient > 1), intake was greater than a level that is considered acceptable. If the ADI was less than the RfD (hazard quotient < 1), intake was less than a level that is considered acceptable. It also is important to recall that the RfD is not a clearly defined value separating high risk from low risk levels.

All of the hazard quotients that Geosyntec Consultants calculated for groups of people consuming surface waters were less than one.

Components not considered/gaps in the assessment/additional studies: As stated previously, ADI calculations without a factor that includes biological half-life tend to underestimate intake and dermal intakes were not calculated.

Section 8: Uncertainty Assessment (pp 39-48 in Appendix F)

This section of Appendix F described uncertainties that may have had an impact on the SLEA. Uncertainties included environmental sampling results, assumptions regarding receptor behavior, and the quantitative representation of chemical toxicity. Geosyntec Consultants indicated that where there was "significant uncertainty," they tried to provide additional conservatism, which would tend to provide additional protections. A few areas of this section are highlighted here.

With respect to sources of uncertainty associated with surface water EPCs, Geosyntec Consultants highlighted the "transient nature of surface water" as the primary source of uncertainty. Each sample collected reflected only the levels of PFAS in surface water at that particular time and may not reflect that levels of PFAS may differ across time. While (described in Section 5) surface water samples were collected at nine discrete times that included months in spring, summer, fall, and winter and also appeared to have included weather events such as Hurricane Florence, these events may not have fully captured average/median levels of PFAS in surface water.

There also may have been inconsistencies in what PFAS were measured across the different surface water samples. In some samples, only HFPO-DA was measured whereas in others, all nine Table 3+ PFAS were measured. Therefore, some PFAS (i.e., Table 3+ PFAS) could be underestimated in surface water samples.

Dermal exposures from soil, well water, and surface water were not evaluated due to the lack of dermal toxicity criteria developed at the state or federal level.

Another major area of significant uncertainty was associated with the hazard characterization. One focus on this section was on discrepancies between the NC DHHS RfD and one derived by authors of a manuscript published in 2019 (Thompson et al., 2019).

Components not considered/gaps in the assessment/additional studies: Pages 47-48 of this section contain erroneous assumptions.

1. "Longer-duration animal studies are more relevant to most human exposure and generally given preference when used to develop toxic potency estimates for humans." While this is a *preference*, it is not a rule or requirement. The database for HFPO-DA contains several sub-chronic studies and only one chronic study. Therefore, the database for sub-chronic studies is richer than for chronic studies, thus supporting the derivation of a RfD from a sub-chronic study.
2. "…the liver lesions in mice are consistent with PPARα activation and, hence, the observed effects are not relevant to humans." The NC DHHS oral RfD was derived from the observation of liver single cell necrosis (cell death) in mice. This particular endpoint, necrosis, is not thought to be a PPARα-mediated key event for liver tumors in rodents (Corton et al., 2018) and therefore is relevant to humans.
3.

Additionally, the oral RfD calculated by the NC DHHS is supported by the draft sub-chronic oral RfD calculated by the U.S. EPA for HFPO-DA (2×10^{-4} mg/kg/day), which also was based on liver single cell necrosis (EPA, 2018b). Therefore, including a discussion of a higher alternative oral RfD derived by Thompson et al. (2019) without including a discussion of the U.S. EPA sub-chronic oral RfD for HFPO-DA is misleading. This section should be removed, or a discussion of the U.S. EPA sub-chronic oral RfD for HFPO-DA should be included.

References Cited

Baynes RE, Dix KJ, Riviere JE. 2012. Distribution and pharmacokinetics models. In: *Pesticide Biotransformation and Distribution* (ed: E. Hodgson). Elsevier Inc. San Diego, CA, USA.

Corton JC, Peters JM, Klaunig JE. 2018. The PPARα-dependent rodent liver tumor response is not relevant to humans: addressing misconceptions. *Archives of Toxicology*. 92:83-119.

NC DHHS. 2017. Questions and answers regarding North Carolina Department of Health and Human Services Updated Risk Assessment for GenX (perfluoro-2-propoxypropanoic acid). https://epi.dph.ncdhhs.gov/oee/pfas/NC%20DHHS%20Health%20Goal%20Q&A.pdf.

Shane HL, Baur R, Lukomska E, Weatherly L, Anderson SE. 2020. Immunotoxicity and allergenic potential induced by topical application of perfluorooctanoic acid (PFOS) in a murine model. *Food and Chemical Toxicology*. 137:111141.

Thompson CM, Fitch SE, Ring C, Rish W, Cullen JM, Haws LC. 2019. Development of an oral reference dose for the perfluorinated compound GenX. *Journal of Applied Toxicology*. 39:1267-1282.

US EPA. 1993. Reference dose (RfD): Description and use in health risk assessments. Background Document 1A. https://www.epa.gov/iris/reference-dose-rfd-description-and-use-health-risk-assessments.

U.S. EPA. 2018a. Method 537.1. Determination of selected per- and polyfluorinated alkyl substances in drinking water by solid phase extraction and liquid chromatography/tandem mass spectrometry. EPA Document #: EPA/600/R-18/352.

U.S. EPA. 2018b. 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 #: 823-P-18-001.