Geosyntec Consultants of NC, PC

OFFSITE SCREENING LEVEL EXPOSURE ASSESSMENT OF SITE ASSOCIATED PFAS - WORKPLAN

Chemours Fayetteville Works

Prepared for

The Chemours Company FC, LLC
Fayetteville Works
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LIST OF ABBREVIATIONS

ADI	Average Daily Intake
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
bgs	Below Ground Surface
Chemours	The Chemours Company FC, LLC
CFPUA	Cape Fear Public Utility Authority
CFRW	Cape Fear River Watch
CY	Calendar Year
DEQ	Department of Environmental Quality
DHHS	Department of Health and Human Services
DuPont	E.I. du Pont de Nemours and Company
EPC	Exposure Point Concentration
EU	Exposure Unit
°F	Degrees Fahrenheit
GI	Gastrointestinal
HDPE	High-Density Polyethylene
HFPO-DA	Hexafluoropropylene Oxide Dimer Acid
km	Kilometer
K_{ow}	Octanol-Water Partition Coefficient
Kuraray	Kuraray America Inc.
ISM	Incremental Sampling Methodology
mg/kg-day	Milligram(s) per Kilogram of Body Weight per Day
mg/L	Milligram(s) per Liter
MSL	Mean Sea Level
NC	North Carolina
ng/L	Nanograms per Liter
NPDES	National Pollutant Discharge Elimination System
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
pKa	Acid Dissociation Constant

LIST OF ABBREVIATIONS (CONTINUED)

PPA	Polymer Processing Aid
PVF	Polyvinyl Fluoride
RfDd	Dermal Reference Dose
RfDo	Oral Reference Dose
RM	River Mile
Site	Chemours Fayetteville Works Plant
SLEA	Screening Level Exposure Assessment
SOP	Standard Operating Procedure
UCL	Upper Confidence Limit on the Mean
UF	Uncertainty Factor
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WET	Whole Effluent Toxicity

1 INTRODUCTION

Geosyntec Consultants of NC, PC (Geosyntec) has prepared this Offsite Screening Level Exposure Assessment (SLEA) of Site-Associated PFAS Workplan for The Chemours Company FC, LLC (Chemours) for the Fayetteville Works facility in Bladen County, North Carolina. The purpose of the SLEA described in this workplan is to estimate potential offsite human exposures to historically-deposited, Site-Associated perfluoroalkyl and polyfluoroalkyl substances (PFAS) using regional[1] concentrations of Site-Associated PFAS compounds in environmental media (e.g., soil, groundwater, surface water) and biota (e.g., fish) in the vicinity of the Site. The SLEA will focus on hexafluoropropylene oxide dimer acid (HFPO-DA[2]) while also estimating human exposures to the 19 other Site-Associated PFAS presently capable of being analyzed using the Table 3+ standard operating protocol (SOP) method. The Site-Associated PFAS that will be considered are listed in Table 1. The SLEA will also present the results of a hazard characterization for HFPO-DA based on intakes quantified in the SLEA and the North Carolina Department of Health and Human Services (NC DHHS) 2017 draft oral reference dose (RfDo).

The SLEA is being performed to support the Groundwater Corrective Action Plan (CAP) required by Paragraph 16 and components of the On and Offsite Assessment required in Paragraph 18 of the executed Consent Order (CO) entered into court on February 25, 2019 and signed by Chemours, the North Carolina Department of Environmental Quality (NCDEQ), and the Cape Fear River Watch (CFRW).

Paragraph 16, requires the submission of a CAP by December 31, 2019 for onsite and offsite groundwater. By estimating offsite exposures to historically-deposited, Site-Associated PFAS, and hazard to offsite receptors associated with historically-deposited HFPO-DA, this SLEA will inform and support corrective action selection.

The focus of the SLEA is on exposures to historically-deposited, Site-Associated PFAS that may be present offsite, which may inform the groundwater CAP. Additionally, historically-deposited PFAS are selected as the focus since Chemours is taking action to reduce air emissions of PFAS from the facility, including installation of a thermal oxidizer by December 31, 2019 that will control all PFAS from routed process streams at an efficiency of 99.99%. This is relevant since offsite, Site-Associated PFAS are believed to primarily originate from aerial deposition stemming from site emissions, as will be

[1] PFAS concentrations and exposures are characterized herein as “regional” on the basis that they do not represent conditions at a specific point of exposure (e.g., in an individual yard or from a specific drinking water well) nor do they represent exposure potential for a specific receptor (e.g., a resident on a specific property).
[2] HFPO-DA is also referred to as GenX.

analyzed in the On and Offsite Assessment report due September 30, 2019. Based on this, the present concentrations of offsite PFAS are expected to diminish over time and current conditions should represent the highest expected concentrations in receiving media going forward. Soils may have received historical releases from facility operations through air deposition. In turn, Site-Associated constituents in soil may be contributed to groundwater through infiltration of the vadose zone. With a reduction in air emissions, associated soil and groundwater concentrations will attenuate over time.

This SLEA will consider relevant exposure scenarios under future potential conditions where Consent Order air emission reduction targets have been achieved. The SLEA will be completed by December 31, 2019 and is presently planned to be provided simultaneously to NCDEQ and CFRW with the Corrective Action Plan submission due on December 31, 2019.

1.1 SLEA Objectives

The objectives of the SLEA are as follows:

1. Develop representative exposure point concentrations (EPCs) for HFPO-DA and the 19 other Site-Associated PFAS in offsite environmental media.
2. Develop estimates of average intake of HFPO-DA and other Site-Associated PFAS from relevant exposure pathways for potential human receptor populations in the vicinity of the Site.
3. Develop estimated ranges of potential associated human health hazard, predicated on intake estimates by pathway and receptor population[3].
4. Identify and evaluate uncertainties associated with limitations in environmental data, and exposure assumptions in the context of the results of the SLEA intake and hazard characterizations to support defensible site and risk management decision-making.

The methodology used in this assessment is consistent with North Carolina risk assessment practices and the United States Environmental Protection Agency's (USEPA) G*uidelines for Exposure Assessment* (USEPA, 1992) and *Draft Guidelines for Human Exposure Assessment* (USEPA, 2016).

[3] The SLEA Hazard Characterization will use the draft RfDo developed by the NC DHHS (2017), which underpins the State's provisional health goal for HFPO-DA in drinking water. The SLEA Uncertainty Assessment will evaluate the implications for use of alternate toxicity criteria, such as the probabilistic RfDo developed by Thompson, et al. (2019) and the USEPA's draft RfDo (USEPA, 2018a). See Section 8.1 for further discussion.

1.2 Overview of HFPO-DA

HFPO-DA is a man-made chemical produced at the Chemours Fayetteville Works Site.

The HFPO-DA compound is a six carbon, branched PFAS molecule that contains an ether bond (i.e., an oxygen atom linking two carbon atoms). HFPO-DA[4] is a clear, colorless liquid completely miscible with water (i.e., infinite solubility in surface water, groundwater, rainwater, leachate) and low octanol-water partitioning capacity (estimated K_{ow} 1.3 – 2.0)[5]. Under normal environmental conditions, HFPO-DA exists as an anionic acid (2.8 acid dissociation constant [pKa])[6] (Hoke et al., 2016). Biodegradability test data (DuPont-A080558; Kaplan, 2010) indicate HFPO-DA is not readily biodegradable, with a half-life in soil, water, air, and sediment greater than 6 months (USEPA, 2018a). As such, HFPO-DA is expected to be relatively stable and persistent in the environment, and resistant to photolysis and hydrolysis (undergoing very slow hydroxyl radical catalyzed indirect photolysis). Based on a calculated Henry's Law Constant, partitioning from water to air may occur as well. When released to air, HFPO-DA is stable and long-range transport is possible, with deposition augmented by scavenging by water droplets/precipitation.

Measured bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) suggest that HFPO-DA has a low potential to bioaccumulate in biota. Multiple fish studies have confirmed BCFs of less than 3 and 30, based on exposure to 0.2 and 0.02 milligrams per liter (mg/L), and BCFs of 1 for higher concentrations (DuPont-A080560 2009; Hoke et al., 2016; Goodband, 2019). Log BAFs, calculated for carp, were 0.86 for blood, 0.5 for liver and 0.61 for muscle. Tissue values indicate a BAF of less than 10 (Pan et al., 2017).

1.3 Document Organization

This document presents the approach, data availability and needs, and interpretation methods to be used in the forthcoming SLEA. This Workplan is organized such that it represents an outline for the SLEA Report.

This document is organized as follows:

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[4] HFPO-DA is used here to refer to: 2,3,3,3-tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)-propanoic acid (CASN 13252-13-6), which has the chemical formula $C_6HF_{11}O_3$.
[5] K_{ow} is the octanol-water partitioning coefficient, the ratio of the equilibrium concentration of a dissolved chemical in a two-phase system of n-octanol and water. n-Octanol serves as a surrogate to biota lipids and K_{ow} values are used as an indicator of a chemical's tendency to bioaccumulate, or to be taken-up by organisms from the environment.
[6] The pKa predicts that HFPO-DA will be in acid form (as a negative ion, or an anion) at pH levels at or above a pH of 2.8.

- Section 1, *Introduction*, presents the objectives of the SLEA and provides an overview of the primary constituents of interest.
- Section 2, *Background*, summarizes conditions in offsite areas in the vicinity of the Site, focusing on those that are relevant to developing a conceptual site model and conceptual exposure model (CEM).
- Section 3, *Conceptual Exposure Model*, identifies potentially complete exposure pathways by which human receptors may come into contact with HFPO-DA and other Site-Associated PFAS compounds in the environment.
- Section 4, *Identification of Offsite Exposure Units*, describes the exposure units for evaluation in the SLEA and their rationale for identification.
- Section 5, *Environmental Datasets*, summarizes the existing Site data and, where applicable, describes the sampling and analysis methods for additional data collection.
- Section 6, *Exposure Point Concentrations*, describes how existing data and data collected per this Workplan will be used to quantify potential human exposure.
- Section 7, *Intake Characterization*, summarizes the methods for quantifying human exposure. In the SLEA Report, this section will be expanded to present the calculated intakes.
- Section 8, *Provisional Hazard Characterization*, will present a description of the methods and toxicological criteria used to derive the set of estimated human health hazard quantitative point estimates for relevant populations and associated complete exposure pathways in the SLEA.
- Section 9, *Uncertainty Assessment*, preliminarily identifies key uncertainties anticipated in the SLEA, which will be updated and expanded upon as the SLEA proceeds.
- Section 10, *Conclusions*, is beyond the scope of the Workplan but serves as place holder for the forthcoming SLEA Report.
- Section 11, *References*, presents the references used in the development of this Workplan.

As indicated above, several of the sections will be expanded to present the findings of field sampling and analysis and data interpretation proposed herein. It should be noted that the Appendices listed in the Table of Contents are not included herein but will be included in the SLEA Report.

2 BACKGROUND

The following section describes the physical setting and operational history of the Site, as well as fate and transport considerations for HFPO-DA.

2.1 Site Description

The Site is located within a 2,177-acre property at 22828 NC Highway 87, approximately 15 miles southeast of the city of Fayetteville, NC along the Bladen-Cumberland county line. Figure 1 presents an overview of the Site. The Site is bounded by NC Highway 87 to the west, Cape Fear River to the east, and by undeveloped areas and farmland to the north and south. Willis and Georgia Branch Creeks, which are tributaries of the Cape Fear River, are located near the northern and southern property boundaries respectively, with the Georgia Branch Creek being offsite for its entire course (Geosyntec, 2019a).

2.2 Site History

The Site property was originally purchased by E.I. du Pont de Nemours and Company (DuPont) in 1970 and the first manufacturing area was constructed shortly thereafter. A former manufacturing area used to produce nylon strapping and elastomeric tape was sold in 1992. DuPont sold its Butacite® and SentryGlas® manufacturing units to Kuraray America Inc. (Kuraray) in June 2014 and subsequently spun off its specialty chemicals business into Chemours in July 2015. Presently, the Site consists of five manufacturing areas used to produce plastic sheeting and resin, fluorochemicals, fluoropolymer sheeting and resin, and intermediates for plastics manufacturing (Parsons, 2014). The five manufacturing areas shown in Figure 1 include: Chemours Monomers IXM; Chemours Polymer Processing Aid (PPA); Kuraray Butacite®; Kuraray SentryGlas®; and DuPont Company polyvinyl fluoride (PVF) resin manufacturing unit. In addition to the manufacturing operations, Chemours operates two natural gas-fired boilers and a wastewater treatment plant for the treatment of sanitary wastewaters from Chemours, Kuraray, and DuPont and process wastewaters from Kuraray and DuPont (Geosyntec, 2019a). Hazardous waste generated during manufacturing activities are managed at the Hazardous Container and Storage Area prior to shipment offsite for treatment, disposal, or recycling (Parsons, 2014).

2.3 Climate

The climate in Bladen County is characterized by relatively mild winters, hot summers, and abundant rainfall. According to the National Weather Service, average monthly temperatures range from a high of 91 degrees Fahrenheit (°F) in July to a low of 33°F in January. Average monthly rainfall ranges from a high of 5.92 inches in July to a low of 2.65 inches in December (Parsons, 2014).

2.4 Topography

The developed portion (manufacturing area) of the Site is located on a relatively flat topographic plateau at an approximate elevation of 145 feet above mean sea level (MSL) and approximately 70 feet above the Cape Fear River floodplain. Surface topography generally remains flat to the west with a gentle increase of about 5 feet to a topographic divide near NC Highway 87. However, ground surface elevations decrease from the topographic plateau at the manufacturing area towards the Cape Fear River to the east as well as its tributaries, Willis Creek to the north and Georgia Branch Creek to the south. Topographic relief from the main manufacturing area decreases by approximately 100 feet in elevation towards the Cape Fear River bank to the east. Inclined topographic relief combined with overland flow and groundwater seeps have created natural drainage networks into the Cape Fear River (Geosyntec, 2019a).

2.5 Cape Fear River and Tributaries

The Cape Fear River and its entire watershed are located in the state of North Carolina. The Cape Fear River drains 9,164 square miles and empties into the Atlantic Ocean near the city of Wilmington, NC. The Site is situated on the western bank of the Cape Fear River; it draws water from the Cape Fear River and returns over 95% of this water via Outfall 002 after being used primarily as non-contact cooling water. Two lock and dam systems with United States Geological Survey (USGS) stream gauges are located downstream of the Site: (1) W.O. Huske Lock and Dam, located 0.5 river miles from the Site (USGS 02105500); and (2) Cape Fear Lock and Dam #1, located 55 river miles downstream (USGS 02105769).

There are three perennial surface water features that are tributaries to the Cape Fear River at or adjacent to the Site. To the north of the Site is Willis Creek, in proximity to the water intake for the Site. To the south of the Site is Georgia Branch Creek which discharges to the Cape Fear River approximately 7,500 feet south of the W.O. Huske Dam. Now discontinued, Old Outfall 002 (adjacent to the Site) discharged into the Cape Fear River approximately 1,350 feet south of the W.O. Huske Dam (Geosyntec, 2019a). Additionally, in January 2019 three groundwater seep features were identified on the hillside leading from the Site to the Cape Fear River. These seeps represent groundwater exiting the aquifer and forming channelized flows of water to the Cape Fear River.

2.6 Geology and Hydrogeology

The Site is located within the Coastal Plain Physiographic Province of North Carolina. The Coastal Plain Physiographic Province extends from the Fall Line, a sinuous and erosionally-defined boundary separating the metamorphic and igneous rocks of the Piedmont Province to the northwest, to the present-day coast. The Coastal Plain

Physiographic Province is characterized by a southeastward thickening wedge of late Cretaceous to Holocene age sediments that overlie a Paleozoic age crystalline basement.

Based on the geologic map of North Carolina, the Site is underlain by the Black Creek Formation which ranges in age from early Campanian through early Maastrichtian of the Late Cretaceous epoch (approximately 66 to 84 million years ago). The Black Creek Formation is divided locally into three sub-units from oldest to youngest: Tar Heel Formation, Bladen Formation, and Donoho Creek Formation. In general, the Black Creek Formation is characterized by lignitic clay with thin beds and laminae of fine-grained micaceous sand as well as thick lenses of cross-bedded sand. The upper portion of the formation may also contain glauconitic, fossiliferous clayey sand lenses (Geosyntec, 2019a).

Based on the lithology logged during Site investigations (Parsons, 2014; Parsons, 2018a; Parsons, 2019), the Site is underlain by the following hydrogeologic units, listed below from ground surface to depth:

- A silty sand unit with thin discontinuous interbedded silt/clay lenses, referred to herein as the Perched Zone.
- A laterally discontinuous, stiff clay lens underlying the Perched Zone. This clay lens appears to be limited in lateral extent to the east, north, and south by local topography and pinches out to the west of the manufacturing area based on lithologic logging and limited geophysical survey. The depth to the top of the clay lens is approximately 15 to 18 feet below ground surface (bgs). The clay lens becomes thinner moving west across the manufacturing area and ranges from approximately 1 foot to approximately 19 feet thick.
- Fine- to medium-grained sand interbedded with silt/clay lenses, the saturated portion of which is herein referred to as the Surficial Aquifer. The sand extends to a depth of approximately 65 feet bgs (elevation of +80 feet MSL).
- Beneath the surficial unit is a 7 to 15 foot-thick, stiff, lignitic clay identified as the Black Creek Confining Unit. This Cretaceous-aged, regionally-extensive unit is encountered at the Site at an approximate elevation of +65 to +77 feet MSL. While the lateral continuity of this unit was verified north-south across the Site through lithologic borings, the east- west extent of this unit has not been verified through borings. However, during recent field work described in the *Creeks, Old Outfall 002 and Seeps Assessment Workplan* (Geosyntec, 2019b), this unit was observed to outcrop along the bluff face adjacent to the Cape Fear River, and along an embankment near Old Outfall 002 at similar elevations.

- Beneath the Black Creek Confining Unit is the regionally-extensive Black Creek Aquifer, which is approximately 8 to 20 feet thick and is encountered at depths between 80 and 100 feet bgs (elevation of approximately +45 to +65 feet MSL).
- Beneath the Black Creek Aquifer is a massive dense clay (with minor sand stringers) that has been identified as the Upper Cape Fear Confining Unit. This unit has not been fully penetrated at the Site.

Hydrostratigraphic units of interest in the vicinity of the Site include a Perched Zone, the Surficial Aquifer, and the Black Creek Aquifer. While the Surficial Aquifer and Black Creek Aquifer are regionally extensive features, the Perched Zone is limited in extent to the top of the clay lens that underlies most of the manufacturing area. These hydrostratigraphic units are described further below:

- Perched Zone – Groundwater in the Perched Zone appears to be controlled by the topography and lateral limits of the clay lens that underlies most of the manufacturing area. Historically, groundwater in the Perched Zone appears to have mainly resulted from: (1) past seepage of water through the bottom of the North/South Sediment Basins that are used to settle out solids from Cape Fear River water; (2) past infiltration of water from the cooling water channel around the Monomers IXM Area; and (3) infiltration of rainfall. The sediment basins and the cooling water channel were lined in November 2018 as part of the ongoing Site remedial actions to reduce infiltration to the Perched Zone. Perched Zone water likely flows in a radial pattern away from a potentiometric high near the sedimentation basins. Where perched water is present, it is encountered from approximately 6 feet bgs at the basins to a depth of approximately 20 feet bgs along the edges of the Perched Zone west of the basins.
- Surficial Aquifer – The Surficial Aquifer is encountered at approximately 40 feet bgs and extends to a depth of approximately 65 feet bgs (elevation of approximately +110 to +80 feet MSL). Groundwater elevations range from approximately 100 to 107 feet above MSL in the western areas of the Site to approximately 93 feet above MSL in the eastern areas of the Site, indicating that groundwater flow is generally toward the Cape Fear River. The water level of the Cape Fear River is typically near +30 feet MSL, which is lower than the base elevation of the Surficial Aquifer. This elevation difference suggests that water from the Perched Zone and the Surficial Aquifer will reach the Cape Fear River from a potential combination of groundwater seepage on the hillslope and subsequent flow to the Cape Fear River (observed), and potential infiltration to the Black Creek Aquifer and subsequent discharge to the Cape Fear River.

- The Black Creek Aquifer – The Black Creek Aquifer is potentially under semi-confined to confined conditions at portions of the Site where it is separated from the overlying Surficial Aquifer by the clay Black Creek Confining unit. As noted above, the lateral extent of the clay confining unit has not been verified towards the eastern portion of the Site. Groundwater flow in the Black Creek Aquifer is toward the Cape Fear River. At the Site, only the Black Creek Aquifer is in direct connection to the Cape Fear River with the potential exception of the Surficial Aquifer during extreme flood events.

Groundwater seeps were observed during recent field work being performed as part of the *Creeks, Old Outfall 002 and Seeps Assessment Workplan* (Geosyntec, 2019b). Groundwater seeps to surface where the Perched Zone, Surficial Zone, and the Black Creek Aquifer intersect the side of the bluff slope below the Facility and flows towards the Cape Fear River in a series of naturally-occurring erosional channels. These channels have been observed to contain a steady flow of water where they intersect groundwater. The three seeps observed on the eastern bluff adjacent to the Cape Fear River from north to south are named Seep A, Seep B, and Seep C (Geosyntec, 2019a).

2.7 Fate and Transport Considerations

HFPO-DA and other Site-Associated PFAS have been detected in soils onsite, in groundwater on- and offsite, and in surface water on- and offsite. Site-Associated PFAS are likely present in offsite soils as well. The On- and Offsite Assessment to be delivered to satisfy the requirements of Paragraph 18 will characterize Site-Associated PFAS in the environment and their present environmental distribution. The SLEA will include a summary of sources, which will be used to inform the development of the CEM [conceptual exposure model].

3 CONCEPTUAL EXPOSURE MODEL

Development of a CEM [conceptual exposure model] is recommended by USEPA (USEPA, 1989) to support interpretation of environmental data and inform site management decisions. The SLEA CEM identifies potentially complete exposure pathways by which receptors could come in contact with historically-deposited, Site-Associated PFAS in environmental media within the offsite Study Area. For an exposure pathway to be complete, the following five elements are necessary:

- a source or release from a source;
- a mechanism of release and transport;
- an exposure medium (i.e., point of contact) for potential receptors;

- an exposure route (e.g., ingestion); and,
- the presence of a receptor population (e.g., residential adult and child).

If an element of the CEM is missing, the exposure pathway is incomplete. For the purposes of the SLEA, source and release/transport mechanism(s) for PFAS are presumed to exist (see Section 2.7). As such, the SLEA will focus on characterizing exposure media, exposure routes, and human receptors to historically-deposited, Site-Associated PFAS. Generally, intake of Site-Associated PFAS will only be quantified for complete pathways but, in some instances for the purpose of informing site management decisions, intake will also be quantified for pathways that are not reasonably anticipated to be complete (e.g., due to current or planned implementation of institutional controls).

The preliminary human health CEM is diagrammatically presented in Figure 2 and its elements are described below.

3.1 Offsite Receptor Populations

The Site contains 2,177 acres of relatively flat, undeveloped open land and woodland bounded by the Cape Fear River on the east, NC Highway 87 on the west, Willis Creek on the north, and farmland on the south (Figure 1). Based on the current Site setting, including surrounding land uses, potential receptors for evaluation in the SLEA and the rationale for their inclusion are summarized below.

- Residents. The nearest residence is approximately 1 km north of Site manufacturing areas. North and northwest of the Site, several residential neighborhoods occur within 5 km of the Site.
- Farmers. Farmers were identified as potential receptors based on the predominance of agricultural land use to the east, south, and west of the Site.
- Gardeners. Residents and farmers may garden on their properties.
- Offsite workers. Although residential and agricultural land uses predominate the areas surrounding the Site, some commercial businesses are also present.
- Recreational Canoeists/Swimmers. The Cape Fear River may be used for recreational purposes, including canoeing and swimming.
- Recreational Anglers. The Cape Fear River may be used for recreational purposes, including fishing.

3.2 Environmental Exposure Media and Routes

The SLEA will focus on evaluating the relative potential for intake from direct and indirect contact with Site-Associated PFAS detected in environmental media from historical deposition. Previous environmental investigations have detected Site Associated PFAS in soil, groundwater, and surface water in the vicinity of the Site and biouptake of PFAS may potentially also occur. Potential exposure media and routes for evaluation in the SLEA are summarized below. Unless otherwise noted below, these media-specific complete exposure pathways will be quantitatively evaluated in the SLEA for relevant receptors. It is important to note that these are hypothetical exposure scenarios developed to evaluate the potential for exposure; in reality, some (or all) of the assumed exposure pathways may be incomplete for an actual receptor.

- **Offsite Surface Soil.** Stack and fugitive emissions to ambient air have resulted in historically-deposited PFAS in offsite soils. The projected 99% reduction in facility-wide air emissions of "GenX compounds" (as defined in the Consent Order) will significantly reduce continuing contribution to Offsite surface soil and associated concentrations are expected to attenuate over time. Offsite residents, farmers, gardeners, and workers are assumed to be directly exposed to surface soil via incidental ingestion and dermal contact. As described in Section 8, dermal absorption studies with HFPO-DA indicate exposure via the dermal pathway is unlikely to be significant (DuPont-25292, 2008); as such, dermal exposure to surface soil will be evaluated qualitatively or semi-quantitatively as part of the SLEA Uncertainty Assessment. Soil intake by offsite commercial workers is likely to be lower than that of other offsite populations (e.g., residents, farmers, and gardeners); therefore, worker exposure to soil will be qualitatively or semi-quantitatively evaluated based on the results of receptors with greater exposure potential.
- **Offsite Subsurface Soil.** Site-Associated PFAS present in offsite subsurface soils originate from aerial PFAS deposition followed by downward infiltration of PFAS through the vadose zone (unsaturated zone). For most receptors, the potential for direct exposure to subsurface soil is incomplete and, relative to surface soil, would likely be insignificant. Surface soil conditions will inform risk management decisions. As such, direct contact with subsurface soil will be qualitatively or semi-quantitatively evaluated as part of the SLEA Uncertainty Assessment.
- **Offsite Groundwater.** Site-Associated PFAS present in offsite groundwater originate from historically-deposited PFAS which have infiltrated from soils to groundwater. Site-Associated PFAS have been detected in groundwater used for drinking water by private residences and farms within the vicinity of the Site. Offsite residents, farmers, gardeners, and workers using groundwater for potable purposes are assumed to be exposed to historically-deposited PFAS via ingestion and dermal contact. Due to their limited dermal absorption (see Section 5),

exposure to PFAS in groundwater via dermal contact is considered an insignificant exposure pathway and, therefore, intake will be qualitatively or semi-quantitatively evaluated as part of the SLEA Uncertainty Assessment. Irrigation-related contact represents a significantly lessened degree of exposure when compared to domestic water use. Thus, irrigation-related exposures will be qualitatively or semi-quantitatively evaluated as part of the SLEA Uncertainty Assessment.

- **Surface Water.** Site-Associated PFAS present in offsite surface water, excluding Willis Creek and the Cape Fear River, stem from offsite groundwater transporting historically-deposited PFAS and subsequent discharge to surface water bodies. Willis Creek and the Cape Fear River also include contributions from onsite, direct release sources to soil and groundwater. Recreationalists have the potential to be exposed to Site-Associated PFAS in surface water (e.g., ponds and creeks near the Site, Cape Fear River) via incidental ingestion and dermal contact (e.g., swimming, canoeing). Approximately eight (8) and 55 miles downstream of the Site, respectively, surface water from the Cape Fear River is withdrawn and treated for use as drinking water at the Bladen Bluffs and Kings Bluff water treatment facilities. Offsite residents, farmers, gardeners, and workers are assumed to use Cape Fear River water for potable purposes and, therefore, assumed to be exposed to Site-Associated PFAS via ingestion and dermal contact. As with groundwater exposure scenarios, dermal contact intakes for surface water are insignificant and will be qualitatively or semi-quantitatively evaluated in the SLEA Uncertainty Assessment. Offsite worker exposure to surface water as tapwater will also be qualitatively or semi-quantitatively evaluated.

- **Terrestrial Biota.** Invertebrates, and other terrestrial biota may potentially assimilate PFAS from soil or, in the case of plants, from soil, pore water, and wet and dry deposited particulates. As such, farmers and gardeners are assumed to be indirectly exposed to Site-Associated PFAS via consumption of plants and livestock. The SLEA will quantitatively evaluate plant intake using biouptake models from administrative authority guidance or the primary literature; other consumable terrestrial biota will be qualitatively or semi-quantitatively evaluated as part of the SLEA Uncertainty Assessment.

- **Fish Tissue**. Aquatic species in the Cape Fear River and surrounding surface water bodies (e.g., local ponds and lakes) may assimilate PFAS from sediment or surface water. As such, recreational anglers are assumed to be indirectly exposed to Site-Associated PFAS via consumption of fish.

3.3 Complete Exposure Pathways

Hypothetical receptor-exposure scenarios developed for the SLEA to quantitatively evaluate intake of historically-deposited, Site-Associated PFAS are summarized below. As noted above, these exposure pathways are assumed to be complete for the purposes of the SLEA but some or all exposure pathways may be incomplete for an actual Offsite receptor.

- Residents (Adult and Child): Surface soil via incidental ingestion and groundwater and surface water[7] as tapwater via ingestion.
- Farmers (Adult and Child): Surface soil via incidental ingestion; groundwater as tapwater via ingestion; and, aboveground leafy vegetables (e.g., lettuce), aboveground fruits (e.g., tomatoes), and belowground vegetables (e.g., carrots) via ingestion.
- Gardeners (Adult and Child): Surface soil via incidental ingestion; groundwater as tap water via ingestion; and, aboveground leafy vegetables (e.g., lettuce), aboveground fruits (e.g., tomatoes), and belowground vegetables (e.g., carrots) via ingestion.
- Recreational Canoeists/Swimmers (Adult and Child): Surface water via incidental ingestion.
- Recreational Anglers (Adult and Child): Fish tissue fillets via ingestion.

Additionally, the SLEA Uncertainty Assessment will include a qualitative or semi-quantitative evaluation of Site-Associated PFAS intake for: (i) direct contact with subsurface soil by residents, farmers, and gardeners; (ii) use of groundwater as irrigation water by farmers and gardeners; (iii) consumption of livestock by farmers; (iv) direct contact with surface soil and use of groundwater and treated surface water as tapwater by offsite workers; and (v) dermal contact with soil, groundwater, and surface water by relevant receptors.

4 IDENTIFICATION OF OFFSITE EXPOSURE UNITS

The selection of exposure units (EUs) for evaluation in the SLEA is premised on the concept that concentrations in environmental media are likely to attenuate with distance from the Site, particularly for groundwater and soil which are the primary offsite exposure media. As such, the offsite study area was conceptualized as three concentric circles surrounding the Site that correspond to radial distances of 2.5, 5, and 10 km. These

[7] Stemming from Bladen and Kings Bluff Cape Fear River intakes and water treatment facilities.

concentric circles were then bisected north-to-south and east-to-west to subdivide the offsite study area into northeast, southeast, southwest, and northwest quadrants. Additionally, the northeast direction quadrant corresponds to the dominant wind direction (ERM, 2018) and the EU that comprise this quadrant (EUs 1, 5, and 9) capture the areas of likely highest historical aerial deposition to soil. Therefore, as shown in Figure 3, the upland EUs for evaluation in the SLEA are:

- EU1: 2.5-km radius, northeast;
- EU2: 2.5-km radius, southeast;
- EU3: 2.5-km radius, southwest;
- EU4: 2.5-km radius, northwest;
- EU5: 5-km radius, northeast;
- EU6: 5-km radius, southeast;
- EU7: 5-km radius, southwest;
- EU8: 5-km radius, northwest;
- EU9: 10-km radius, northeast;
- EU10: 10-km radius, southeast;
- EU11: 10-km radius, southwest; and
- EU12: 10-km radius, northwest.

The Cape Fear River was also subdivided into several EUs, where:

- EU13: upstream locations;
- EU14: Site-adjacent locations;
- EU15: downstream location at Bladen Bluffs; and
- EU16: downstream location at Kings Bluff.

Depending on the outcomes of access agreements currently being negotiated, two lakes / ponds located in the vicinity of the Site may be designated as additional SLEA EUs.

For each upland EU (EU1 through EU12), exposure to surface soil, groundwater (as tapwater), and produce will be quantitatively evaluated. For each Cape Fear River EU and the two Lake EUs (as yet undefined), exposure to surface water will be quantitatively evaluated. Fish tissue consumption will be quantitatively evaluated at EU13, EU14, and EU15. Fish tissue consumption at EU16 (55 miles downstream) will be qualitatively or semi-quantitatively evaluated based on the findings at EU15 (8 miles downstream).

Additionally, treated surface water at EU15 and EU16 will be quantitatively evaluated as tapwater.

5 ENVIRONMENTAL DATASETS

This section describes existing datasets and additional data to be collected in the summer of 2019 to support derivation of EPCs for the SLEA. Analytical datasets for evaluation in the SLEA will be presented in Appendix B of the SLEA.

5.1 Soil

The SLEA will characterize Site-Associated PFAS intake from soil using data collected as described in this section. Chemours' contractors will conduct the offsite soil sampling. The goal of the soil sampling investigation is to characterize regional soil conditions in surficial and subsurface depth intervals for each of the 12 EUs, defined in Section 4 (Figure 3). The EUs are arrayed by quadrant and proximity, extending to a distance of 10 km from the Site such that they range in size and include units that are very large (e.g., EUs 9, 10, 11, and 12).

5.1.1 Surface Soil

Surface soil is defined as 0 to 6 inches below ground surface (bgs). Surface soil sampling will be conducted according to an incremental sampling methodology (ISM) that is in accordance with NCDEQ's recommendations for collecting composite soil samples from large areas without visible contamination. (see Appendix A of the *Registered Environmental Consultant Program, Implementation Guidance* (NCDEQ, 2015)). The ISM employs a systematic composite sampling method and will thereby enable a more complete assessment of the large study area where discrete sampling is impractical (e.g., representativeness, coverage, schedule). The approach will result in EPCs that are characteristic of regional conditions and exposures.

The investigation will be organized by EU. Prior to field mobilization, each ISM-based EU will be gridded via ordinary or area-of-influence kriging to define 30 random sampling locations, or nodes. Areas that the project team knows to be inaccessible will be excluded from the grid. Individual sample aliquots will be collected from each of the 30 nodes in a given EU. Aliquots will be collected from the 0 to 6-inches bgs soil depth using stainless steel bowls and spoons. These aliquots will be homogenized in the field and composited into a single sample for laboratory analysis, for a total of 12 surface soil samples. Sampling locations will be recorded via global positioning system. If samples are to be collected from a location on private property, the field team will first gain verbal access consent from the resident or owner of the property. To the best of their ability, field personnel will collect samples from each of the random nodes identified in the planning documents; however, sampling locations may be modified due to accessibility issues or hazards encountered in the field. Repositioning of planned sample locations will be marked in the field and recorded via Global Positioning System (GPS) coordinates. Field personnel will collect quality assurance/quality control samples (i.e., duplicates, matrix spikes/matrix spike duplicates, and equipment blanks); however, in the interests of performing this SLEA in a timeframe capable of supporting the development of a CAP by December 31, 2019 replicate samples will not be collected.

Composited samples will be shipped under chain of custody to a TestAmerica analytical laboratory for analysis of HFPO-DA and Site-Associated PFAS per the Table 3/3+ SOP. Where analytical data do not indicate significant variability between EUs, multiple EUs may be pooled to derive an ancillary line of evidence for exposure.

5.1.2 Subsurface Soil

Subsurface soil is defined as 0 to 4 feet bgs. One subsurface sample (targeting the 3-4 ft bgs soil horizon) will be collected from each EU to characterize the unsaturated, subsurface soil, for a total of 12 subsurface soil samples. For each EU, the subsurface sampling location will be selected at random from one of the 30 surface sampling locations identified in Section 5.1.1. Using a hand auger, field personnel will collect the samples from approximately 4 feet bgs. Samples will be shipped via chain of custody to a TestAmerica analytical laboratory for analysis of HFPO-DA and Site-Associated PFAS per the Table 3/3+ SOP (Workplan Table 1). Subsurface soil data may be pooled by quadrant, or in their entirety, to provide a secondary line of evidence to assess leaching potential for the greater region, and to corroborate trend analyses in the groundwater empirical dataset.

5.2 Groundwater

The SLEA will use existing offsite groundwater data collected from private residences to characterize the spectrum of domestic drinking water intake and use in each of the 12 upland EUs. Offsite groundwater samples have been collected from private residences prior to the Consent Order and are now also to be collected as part of implementation of Consent Order Paragraph 21. PFAS analytical groundwater data will be compiled from the Environmental Information Management system for raw drinking water samples (i.e., mid- and post- filtration results will be excluded) collected from offsite residential private drinking water wells from 2017 to 2019. Offsite private drinking water wells are screened in both the Surficial and Black Creek Aquifers, based on a review of resident-reported well depths and offsite geological well records retrieved from www.ncwater.org. There were 55 wells with lithology and geophysical data available in the vicinity of the Site. Offsite well data distributions will be examined and reported in the *Paragraph 18 On and Offsite Assessment Report* submitted by 30 September 2019.

There are over 1,000 wells represented in the existing dataset and groundwater sampling is ongoing per the requirements of the CO. Additionally, more recent data made available will be considered within the context of the SLEA; however, no additional groundwater data collection effort is proposed in this Workplan. Wells were sampled for up to 48 PFAS compounds using various analytical laboratories and methods (note, not all analytes were sampled at each well). The locations of all offsite groundwater wells with posted HFPO-DA concentrations are presented on Figure 4. HFPO-DA results were mapped for presentation because this analyte was analyzed most frequently.

Only the most recent sampling data collected from each well will be used in the exposure assessment. Data will be censored for the most recent date sampled for each location/Site-Associated PFAS analyte pair. Where duplicate data exists for a well/analyte pair (e.g., both primary and field duplicate sample collected), the highest concentration result will be retained for analysis. Where both 2017 and 2019 data exist for an analyte/well pair, the values may be compared to assess temporal changes in concentration.

The sampling data from individual wells will be pooled for each EU to derive EU-specific EPCs for each Site-Associated PFAS constituent. ProUCL Version 5.1 (USEPA, 2015a) will be used to calculate the mean, maximum, and 95% UCLs for use as EPCs for each upland EU. Where datasets for an EU contain enough 2018 and 2019 data points to calculate the UCLs, 2017 data may be eliminated from the dataset so the EPCs represent most recent conditions. Only analytes included in the Table 3+ SOP (Table 1) will be evaluated. Where applicable, multiple EUs may be combined to provide ancillary lines of evidence to characterize groundwater conditions from a greater regional perspective.

Groundwater-as-drinking water, via the spectrum of domestic water usage, will be assessed based on available data. As part of the CO implementation, Chemours is required to offer permanent replacement drinking water (in the form of public water or whole building filtration systems) when private wells have HFPO-DA detected above 140 nanograms per liter (ng/L). When any individual PFAS listed in CO Attachment C, exceeds 10 ng/L or when total PFAS listed in CO Attachment C exceed 70 ng/L, Chemours is required to offer residents up to three under-the-sink reverse osmosis drinking water systems. Chemours is required to offer temporary replacement water supplies (i.e., bottled water) to residents qualifying for a filtration or reverse osmosis system until these systems have been provided. The expected order-of-magnitude concentration reductions as a result of filtration or reverse osmosis will be addressed under an assessment of expected future conditions and presented within the context of the SLEA Hazard Characterization, Uncertainty Assessment, and report conclusions to aid in site and risk management decision criteria.

5.3 Surface Water

The SLEA will characterize PFAS intake using existing surface water data and additional samples collected at select locations, as described below. Surface water data will be used to calculate EPCs for recreational swimming exposure conditions for the Cape Fear River and up to two lakes/ponds in the surrounding area. Geosyntec will develop Cape Fear River EPCs for upstream, Site adjacent, and downstream surface water exposure points to evaluate recreational exposure and EPCs for post-treatment downstream surface water to evaluate potable use exposure at Bladen and Kings Bluffs. EPCs representative of local lakes/ponds (as yet undefined/identified) will be based on new sampling data to be collected by Chemours' contractors for this SLEA (if access to conduct sampling can be obtained); only recreational exposures (e.g., fishing, swimming) will be evaluated for the lakes/ponds.

5.3.1 Previous Surface Water Sampling

Geosyntec will compile existing surface water data collected from the Cape Fear River during five (5) previous sampling events:

- Local Program surface water sampling (September 2017);
- Local Program surface water sampling (May 2018);
- Regional Program surface water sampling (June 2018);
- Post-Florence surface water sampling (October-December 2018); and
- Spring 2019 surface water sampling (February 2019).

Sampling methods for these events are described in detail in the following reports: Cape Fear River Surface Water Sampling Plan (Parsons, 2017a); Additional Cape Fear River Surface Water Sampling Plan (Geosyntec, 2018a); Addendum to Additional Cape Fear River Surface Water Sampling Plan (Geosyntec, 2018b); Post Hurricane Florence Sampling Plan (Geosyntec, 2018c); and Creeks, Old Outfall 002 and Seeps Assessment Workplan (Geosyntec, 2019b). Results of these sampling events were reported in: Cape Fear River Surface Water Sampling Memorandum (Parsons, 2017b); Assessment of the Chemical and Spatial Distribution of PFAS in the Cape Fear River (Geosyntec, 2018d); and Post Hurricane Florence PFAS Characterization Report (Geosyntec, 2018e). These surface water sampling events are summarized below.

Local sampling programs conducted by Parsons in September 2017 and May 2018 focused on areas directly upstream, adjacent to, and downstream of the Site (Geosyntec, 2018d). The associated surface water sampling locations along the Cape Fear River include Cape Fear River-01 (CFR-01) through CFR-09 (Figure 5). At each surface water sampling location, four samples were collected along a transect to assess the lateral and vertical concentration distributions in the river (Figure 6). Samples collected in the September 2017 and May 2018 events were analyzed for perfluorinated carboxylic acids, perfluorosulfonic acids, and HFPO-DA (Geosyntec, 2018d).

A regional sampling program was established to characterize PFAS distribution from the confluence of the Deep and Haw Rivers [River Mile (RM)-0] to the Kings Bluff Intake Canal, where the City of Wilmington and the Counties of Pender and Brunswick draw water (RM-132) (Figure 7). A sampling event was conducted under this program by Parsons in June 2018. A total of 16 surface water samples were collected from discrete locations along the Cape Fear River. To the greatest extent practicable, samples were collected from the middle depth of the water column at the thalweg, i.e., the deepest portion of the river channel (Figure 6). The associated sample names indicate the miles from the start of the Cape Fear River and are denoted by RM-X. Samples were analyzed according to Method 8321, Method 537, and Method Table 3 SOP. Some Regional Program sampling locations are co-located with those from the Local Program sampling locations, for example RM-66/CFR-01 and RM-76/CFR-05 (Geosyntec, 2018d).

An assessment was conducted in October and December of CY2018 to assess the effect of Hurricane Florence on the distribution of PFAS in the river (Geosyntec, 2018c). As part of the assessment, the following five (5) surface water samples were collected from the middle of the thalweg of the Cape Fear River: three upstream locations (RM-60, CFR-03, RM-76) and two downstream locations (RM-83 and RM-132) of the Site. Samples were analyzed according to Method 537, Method Table 3 SOP, as well as Method Table 3+ SOP at the Chemours Fluoroproduct Analytical Group.

In the spring of CY2019, five (5) additional samples were collected from the middle of the thalweg of the Cape Fear River at RM-56, RM-68, RM-76, RM-84 and RM-132 (the last two locations correspond to the intakes for Bladen and Kings Bluffs, respectively). Samples were analyzed according to Method 537 Modified and Method Table 3+ SOP.

Finally, additional data from surface/drinking water intakes located at Kings Bluff and Bladen Bluffs were obtained from a NCDEQ website[8] and from the Cape Fear Public Utility Authority (CFPUA) website[9], respectively.

5.3.2 Proposed Surface Water Sampling

The collection of additional surface water samples at locations CFR-04 and CFR-07 is proposed to expand the dataset for the area adjacent to the Site and, in the case of CFR-07,

[8] https://deq.nc.gov/news/key-issues/genx-investigation
[9] https://www.cfpua.org/692/Drinking-Water-Quality

to evaluate temporal trends from CY2017 through CY2019 (Figure 5). Four (4) samples will be collected along an east-west transect as described below (Figure 6):

- West Sample – located 25% of the distance across the channel from the west shore at a depth of 1-foot below water surface. This location is closest to the Site because the Site is on the west side of the Cape Fear River.
- Center Top Sample – located in the middle of the channel at depth of 1-foot below surface.
- Center Middle Sample – located in the middle of the channel, halfway between surface and river bottom.
- East – located 25% of the distance across the channel from the east shore at a depth of 1-foot below surface.

Chemours' contractors will collect the samples using a peristaltic pump, new dedicated high-density polyethylene (HDPE) tubing, and dedicated silicone tubing for the pump head at each location. The tubing will be lowered to the specified sampling depth below the water surface using an anchor weight and the tubing positioned to point upwards. Surface water will be pumped directly from submerged tubing through a Horiba water quality meter until turbidity measurements are below 20 nephelometric turbidity units and all other field parameters (pH, temperature, specific conductivity, dissolved oxygen, oxidation-reduction potential) are stabilized within ±10% over a 5-minute interval. Once water passing through the pump head and the readings appear stable, the Horiba will be disconnected, the tubing cut to provide a new, clean end, and grab samples collected from the discharge of the peristaltic pump in new 250-milliliter HDPE bottles. Samples will be shipped on ice via chain of custody for analytical analysis via Method Table 3+ SOP (Table 1).

The above existing and additional surface water data will be compiled into upstream, Site adjacent, and downstream surface water datasets. Geosyntec will pool data from sampling locations RM-66/CFR-01 and RM-68 by year to represent upstream conditions. Similarly, Geosyntec will pool data from CFR-04, CFR-05, CFR-06/RM-76, and CFR-07 by year to generate Site adjacent datasets for CY2017, CY2018, and CY2019. Geosyntec will analyze each Site adjacent dataset for seasonal reductions in PFAS concentrations as a result of increased flow in the spring, as well as overall trends in PFAS concentrations. Lastly, Geosyntec will evaluate data from sampling locations RM-84 and RM-132, which correspond to drinking water intakes at Bladen Bluffs and Kings Bluff respectively, to generate two downstream datasets. Data collected from additional downstream locations in CY2019 will be excluded from the dataset while publicly available data from the CFPUA will be incorporated into the corresponding datasets. The data will be segregated by year and pre- or post-treatment. The pre-treatment dataset will be used to assess recreational exposure concentrations. (Post-treatment data will be used to assess drinking water exposures.) The upstream, Site-adjacent, and downstream pre-treatment datasets will be used to assess recreational swimming exposure concentrations at various points along Cape Fear River.

Geosyntec proposes the collection of surface water samples from two local lakes/ponds based on gaining access agreements from the owners of the lakes/ponds. If they are granted access to the lakes/ponds, Chemours' contractors will collect three (3) randomly-located surface water samples in each lake/pond. Lake/pond surface water samples will be collected by lowering the tubing to the approximate middle depth of the surface water column. Samples will be shipped on ice via chain of custody for analysis via Method Table 3+ SOP (Table 1). The three (3) samples from each lake/pond sets will be pooled and two sets of EPCs (i.e., one per lake/pond) will be developed representative of the maximum detected and mean concentrations. Furthermore, these data will be considered in light of tissue concentrations in fish collected from these same water bodies (described below).

5.4 Fish

The SLEA will characterize PFAS intake from recreational fish consumption using tissue samples collected per this Workplan. Chemours' contractor will conduct the fish tissue sampling. Fish tissue samples have not previously been collected for the Site. Fish will be collected from four (4) sampling points within the Cape Fear River: one location upstream from the Site (RM-68), two locations adjacent to the Site (CFR-06 and CFR-07), and one location downstream from the Site (RM-84/Bladen Bluffs). RM-68 is located approximately 10 miles north of the Site and far exceeds the expected home range for recreational sport fish targeted by anglers in the Site vicinity (Lewis and Flickinger, 1967). CFR-06 and CFR-07 represent points below the Site outfalls, above and below Huske Dam, respectively (effectively separating sportfish populations). RM-84 is located approximately eight (8) miles downstream of the Site and will be used to assess attenuation in relation to Site adjacent samples. Two additional water bodies (lakes/ponds, as yet unidentified/undefined), in the vicinity of the Site will be considered as potential recreational exposure points.

At each sampling location, Chemours' contractors will attempt to collect enough fish of the same species, representative of a common recreational species (e.g., large- or smallmouth bass) and size (consistent with State of North Carolina recreational fishing regulations), to comprise three (3) samples for laboratory analysis. Fish will be collected by either electrofishing or traditional rod-and-reel methods, depending on local conditions. During electrofishing, an electric current is transmitted from a submerged anode to cathode, causing fish that cross the electric field to either be stunned or swim toward the anode where they can be caught using a dip net. The efficacy of electrofishing is limited by the extent of the electric field (generally depth), and this method may fail to capture fish that tend to live below the reach of the electric current. Where this is the case, a rod-and reel method may be necessary to catch deeper-dwelling fish. Fish fillets (i.e., muscle tissue) will be preserved on ice and submitted to TestAmerica under chain of custody for analysis of HFPO-DA and Site-Associated PFAS per the Table 3/3+ SOP. Where necessary, fish tissue samples from multiple species (e.g., bass, catfish, panfish) may be pooled to generate required sample volumes. Fish tissue samples will be used to assess potential intake associated with recreational angler ingestion, thus only recreational sport fish, per State of NC fishing regulations, will be targeted.

Fish tissue concentrations from the four (4) Cape Fear River sampling locations will be compared to assess location-specific intake potential and system attenuation with increased distance from source(s). These 12 sample results will also be pooled, and ProUCL Version 5.1 will be used to derive constituent-specific 95% UCLs for the greater Cape Fear River.

Fish tissue concentrations from the lakes/ponds will be compared to assess location-specific intake potential and system attenuation with increased distance from source(s). The three (3) samples from each lake/pond will also be pooled to develop mean EPCs for each pond/lake.

Fish tissue concentrations from the Cape Fear River and local lakes/ponds will support assessment of recreational angler intake.

5.5 Homegrown Fruits and Vegetables

The SLEA will characterize Site-Associated PFAS intake from homegrown produce using existing air data and soil data collected per this Workplan (see Section 5.2). Geosyntec will assess the potential exposure from ingestion of homegrown produce by modeling HFPO-DA concentrations in aboveground leafy vegetables (e.g., lettuce), aboveground fruits (e.g., tomatoes), and belowground vegetables (e.g., carrots).

Chemours' contractors will provide wet and dry deposition data as a function of air modeling output from Site emissions.

Chemours created a regional deposition model for emissions of HFPO-DA from both point and fugitive sources identified at the Site. The eight (8) sources include the Vinyl Ethers North Division, Vinyl Ethers South, and PPA Process Stacks and associated fugitive emissions, as well as the Polymers Process and Semi-Works Process Stacks. Chemours used the latest version of the regulatory dispersion model and supporting programs: AERMOD (version 1621r), AERMAP (version 11103), and BPIP (version

04274), and local meteorological data collected from 2012 through 2016 that was pre-processed for AERMOD by the NCDEQ.

Chemours previously presented the deposition modeling results in the 2018 document, *Modeling Report: HFPO-DA Atmospheric Deposition and Screening Groundwater Effects, Fayetteville Works Facility, Fayetteville, NC* (ERM, 2018). To assist Geosyntec's SLEA, this modeling effort was refined to account for further emissions control measures, including the thermal oxidizer, to achieve a 99% reduction in stack emissions.

Depositional and soil data (Section 5.1.1) will be used to support modeled plant biouptake, utilizing methodologies presented in USEPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (USEPA, 2005a). The produce exposure assessment is limited to HFPO-DA based on its reliance on the deposition model. Empirical soil characterization data will also be used to derive other model input parameters.

6 EXPOSURE POINT CONCENTRATIONS

EPCs will be calculated on an EU-specific basis. When possible, EPCs based on the mean, 95% UCL, and maximum detected concentration will be evaluated in the SLEA to provide a range of potential intake estimates. Mean and UCL concentrations will be calculated using the ProUCL Version 5.1. ProUCL outputs will be provided as Appendix C to the SLEA Report. The bullets, listed below, discuss media-specific considerations for EPC calculation:

- Soil. One surface soil sample comprised of 30 increments will be collected from each upland EU. Hence, surface soil EPCs will be equivalent to single sample, maximum detected concentrations (that functionally represent an EU-wide average). An assessment of post-abatement, attenuated soil conditions will also be advanced.
- Groundwater as Potable Water. There is a large database of groundwater data from the offsite study area (over 1,000 wells), particularly for downgradient wells located north of the Site. Existing groundwater data will be segregated by EU and the most recent data from each EU will be given preference for inclusion in the dataset to underpin the EPC calculation. A mean, UCL, and maximum EPC will be developed for each upland EU. An assessment of post-abatement, attenuated groundwater conditions will also be advanced.
- Surface Water for Recreational Use. Surface water EPCs for recreational use exposure scenarios will be developed for the four (4) Cape Fear River EUs. For

the one upstream and two downstream EUs, recreational EPCs will be developed using existing surface water data; pretreatment data will be used for the downstream recreational use EPCs. Recreational EPCs for the Site-adjacent EU will be developed from existing data and data collected upstream and downstream of the Huske Dam in support of the SLEA. Mean, 95% UCL, and maximum EPCs (where supported by the datasets) will be developed for each surface water EU. Surface water conditions in two additional surface water bodies (lakes/ponds) will be assessed for recreational exposure as well. Mean, maximum, and UCL EPCs will be developed, where defensible (i.e., with sufficient data) in assessment of these exposure conditions.

- Surface Water as Potable Water. Surface water intakes for potable use are located at the two downstream EUs (RM-84/Bladen Bluffs and RM-132/Kings Bluff). Existing post-treatment surface water data will be used to develop mean, UCL, and maximum EPCs for each downstream EU.

- Fish Tissue. Fish fillet sampling is proposed in support of the SLEA at EU13 (upstream), EU14 (Site-adjacent, with two sample locations), and EU15 (Bladen Bluffs). Three fish are proposed to be collected at each location. This sample size (n=3) precludes UCL calculation at individual EUs; however, mean and maximum EPCs will be developed for each sampling location for use in the SLEA. Note that at the Site-adjacent EU14 locations, fish will be collected from above and below the Huske Dam for the purposes of evaluating biouptake and potentially calculating a Site-adjacent UCL from the proposed six (6) samples. Fish tissue concentrations (EPCs represented by the maximum detected and mean concentrations) in two additional lake/pond surface water bodies (as yet unidentified/undefined) will be characterized and support recreational angler complete exposure pathways (i.e., ingestion of fish).

- Produce (e.g., Lettuce, Tomatoes, Carrots). Local, homegrown fruit and vegetable sampling is not proposed at this time. Concentrations of HFPO-DA in lettuce, tomatoes, and carrots will be modeled from soil EPCs and modeled wet and dry air depositional rates on an EU-basis. EPCs for aboveground fruits, aboveground leafy vegetables and belowground vegetables (tubers) will be developed to represent mean, 95% UCL and maximum projected concentrations for each upland EU (EUs 1though 12). Modeling inputs and outputs related to the produce pathway will be presented in Appendix E of the SLEA Report. The SLEA Uncertainty Assessment will include a discussion of available, localized wet and dry deposition as a secondary line of evidence to characterize homegrown produce. The Uncertainty Assessment will also address the effects of the model selection/assumptions and EPC calculation on the overall estimates of intake and hazard.

Pending the results of the EU-specific analysis, additional aggregation of data (i.e., multi-EU approach) to reflect larger regional phenomena may be considered in the SLEA.

7 INTAKE CHARACTERIZATION

For the SLEA, intake of PFAS will be quantified as an average daily intake (ADI), expressed in units of milligrams of constituent per kilogram of body weight per day (mg/kg-day). Intake will be calculated for each route and then summed by exposure medium (e.g., soil, groundwater). Total intake for each receptor from relevant exposure media identified in this Workplan will also be calculated. For residents, farmers, gardeners, and recreationalists, two age groups will be considered: a child age 0 to 6 years and an aggregated, age-adjusted child/adult receptor, reflective of 0 to 26 years of age.

7.1 Intake Equations and Inputs

The equations used to calculate intake are based on USEPA guidance, including the *Risk Assessment Guidance for Superfund* (USEPA, 1989); and the *Regional Screening Levels User's Guide* (USEPA, 2019a). Intake assumptions were developed based on USEPA guidance, including the *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors* and associated updates (USEPA, 2014; 2015b) and the *Exposure Factors Handbook* and associated updates (USEPA, 2011; 2017; 2018a, b, c; 2019b). Inputs and equations are presented in Appendix F, which will also be included in the SLEA Report.

7.2 Intake Characterization Results

The SLEA will compare intake estimates across receptors and media and provide a relative ranking of intake.

8 PROVISIONAL HAZARD CHARACTERIZATION

The intended purpose of the SLEA is to help foster an understanding of which complete exposure pathways of historically-deposited Site Associated PFAS are likely to be the most significant contributors of overall human exposure on a regional basis. The relative ranking of exposures resulting from the SLEA will be used to focus future evaluations of those pathways that will be relevant to informing risk management decisions and excluding pathways that, albeit potentially complete, are insignificant relative to overall exposure potential.

Although the intended objective of the SLEA is to provide a relative ranking of exposure pathways, the SLEA will provide perspective on the quantitative point estimates of hazard. There are presently neither federal nor state regulatory standards for HFPO-DA in water, soil, air, or food. However, a draft RfDo has been developed by the NC DHHS (DHHS 2017) and this value underpins development of the State's provisional health goal for HFPO-DA in drinking water of 140 ng/L (NCDEQ and DHHS, 2018). The DHHS-derived RfDo will underpin the quantitative estimates of regional hazard potential associated with relevant complete human health exposure pathways in the context of the SLEA.

8.1 Reference Dose

A provisional Hazard Characterization will be included in the SLEA. The Hazard Characterization will be predicated on the current RfDo developed by the NC DHHS, 0.0001 mg/kg-day, which underpins the State's provisional HFPO-DA health goal of 140 ng/L for drinking water (DHHS, 2017; NCDEQ and NC DHHS, 2018).

A recent study of GenX (Thompson, et al., 2019) has proposed an additional, provisional RfDo predicated on benchmark dose modeling, considering deterministic and probabilistic developmental techniques. The probabilistic RfDo of 0.01 mg/kg-day, represents the more conservative value from this study and will be considered within the context of the Uncertainty Assessment as a basis for bounding values in critical review of the Hazard Characterization.

A draft RfDo for HFPO-DA of 8E-05 mg/kg/day has also been issued by USEPA for public comment (USEPA, 2018a). The SLEA Uncertainty Assessment will evaluate the implications for this toxicity criterion, if adopted at the federal level in the future and assess its use to bound risk management decisions.

8.2 Route-Specific Hazard Estimates

8.2.1 Ingestion

The 1E-04 mg/kg-day chronic RfDo, developed by NC DHHS (NCDEQ and NC DHHS, 2018) will be used in the SLEA to assess ingestion-based pathways (soil, drinking water, surface water, fish, and homegrown fruits and vegetables) to derive a range of hazard quotients (HQs).

8.2.2 Dermal

No dermal toxicity criteria have been developed at the federal or state level. As such, the dermal reference dose (RfDd) necessitate route-to-route extrapolation from the RfDo, which requires information on gastrointestinal absorption efficiency. Absorption efficiency following oral administration is expected to be above 90%. Consistent with USEPA (2004) dermal risk assessment guidance, based on this high absorption efficiency, no absorption-based adjustment is used for route-to-route extrapolation. Therefore, a provisional RfDd is assumed to be equivalent to the NC DHHS RfDo of 1E-04 mg/kg-day (DHHS, 2017).

Exposure studies indicate dermal uptake in animals is undetectable at low doses typical of environmental exposure and human uptake is more than order of magnitude lower than animal uptake. For human exposures, dermal exposure is expected to be insignificant relative to ingestion exposure. Therefore, dermal intake will not be quantified as part of the SLEA. However, the dermal pathway may be further evaluated as part of the SLEA Uncertainty Assessment.

8.3 Hazard Characterization Summary

In the forthcoming SLEA, this section will present a discussion of relevant estimates of human health hazard, limited to HFPO-DA, by receptor type and pathway (i.e., media and exposure route). Hazard calculations will be presented in tabular format in Appendix G of the SLEA Report, with summary tables included as part of the main body of the report. Hazard estimates for additional Site-Associated PFAS will not be advanced based on the absence of administrative authority-promulgated toxicological criteria.

Hazard estimates for HFPO-DA will be quantified by dividing the ADI (mg/kg-day) by the NC DHHS RfDo (mg/kg-day). Hazard estimates will be calculated for each exposure route and then summed by exposure medium (e.g., soil, tapwater). Total hazards for each receptor from all relevant exposure media will also be calculated.

9 UNCERTAINTY ASSESSMENT

The SLEA Uncertainty Assessment will discuss uncertainties which are expected to have a material impact on understanding of exposure, the estimates of intake, and quantitative point estimates of hazard. Uncertainties are inherent in the process of quantifying theoretical exposure (and hazard) due to the use of environmental sampling results, assumptions regarding exposure, and the quantitative representation of chemical toxicity. Analysis of the critical areas of uncertainty in an assessment provides a better understanding of the quantitative results through the identification of the uncertainties that most significantly affect the results.

Examples of this source of uncertainty that could affect the results and conclusions of the SLEA are related to:

- Laboratory analytical results and detection capabilities;

- Environmental variability and use of ISM to characterize soil over broad exposure areas;
- EPC calculation methods, including use of modeled values in the absence of empirical data (e.g., for vegetable EPCs);
- Inclusion/exclusion of insignificant exposure pathways;
- An assessment of upper-bound estimates of contact and intake;
- Future potential exposures given that the current condition is conservative and that attenuation of concentrations in all contact media is expected over time;
- An assessment of additional lines of evidence in the absence of empirical data (e.g., using a surface water/fish tissue scaling exercise to estimate fish tissue concentrations in local lakes/ponds);
- Evaluation of sediment exposures;
- Use of default intake parameters; and
- Anthropogenic background contributions.

10 CONCLUSIONS

The SLEA will present a summary of findings to support defensible risk management decision making.

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TABLES

TABLE 1 - Method Table 3+ SOP Analyte List
Chemours Fayetteville Works, North Carolina

Analytical Method	Common Name	Chemical Name	CASN	Chemical Formula	PQL (ng/L)	
					TestAmerica	Eurofins Lancaster
Table 3+ SOP	HFPO-DA	Hexafluoropropylene oxide dimer acid	13252-13-6	C6HF11O3	2.0	2.0
	PEPA	Perfluoroethoxypropyl carboxylic acid	267239-61-2	C5HF9O3	20	20
	PFECA-G	Perfluoro-4-isopropoxybutanoic acid	801212-59-9	C12H9F9O3S	2.0	2.0
	PFMOAA	Perfluoro-2-methoxyaceticacid	674-13-5	C3HF5O3	5.0	5.0
	PFO2HxA	Perfluoro(3,5-dioxahexanoic) acid	39492-88-1	C4HF7O4	2.0	2.0
	PFO3OA	Perfluoro(3,5,7-trioxaoctanoic) acid	39492-89-2	C5HF9O5	2.0	2.0
	PFO4DA	Perfluoro(3,5,7,9-tetraoxadecanoic) acid	39492-90-5	C6HF11O6	2.0	2.0
	PMPA	Perfluoromethoxypropyl carboxylic acid	13140-29-9	C4HF7O3	10	10
	Hydro-EVE Acid	Perfluoroethoxsypropanoic acid	773804-62-9	C8H2F14O4	2.0	2.0
	EVE Acid	Perflouroethoxypropionic acid	69087-46-3	C8HF13O4	2.0	2.0
	PFECA B	Perfluoro-3,6-dioxaheptanoic acid	151772-58-6	C5HF9O4	2.0	2.0
	R-EVE	R-EVE	N/A	C8H2F12O5	2.0	2.0
	PFO5DA	Perfluoro-3,5,7,9,11-pentaoxadodecanoic acid	39492-91-6	C7HF13O7	2.0	2.0
	Byproduct 4	Byproduct 4	N/A	C7H2F12O6S	2.0	2.0
	Byproduct 6	Byproduct 6	N/A	C6H2F12O4S	2.0	2.0
	Byproduct 5	Byproduct 5	N/A	C7H3F11O7S	2.0	2.0
	NVHOS	Perflouroethoxysulfonic acid	1132933-86-8	C4H2F8O4S	2.0	2.0
	PES	Perfluoroethoxyethanesulfonic acid	113507-82-7	C4HF9O4S	2.0	2.0
	PFESA-BP1	Byproduct 1	29311-67-9	C7HF13O5S	2.0	2.0
	PFESA-BP2	Byproduct 2	749836-20-2	C7H2F14O5S	2.0	2.0

Notes:

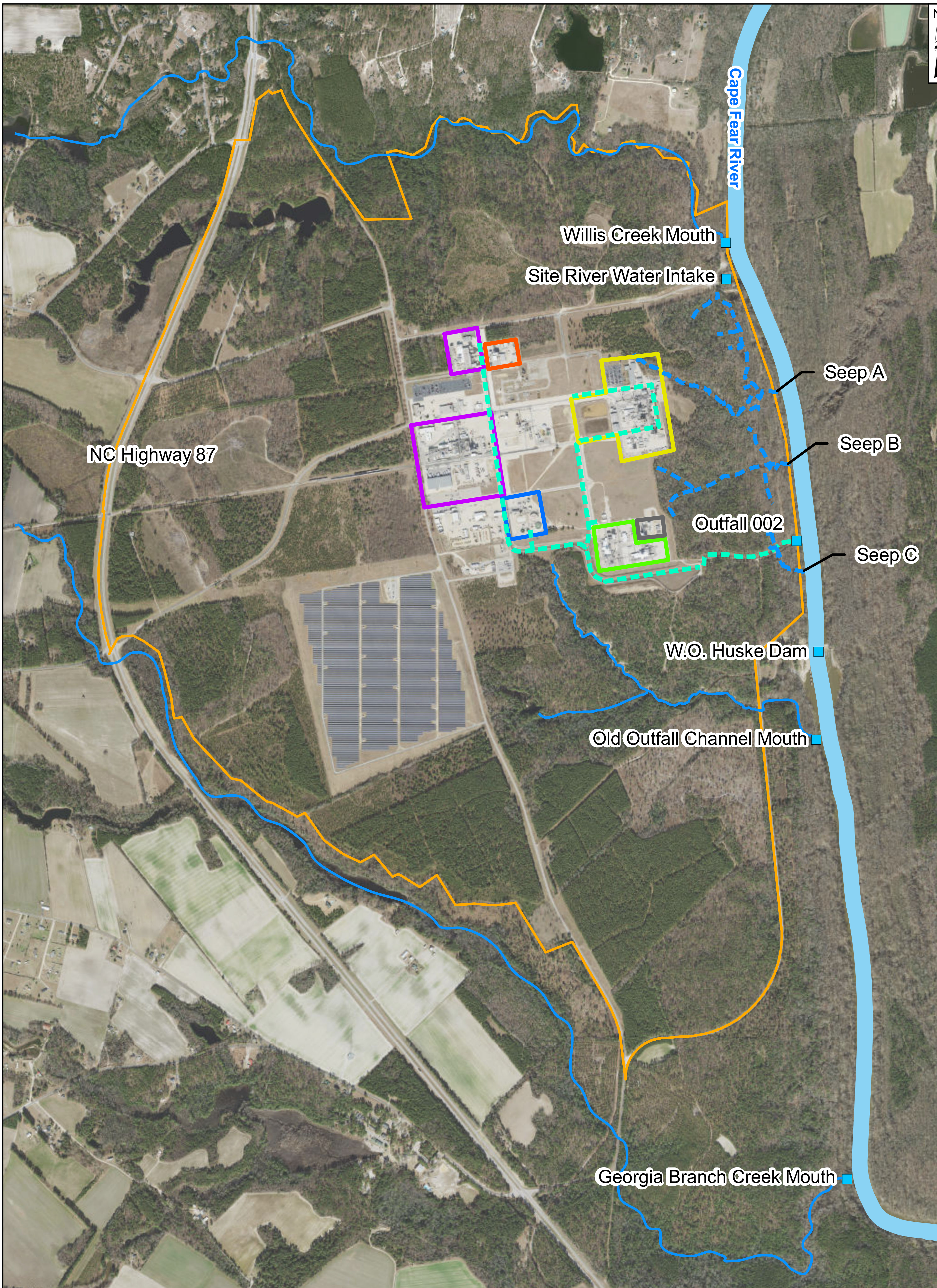
SOP - Standard Operating Protocol

PQL - practical quantitation limit

ng/L - nanograms per liter

Common PFAS MMF, MTP, DFSA, and PPF were excluded from this list due to issues with analytical methods.

FIGURES



Legend

- Site Features
- Cape Fear River
- Nearby Tributaries
- Observed Seep (Natural Drainage)
- Site Drainage Network
- Site Boundary

Areas at Site

- Chemours Monomers IXM
- Chemours PPA
- Dupont / Dow Leased
- Kuraray America Leased
- Former DuPont PMDF Production Area
- Wastewater Treatment Plant

Notes:
Basemap Sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

2,000 1,000 0 2,000 Feet

Site Location

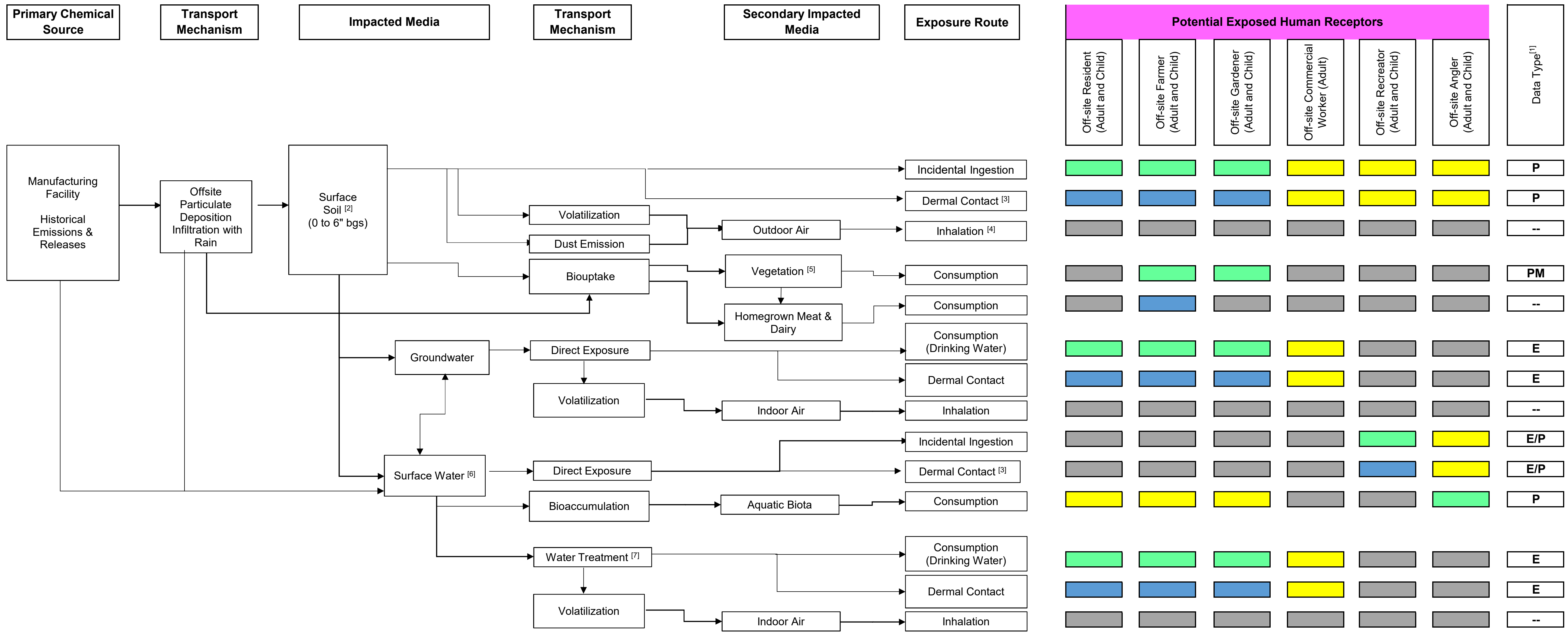
Chemours Fayetteville Works, North Carolina

Geosyntec consultants

Geosyntec Consultants of NC, PC
NC License No.: C-3500 and C-295

Raleigh	July 2019	Figure 1

Path: E:\TR0726\CapeFear_Report_2019\TR0726_SiteFeatures.mxd; JK; 04/10/2019



Notes:

[1] Data Types: E (Existing); P (Proposed); M (Modeled); "--" (Not Applicable)

[2] Subsurface soil will be qualitatively/semi-quantitatively evaluated in the SLEA.

[3] Dermal exposure pathways will be qualitatively evaluated in the SLEA. If the ingestion-based results indicate the dermal pathway may affect risk management decisions, a quantitative analysis may be considered.

[4] Soil particulates and vapors in ambient air will not be evaluated in the SLEA as this pathway is unlikely to be significant.

[5] Produce concentrations will be estimated from soil data and deposition rate data.

[6] Based on the chemical characteristics of PFAS, investigation of sediment is not included as part of the SLEA.

[7] Pathway is applicable to downstream surface water sampling stations only (i.e., Bladen and Kings Bluffs).

(Green) Complete exposure pathway proposed for quantitative evaluation of potential intake.

(Blue) Potentially complete pathway with limited potential for intake. Proposed for semi-quantitative/qualitative assessment.

(Yellow) Potentially complete pathway evaluated using a higher-exposure receptor, where:

- Worker exposure to soil and tapwater is excluded from quantitative evaluation on the basis that risk management based on residents will be protective of the receptor group.
- Recreationalist exposure to soil is excluded from quantitative evaluation on the basis that risk management based on residents will be protective of the receptor group.
- Angler exposure to surface water is excluded from quantitative evaluation on the basis that risk management based on swimmers and residents, respectively, will be protective of the receptor group.
- Resident, farmer, and gardener fish consumption is excluded from quantitative evaluation on the basis that risk management based on recreational anglers will be protective of these receptor groups.

(Gray) Incomplete or insignificant exposure pathway; no evaluation or management action is necessary.

Conceptual Exposure Model to PFAS Historically Deposited Offsite

Chemours Fayetteville Works, North Carolina

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Figure 2

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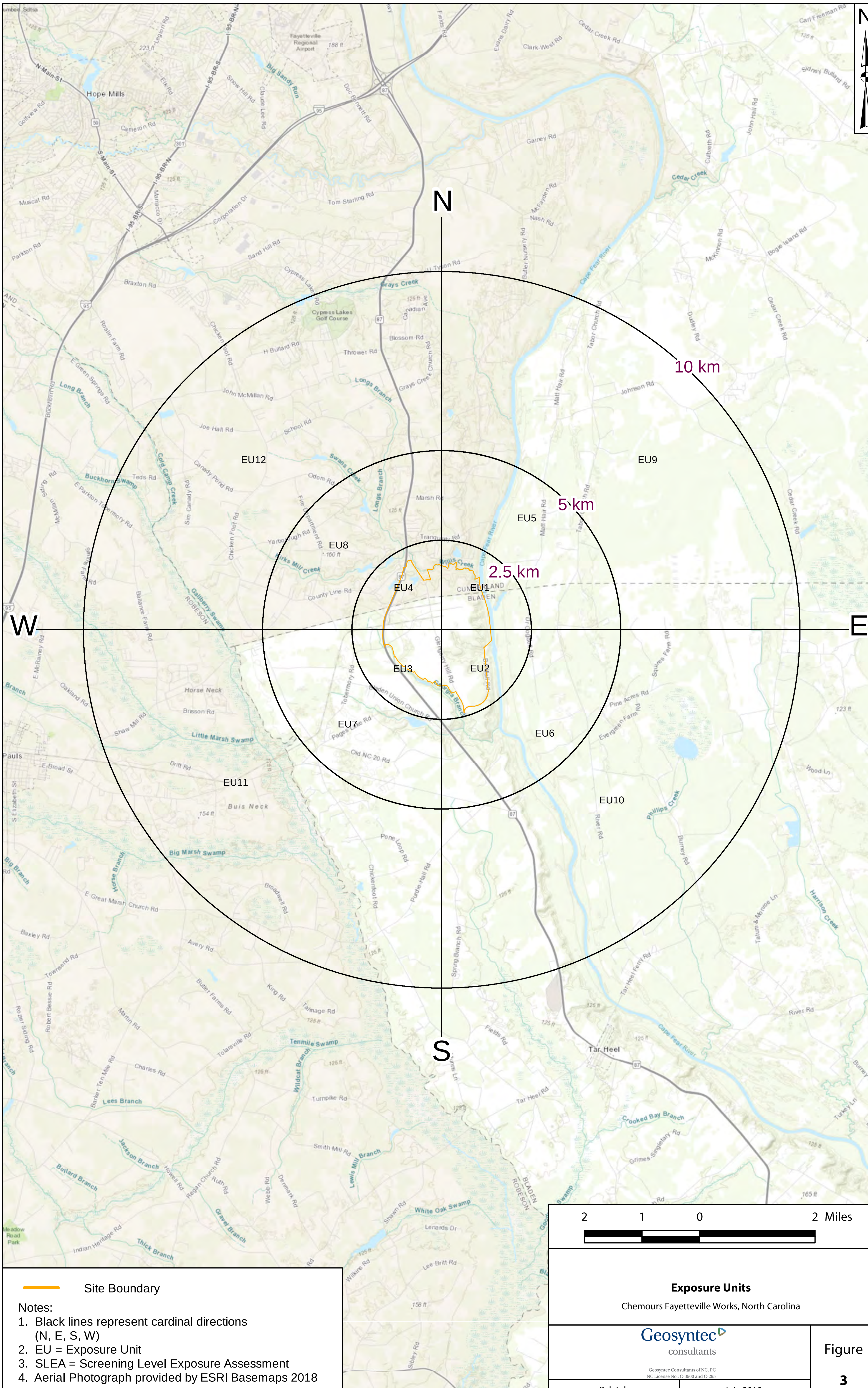

Site Boundary

Notes:
1. Black lines represent cardinal directions (N, E, S, W)
2. EU = Exposure Unit
3. SLEA = Screening Level Exposure Assessment
4. Aerial Photograph provided by ESRI Basemaps 2018

Exposure Units

Chemours Fayetteville Works, North Carolina

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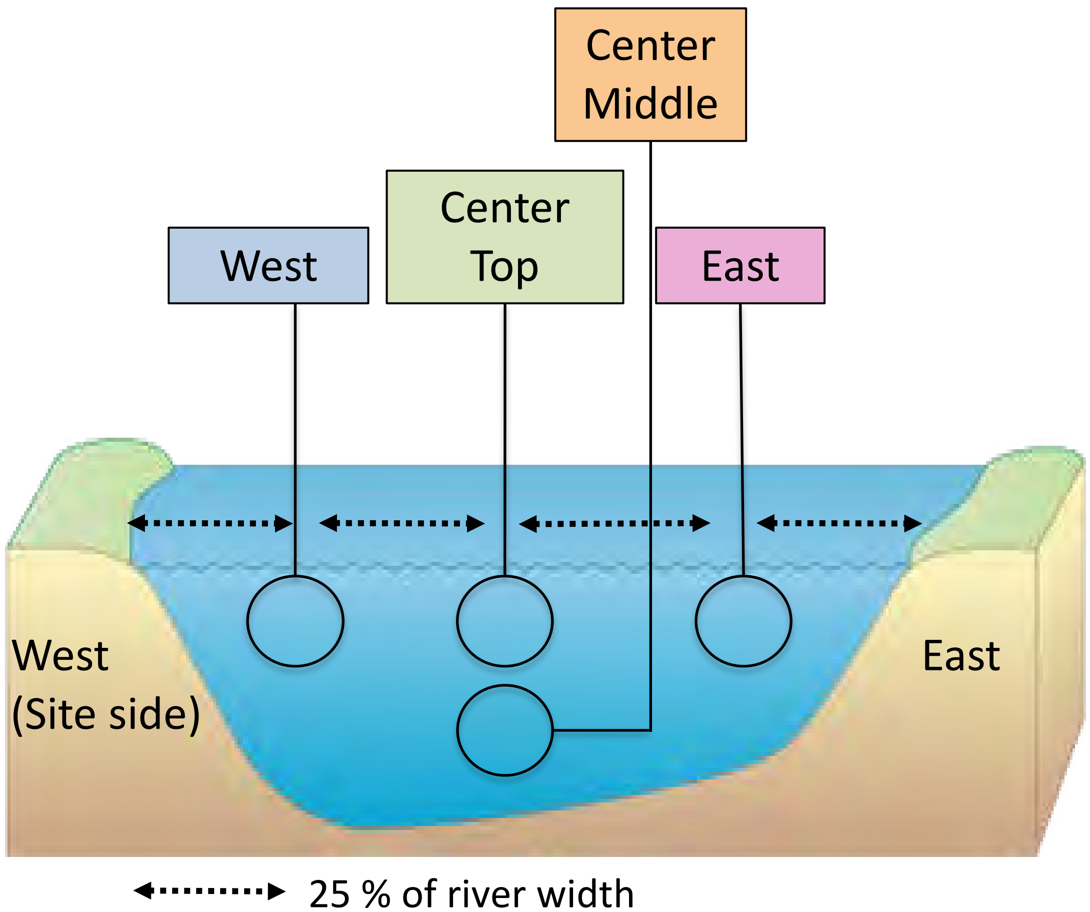
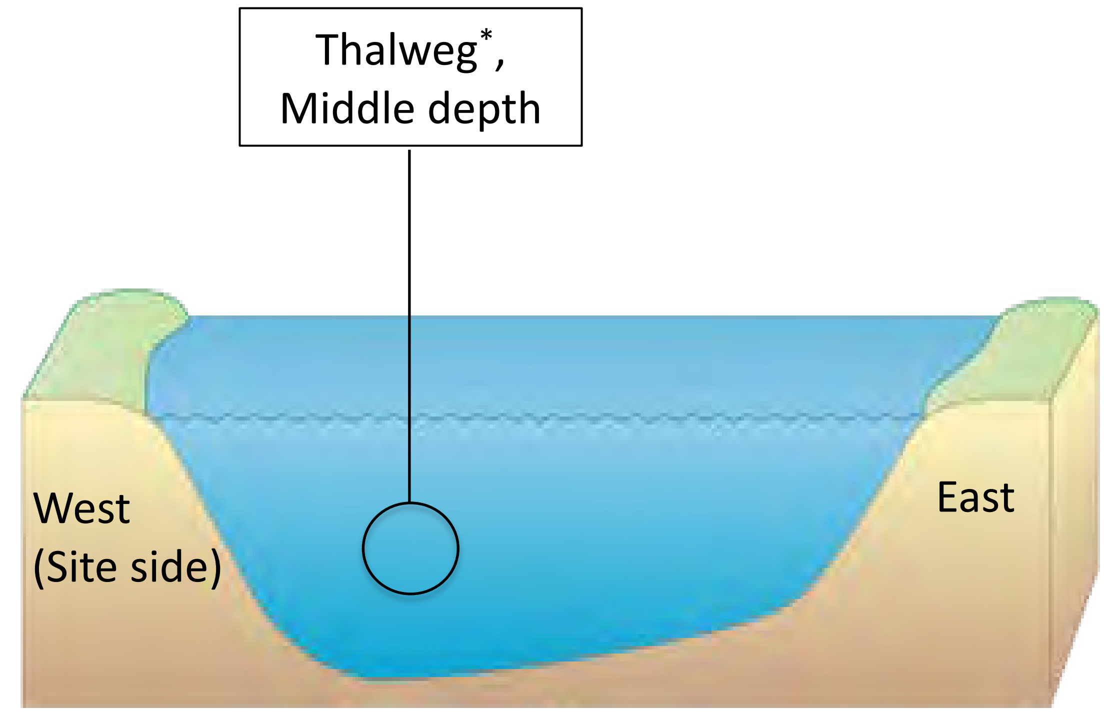
Figure 3

Local River Programs & Additional Sampling



Sampling Location Selection Rationale:
Assess how concentrations differ across cross-section, particularly close to Site

Regional River Program



*Thalweg: Deepest part of the channel cross section

Sampling Location Selection Rationale:
Assess how concentrations vary along the length of the river. The majority of flow occurs at the thalweg, which is typically the most mixed part of river and expected to be representative of average concentrations.

River Sampling Diagram
Chemours Fayetteville Works, North Carolina

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Figure 6