April 15, 2024

New York State Department of Environmental Conservation
232 Golf Course Road
Warrensburg, New York 12885
Attention: Beth Magee; Deputy Regional Permit Administrator

RE: Notice of Incomplete Application; ESMI of New York

Dear Ms. Magee,

ESMI of New York (ESMI), a Clean Earth Company, is submitting the attached response to the *Notice of Incomplete Application* (NoIA) received by ESMI on March 15, 2024 for *Application ID: 5-5330-00038/00027*, *Batch Number: 1018418*. The NoIA was in response to the ESMI request for a Research, Development, and Demonstration Project to demonstrate the ability of ESMI's thermal desorption technology to treat media contaminated with Per- and Poly-fluoroalkyl Substances (PFAS) (RD&D Project; submitted to NYSDEC on December 29, 2023) to soil concentration acceptable for beneficial reuse in accordance with NYSDEC Guidance[1] and to control process effluent air emissions to a level acceptable to regulatory agencies within the State of New York[2].

In review of the NoIA, ESMI offers the following response and information to Items identifies in the document. (NoIA can be referenced in Attachment A.)

Item 1:

a) AERMOD Modeling Protocol and modified AERMOD Dispersion and Deposition Model (modifications identified in Item 4 and Item 5) will be submitted and included in Attachment B of this document by the end of day on Thursday, April 18, 2024. Timeline for the modeling update pushed due to vacation schedules at C.T. Male Associates. (Reference the RD&D Project application for C.T. Male Associates involvement in the modeling process.)

Item 2:

a) Since AERMOD version 19191, Method 2 deposition modeling has been reclassified from a non-default option to an alpha option as the Method 2 deposition algorithms undergo further evaluation. Therefore, deposition modeling was completed using Method 1 as it is the default option in AERMOD and that particle size distribution is known as particle size distribution in Barton et al., 2006 was used in the deposition modeling.

   A particle density of 1.8 g/cm3 was used in the modeling analyses as it is representative of the contaminants to be modeled, PFOA, PFOS, PFHxS, PFNA, and PFBS, which range from 1.780 to 1.841 g/cm3. (Page 32 of the RD&D Project submittal PDF.)

---

[1] Sampling, Analysis, and Assessment of Per- and Polyfluoroalkyl Substances under NYSDEC's Part 375 Remedial Programs; April 2023

[2] NYSDEC, DAR-1, Guidelines for the Evaluation and Control of Ambient Air Contaminants Under 6NYCRR Part 212

Item 3:

a) ESMI is presuming NYSDEC is referencing the 40-PFAS compounds identified in Appendix G of the NYSDEC Sampling, Analysis, and Assessment of Per- and Polyfluoroalkyl Substances (PFAS) under NYSDEC's Part 375 Remedial Programs, dated April 2023 (NYSDEC PFAS Guidance Document). EPA Method 1633, utilizing the Eurofins EPA 1633 Analyte List, tests for 40-PFAS compounds while the Eurofins PFAS Extended Analyte List tests for 70-PFAS compounds; https://www.eurofinsus.com/environment-testing/pfas-testing/pfas-analyte-lists/ . (Eurofins is referenced to set a basis for analytical methods currently available by a commercial laboratory.)

   Using Eurofins PFAS Analyte Lists, PFAS compound boiling point tables for EPA Method 1633, and the Eurofins PFAS Extended List were generated and are within Attachment C. Also included for reference if Appendix G of the NYSDEC PFAS Guidance Document.

   Since ESMI could not identify boiling points for all the PFAS compounds in the PFAS Analyte Lists, Eurofins and Pace Analytical were consulted to determine if boiling points of these compounds existed. Therefore, for PFAS compounds that do not have a boiling point listed, no boiling point was able to be identified. If ESMI receives additional data from Eurofins or Pace Analytical, or information becomes available via other sources, ESMI will share the information with NYSDEC.

   For those compounds with multiple boiling points provide in the tables, the multiple temperatures were derived from the predicted boiling point with the +/- variance accounted for in the temperatures listed. For example, 10:2 FTCA is referenced to have a boiling point of 256.0±35.0 °C (Predicted). In the table, 10:2 FTCA is listed of having the boiling points of 221°C, 256°C, and 291°C.

   The highest noted PFAS boiling point was for Perfluorohexane sulfonic acid, 845.6°F. Please note the below discussion on boiling points and operating temperatures. ESMI does not believe that the boiling point for all compounds must be exceeded for them to desorb from contaminated soil.

b) The primary treatment unit (rotary kiln) of the TDU operates under negative pressure. Negative pressure decreases the boiling point of contaminants being treated within the system. For example, the following coal tar/MGP contaminated have higher boiling points than current ESMI operating temperatures for coal tar/MGP contaminated soil:

○ Dibenzo (a,h) Anthracene:	975°F
○ Indeno (1,2,3-cd) Pyrene:	996°F
○ Benzo (g,h,i) Perylene:	up to 1020°F

Item 3(continued):

During the 2014 Report for Proof of Performance Evaluation of the New Thermal Oxidizer, the following primary treatment unit temperatures were averaged per each Test and treatment soil analysis resulted in non-detect levels for the compounds noted above. demonstrating that the boiling point for a particular compound does not need to be exceeded to desorb the compound from a soil matrix.

- Test #1: 886°F; Test #2: 894.8°F; Test #3: 925°F
- Test #4: 902°F; Test #5: 911°F; Test #6: 910°F

ESMI currently operates under similar conditions and receives similar results with the noted compounds.

c) ESMI acknowledges on Page 7 of the RD&D Project submittal that soil organic matter plays a role in PFAS retention within the soil matrix. Through analysis to be completed during this RD&D Project, ESMI hopes to develop scientific data that will help identify how soil organic matter alters PFAS retention in soil matrices.

Item 4:

a) Table 2 has been updated accordingly and is contained in Attachment D.
    - The term "max annual hourly dispersion rate" has been updated.
    - Table 2, page 11 of the RD&D Project submittal PDF, superscripts have been corrected.

Item 5:

a) ESMI, as referenced in NoIA Item 5, anticipated that modeling may need to be updated based on actual PFAS concentration identified in soil to be treated during the RD&D Project. ESMI also noted that "*ESMI has not engaged in identifying soil sources for the RD&D Project and will not actively seek soil for the project until NYSDEC had provided authorization for the RD&D Project.*". (Page 13 of the RD&D Project submittal PDF). Engagement to identify soil sources did not seem prudent without a RD&D Permit since asking clients to hold PFAS contaminated soil for an undefined period without a treatment commitment was not viewed as proper client management practice. Until such time that soil(s) for the project have been identified, the assumption submitted by NYSDEC will not be able to be confirmed.

Item 6:

a) The "Representative" PFAS of 0.1 g/s is an arbitrary value and was modeled as a screening level to allow emissions of other PFAS contaminants to be estimated by scaling the "Representative" PFAS modeling results. This "Representative" PFAS value is not indicative of the actual estimated facility emissions or modeling for any particular PFAS result(s).

Item 7:

a) ESMI submitted to NYSDEC on April 11, 2024 an email requesting clarification on the determination that a Public Participation Plan (PPP) is required pursuant to DEC Commissioner Policy 29 (DEC CP 29). The email is provided in Attachment E.

   The premise for the clarification is DEC CP 29 states a PPP "… shall apply to applications for major projects and major modifications…". ESMI believes that Research, Development, and Demonstration Permits, as defined by State regulation, are minor projects. Based on the references provided in the noted email, ESMI does not believe that a PPP is required for the RD&D Project. ESMI is awaiting response to the clarification by NYSDEC.

ESMI looks forward to continuing collaborating with the State to develop a research project that will assist all parties in identifying scientific data can be utilized to determine how PFAS contaminated soils can be managed in New York State. Should you have any questions on this document, its contents, or require additional information, please do not hesitate to contact us.

Sincerely,

Robert Martin

Technical Director
P: 518.747.5500
E: rmartin@cleanearthinc.com

Attachment A

Notice of Incomplete Application; Received March 15, 2024

New York State Department of Environmental Conservation

Notice of Incomplete Application - This is NOT a Permit

Application ID: 5-5330-00038/00027 *Batch Number*: 1018418

Facility: Environmental Soil Management of New York LLC dba ESMI A Clean Earth Company
304 Towpath Rd
Fort Edward, NY 12828

Contact: ENVIRONMENTAL SOIL MANAGEMENT INC *Owner ID*: 39045
304 TOWPATH LN
FORT EDWARD, NY 12828-1754

Permit(s) Applied for: 1 - Article 27 Title 7 Solid Waste Management

Project Location: in FORT EDWARD in WASHINGTON COUNTY

Your application for Permit is incomplete. The following items are required:

1. We have no record of receiving or approving a modeling protocol for this project. Please provide a modeling protocol.

2. The PFAS 'deposition' modeling methodology indicated in Section 3.5.1 and used in this analysis is not approved for use in New York State for regulatory purposes. While deposition "Method 1" may be allowed under the default option within AERMOD, it is only used when a significant fraction of the emitted particles have sizes greater than 10 µm, or when the emitted particle size distribution is explicitly known. The information in the report does not support either of these conditions.

3. Table 1 on PDF Page #7: The list of PFAS compounds for which the Boiling Points (BPs) are provided is incomplete in comparison to the full analyte lists for the newest sampling techniques available for measuring the concentrations of various PFAS compounds in the different environmental media (e.g., soil water/liquid, air). It also likely would not represent all the PFAS compounds present in the contaminated soil that will be processed at the facility during this R&D project. Please consider the following:

- It is known that the energy needed to volatilize the PFAS compounds (and thus their BPs), as well as their adherence to the soil's organic content (Total Organic Carbon or TOC), all increase as the length of the PFAS compounds within the same class increases. This can be seen in the increasing BPs of the top six PFAS compounds listed in Table 1 (which are all carboxylates increasing by one addition Carbon (C) in length starting with the 5-C chain length Perfluoropentanoic Acid (PFPeA) at the top and extending through the 10-C chain length PFDA).
- It is also known that the sulfonates class of PFAS adhere more tightly to the TOC in the soil than the carboxylates of the same C-chain length do. Only the 8-C chain length sulfonate of PFOS is included in the Table 1 list (i.e., the bottom PFAS). This relationship can be seen when comparing the BPs of the 8-C chain length PFAS species of these two classes (i.e., PFOA vs PFOS).
- Therefore, if there are larger sulfonate PFAS compounds contaminating the soils being processed (similar to what's being indicated for the carboxylates), they'd be believed to have even higher BPs associated with them.

Given the much more expanded list of analytes associated with the newer PFAS test methods in the various environmental media, the testing that will be performed on the soils being processed by ESMI will result in additional PFAS compounds that are present in the soil for which the BPs need to be obtained and provided to the Department, so it can be assured that the operating temperature of the Primary Treatment Unit (PTU) is established at a level exceeding the highest BP of the various PFAS compounds present.

4. Table 2 on PDF Page #11: The AGC for CF4 derived by the DOH is incorrectly listed in Table 2. The interim CF4 AGC that the DOH derived is 0.33 mg/m3 (i.e., 330 ug/m3), not the 0.332 ug/m3 that is indicated in Table 2.

The term "max annual hourly dispersion concentration" used in the Table 2 column header appears to be a typo, as it is referencing the maximum annual dispersion concentration. This term is also used in a number of other instances in the combined document, such as the headings of various figures contained in Attachments A & B. The superscripts referenced in the notations associated with Table 2 are not included in the table itself to note where they are applicable.

5. Paragraph 2 on PDF Page #12: The modeling will very likely need to be re-run, as there will be many additional PFAS compounds that will be measured/quantified beyond those included in this submittal (due to the limited number of PFAS compounds represented). So, the assumption is that the total combined PFAS sum will be greater than what was used in the modeling performed and will need to be used in the re-running of the modeling (or at minimum used to adjust the results based on the relative increase in the total combined PFAS emission rate).

6. Attachment A & B Tables on PDF Pages #45 & 83, respectively: The tables list "Representative" PFAS at 0.1 g/s and the associated modeling results. It is not clear what the 0.1 g/s "Representative" PFAS emission rate is and how it is determined.

7. The facility is located approximately one mile from the Hudson Falls Environmental Justice and Disadvantaged Communities area, as shown on the maps available at: https://dec.ny.gov/get-involved/environmental-justice/gis-tools and https://www.nyserda.ny.gov/ny/disadvantaged-communities. Pursuant to DEC Commissioner Policy 29, Environmental Justice and Permitting, available here: https://dec.ny.gov/regulatory/guidance-and-policy-documents/commissioner-policy-29-environmental-justice-and-permitting
DEC's initial screening indicates that the facility may have potential adverse environmental impacts on these areas and, as such, you must prepare a Public Participation Plan (PPP) that satisfies the requirements of CP-29 Part V.D. Please plan to hold one public informational meeting, as detailed in the attached PPP template, within the DAC/EJ area and have a records repository available for public review at the library in Hudson Falls.

In accordance with 6 NYCRR § 621.3(a)(3), your application is incomplete until a PPP has been prepared and submitted to DEC for review and approval.

Please submit requested information by April 15, 2024
No further action can be taken until all of these materials are received.

Contact Person:
BETH A MAGEE
NYSDEC
232 Golf Course Rd
Warrensburg, NY 12885

*Signature:*_______________________

Date: March 14, 2024

Attachment B
AERMOD Protocol and AERMOD Modeling

To be updated and provided by the end of April 18, 2024

July 2023
Updated April 18, 2024

Protocol for Emission Point Modeling Using AERMOD Software

Clean Earth LLC
304 Towpath Lane
Village of Fort Edward,
Washington County, New York

Prepared for:

CLEAN EARTH LLC
304 Towpath Lane
Fort Edward, New York 12828

Prepared by:

C.T. MALE ASSOCIATES
50 Century Hill Drive
Latham, New York 12110
(518) 786-7400
FAX (518) 786-7299

C.T. Male Project No.: 22.2756

Unauthorized alteration or addition to this document is a violation of New York State Education Law.

PROTOCOL FOR EMISSION POINT MODELING USING AERMOD SOFTWARE
CLEAN EARTH LLC, 304 TOWPATH LANE
VILLAGE OF FORT EDWARD, WASHINGTON COUNTY, NEW YORK

TABLE OF CONTENTS

FIGURES

1.0 PROJECT OVERVIEW

Clean Earth LLC (Clean Earth) owns and operates an existing facility permitted under an Air State Facility Permit issued by the New York State Department of Environmental Conservation (NYSDEC), Permit ID 5-5330-00038/00021. The permit is listed as being issued under the facility name of "Environmental Soil Management of New York LLC dba ESMI A Clean Earth Company". The facility is in the process of preparing for requesting authorization to treat Per- and polyfluoroalkyl substances (PFAS) contaminated media. The work is being completed for the Clean Earth facility located at 304 Towpath Lane in the Village of Fort Edward, Washington County, New York. This protocol has been prepared to conduct air dispersion/deposition modeling of the facility's proposed operations to estimate the level of impact associated with PFAS emissions from the facility.

Under this protocol, the air dispersion/deposition modeling will be completed in accordance with generally accepted modeling practices and will utilize software which runs the current version of the United States Environmental Protection Agency's (USEPA) AERMOD software as detailed in Section 2. Estimated contaminant-specific hourly and annual maximum hourly concentrations will be derived from the model and will be based on a range of PFAS control efficiency for the soil treated at the facility.

The modeling described within this protocol does not include an attempt to predict groundwater or surface water concentrations that may result from air deposition because there is currently no accepted method for such an evaluation.

The contaminants to be evaluated include the following USEPA regulated Per- and polyfluoroalkyl substances (PFAS) compounds; perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorohexane sulfonate (PFHxS), and perfluorobutane sulfonate (PFBS). This analysis will also include dispersion modeling of Hydrogen Fluoride (HF) and Carbon Tetrafluoride (CF_4) per the request of the NYSDEC. As HF and CF_4 are not particulates, only dispersion modeling will be completed for these compounds.

2.0 MODELING SOFTWARE

2.1 Selection of AERMOD Software

In accordance with NYSDEC Policy DAR-10: NYSDEC Guidelines on Dispersion Modeling Procedures for Air Quality Impact Analysis, this protocol intends to follow the Division of Air Resources' recommended dispersion modeling procedures for conducting ambient impact analyses. By following these procedures, the protocol also follows the USEPA approved methodologies, as incorporated in Appendix W of 40 CFR Part 51 regulations. In performing such assessments, a set of recommended and acceptable procedures has been defined by USEPA and NYSDEC to assist source applicants to assure the proper application of the modeling analysis. As detailed within DAR-10, source analyses at major sources should adhere strictly to the requirements and preferred modeling procedures described in the USEPA Guidelines, with the added requirements of NYSDEC on the application of AERMOD.

2.2 Description of AERMOD Software

AERMOD is a regulatory steady-state plume modeling system with three separate components: AERMOD (Dispersion Model), AERMAP (Terrain Preprocessor), and AERMET (Meteorological Preprocessor). AERMAP characterizes the terrain, and generates receptor grids for the AERMOD dispersion model, while AERMET provides AERMOD with the meteorological information it needs to characterize the planetary boundary layer.

AERMET uses meteorological data and surface characteristics to calculate boundary layer parameters (e.g., mixing height, friction velocity, etc.) needed by AERMOD. This data is representative of the meteorology in the modeling domain.

AERMAP uses gridded terrain data for the modeling area to calculate a representative terrain-influence height associated with each receptor location. The gridded data is supplied to AERMAP in the format of the Digital Elevation Model (DEM) data from the United States Geological Survey (USGS). The terrain preprocessor can also be used to compute elevations for both discrete receptors and receptor grids.

In developing AERMOD, AERMIC adopted design criteria to yield a model with desirable regulatory attributes. It was felt that the model should: 1) provide reasonable concentration estimates under a wide variety of conditions with minimal discontinuities; 2) be user friendly and require reasonable input data and computer resources as is the case with the ISCST3 model; 3) capture the essential physical processes while remaining fundamentally simple; and, 4) accommodate modifications with ease as the science evolves.

In order to provide consideration to downwash, cavity impacts, and building wakes and eddies, the software incorporates a feature known as the Building Profile Input Program (BPIP). The BPIP incorporates a program that calculates building heights (BH) and projected building widths (PBW), and is designed to determine whether or not a stack is being subjected to wake effects from a structure or structures, and may lead to different BH and PBW values than those calculated for GEP. These calculations are performed only if a stack is being influenced by structure wake effects.

The current version of AERMOD, version 23132 will be used to complete the proposed Air Dispersion Modeling. If a newer version of AERMOD is released during the review period for this protocol, the most current version would be used in place of 23132.

3.0 SUMMARY OF MODEL INPUTS

3.1 Facility Modeling Parameters

Design data for the facility will be used as the basis for running the model in conjunction with the anticipated maximum operations which would involve thermal treatment of PFAS containing soil through thermal desorption. The model input data includes emission point parameters (stack location, stack base elevation, emission rate, stack height, stack exit temperature, stack gas velocity and stack diameter), as well as existing building footprints and heights. The model is capable of being run using specific area settings (i.e., urban or rural settings), and will utilize the rural setting based on the layout of the facility and surrounding area.

In order to accommodate various input values based on a range of control efficiency for PFAS in soil to be treated (99.90 – 99.99%) and because all emissions come from one stack, the modeling may be completed using a unit emission rate (1 gram per second (g/s)) and then scaling the modeling results instead of modeling each scenario separately.

3.2 Receptor Area to be Modeled

The modeling will be conducted for the area in the vicinity of the site, with the receptors oriented in a Cartesian grid pattern set up following the initial receptor grid spacing suggested in DAR-10: NYSDEC Guidelines on Dispersion Modeling Procedures for Air Quality Impact Analysis:

- Receptor spacing of 25m along the facility property line;
- 25m receptor spacing from the center of the facility to the facility property line;
- 70m receptor spacing from the facility property line to 1km;
- 100m spacing from 1km to 2km; and
- 250m spacing from 2km to 5km.

A total of 4,001 receptors (including sensitive receptors) will be modeled under this scenario, covering an area of approximately 100,000,000 square meters (±24,700 acres), and includes areas mapped as Potential Environmental Justice Area (PEJA) Community

15000US361150801001 in the Village of Hudson Falls, and a small portion of PEJA Community 15000US361130705002 on the eastern edge of the City of Glens Falls.

As recommended in DAR-10, a 25m receptor spacing within the property boundaries is included as public access is not precluded by means of a fence or other physical barrier. All receptor data corresponds to the interpolated ground level elevation as assigned by AERMAP.

Online resources were consulted to identify the location of additional, discrete sensitive receptors such as schools, hospitals, parks, nursing homes and daycares within the modeling area. A summary of the sensitive receptors within 2 km of the site are summarized in Table 1. Figure 3 provides a depiction of the receptor grid including the sensitive receptors.

Table 1 – List of Sensitive Receptors Within Modeling Area

Facility Name	Location (UTM Coordinates)	Approximate Distance from Facility (km)
Fort Edward Jr. Sr. High School	614811.26m, 4792114.38m	0.97
School on Burgoyne	615068.06m, 4793260.20m	0.83
Fort Edward Village Recreation	615168.68m, 4791200.98m	0.86
Learning Express Family Daycare	614061.73m, 4792415.84m	1.75
A Mother's Dream Daycare	614550.77m, 4794149.78m	1.80
Fort Edward-Kingsbury Health Center	614987.73m, 4791610.57m	1.38
Fort Edward Village Recreation	615155.76m, 4792128.53m	0.85
Wedgewood Golf Club	616233.14m, 4792572.79m	0.85
Mullen Park	615253.85m, 4792023.77m	0.85

3.3 AERMAP Data Input

The current version of AERMAP, version 18081 will be used to complete the proposed Air Dispersion Modeling. The AERMAP terrain preprocessor will utilize USGS 7.5 Minute Native Format DEM topographical data for the Hudson Falls, Fort Miller, Gansevoort, and Glens Falls, New York quadrangles, data which provides a resolution of 10 meters.

3.4 AERMET Data Input

The AERMET meteorological preprocessor will utilize surface and upper air data for the most recently available five year period from the NYSDEC, which includes the years 2017-2021. The National Weather Service (NWS) website indicates that climate data for the region of the project site is available from five regional climatology reporting locations: Albany, NY; Bennington, VT; Glens Falls, NY; Pittsfield, MA; and Poughkeepsie, NY. The Glens Falls location is closest to the site, and as such, was chosen as the most representative climate data for the facility. The meteorological data provided by the NYSDEC includes surface data for Glens Falls, and upper air data from Albany.

3.5 AERMOD Data Input

PFAS emissions estimates for on-site activities will be generated based on maximum material processing capacity for equipment on-site and will evaluate a range of performance of PFAS removal of the treatment system (99.90% and 99.99%). As the feed material will vary from project to project, data will be evaluated from existing PFAS containing soils as part of the input data.

Using the emission point data, the layout of the site buildings, the model will calculate the concentration of PFAS from the emissions from the emission point. The model will consider complex terrain through incorporating the AERMAP program into the modeling scenario. USGS topographical data will be imported into the modeling software to account for the complex terrain (i.e., those areas where the terrain exceeds the stack base elevation). For deposition calculations from AERMOD, particle size information is needed and data to be used is described in Section 3.5.1.

A “Representative” PFAS input of 0.1 g/s will be modeled as an arbitrary value and as a screening level to allow for emissions of contaminants to be estimated by scaling the “Representative” PFAS modeling results. This “Representative” PFAS value is not indicative of the actual estimated facility emissions or modeling results.

3.5.1 Particle Deposition Parameters

Ambient air measurements for the PFAS compounds of interest (Barton et al., 2006; Dreyer et al., 2015; Shin et al., 2012; Paustenbach et al., 2007) have shown that these compounds are primarily present in particulate form (and not in the vapor phase), therefore, conducting particulate deposition modeling is appropriate.

For estimating particulate deposition, the AERMOD model allows the user to input particle information in one of two ways. Method 1 is used when the particle size distribution is reasonably well known and a majority of the particulate are larger than 10 microns in diameter. Method 2 may be used when the particle size distribution is not well known and the majority of the particulate is less than 10 microns in diameter.

It is noted that since AERMOD version 19191, Method 2 deposition modeling has been reclassified from a non-default option to an alpha option as the Method 2 deposition algorithms undergo further evaluation. Therefore, C.T. Male will complete deposition modeling using Method 1 as it is the default option in AERMOD. For comparison purposes only, since it is an alpha option, Method 2 will also run for the facility’s operations in an attempt to provide a range of deposition values.

Method 1

For Method 1 deposition, the particle size distribution in Barton et al., 2006 will be used. This particle size distribution reflects ambient air measurements downwind of a manufacturing facility. As noted above, because Method 1 deposition is typically used for particulates greater than 10 microns in diameter, the applicability of this method for estimating deposition is uncertain. A particle density of 1.8 g/cm^3 will be used in the modeling analyses as it is representative of the contaminants to be modeled, PFOA, PFOS, PFHxS, PFNA, PFBS and HPFO-DA, which range from 1.748 to 1.841 g/cm^3.

Method 2

For Method 2 deposition, the modeling parameters in Barton et al., 2010, which assumed a fine particle fraction (particles < 2.5 µm) of 0.61, will be used. These parameters likely overestimate the fraction of particles greater than 2.5 µm being emitted from a treatment system which utilizes a secondary treatment unit with oxidation temperatures ranging from 1500-2100°F (which are typically assumed to be 100% $PM_{2.5}$ or less), however, these parameter values were shown (Barton et al., 2010) to provide reasonable modeling results as compared to monitored data.

Model Output

The model will be used to calculate annual deposition (total, wet, and dry) in $g/m^2/year$.

3.5.2 Stack and Deposition Parameters

Stack and deposition parameters to be utilized in the dispersion/deposition modeling include:

Table 1 – Stack Parameters (from 2014 Stack Testing)

Stack Height	55 feet
Stack Diameter	3.67 feet
Flow Rate	56,181 ACFM (average from stack test)
Exit Velocity	88.68 feet/second (average from stack test)
Exit Temperature	398°F

Table 2 – Deposition Parameters (Method 1 Parameters[1])

Particle Diameter (µm)	Mass Fraction %
>4.0	5.6
1.7	12.9
0.8	9.2
0.5	7.2
0.3	5.3
<0.28	59.8

[1] – Method 1 deposition parameters from Barton et al., 2006, Table 4

Table 3 – Deposition Parameters (Method 2 Parameters[1])

Particle Diameter (µm)	Mass Fraction %
<2.5	61

[1] – Method 2 deposition parameters from Barton, 2010

The calculations will account for the annual total deposition (dry + wet) using the maximum annual deposition at each receptor and results will be presented from Method 1 as the primary modeling and Method 2 for comparison purposes.

4.0 SUMMARY OF MODELING RESULTS

The AERMOD modeling analysis will account for the operations currently contemplated for the facility, including operation of the facility’s thermal desorption system for the treatment of PFAS containing soil. Modeling data will include the dimensions and footprints of the facility’s buildings, as well as specific information relative to the emission point. The model incorporates topographical data from the USGS, and meteorological data from Glens Falls and Albany Airports.

A summary of the model results will be presented within the summary report, which will include graphical representations of the model output at 99.90% and 99.99%, respectively.

The results of the modeling software specific to air dispersion modeling will be compared to the AGC and SGC values for individual contaminants as determined by the NYSDEC, and as listed within the NYSDEC document titled “DAR-1 AGC/SGC Tables”. As a conservative approach, the sum of the five (5) modeled PFAS compounds will be compared to the individual AGC for PFOA. CF4 does not have an established AGC, and the value presented is based on the recommendation of the New York State Department of Health (NYSDOH) in their October 2023 assessment.

4.1 Locations of Maximum Concentration Receptors

The location of the receptor for the maximum concentration will be provided within the summary report. Isopleths indicating the results of the modeling demonstrating the concentrations of PFAS will also be included within the summary report.

5.0 REFERENCES

Barton, C.A., Butler, L.E., Zarzecki, C.J., Flaherty, J., and Kaiser, M., 2006. Characterizing Perfluorooctanoate in Ambient Air near the Fence Line of a Manufacturing Facility: Comparing Modeled and Monitored Values. Journal of the Air & Waste Management Association, 56:48-55.

Barton, C.A., Zarzecki, C.J., and Russell, M.H., 2010. A Site-Specific Screening Comparison of Modeled and Monitored Air Dispersion and Deposition for Perfluorooctanoate. Journal of the Air & Waste Management Association, 60:4, 402-411, DOI:10.3155/1047-3289.60.4.402

Dreyer, A., Kirchgeorg, T., Weinberg, I., and Matthias, V. 2015. Particle-size Distribution of Airborne Poly- and Perfluorinated Alkyl Substances. Chemosphere, 129 (2015), 142-149, dx.doi.org/10.1016/j.chemosphere.2014.06.069

Paustenbach, D.J., Panko, J.M., Scott, P.K., and Unice, K.M., 2007. A Methodology for Estimating Human Exposure to Perflurooctanoic Acid (PFOA): A Retrospective Exposure Assessment of a Community (1951e2003). Journal of Toxicology and Environmental Health 70, 28-57

Shin, H.-M., Vieira, V.M., Ryan, P.B., Detwiler, R., Sanders, B., Steenland, K., and Bartell, S.M., 2011. Environmental Fate and Transport Modeling for Perfluorooctanoic Acid Emitted from the Washington Works Facility in West Virginia. Environmental Science and Technology, 2011, 45, 14351442, dx.doi.org/10.1021/es102769t

Shin, H.-M., Ryan, P.B., Vieira, V.M., and Bartell, S.M., 2012. Modeling the Air-Soil Pathway of Perfluorooctanoic Acid in the Mid-Ohio Valley Using Linked Air Dispersion and Vadose Zone Models. Atmospheric Environment, 51 (2012), 67-74, doi:10.1016/j.atmosenv.2012.01.049

United States Environmental Protection Agency (ongoing) – American Meteorological Society / EPA Regulatory Model - AERMOD Modeling System currently located and documented at EPA Home>> Air & Radiation>> Technology Transfer Network>> Support Center for Regulatory Atmospheric Modeling>> Preferred/Recommended Models

FIGURES

MAP REFERENCE
United States Geological Survey
7.5 Minute Series Topographic Map
Quadrangle: Hudson Falls, NY
Date: 2019

N
W E
S

CIVIL ENGINEERING
ENVIRONMENTAL SERVICES
SURVEY SERVICES
LAND SERVICES
ARCHITECTURE
ENERGY & BUILDING SYSTEMS SERVICES
ELECTRICAL ENGINEERING

C.T. MALE ASSOCIATES
Engineering, Surveying, Architecture, Landscape Architecture & Geology, D.P.C.
50 CENTURY HILL DRIVE, LATHAM, NEW YORK 12110
PHONE (518) 786-7400 FAX (518) 786-7299

FIGURE 1 SITE LOCATION MAP

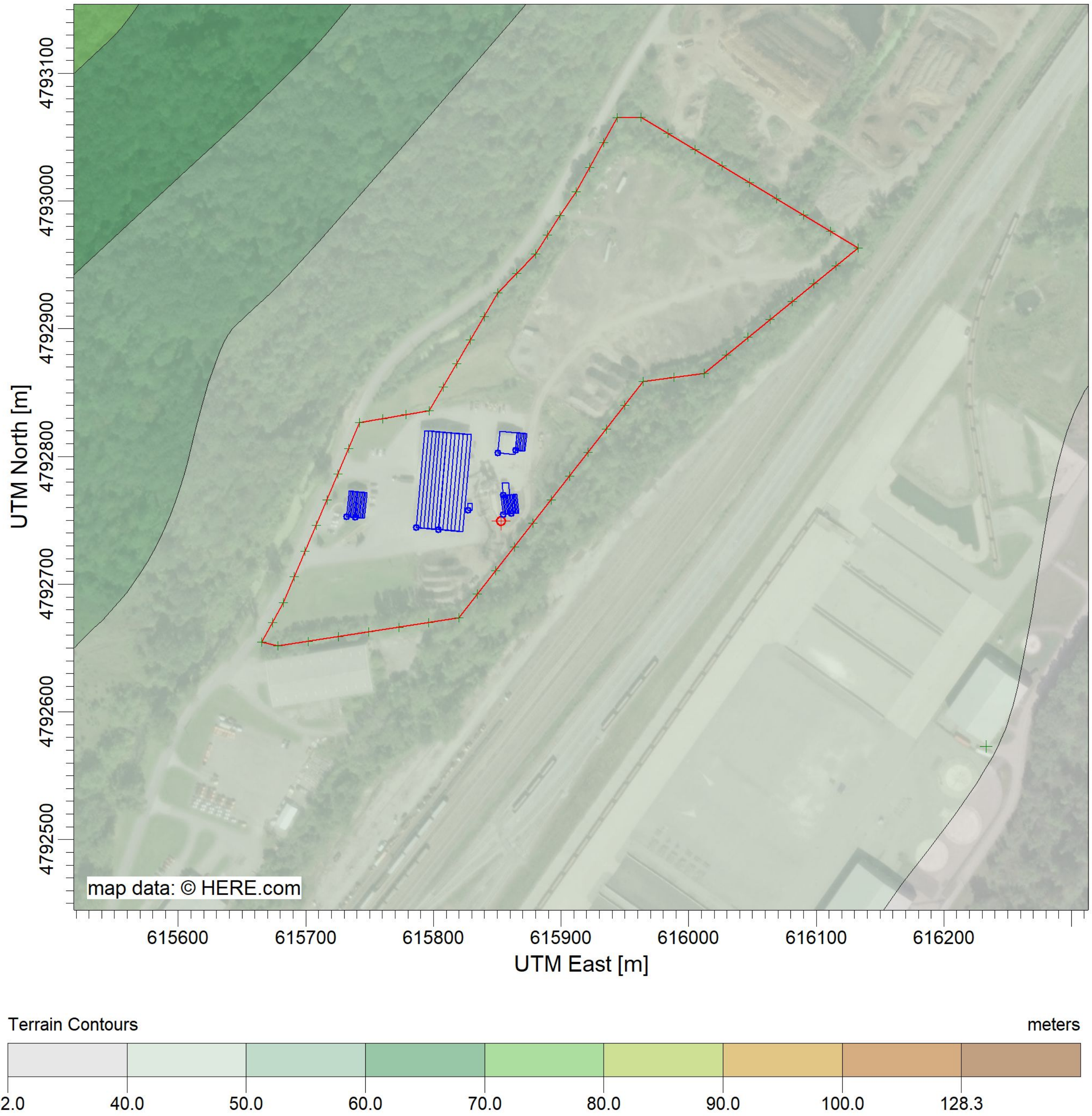
CLEAN EARTH, FORT EDWARD FACILITY

VILLAGE OF FORT EDWARD	WASHINGTON COUNTY, NY

SCALE: 1" = ±2,000'
DRAFTER: L.HAND
PROJECT No. 22.2756

PROJECT TITLE:

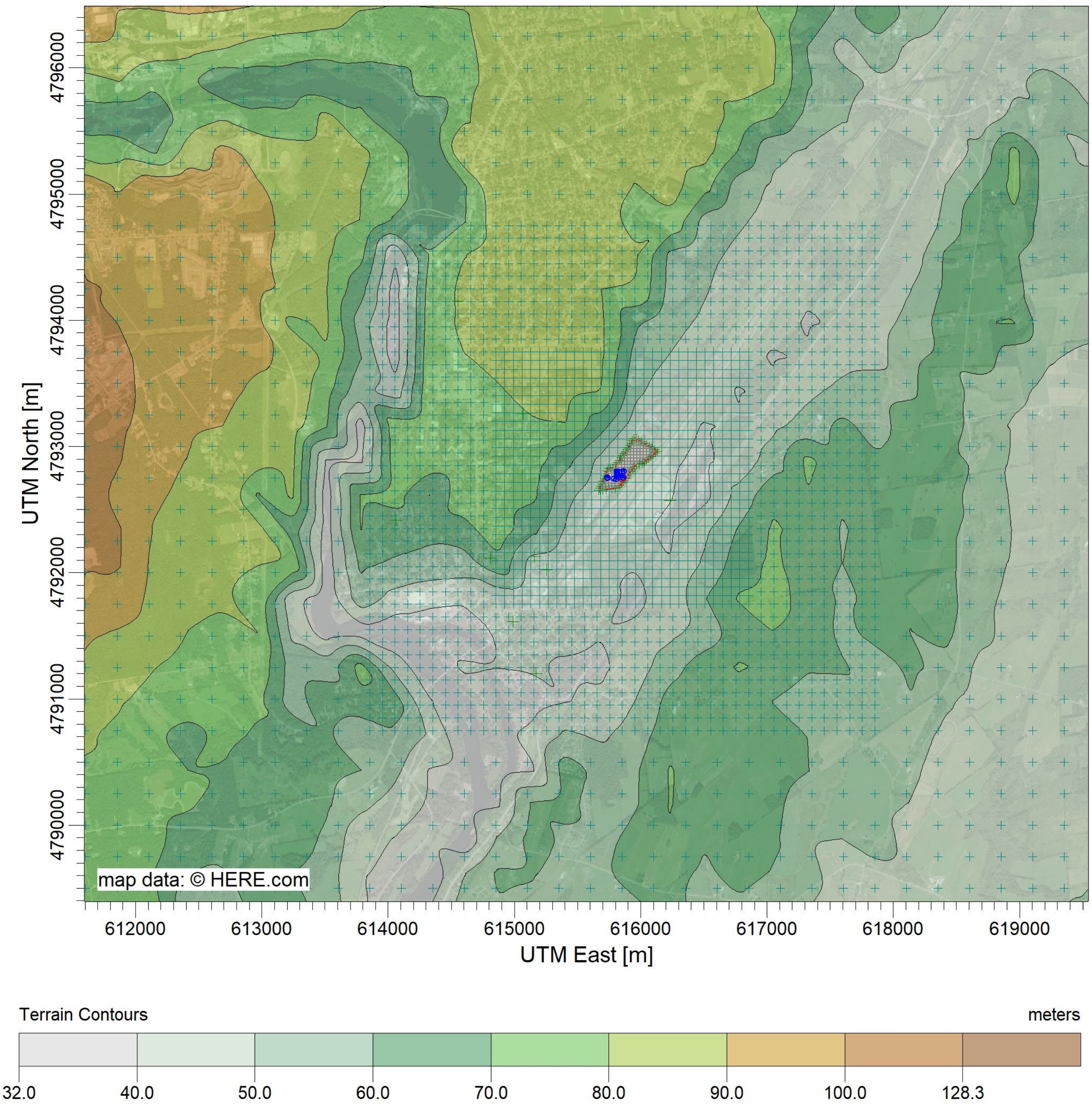
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Facility Building, Emission Points, Elevations and Property Line



COMMENTS:	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**
		SCALE: 1:5,000 0 0.1 km
		DATE: **5/8/2023**
		PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Receptor Grid Depiction



COMMENTS:

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

SCALE: 1:50,000

0 2 km

DATE:
5/8/2023

PROJECT NO.:
22.2756

December 2023
Updated April 2024

Summary of Emission Point Modeling Using AERMOD Software

Clean Earth LLC
304 Towpath Lane
Village of Fort Edward,
Washington County, New York

Prepared for:

CLEAN EARTH LLC
304 Towpath Lane
Fort Edward, New York 12828

Prepared by:

C.T. MALE ASSOCIATES
50 Century Hill Drive
Latham, New York 12110
(518) 786-7400
FAX (518) 786-7299

C.T. Male Project No.: 22.2756

Unauthorized alteration or addition to this document is a violation of New York State Education Law.

SUMMARY OF EMISSION POINT MODELING USING AERMOD SOFTWARE
CLEAN EARTH LLC, 304 TOWPATH LANE
VILLAGE OF FORT EDWARD, WASHINGTON COUNTY, NEW YORK

TABLE OF CONTENTS

FIGURES

SUMMARY OF EMISSION POINT MODELING USING AERMOD SOFTWARE
CLEAN EARTH LLC, 304 TOWPATH LANE
VILLAGE OF FORT EDWARD, WASHINGTON COUNTY, NEW YORK

TABLE OF CONTENTS

ATTACHMENTS

1.0 PROJECT OVERVIEW

Clean Earth LLC (Clean Earth) owns and operates an existing facility permitted under an Air State Facility Permit issued by the New York State Department of Environmental Conservation (NYSDEC), Permit ID 5-5330-00038/00021. The permit is listed as being issued under the facility name of "Environmental Soil Management of New York LLC dba ESMI A Clean Earth Company". The facility is in the process of preparing for requesting authorization to treat Per- and polyfluoroalkyl substances (PFAS) contaminated media. The work is being completed for the Clean Earth facility located at 304 Towpath Lane in the Village of Fort Edward, Washington County, New York. This project conducted air dispersion/deposition modeling of the facility's proposed operations in order to estimate the level of impact associated with PFAS emissions from the facility.

In accordance with the previously prepared protocol, the air dispersion/deposition modeling was completed in accordance with generally accepted modeling practices and utilized software which runs the current version of the United States Environmental Protection Agency's (USEPA) AERMOD software as detailed in Section 2. Estimated contaminant-specific maximum deposition was derived from the model based on the estimated PFAS control efficiency for the soil treated at the facility and anticipated PFAS levels in incoming soil.

The modeling described within this report does not include an attempt to predict groundwater or surface water concentrations that may result from air deposition because there is currently no accepted method for such an evaluation.

The contaminants evaluated relative to dispersion and deposition include the following USEPA regulated Per- and polyfluoroalkyl substances (PFAS) compounds; perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorohexane sulfonate (PFHxS), and perfluorobutane sulfonate (PFBS). This analysis also includes dispersion modeling of Hydrogen Fluoride (HF) and Carbon Tetrafluoride (CF_4) per the request of the NYSDEC. As HF and CF_4 are not particulates, only dispersion modeling was completed for these compounds.

2.0 MODELING SOFTWARE

2.1 Selection of AERMOD Software

In accordance with NYSDEC Policy DAR-10: NYSDEC Guidelines on Dispersion Modeling Procedures for Air Quality Impact Analysis, this project followed the Division of Air Resources' recommended dispersion modeling procedures for conducting ambient impact analyses. By following these procedures, the protocol also followed the USEPA approved methodologies, as incorporated in Appendix W of 40 CFR Part 51 regulations. In performing such assessments, a set of recommended and acceptable procedures has been defined by USEPA and NYSDEC to assist source applicants to assure the proper application of the modeling analysis. As detailed within DAR-10, source analyses at major sources should adhere strictly to the requirements and preferred modeling procedures described in the USEPA Guidelines, with the added requirements of NYSDEC on the application of AERMOD.

2.2 Description of AERMOD Software

AERMOD is a regulatory steady-state plume modeling system with three separate components: AERMOD (Dispersion Model), AERMAP (Terrain Preprocessor), and AERMET (Meteorological Preprocessor). AERMAP characterizes the terrain, and generates receptor grids for the AERMOD dispersion model, while AERMET provides AERMOD with the meteorological information it needs to characterize the planetary boundary layer.

AERMET uses meteorological data and surface characteristics to calculate boundary layer parameters (e.g., mixing height, friction velocity, etc.) needed by AERMOD. This data is representative of the meteorology in the modeling domain.

AERMAP uses gridded terrain data for the modeling area to calculate a representative terrain-influence height associated with each receptor location. The gridded data is supplied to AERMAP in the format of the Digital Elevation Model (DEM) data from the United States Geological Survey (USGS). The terrain preprocessor can also be used to compute elevations for both discrete receptors and receptor grids.

In developing AERMOD, AERMIC adopted design criteria to yield a model with desirable regulatory attributes. It was felt that the model should: 1) provide reasonable concentration estimates under a wide variety of conditions with minimal discontinuities; 2) be user friendly and require reasonable input data and computer resources as is the case with the ISCST3 model; 3) capture the essential physical processes while remaining fundamentally simple; and, 4) accommodate modifications with ease as the science evolves.

In order to provide consideration to downwash, cavity impacts, and building wakes and eddies, the software incorporates a feature known as the Building Profile Input Program (BPIP). The BPIP incorporates a program that calculates building heights (BH) and projected building widths (PBW), and is designed to determine whether or not a stack is being subjected to wake effects from a structure or structures, and may lead to different BH and PBW values than those calculated for GEP. These calculations are performed only if a stack is being influenced by structure wake effects.

The current version of AERMOD, version 23132 was used to complete the Air Dispersion/Deposition Modeling.

3.0 SUMMARY OF MODEL INPUTS

3.1 Facility Modeling Parameters

Design data for the facility was used as the basis for running the model in conjunction with the anticipated maximum operations which would involve thermal treatment of PFAS containing soil through thermal desorption. The model input data includes emission point parameters (stack location, stack base elevation, emission rate, stack height, stack exit temperature, stack gas velocity and stack diameter), as well as existing building footprints and heights. The model is capable of being run using specific area settings (i.e., urban or rural settings), and utilized the rural setting based on the layout of the facility and surrounding area.

In order to estimate anticipated facility emissions, destruction efficiencies of 99.90% and 99.99% were used for PFAS in soil to be treated. A summary of deposition (for PFAS) and dispersion (for PFAS, HF and CF_4) modeling results with graphical representations of outputs are included in Attachment A and Attachment B for destruction efficiencies of 99.90% and 99.99%, respectively.

3.2 Receptor Area Modeled

The modeling was conducted for the area in the vicinity of the site, with the receptors oriented in a Cartesian grid pattern set up following the initial receptor grid spacing suggested in DAR-10: NYSDEC Guidelines on Dispersion Modeling Procedures for Air Quality Impact Analysis:

- Receptor spacing of 25m along the facility property line;
- 25m receptor spacing from the center of the facility to the facility property line;
- 70m receptor spacing from the facility property line to 1km;
- 100m spacing from 1km to 2km; and
- 250m spacing from 2km to 5km.

A total of 4,001 receptors (including sensitive receptors) were modeled under this scenario, covering an area of approximately 100,000,000 square meters (±24,700 acres), and includes areas mapped as Potential Environmental Justice Area (PEJA) Community

15000US361150801001 in the Village of Hudson Falls, and a small portion of PEJA Community 15000US361130705002 on the eastern edge of the City of Glens Falls.

As recommended in DAR-10, a 25m receptor spacing within the property boundaries was included as public access is not precluded by means of a fence or other physical barrier. All receptor data corresponds to the interpolated ground level elevation as assigned by AERMAP.

Online resources were consulted to identify the location of additional, discrete sensitive receptors such as schools, hospitals, parks, nursing homes and daycares within the modeling area. A summary of the sensitive receptors within 2 km of the site are summarized in Table 1. Figure 3 provides a depiction of the receptor grid including the sensitive receptors.

Table 1 – List of Sensitive Receptors Within Modeling Area

Facility Name	Location (UTM Coordinates)	Approximate Distance from Facility (km)
Fort Edward Jr. Sr. High School	614811.26m, 4792114.38m	0.97
School on Burgoyne	615068.06m, 4793260.20m	0.83
Fort Edward Village Recreation	615168.68m, 4791200.98m	0.86
Learning Express Family Daycare	614061.73m, 4792415.84m	1.75
A Mother's Dream Daycare	614550.77m, 4794149.78m	1.80
Fort Edward-Kingsbury Health Center	614987.73m, 4791610.57m	1.38
Fort Edward Village Recreation	615155.76m, 4792128.53m	0.85
Wedgewood Golf Club	616233.14m, 4792572.79m	0.85
Mullen Park	615253.85m, 4792023.77m	0.85

3.3 AERMAP Data Input

The current version of AERMAP, version 18081 was used to complete the proposed Air Dispersion Modeling. The AERMAP terrain preprocessor will utilize USGS 7.5 Minute Native Format DEM topographical data for the Hudson Falls, Fort Miller, Gansevoort, and Glens Falls, New York quadrangles, data which provides a resolution of 10 meters.

3.4 AERMET Data Input

The AERMET meteorological preprocessor utilized surface and upper air data for the most recently available five year period from the NYSDEC, which includes the years 2017-2021. The National Weather Service (NWS) website indicates that climate data for the region of the project site is available from five regional climatology reporting locations: Albany, NY; Bennington, VT; Glens Falls, NY; Pittsfield, MA; and Poughkeepsie, NY. The Glens Falls location is closest to the site, and as such, was chosen as the most representative climate data for the facility. The meteorological data provided by the NYSDEC includes surface data for Glens Falls, and upper air data from Albany.

3.5 AERMOD Data Input

PFAS emissions estimates for on-site activities were generated based on maximum material processing capacity for equipment on-site and estimated destruction efficiencies of PFAS of the treatment system at 99.90% and 99.99% . As the feed material will vary from project to project, data was evaluated from existing PFAS containing soils as part of the input data.

Using the emission point data, the layout of the site buildings, the model calculated the concentration of PFAS from the emissions from the emission point. The model considered complex terrain through incorporating the AERMAP program into the modeling scenario. USGS topographical data was imported into the modeling software to account for the complex terrain (i.e., those areas where the terrain exceeds the stack base elevation). For deposition calculations from AERMOD, particle size information is needed and data to be used is described in Section 3.5.1.

A “Representative” PFAS input of 0.1 g/s was also modeled as an arbitrary value and as a screening level to allow for emissions of contaminants to be estimated by scaling the “Representative” PFAS modeling results. This “Representative” PFAS value is not indicative of the actual estimated facility emissions or modeling results.

3.5.1 Particle Deposition Parameters

Ambient air measurements for the PFAS compounds of interest (Barton et al., 2006; Dreyer et al., 2015; Shin et al., 2012; Paustenbach et al., 2007) have shown that these compounds are primarily present in particulate form (and not in the vapor phase), therefore, conducting particulate deposition modeling is appropriate.

For estimating particulate deposition, the AERMOD model allows the user to input particle information in one of two ways. Method 1 is used when the particle size distribution is reasonably well known and a majority of the particulate are larger than 10 microns in diameter. Method 2 may be used when the particle size distribution is not well known and the majority of the particulate is less than 10 microns in diameter.

It is noted that since AERMOD version 19191, Method 2 deposition modeling has been reclassified from a non-default option to an alpha option as the Method 2 deposition algorithms undergo further evaluation. Therefore, C.T. Male completed deposition modeling using Method 1 as it is the default option in AERMOD. For comparison purposes only, since it is an alpha option, Method 2 was also run for the facility’s operations in an attempt to provide a range of deposition values.

Method 1

For Method 1 deposition, the particle size distribution in Barton et al., 2006 was used. This particle size distribution reflects ambient air measurements downwind of a manufacturing facility. As noted above, because Method 1 deposition is typically used for particulates greater than 10 microns in diameter, the applicability of this method for estimating deposition is uncertain. A particle density of 1.8 g/cm^3 was used in the modeling analyses as it is representative of the contaminants to be modeled, PFOA, PFOS, PFHxS, PFNA, and PFBS, which range from 1.780 to 1.841 g/cm^3.

Method 2

For Method 2 deposition, the modeling parameters in Barton et al., 2010, which assumed a fine particle fraction (particles < 2.5 µm) of 0.61, were used. These parameters likely overestimate the fraction of particles greater than 2.5 µm being emitted from a treatment system which utilizes a secondary treatment unit with oxidation temperatures ranging from 1500-2100°F (which are typically assumed to be 100% $PM_{2.5}$ or less), however, these parameter values were shown (Barton et al., 2010) to provide reasonable modeling results as compared to monitored data.

Model Output

For PFOA, PFOS, PFHxS, PFNA, and PFBS compounds, the model was used to calculate annual deposition (total, wet, and dry) in $g/m^2/year$.

3.5.2 Stack and Deposition Parameters

Stack and deposition parameters utilized in the dispersion/deposition modeling include:

Table 1 – Stack Parameters (from 2014 Stack Testing)

Stack Height	55 feet
Stack Diameter	3.67 feet
Flow Rate	56,181 ACFM (average from stack test)
Exit Velocity	88.68 feet/second (average from stack test)
Exit Temperature	398°F

Table 2 – Deposition Parameters (Method 1 Parameters[1])

Particle Diameter (µm)	**Mass Fraction %**
>4.0	5.6
1.7	12.9
0.8	9.2
0.5	7.2
0.3	5.3
<0.28	59.8

[1] – Method 1 deposition parameters from Barton et al., 2006, Table 4

Table 3 – Deposition Parameters (Method 2 Parameters[1])

Particle Diameter (µm)	**Mass Fraction %**
<2.5	61

[1] – Method 2 deposition parameters from Barton, 2010

The calculations accounted for the annual total deposition (dry + wet) using the maximum annual deposition at each receptor and results will are presented from Method 1 as the primary modeling and Method 2 for comparison purposes.

4.0 SUMMARY OF MODELING RESULTS

The AERMOD modeling analysis accounts for the operations currently contemplated for the facility, including operation of the facility's thermal desorption system for the treatment of PFAS containing soil. Modeling data included the dimensions and footprints of the facility's buildings, as well as specific information relative to the emission point. The model incorporates topographical data from the USGS, and meteorological data from Glens Falls and Albany Airports. A summary of the model results is presented within the summary report in Attachments A and B, which also include graphical representations of the model output at 99.90% and 99.99%, respectively.

The results of the modeling software specific to air dispersion modeling were subsequently compared to the AGC and SGC values for individual contaminants as determined by the NYSDEC, and as listed within the NYSDEC document titled "DAR-1 AGC/SGC Tables". A summary of the modeled maximum hourly concentration and annual concentrations, and a comparison of those values to the established SGC and AGC values are presented below. As a conservative approach, the sum of the five (5) modeled PFAS compounds was compared to the individual AGC for PFOA. CF_4 does not have an established AGC, and the value presented herein is based on the recommendation of the New York State Department of Health (NYSDOH) in their October 2023 assessment, included as Attachment C. The summary table shows that the modeled concentrations will not result in exceeding concentrations established by the NYSDEC or NYSDOH, which were developed to be protective of human health and the environment.

Table 4 – Summary of Concentration Data from Modeling (Using Method 1)

Contaminant	Max Hourly Dispersion Concentration	SGC	% of SGC	Max Annual Dispersion	AGC	% of AGC
	All values in ug/m³					
Total Sampled PFAS (99.9% DRE, full receptor grid)	2.75E-05	N/A	N/A	2.72E-07	0.0053[1]	0.005%
Total Sampled PFAS (99.9% DRE, 1.5 mile endpoint)	5.39E-06	N/A	N/A	7.08E-08	0.0053[1]	0.001%
Hydrogen Fluoride (HF)	1.26	5.6	23%	0.0124	0.071	17%
Carbon Tetrafluoride (CF_4)	5.28E-03	N/A	N/A	5.21E-05	330[2]	1.74E-05%

[1] – Individual AGC for PFOA

[2] – NYSDOH recommended AGC, not formally accepted by the NYSDEC

Table 5 – Sum of PFAS Compounds Deposition Data from Modeling (Methods 1 & 2)

Contaminant	Low Year Maximum	Low Year	High Year Maximum	High Year	Method
	All values in g/m²				
Total Sampled PFAS (99.9% DRE, full receptor grid)	2.286E-08	Year 4 of 5	2.988E-08	Year 5 of 5	Method 1
Total Sampled PFAS (99.9% DRE, full receptor grid)	1.124E-06	Year 4 of 5	1.487E-06	Year 5 of 5	Method 2
Total Sampled PFAS (99.9% DRE, 1.5 mile endpoint)	1.014E-09	Year 4 of 5	9.092E-10	Year 5 of 5	Method 1
Total Sampled PFAS (99.9% DRE, 1.5 mile endpoint)	1.036E-08	Year 4 of 5	1.374E-08	Year 5 of 5	Method 2

This table provides data regarding the variation in modeled deposition using Methods 1 and 2 for the same input scenarios (i.e., same emissions using the full receptor grid and at the 1.5 mile endpoint).

4.1 Locations of Maximum Concentration Receptors

The location of the receptor for the maximum concentration is provided within the summary report. Isopleths indicating the results of the modeling demonstrating the concentrations of PFAS are also included within the summary report. None of the maximum concentration receptors was located in close proximity to any of the sensitive receptors. The maximum receptor for all model runs was located on-site, approximately 18 meters southwest of the emission point.

5.0 REFERENCES

Barton, C.A., Butler, L.E., Zarzecki, C.J., Flaherty, J., and Kaiser, M., 2006. Characterizing Perfluorooctanoate in Ambient Air near the Fence Line of a Manufacturing Facility: Comparing Modeled and Monitored Values. Journal of the Air & Waste Management Association, 56:48-55.

Barton, C.A., Zarzecki, C.J., and Russell, M.H., 2010. A Site-Specific Screening Comparison of Modeled and Monitored Air Dispersion and Deposition for Perfluorooctanoate. Journal of the Air & Waste Management Association, 60:4, 402-411, DOI:10.3155/1047-3289.60.4.402

Dreyer, A., Kirchgeorg, T., Weinberg, I., and Matthias, V. 2015. Particle-size Distribution of Airborne Poly- and Perfluorinated Alkyl Substances. Chemosphere, 129 (2015), 142-149, dx.doi.org/10.1016/j.chemosphere.2014.06.069

Paustenbach, D.J., Panko, J.M., Scott, P.K., and Unice, K.M., 2007. A Methodology for Estimating Human Exposure to Perflurooctanoic Acid (PFOA): A Retrospective Exposure Assessment of a Community (1951e2003). Journal of Toxicology and Environmental Health 70, 28-57

Shin, H.-M., Vieira, V.M., Ryan, P.B., Detwiler, R., Sanders, B., Steenland, K., and Bartell, S.M., 2011. Environmental Fate and Transport Modeling for Perfluorooctanoic Acid Emitted from the Washington Works Facility in West Virginia. Environmental Science and Technology, 2011, 45, 14351442, dx.doi.org/10.1021/es102769t

Shin, H.-M., Ryan, P.B., Vieira, V.M., and Bartell, S.M., 2012. Modeling the Air-Soil Pathway of Perfluorooctanoic Acid in the Mid-Ohio Valley Using Linked Air Dispersion and Vadose Zone Models. Atmospheric Environment, 51 (2012), 67-74, doi:10.1016/j.atmosenv.2012.01.049

United States Environmental Protection Agency (ongoing) – American Meteorological Society / EPA Regulatory Model - AERMOD Modeling System currently located and documented at EPA Home>> Air & Radiation>> Technology Transfer Network>> Support Center for Regulatory Atmospheric Modeling>> Preferred/Recommended Models

Figure 1

Site Location Map

MAP REFERENCE
United States Geological Survey
7.5 Minute Series Topographic Map
Quadrangle: Hudson Falls, NY
Date: 2019

CIVIL ENGINEERING
ENVIRONMENTAL SERVICES
SURVEY SERVICES
LAND SERVICES
ARCHITECTURE
ENERGY & BUILDING SYSTEMS SERVICES
ELECTRICAL ENGINEERING

C.T. MALE ASSOCIATES
Engineering, Surveying, Architecture, Landscape Architecture & Geology, D.P.C.
50 CENTURY HILL DRIVE, LATHAM, NEW YORK 12110
PHONE (518) 786-7400 FAX (518) 786-7299

FIGURE 1 SITE LOCATION MAP

CLEAN EARTH, FORT EDWARD FACILITY

VILLAGE OF FORT EDWARD
WASHINGTON COUNTY, NY

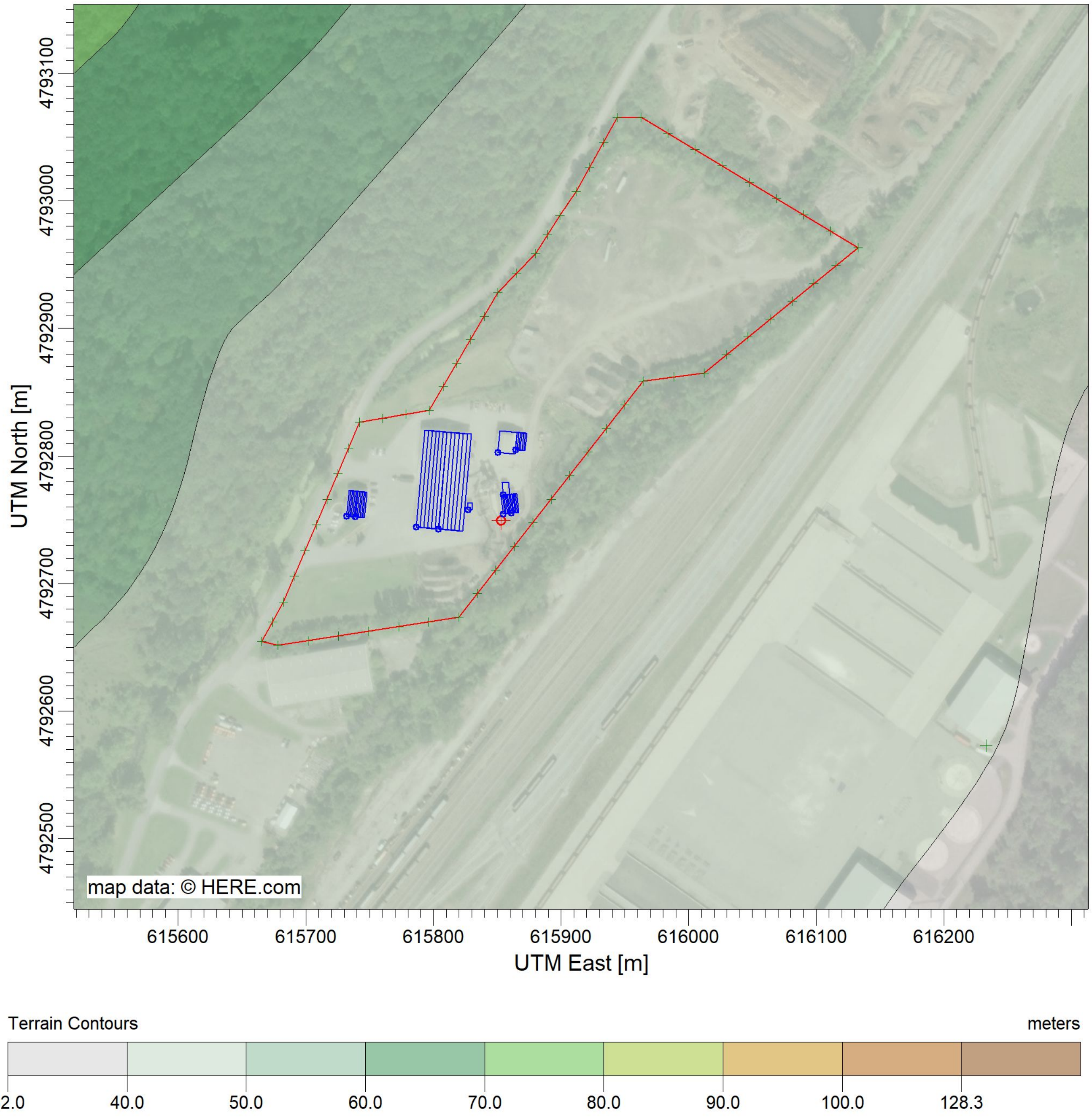
SCALE: 1" = ±2,000'
DRAFTER: L.HAND
PROJECT No. 22.2756

Figure 2

Facility Buildings, Emission Points, Elevation and Property Line Map

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Facility Building, Emission Points, Elevations and Property Line



COMMENTS:

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

SCALE: 1:5,000

0 ▬ 0.1 km

DATE:

5/8/2023

PROJECT NO.:

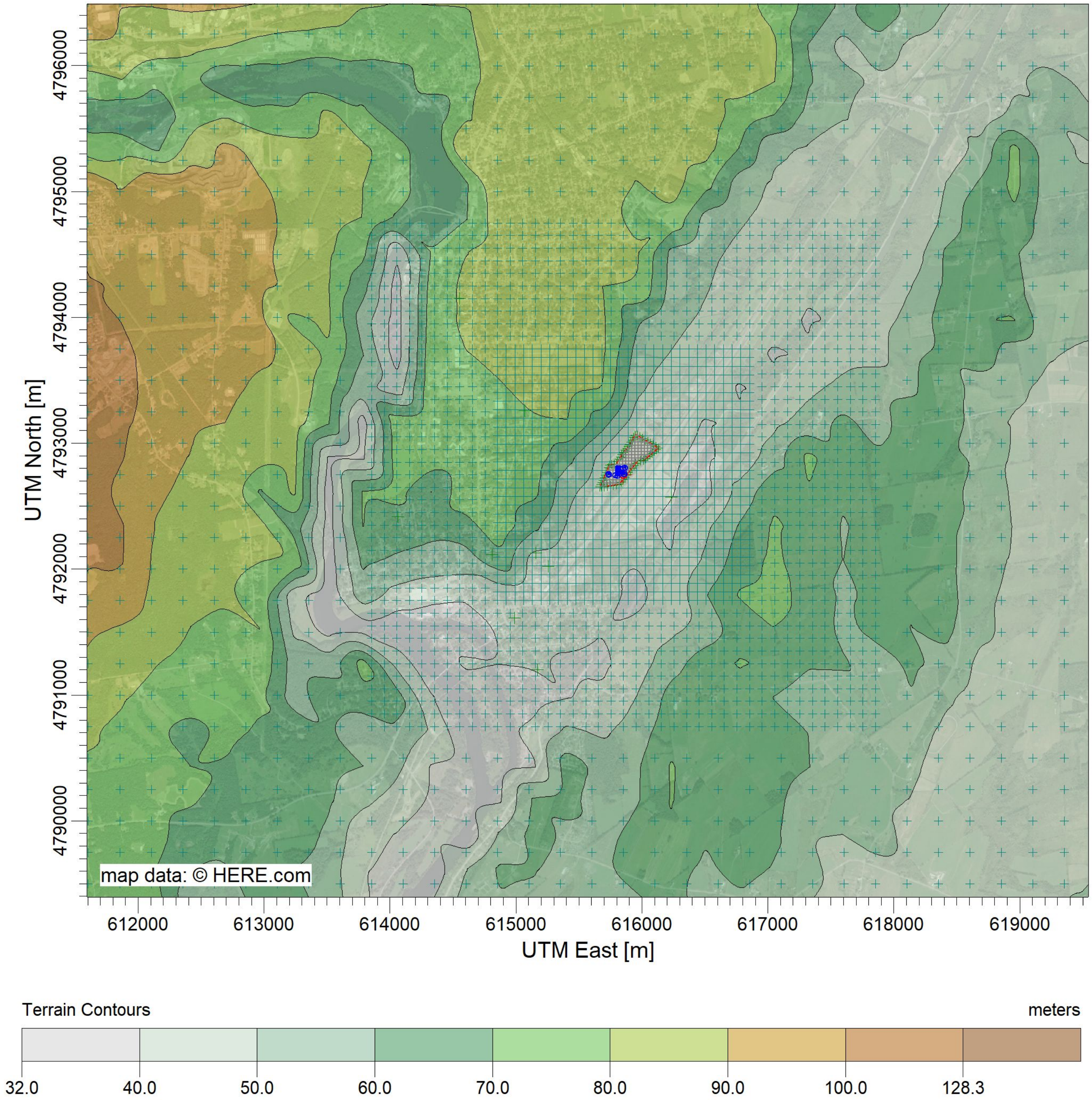
22.2756

Figure 3

Receptor Grid Depiction Map

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Receptor Grid Depiction



COMMENTS:	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
		SCALE: 1:50,000 0 2 km	
		DATE: **5/8/2023**	PROJECT NO.: **22.2756**

AERMOD View - Lakes Environmental Software

C:\Data\Lakes\CEFE2023\CEFE2023.isc

Attachment A

Summary of Dispersion and Deposition Modeling Results and Graphical Representations of Output at 99.90% Destruction Efficiency

C.T. Male Associates

Clean Earth Fort Edward, NY Site
Air Deposition Modeling Results
C.T. Male Project No.: 22.2756

Summary of Modeling Results at
99.90% Destruction Efficiency

Compound	CAS#	Soil Concentration (in ppb)	Emission Rate based on 99.90% DRE (in g/s)	Deposition Results (in g/m^2)[1]				Dispersion Results (in ug/m^3)		File Name
				Low Year Maximum	Low Year	High Year Maximum	High Year	Maximum Hourly	Maximum Annual	
Perfluorobutane Sulfonate (PFBS)	375-73-5	0.085	6.42589E-10	2.17166E-11	4 of 5	2.83866E-11	5 of 5	2.61465E-08	2.58227E-10	PFBS9990
Perfluorooctanoic acid (PFOA)	335-67-1	4.482	3.38833E-08	1.14510E-09	4 of 5	1.49681E-09	5 of 5	1.37869E-06	1.36161E-08	PFOA9990
Perfluorononanoic acid (PFNA)	375-95-1	2.061	1.55809E-08	5.26564E-10	4 of 5	6.88292E-10	5 of 5	6.33975E-07	6.26124E-09	PFNA9990
Perfluorohexanesulfonic acid (PFHxS)	335-46-4	0.220	1.66317E-09	5.62077E-11	4 of 5	7.34712E-11	5 of 5	6.76733E-08	6.68352E-10	PFHS9990
Perfluorooctanesulfonic acid (PFOS)	1763-23-1	58.793	4.44467E-07	1.50210E-08	4 of 5	1.96345E-08	5 of 5	1.80851E-05	1.78611E-07	PFOS9990
Sum of all PFAS Compounds[2] (Method 1 Deposition)	N/A	89.485	6.76495E-07	2.28625E-08	4 of 5	2.98844E-08	5 of 5	2.75261E-05	2.71852E-07	PFAS9990
Sum of all PFAS Compounds[2] (Method 2 Deposition)				1.12484E-06	4 of 5	1.48651E-06	5 of 5			PFAS9990-2
Sum of all PFAS Compounds (1.5 mile endpoint)[2] (Method 1 Deposition)	N/A	89.485	6.76495E-07	1.01361E-09	4 of 5	9.09221E-10	5 of 5	5.39259E-06	7.08090E-08	PFASENDP
Sum of all PFAS Compounds (1.5 mile endpoint)[2] (Method 2 Deposition)				1.03588E-08	4 of 5	1.37361E-08	5 of 5			PFASENDP-2
Hydrogen Fluoride (HF)[3]	7664-39-3	N/A	3.08737E-02	N/A[5]				1.25623	1.24067E-02	HF
Carbon Tetrafluoride (CF_4)[4]	75-73-0	N/A	1.29685E-04					5.27681E-03	5.21146E-05	CF4
"Representative" PFAS at 0.1 g/s	N/A	N/A	0.1	3.37955E-03	4 of 5	4.41754E-03	5 of 5	4.06893	4.01854E-02	CEFE2023

[1] - Results based on 5 years of climate data with AERMOD generating annual depostion. Results show the highest and lowest individual year per model run.

[2] - Sum of all sampled PFAS compounds.

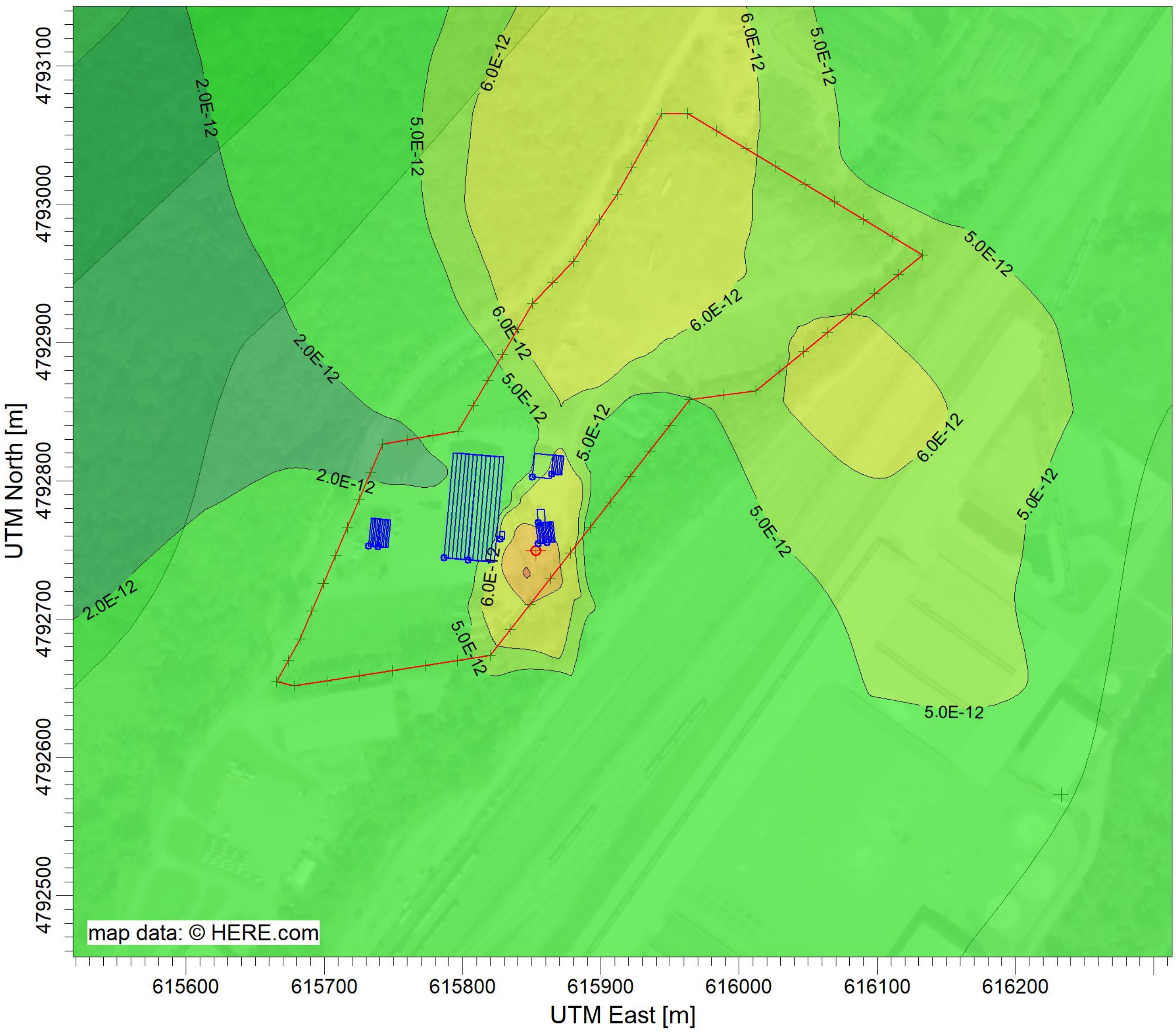
[3] - Calculated emission rate based on conversion of all fluorine within PFAS compounds to hydrofluoric acid.

[4] - Calculated emission rate based on the following article:
Jonathan D. Krug, Paul M. Lemieux, Chun-Wai Lee, Jeffrey V. Ryan, Peter H. Kariher, Erin P. Shields, Lindsay C. Wickersham, Martin K. Denison, Kevin A. Davis, David A. Swensen, R. Preston Burnette, Jost O.L. Wendt & William P. Linak (2022) Combustion of C1 and C2 PFAS: Kinetic modeling and experiments, Journal of the Air & Waste Management Association, 72:3, 256-270, DOI: 10.1080/10962247.2021.2021317

[5] - Compound does not behave as a particulate therefore deposition modeling is not applicable.

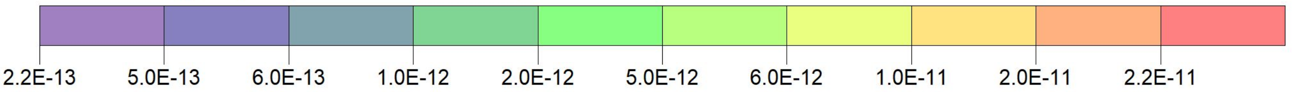
PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Annual Average Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

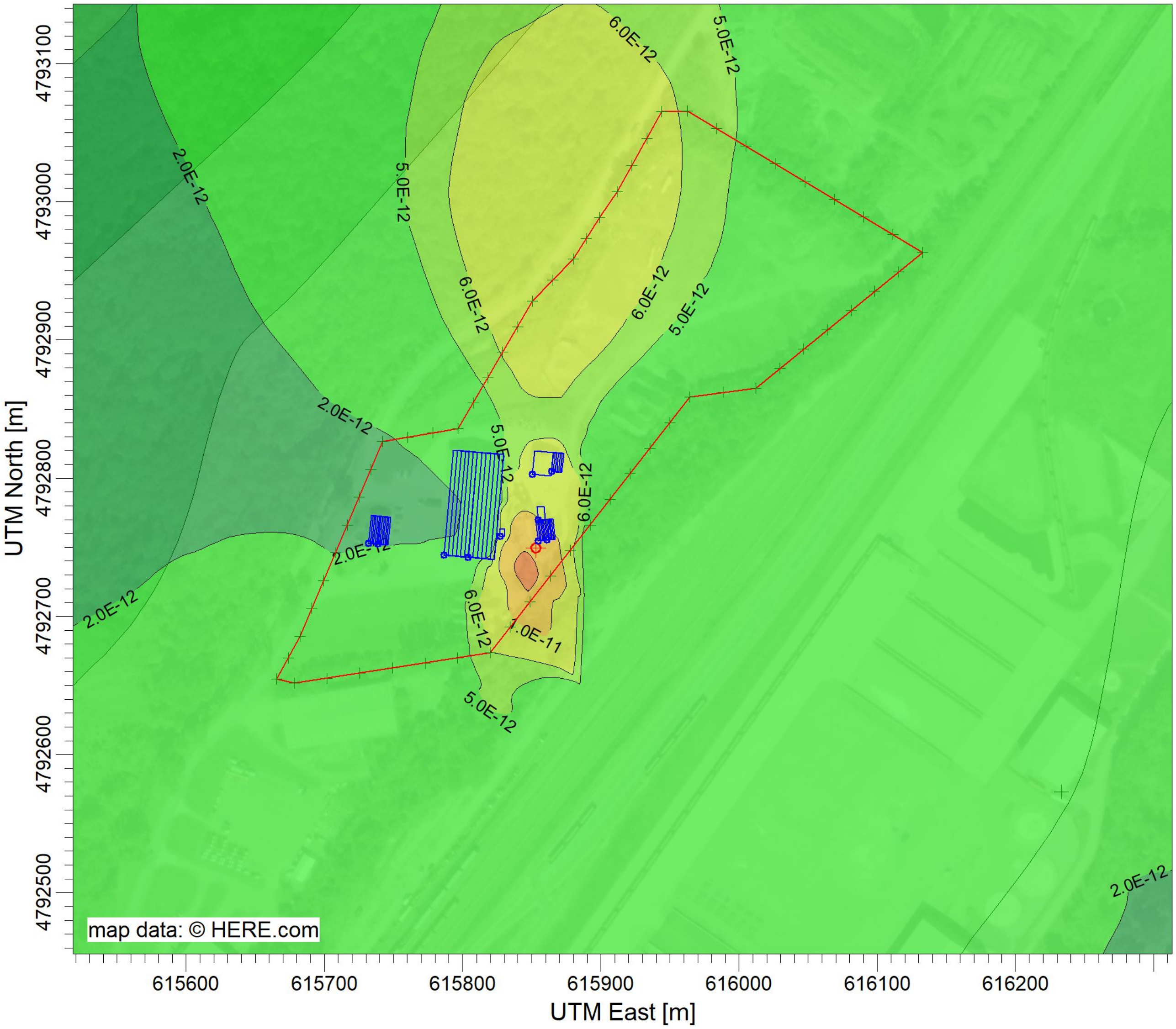
Max: 2.2E-11 [g/m^2] at (615846.24, 4792732.92)



COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **2.2E-11 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Annual Average Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 2.8E-11 [g/m^2] at (615846.24, 4792732.92)

🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥
2.8E-13	5.0E-13	6.0E-13	1.0E-12	2.0E-12	5.0E-12	6.0E-12	1.0E-11	2.0E-11	2.8E-11

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:
2.8E-11 g/m^2

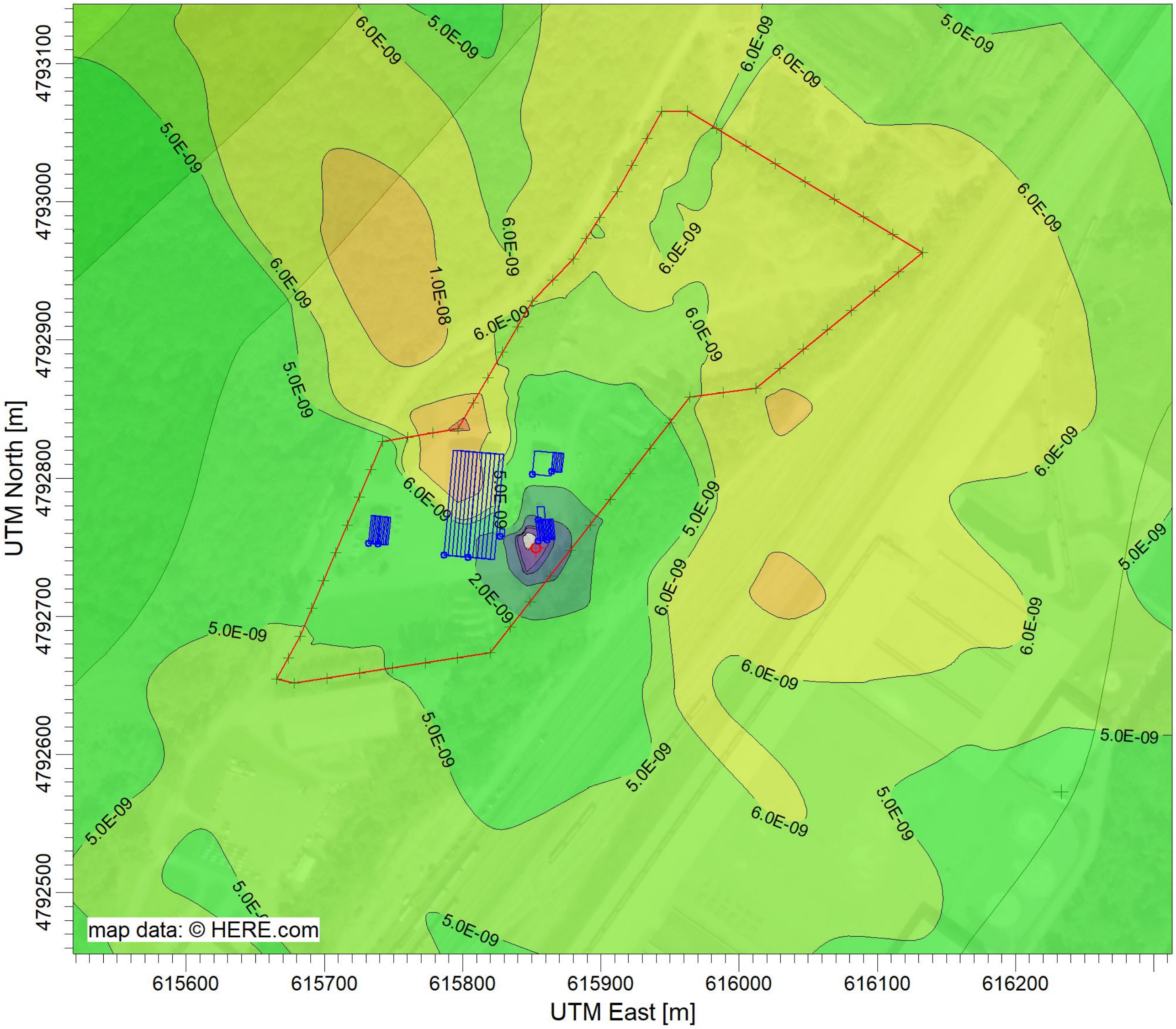
DATE:
8/29/2023

PROJECT NO.:
22.2756

AERMOD View - Lakes Environmental Software C:\Data\Lakes\CEFE2023 - All Runs\PFBS9990\PFBS9990.isc

PROJECT TITLE:

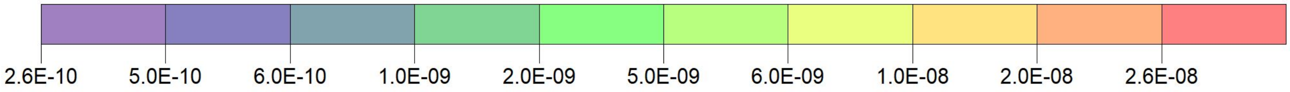
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 2.6E-08 [ug/m^3] at (615796.68, 4792835.91)



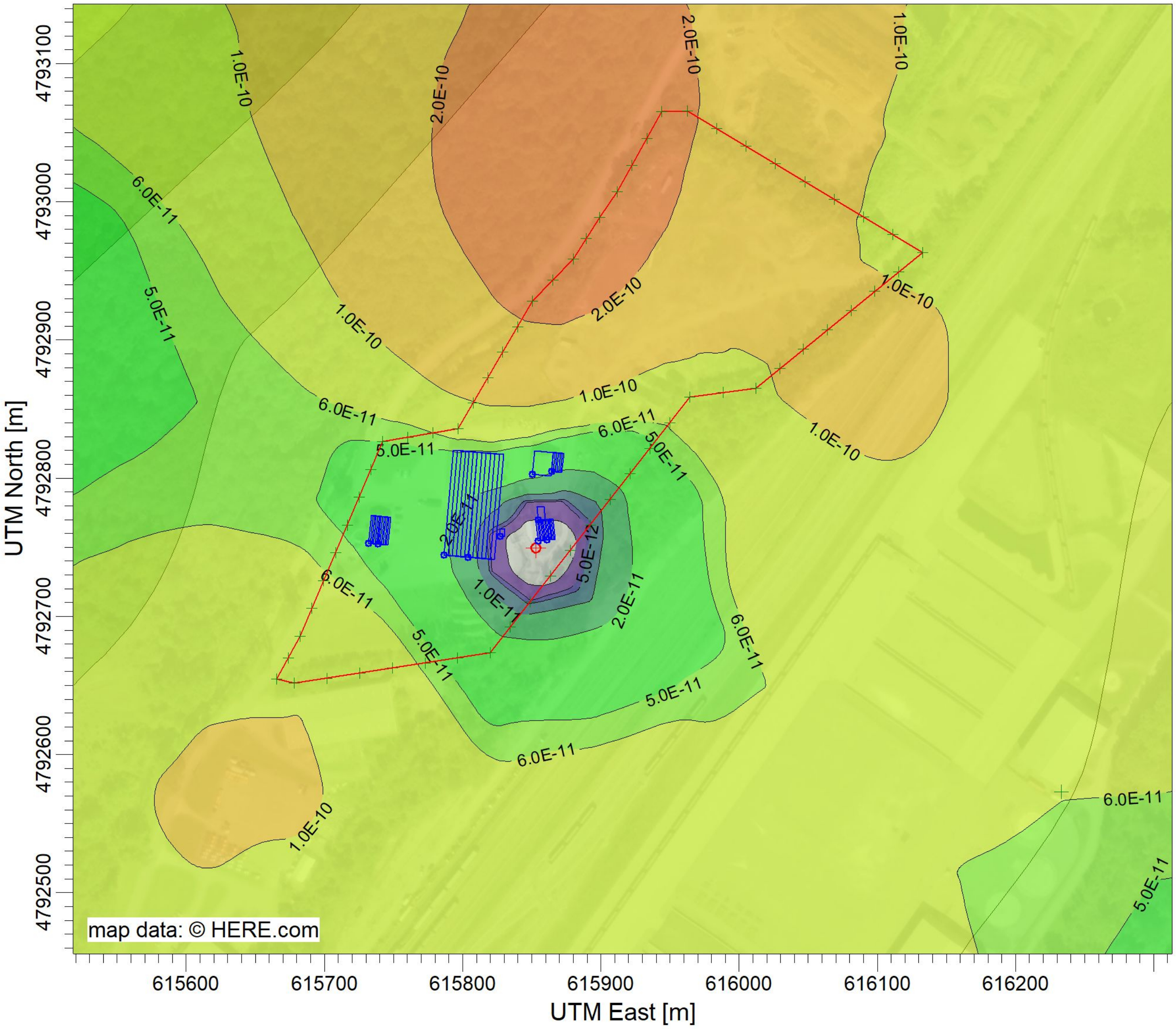
COMMENTS: Air Dispersion Results Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 0.1 km	
	MAX: **2.6E-08 ug/m^3**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

AERMOD View - Lakes Environmental Software

C:\Data\Lakes\CEFE2023 - All Runs\PFBS9990\PFBS9990.isc

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 2.6E-10 [ug/m^3] at (615888.44, 4792991.00)

2.6E-12 5.0E-12 6.0E-12 1.0E-11 2.0E-11 5.0E-11 6.0E-11 1.0E-10 2.0E-10 2.6E-10

COMMENTS:

Air Dispersion Results

Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Concentration

SCALE: 1:5,000

0 0.1 km

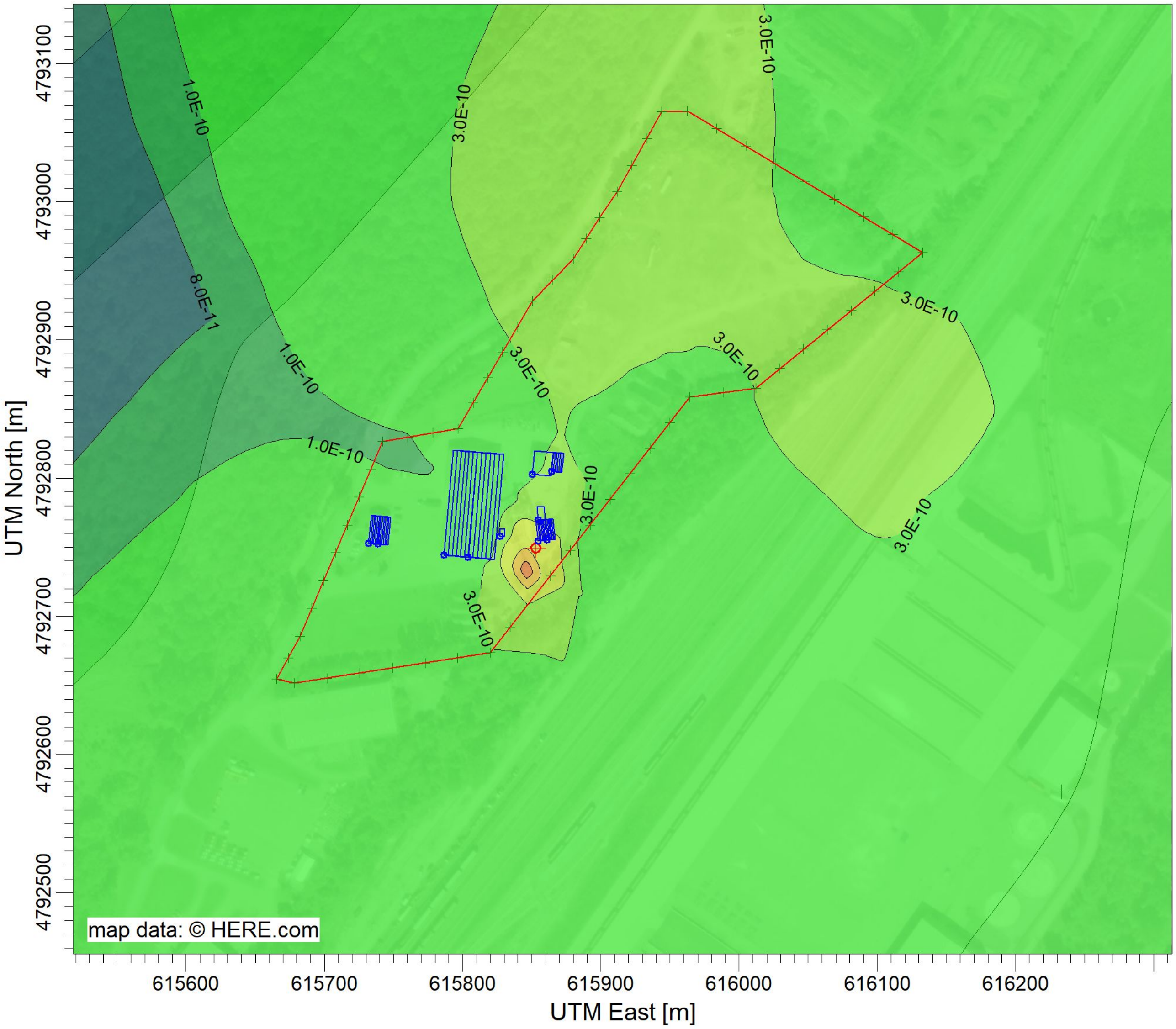
MAX:
2.6E-10 ug/m^3

DATE:
8/29/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 1.1E-09 [g/m^2] at (615846.24, 4792732.92)

1.1E-11 3.0E-11 5.0E-11 8.0E-11 1.0E-10 3.0E-10 5.0E-10 8.0E-10 1.0E-09 1.1E-09

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:

1.1E-09 g/m^2

DATE:

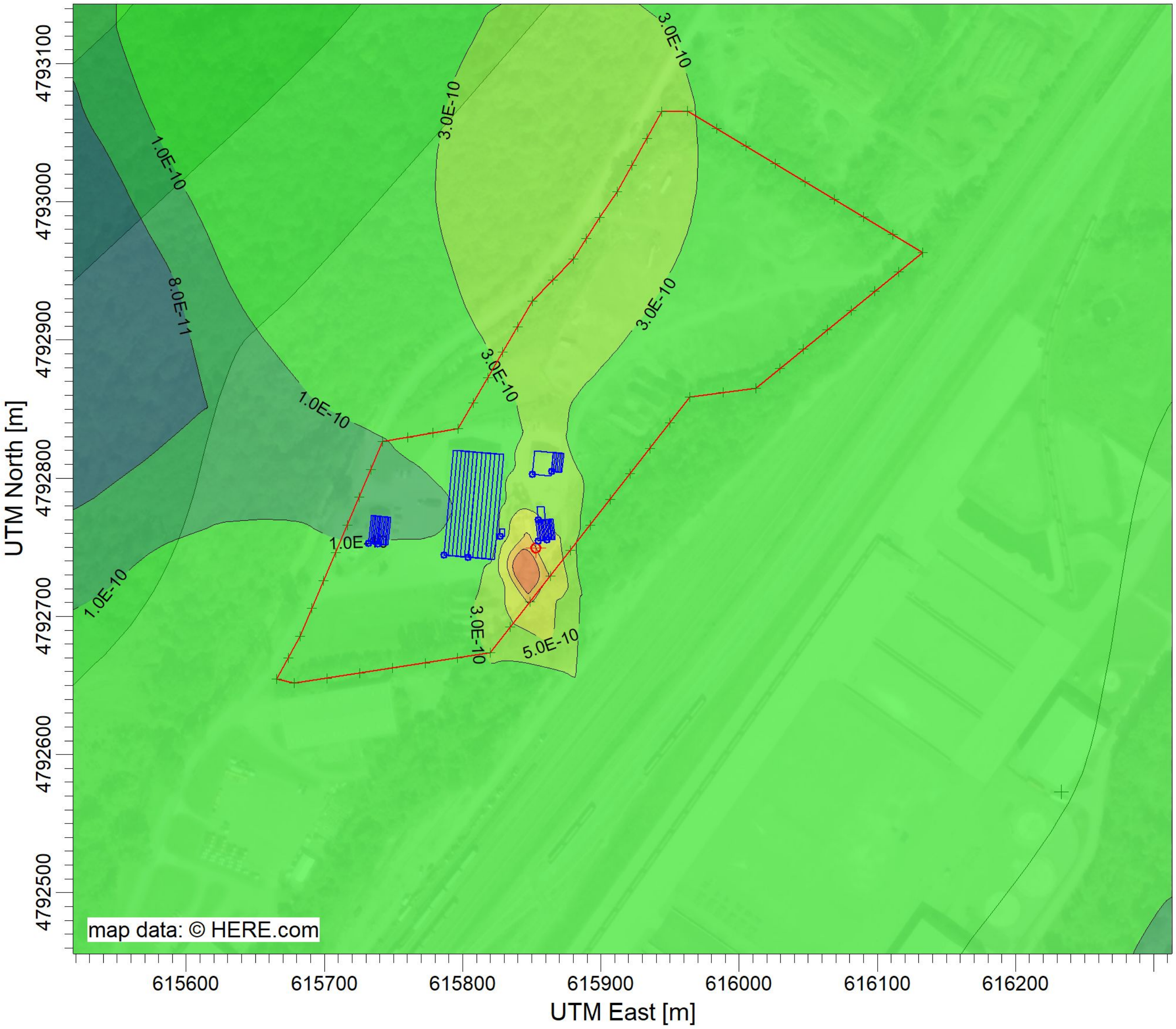
8/29/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

g/m^2

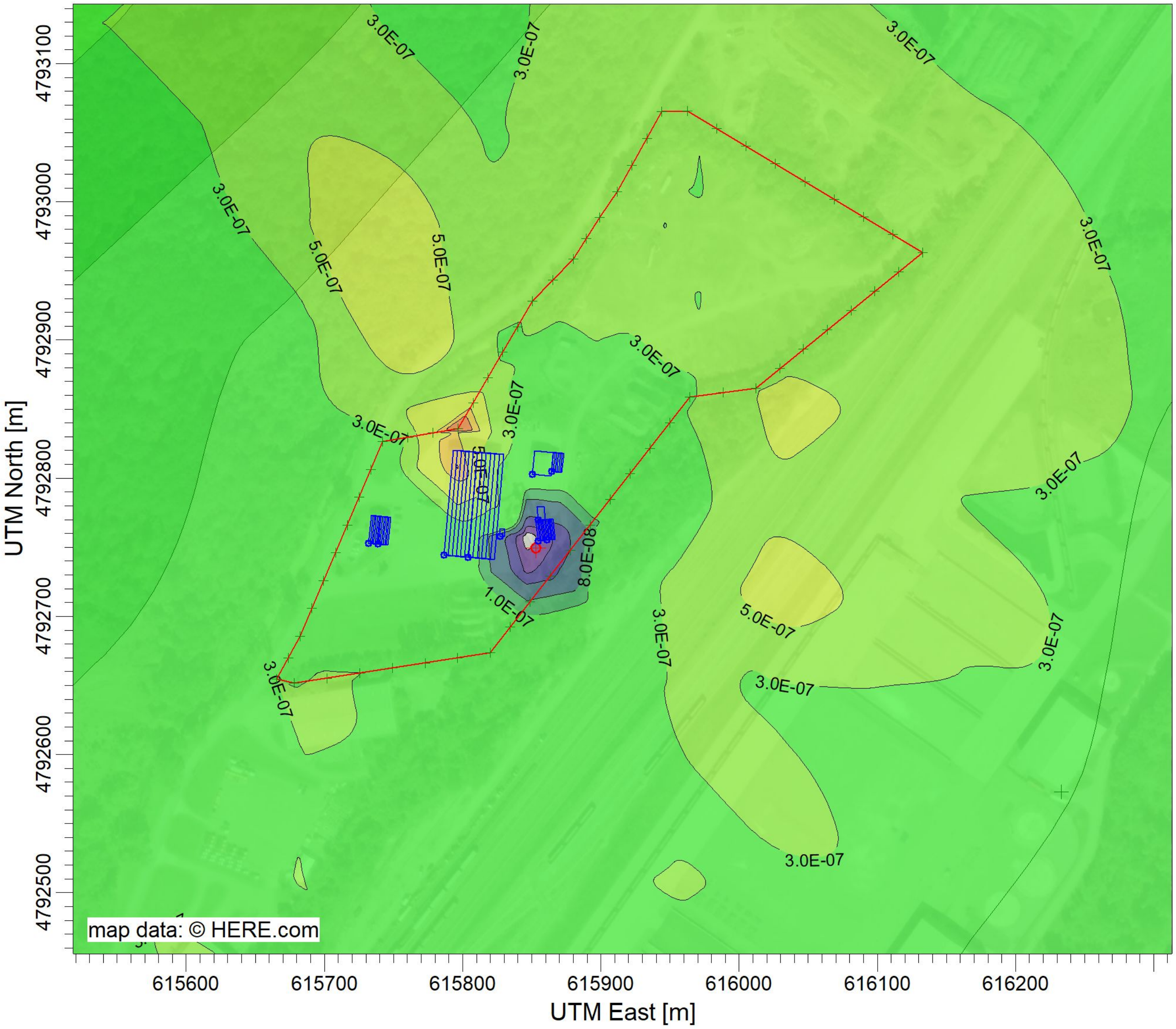
Max: 1.5E-09 [g/m^2] at (615846.24, 4792732.92)

1.5E-11	3.0E-11	5.0E-11	8.0E-11	1.0E-10	3.0E-10	5.0E-10	8.0E-10	1.0E-09	1.5E-09

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 ▬▬▬ 0.1 km	
	MAX: **1.5E-09 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.4E-06 [ug/m^3] at (615796.68, 4792835.91)

1.4E-08 | 3.0E-08 | 5.0E-08 | 8.0E-08 | 1.0E-07 | 3.0E-07 | 5.0E-07 | 8.0E-07 | 1.0E-06 | 1.4E-06

COMMENTS:

Air Dispersion Results

Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE:

1:5,000

0 ▬▬▬▬ 0.1 km

MAX:

1.4E-06 ug/m^3

DATE:

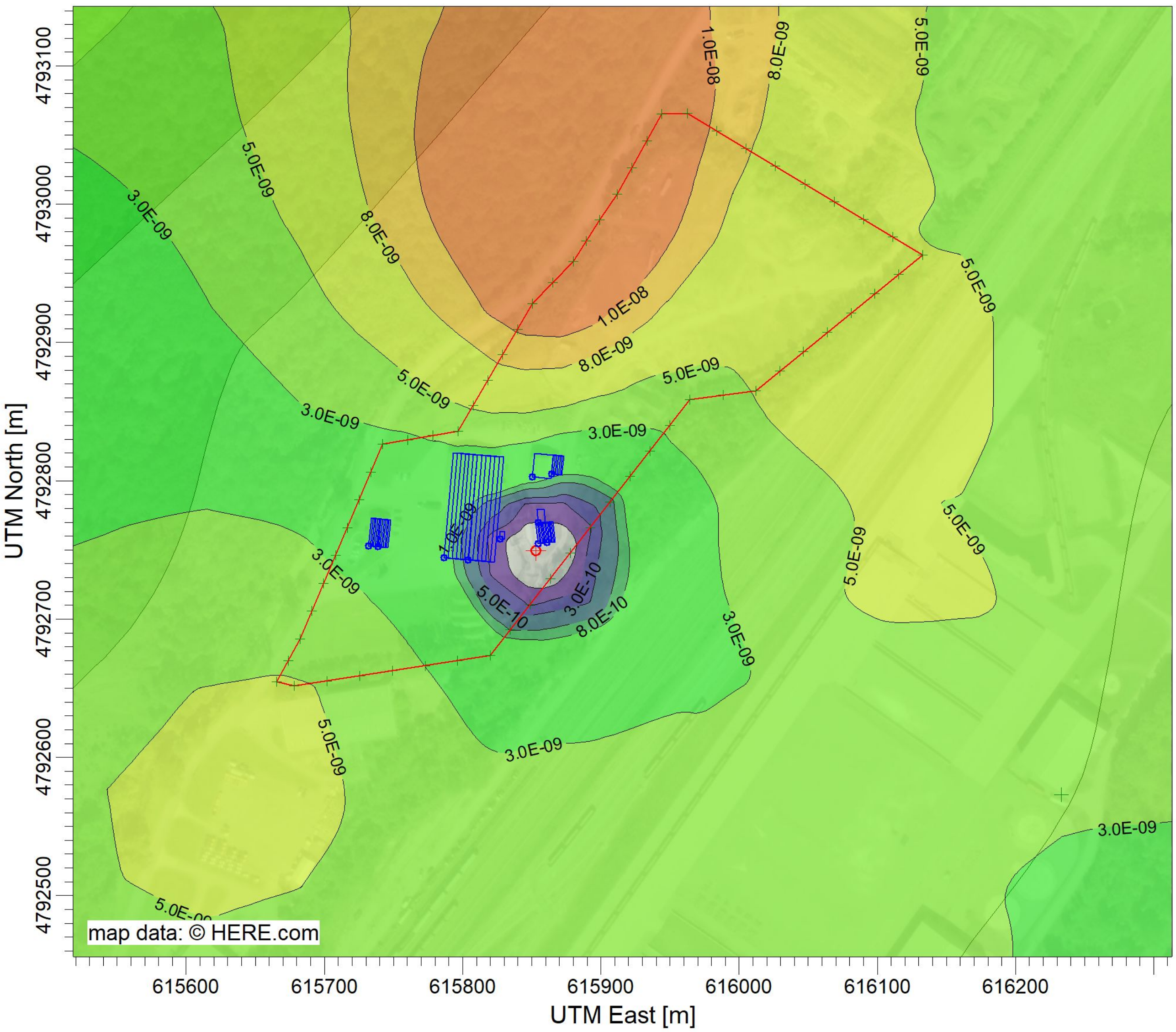
8/29/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 1.4E-08 [ug/m^3] at (615888.44, 4792991.00)

🟪 🟪 🟦 🟩 🟩 🟩 🟨 🟧 🟧 🟥

1.4E-10 3.0E-10 5.0E-10 8.0E-10 1.0E-09 3.0E-09 5.0E-09 8.0E-09 1.0E-08 1.4E-08

COMMENTS:

Air Dispersion Results

Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Concentration

SCALE: 1:5,000

0 0.1 km

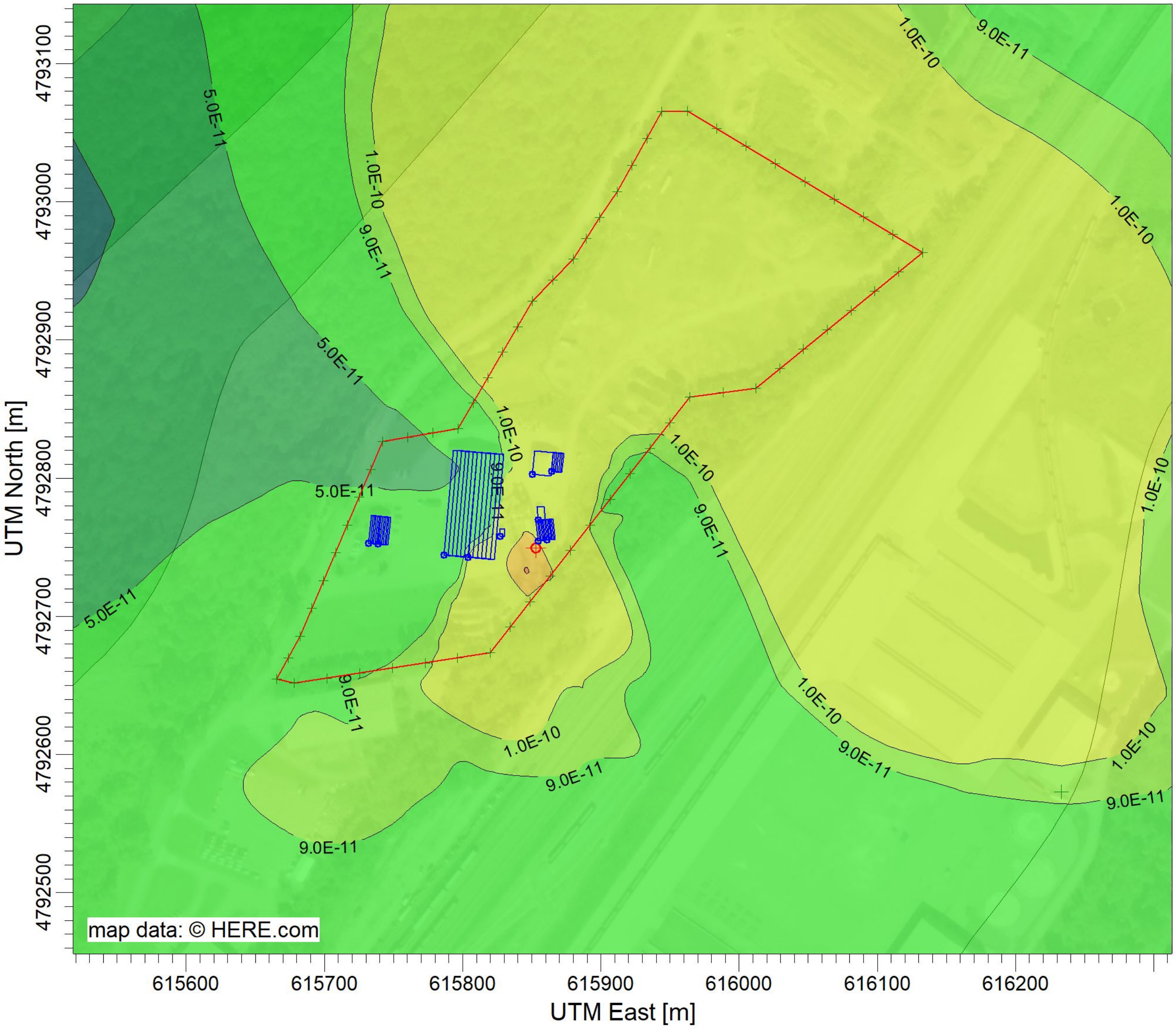
MAX:
1.4E-08 ug/m^3

DATE:
8/29/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

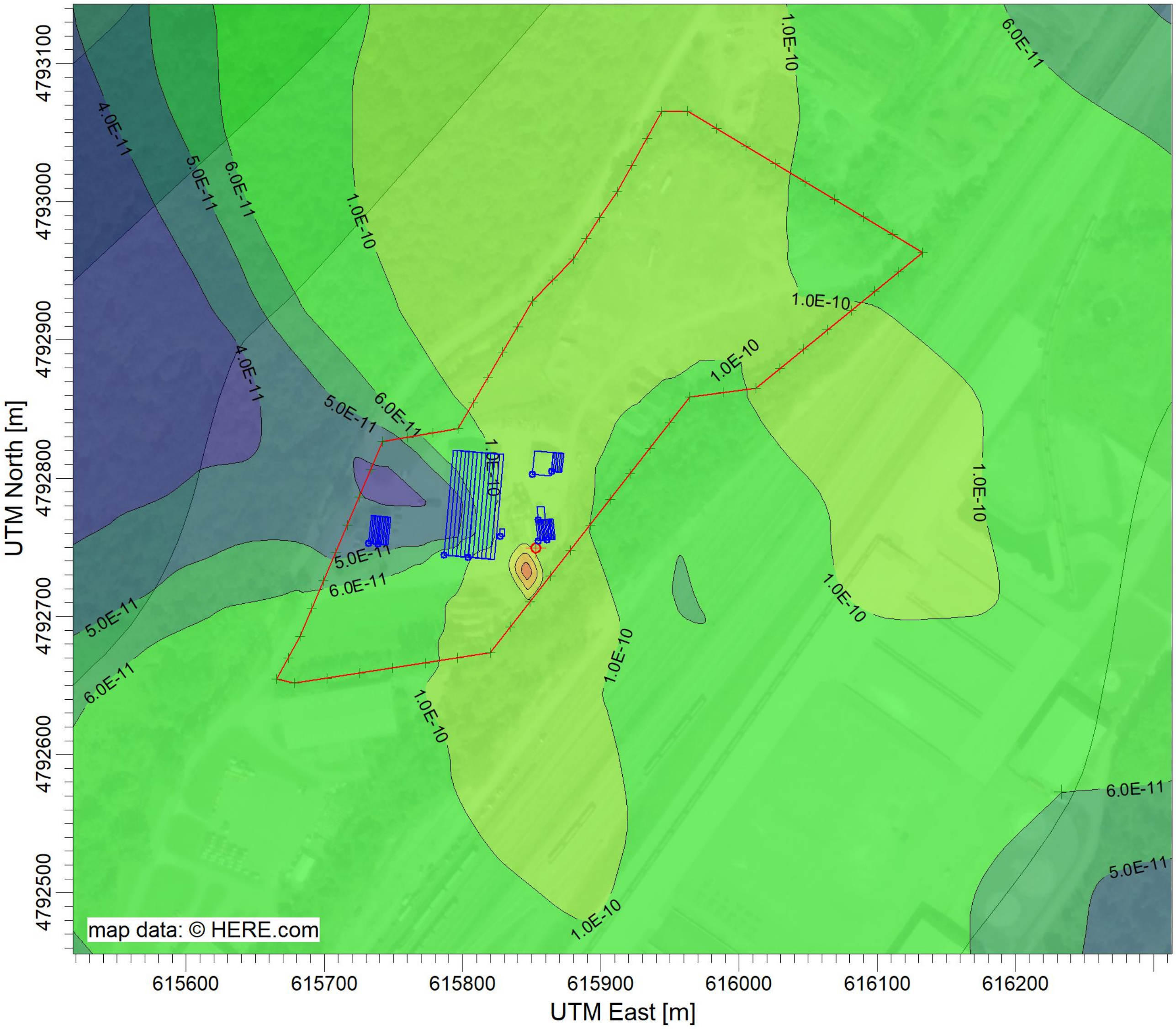
Max: 5.3E-10 [g/m^2] at (615846.24, 4792732.92)

5.3E-12 🟪 9.0E-12 🟪 1.0E-11 ▨ 3.0E-11 🟩 5.0E-11 🟩 9.0E-11 🟩 1.0E-10 🟨 3.0E-10 🟨 5.0E-10 🟧 5.3E-10 🟥

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 ▬▬ 0.1 km	
	MAX: **5.3E-10 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 6.9E-10 [g/m^2] at (615846.24, 4792732.92)

6.9E-12	1.0E-11	4.0E-11	5.0E-11	6.0E-11	1.0E-10	4.0E-10	5.0E-10	6.0E-10	6.9E-10

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **6.9E-10 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE

PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

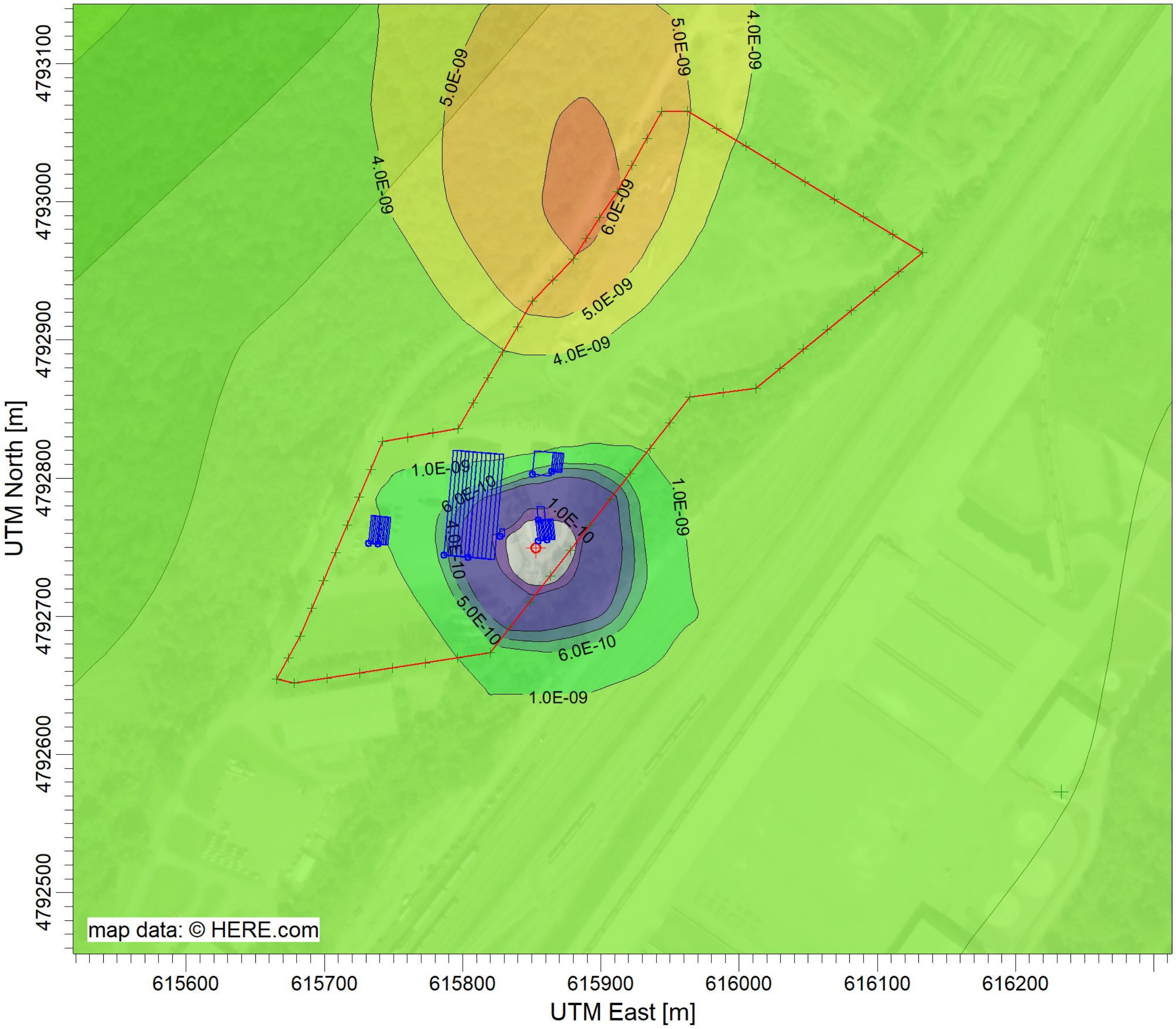
Max: 6.3E-07 [ug/m^3] at (615796.68, 4792835.91)

6.3E-09	1.0E-08	4.0E-08	5.0E-08	6.0E-08	1.0E-07	4.0E-07	5.0E-07	6.0E-07	6.3E-07
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟧	🟧	🟥

COMMENTS: Air Dispersion Results Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 0.1 km	
	MAX: **6.3E-07 ug/m^3**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 6.3E-09 [ug/m^3] at (615888.44, 4792991.00)

6.3E-11	1.0E-10	4.0E-10	5.0E-10	6.0E-10	1.0E-09	4.0E-09	5.0E-09	6.0E-09	6.3E-09
🟪	🟦	▨	🟩	🟩	🟩	🟨	🟧	🟧	🟥

COMMENTS:

Air Dispersion Results

Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg

SOURCES:
1

RECEPTORS:
4001

OUTPUT TYPE:
Concentration

MAX:
6.3E-09 ug/m^3

COMPANY NAME:
C.T. Male Associates

MODELER:
C.T. Male Staff

SCALE: 1:5,000

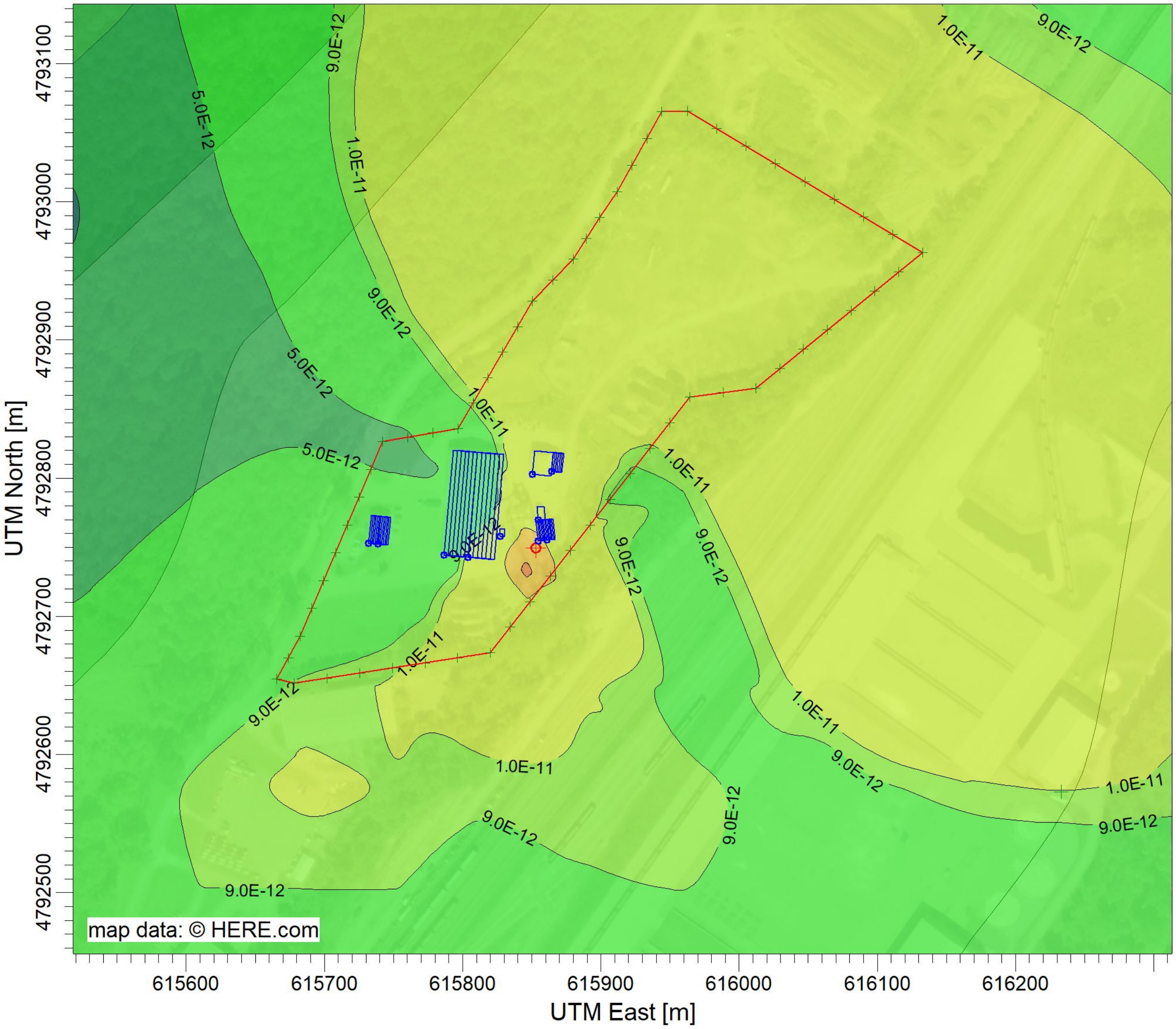
0 0.1 km

DATE:
8/29/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

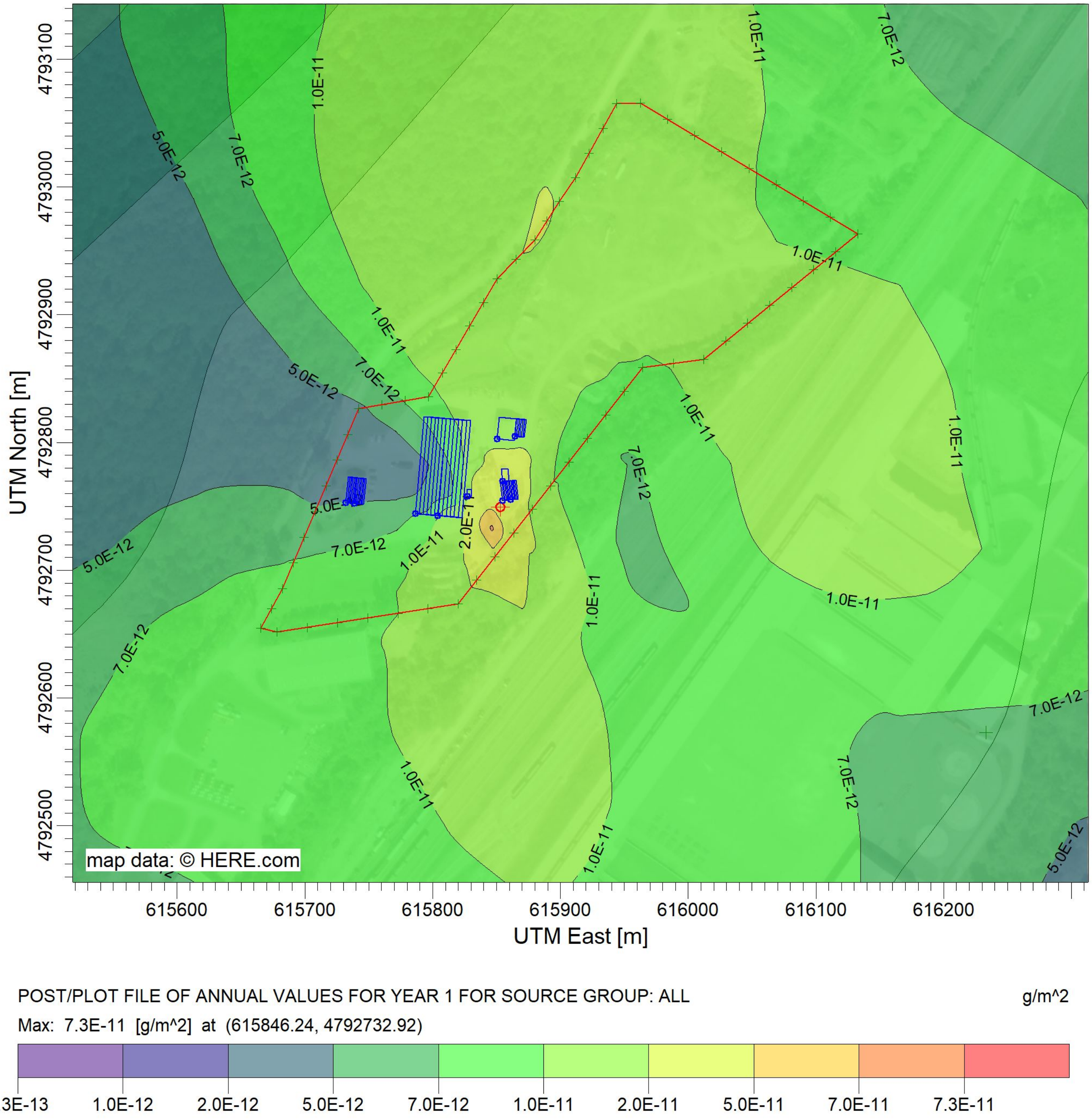
Max: 5.6E-11 [g/m^2] at (615846.24, 4792732.92)

5.6E-13	9.0E-13	1.0E-12	3.0E-12	5.0E-12	9.0E-12	1.0E-11	3.0E-11	5.0E-11	5.6E-11
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **5.6E-11 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

g/m^2

Max: 7.3E-11 [g/m^2] at (615846.24, 4792732.92)

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. MALE ASSOCIATES

RECEPTORS:

4001

MODELER:

C.T. MALE STAFF

OUTPUT TYPE:

Total Depos.

SCALE:

1:5,000

0 0.1 km

MAX:

7.3E-11 g/m^2

DATE:

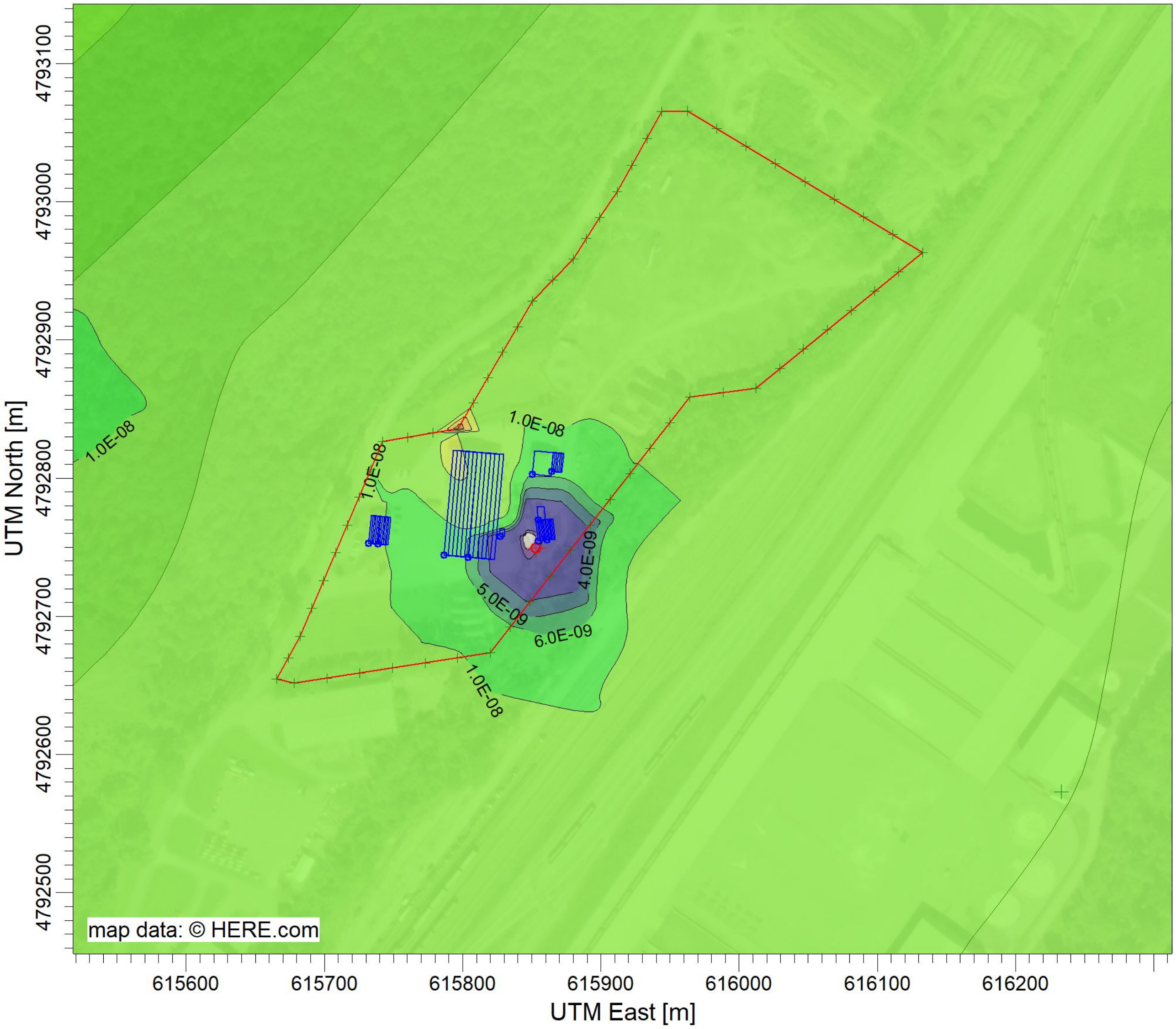
12/19/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 6.8E-08 [ug/m^3] at (615796.68, 4792835.91)

6.8E-10 1.0E-09 4.0E-09 5.0E-09 6.0E-09 1.0E-08 4.0E-08 5.0E-08 6.0E-08 6.8E-08

COMMENTS:

Air Dispersion Results

Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Concentration

SCALE:
1:5,000
0 0.1 km

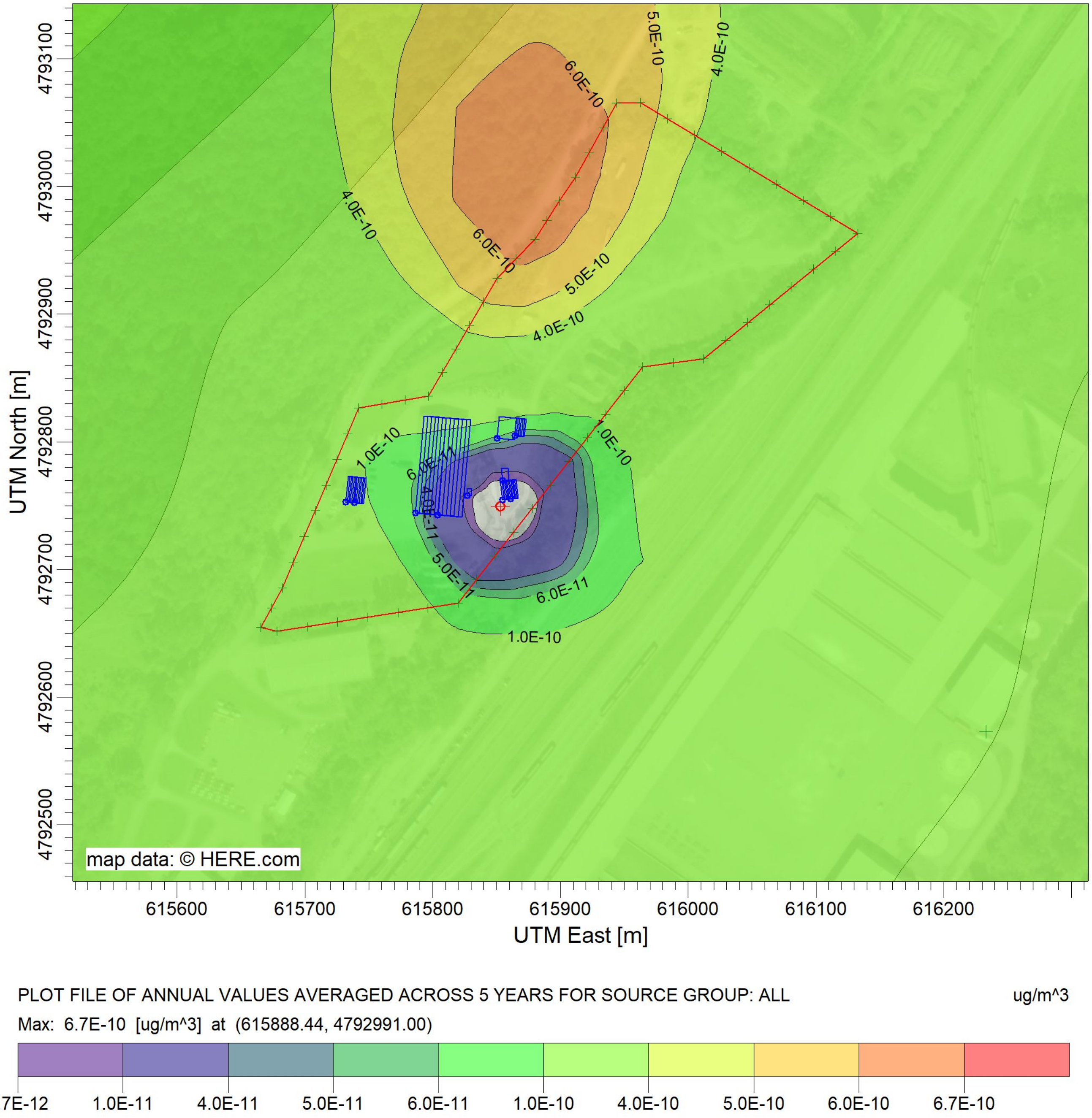
MAX:
6.8E-08 ug/m^3

DATE:
8/29/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

Max: 6.7E-10 [ug/m^3] at (615888.44, 4792991.00)

COMMENTS:

Air Dispersion Results

Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Concentration

SCALE: 1:5,000

0 ▬▬ 0.1 km

MAX:
6.7E-10 ug/m^3

DATE:
8/29/2023

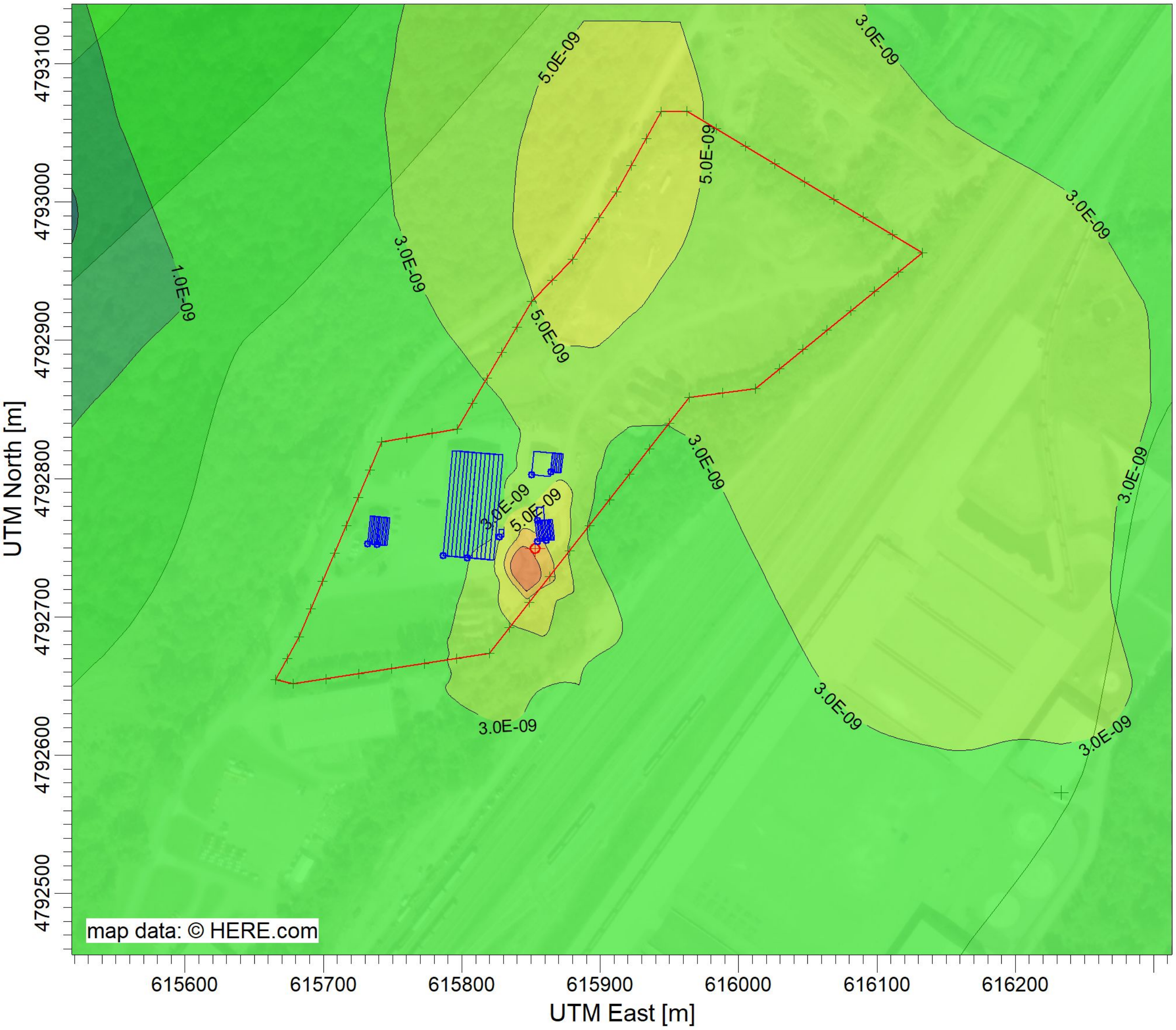
PROJECT NO.:
22.2756

AERMOD View - Lakes Environmental Software

C:\Data\Lakes\CEFE2023 - All Runs\PFHS9990\PFHS9990.isc

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

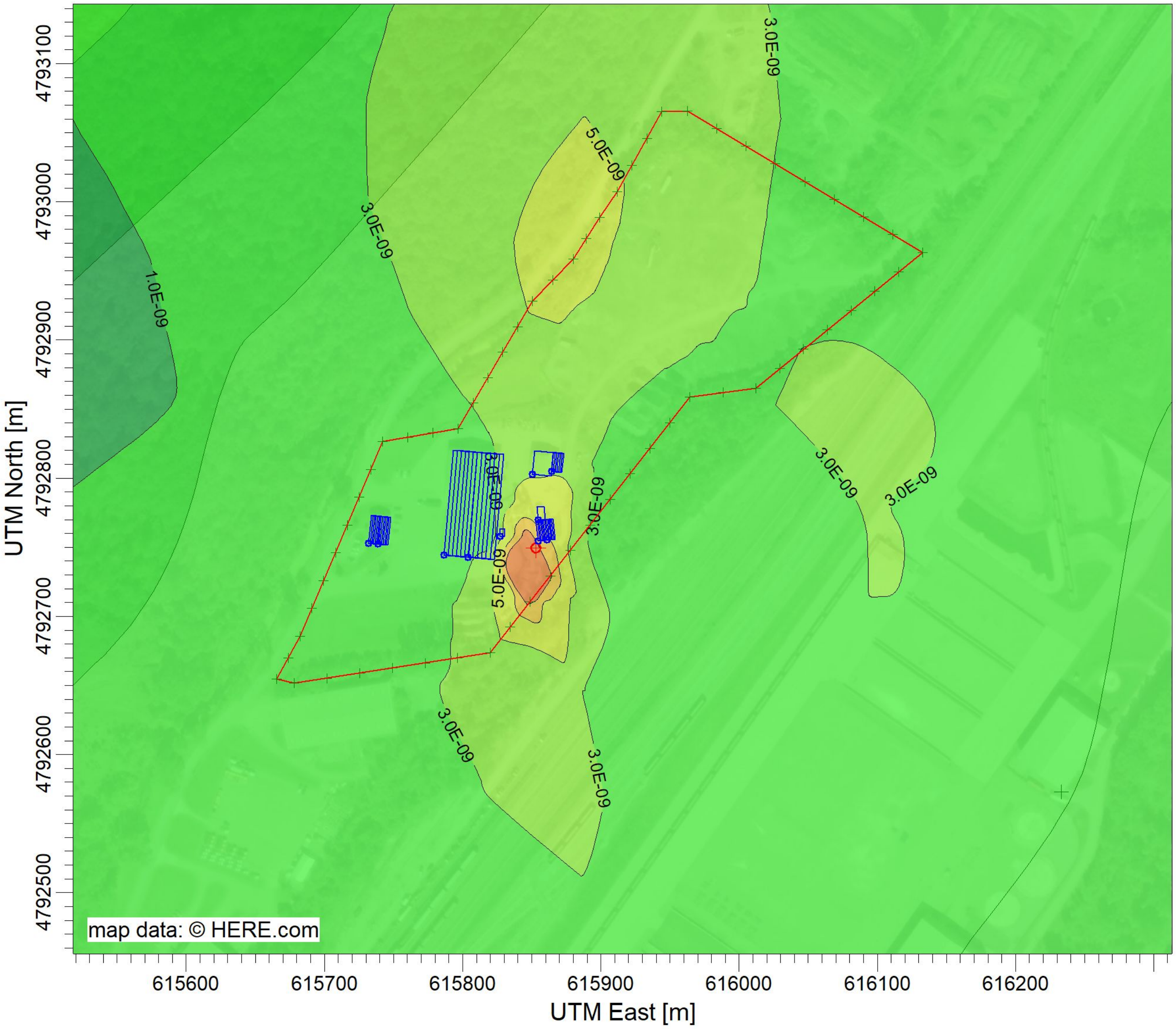
Max: 1.5E-08 [g/m^2] at (615846.24, 4792732.92)

1.5E-10	3.0E-10	5.0E-10	8.0E-10	1.0E-09	3.0E-09	5.0E-09	8.0E-09	1.0E-08	1.5E-08
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 ▬ 0.1 km	
	MAX: **1.5E-08 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 2.0E-08 [g/m^2] at (615846.24, 4792732.92)

2.0E-10 3.0E-10 5.0E-10 8.0E-10 1.0E-09 3.0E-09 5.0E-09 8.0E-09 1.0E-08 2.0E-08

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Total Depos.

SCALE: 1:5,000

0 0.1 km

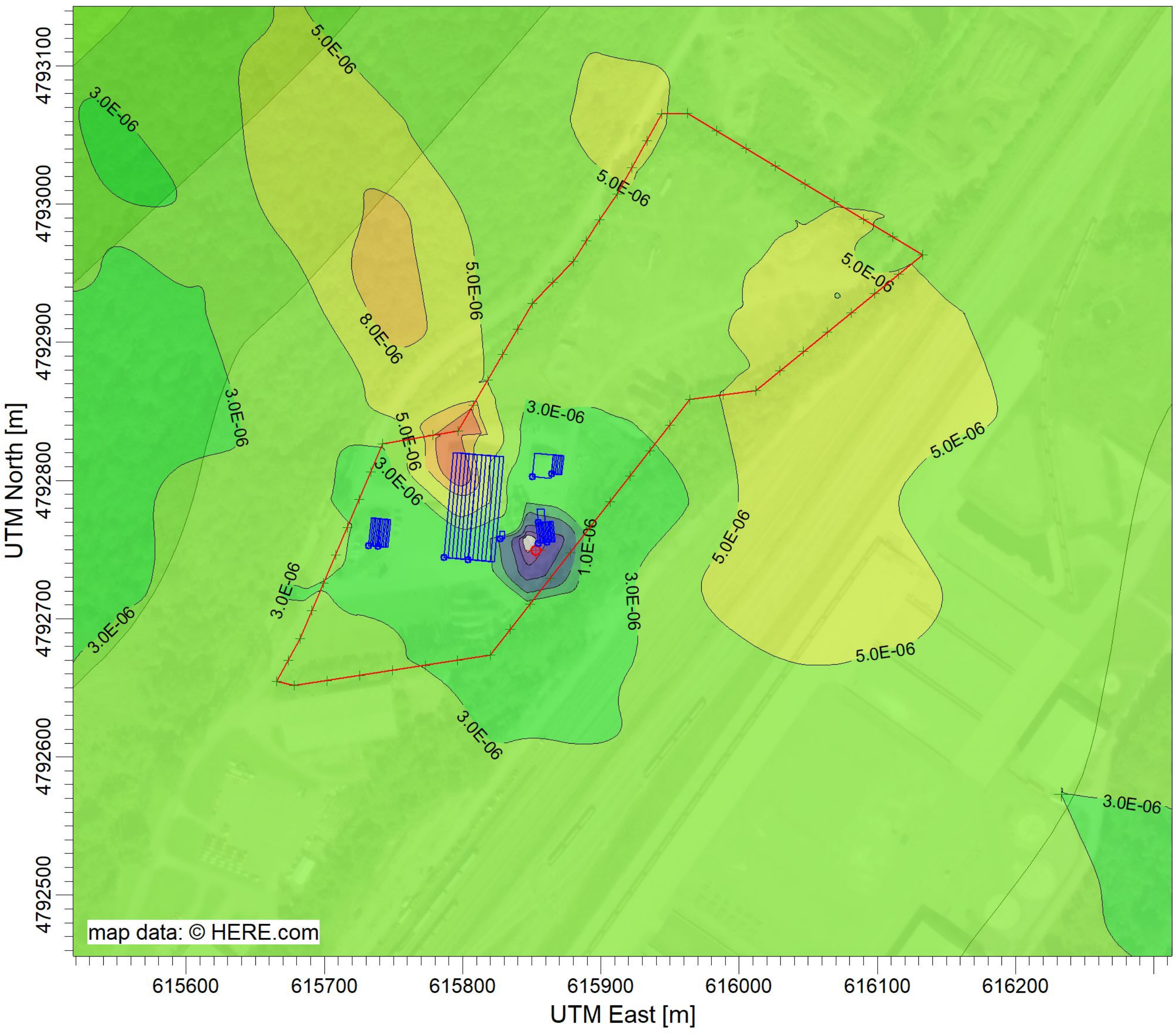
MAX:
2.0E-08 g/m^2

DATE:
8/29/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

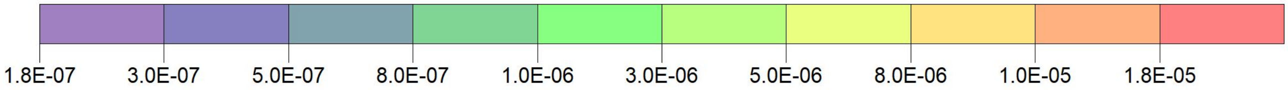
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.8E-05 [ug/m^3] at (615796.68, 4792835.91)



COMMENTS:

Air Dispersion Results

Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Concentration

SCALE: 1:5,000

0 ▬ 0.1 km

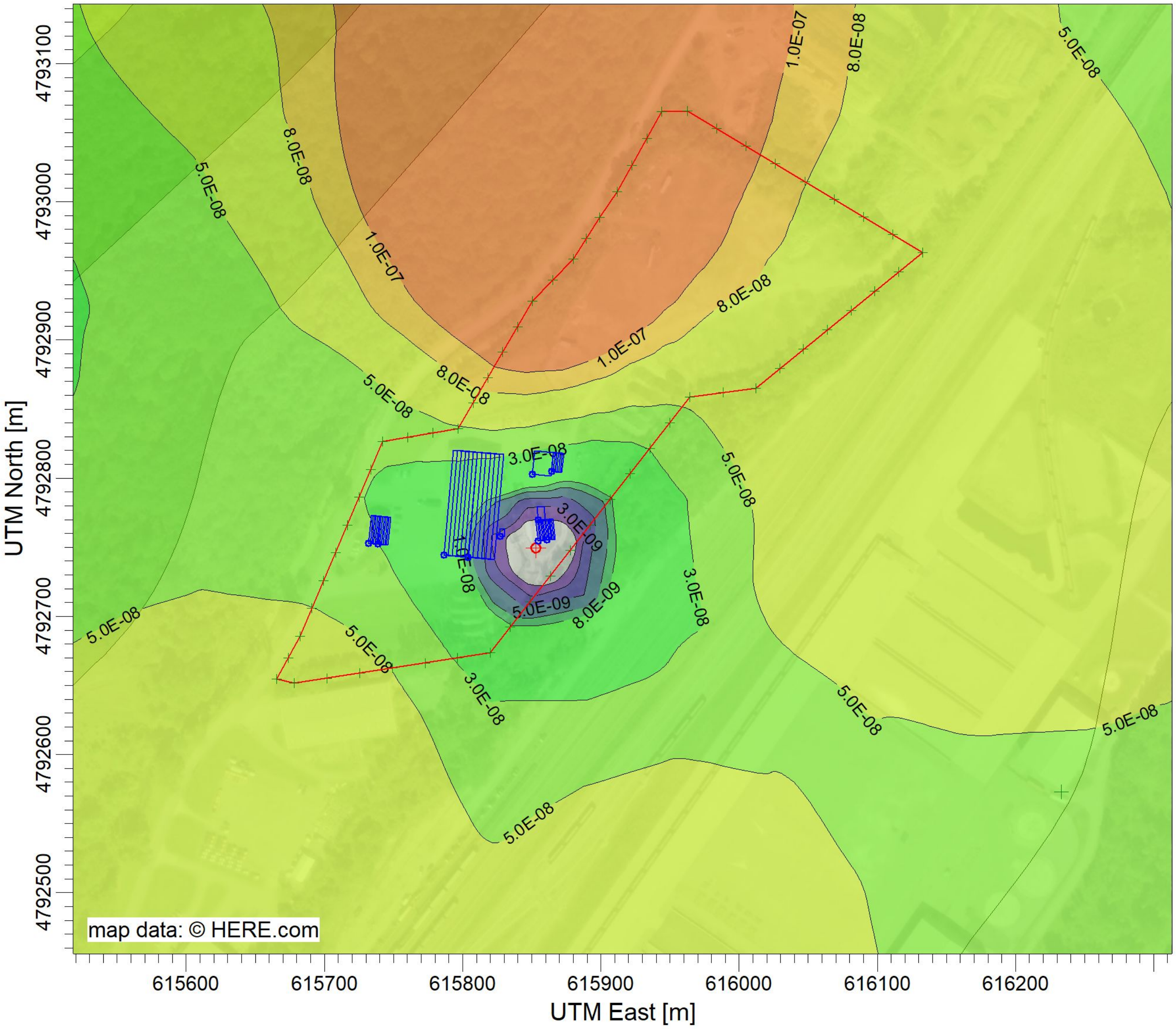
MAX:
1.8E-05 ug/m^3

DATE:
8/29/2023

PROJECT NO.:
22.2756

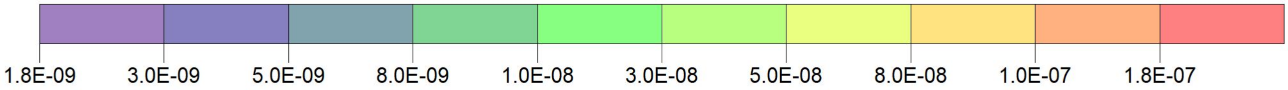
PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 1.8E-07 [ug/m^3] at (615888.44, 4792991.00)



COMMENTS:

Air Dispersion Results

Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE: 1:5,000

0 0.1 km

MAX:

1.8E-07 ug/m^3

DATE:

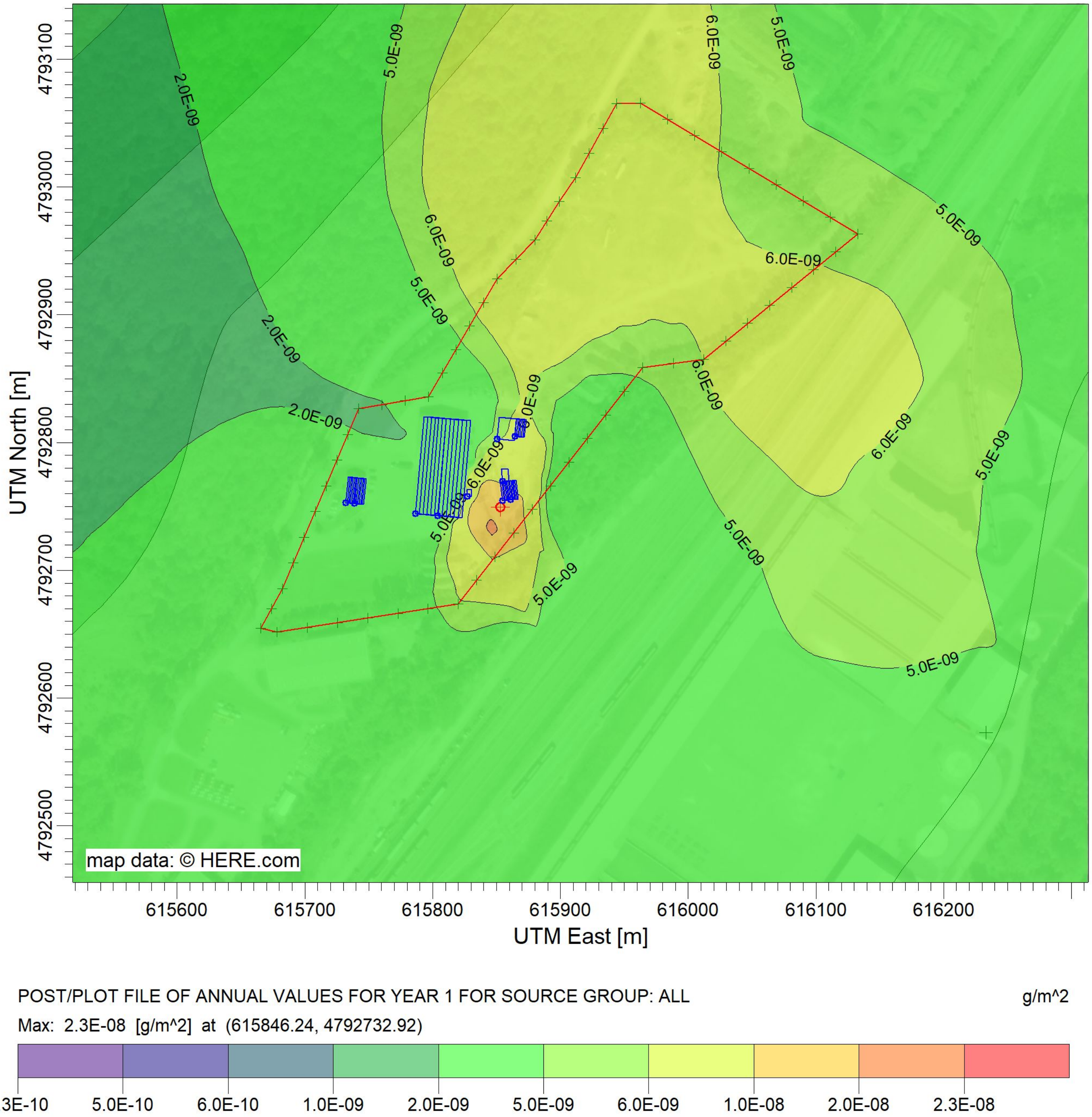
8/29/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE


POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

g/m^2

Max: 2.3E-08 [g/m^2] at (615846.24, 4792732.92)

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 ▬ 0.1 km

MAX:

2.3E-08 g/m^2

DATE:

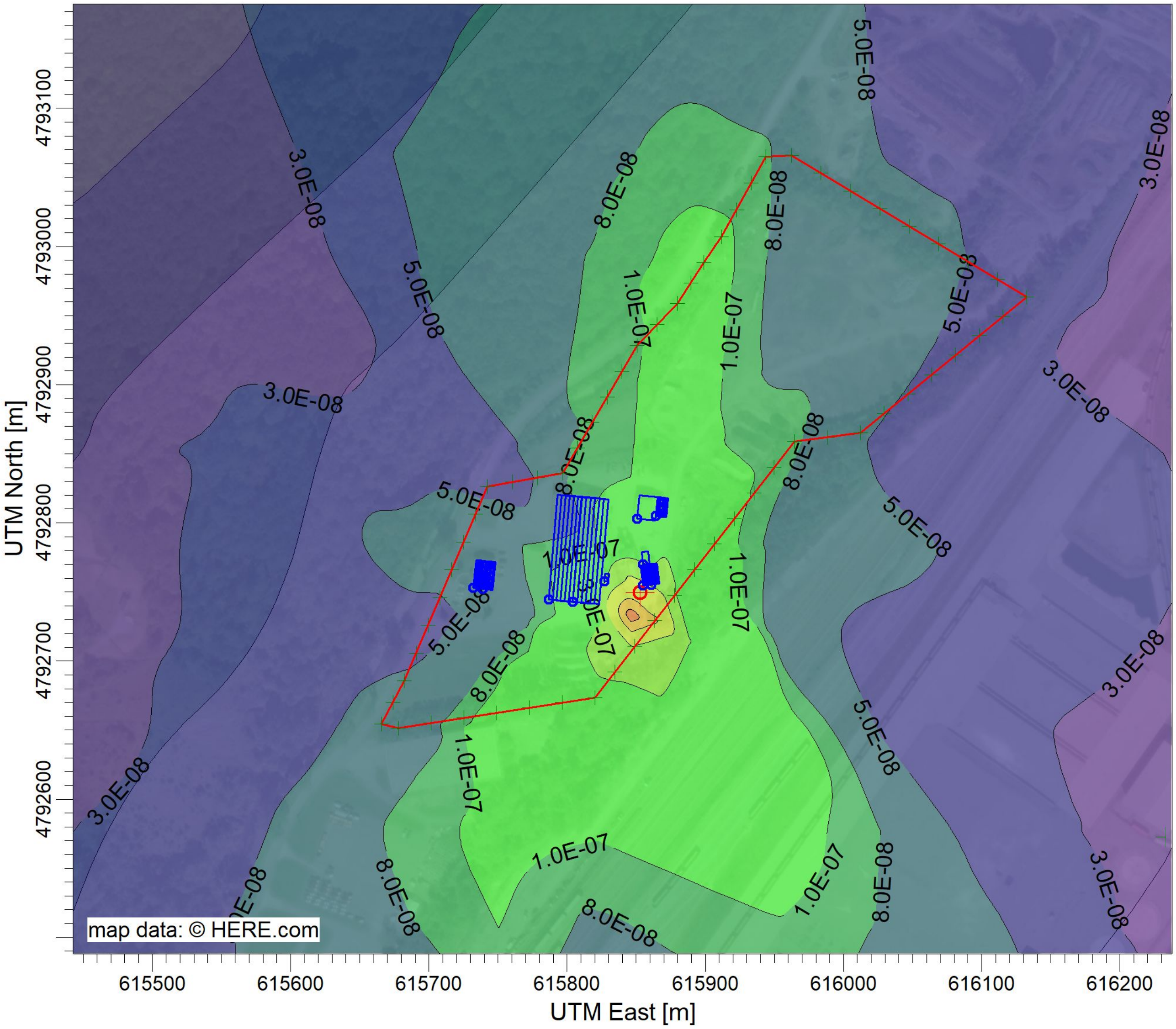
9/1/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

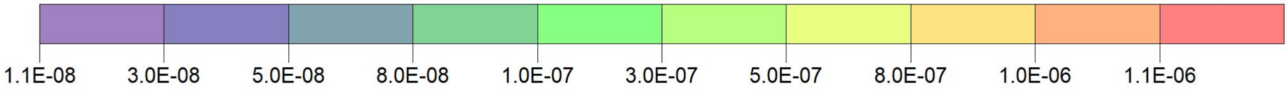
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

g/m^2

Max: 1.1E-06 [g/m^2] at (615846.24, 4792732.92)



COMMENTS: Method 2 Analysis for PM-2.5 to represent PFAS Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 ▬ 0.1 km
	MAX: **1.1E-06 g/m^2**	DATE: **4/18/2024**

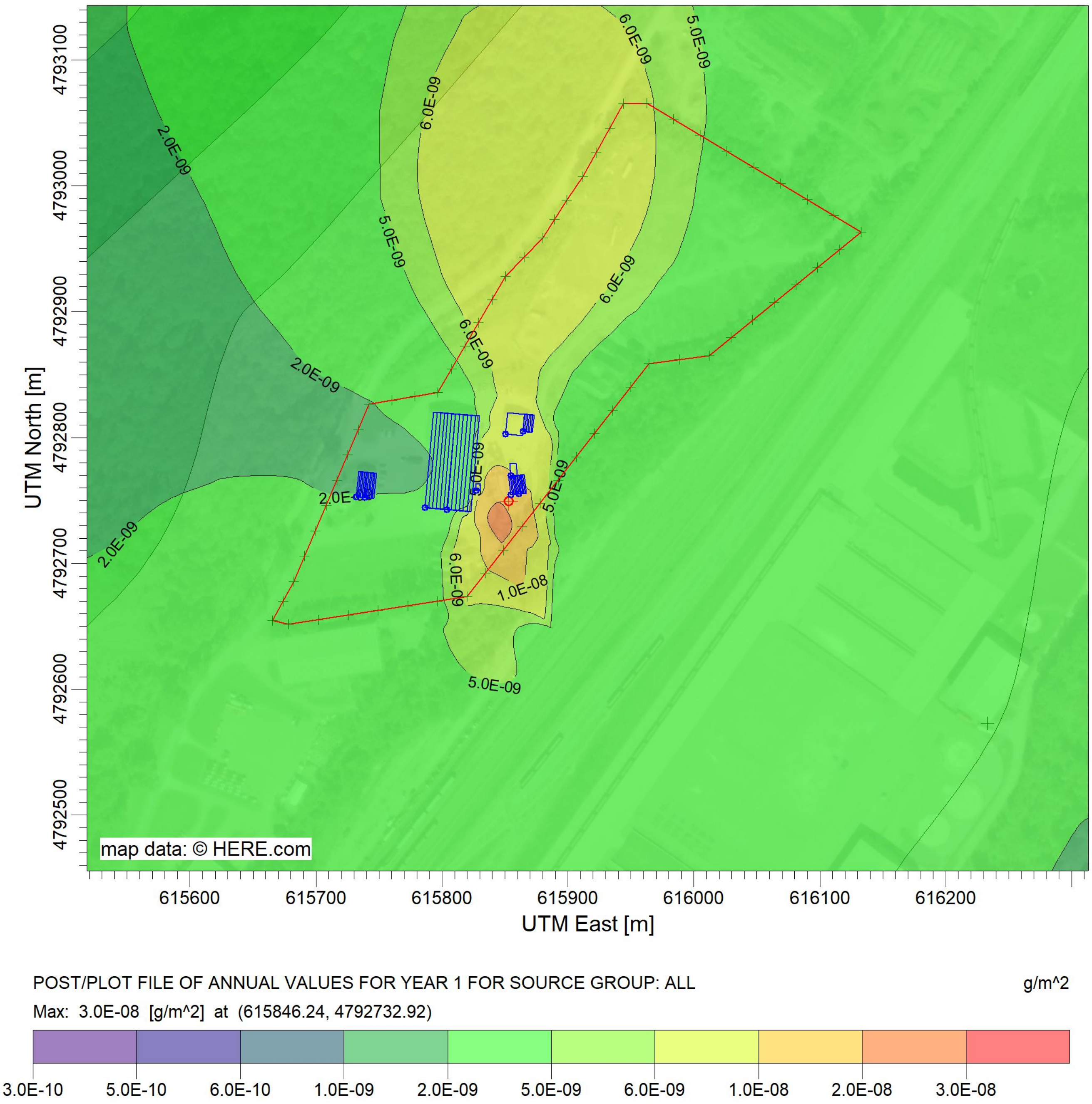
PROJECT NO.: **22.2756**

AERMOD View - Lakes Environmental Software

C:\Data\Lakes\CEFE2023 - All Runs\PFAS9990-2\PFAS9990-2.isc

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 3.0E-08 [g/m^2] at (615846.24, 4792732.92)

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:

3.0E-08 g/m^2

DATE:

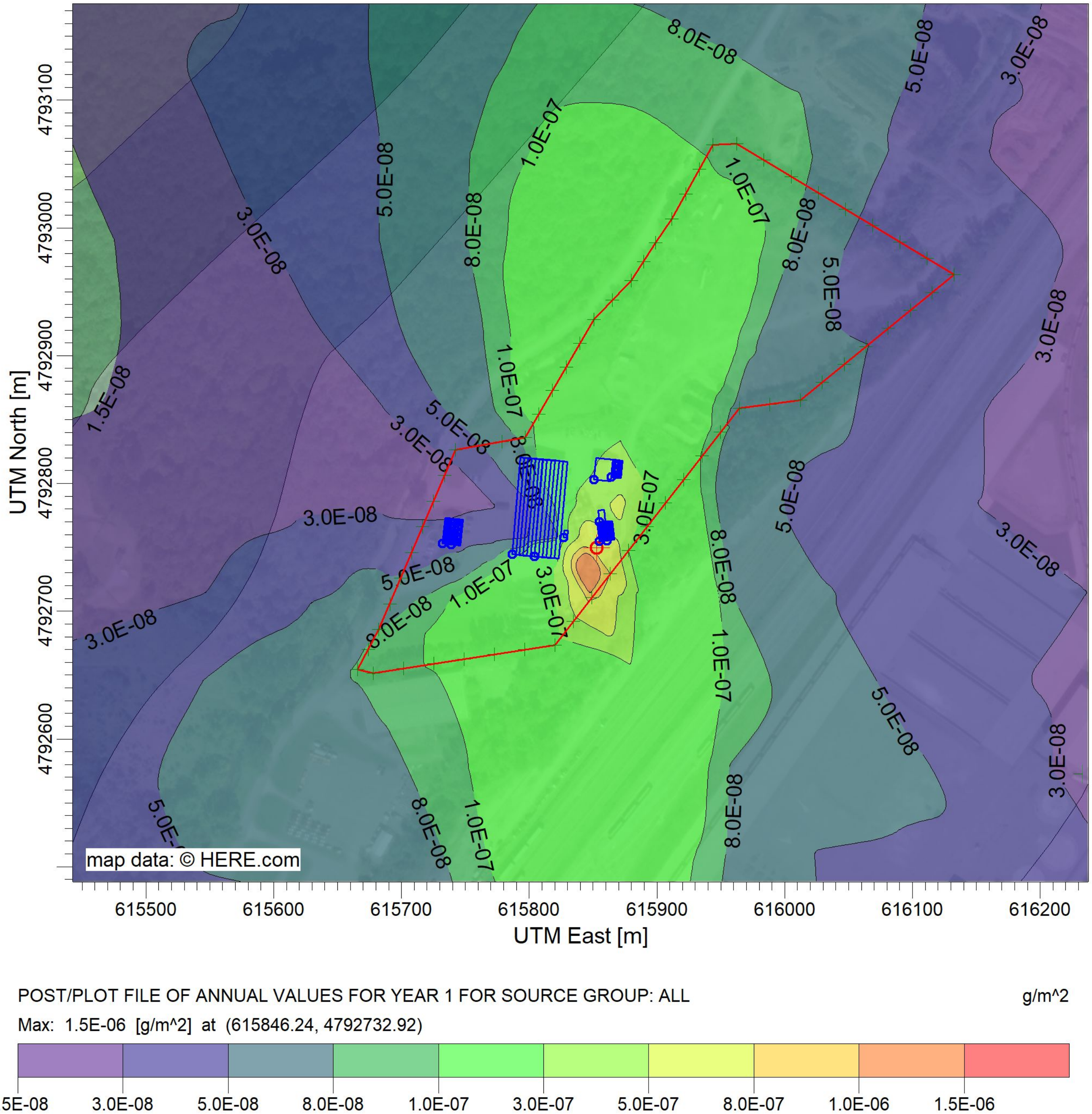
9/1/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

Max: 1.5E-06 [g/m^2] at (615846.24, 4792732.92)

COMMENTS:

Method 2 Analysis for PM-2.5 to represent PFAS

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Total Depos.

SCALE: 1:5,000

0 0.1 km

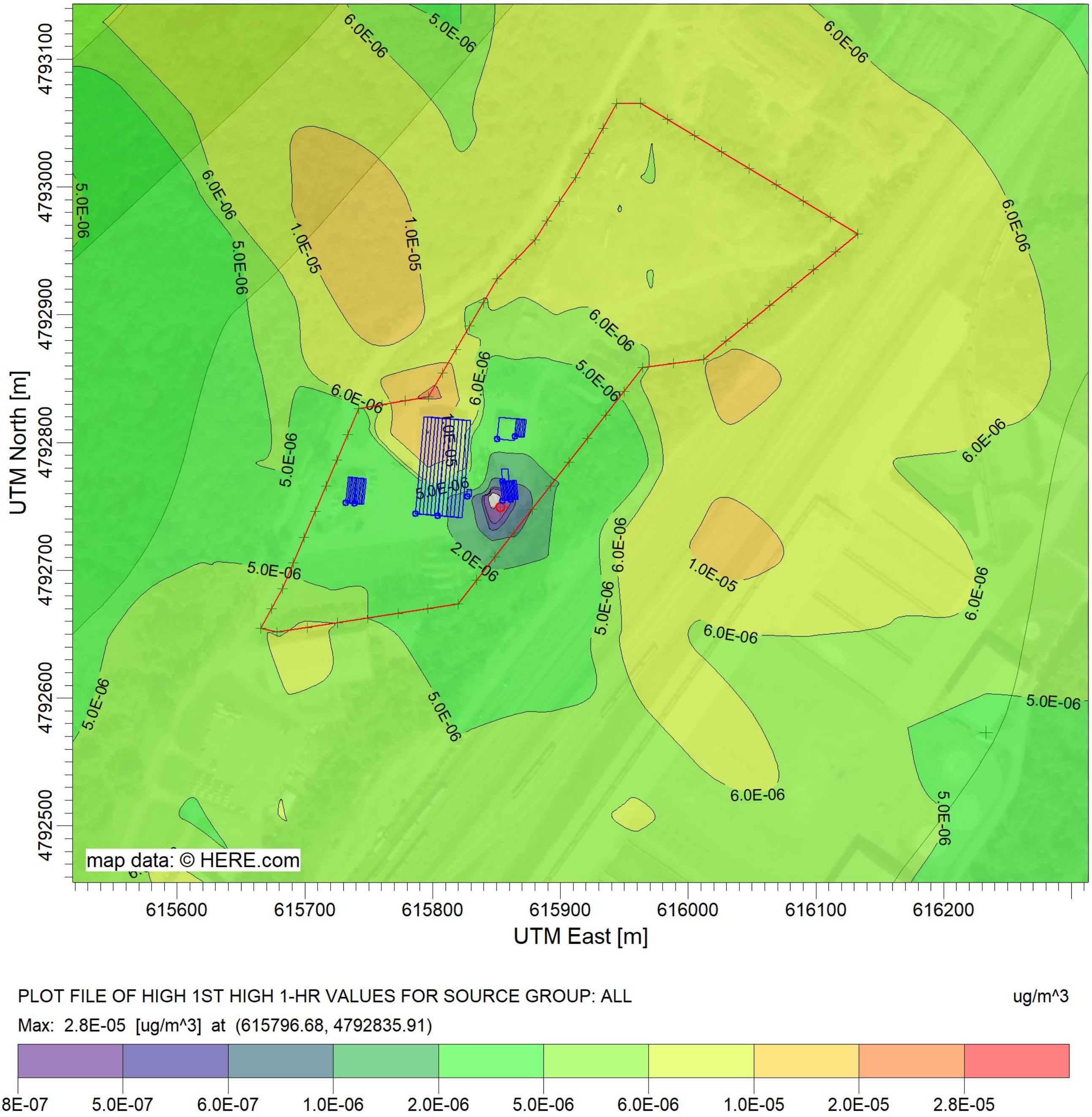
MAX:
1.5E-06 g/m^2

DATE:
4/18/2024

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 2.8E-05 [ug/m^3] at (615796.68, 4792835.91)

COMMENTS:

Air Dispersion Results

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE:

1:5,000

0 0.1 km

MAX:

2.8E-05 ug/m^3

DATE:

9/1/2023

PROJECT NO.:

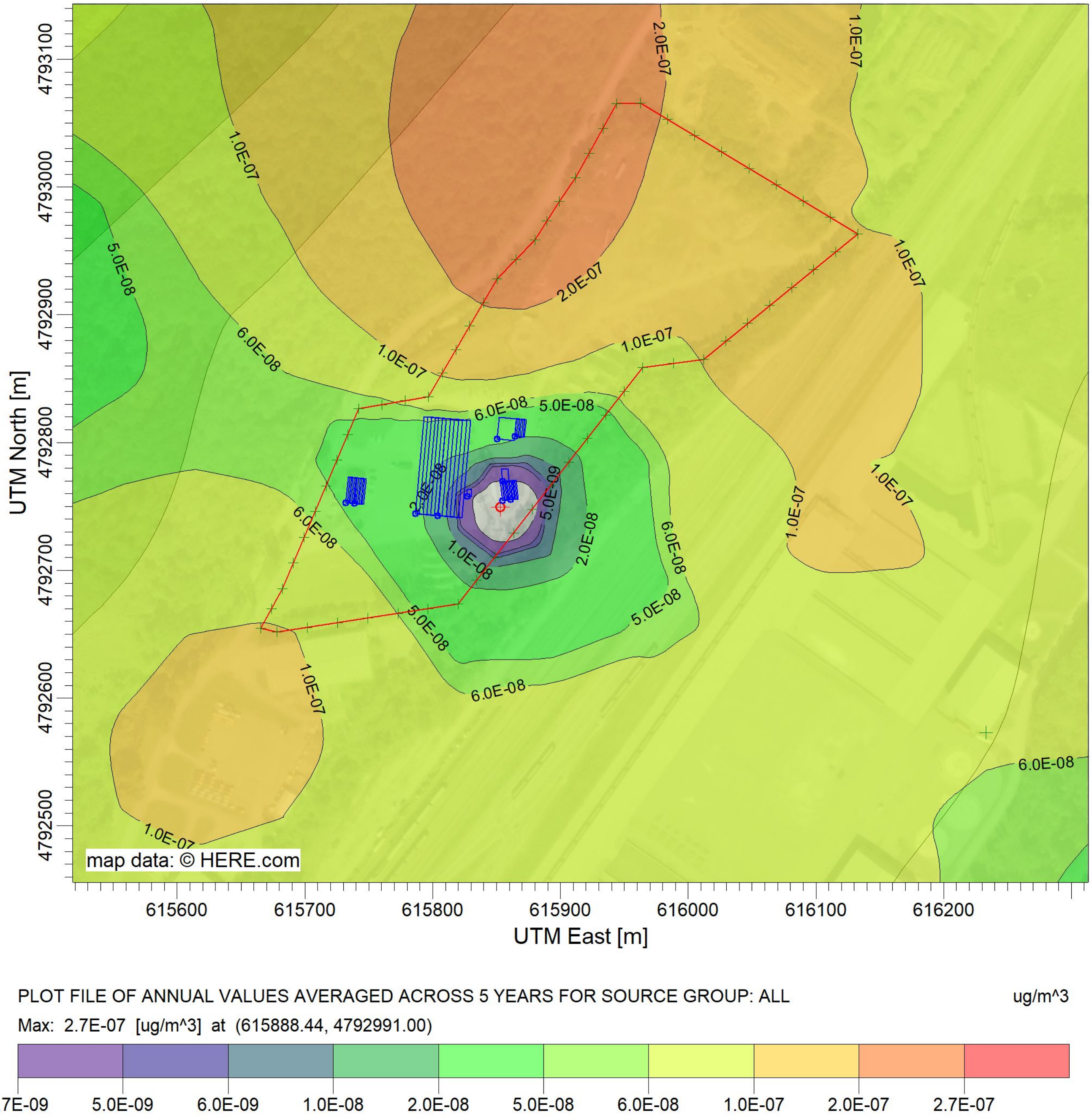
22.2756

AERMOD View - Lakes Environmental Software

C:\Data\Lakes\CEFE2023 - All Runs\PFAS9990\PFAS9990.isc

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 2.7E-07 [ug/m^3] at (615888.44, 4792991.00)

COMMENTS:

Air Dispersion Results

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE: 1:5,000

0 0.1 km

MAX:

2.7E-07 ug/m^3

DATE:

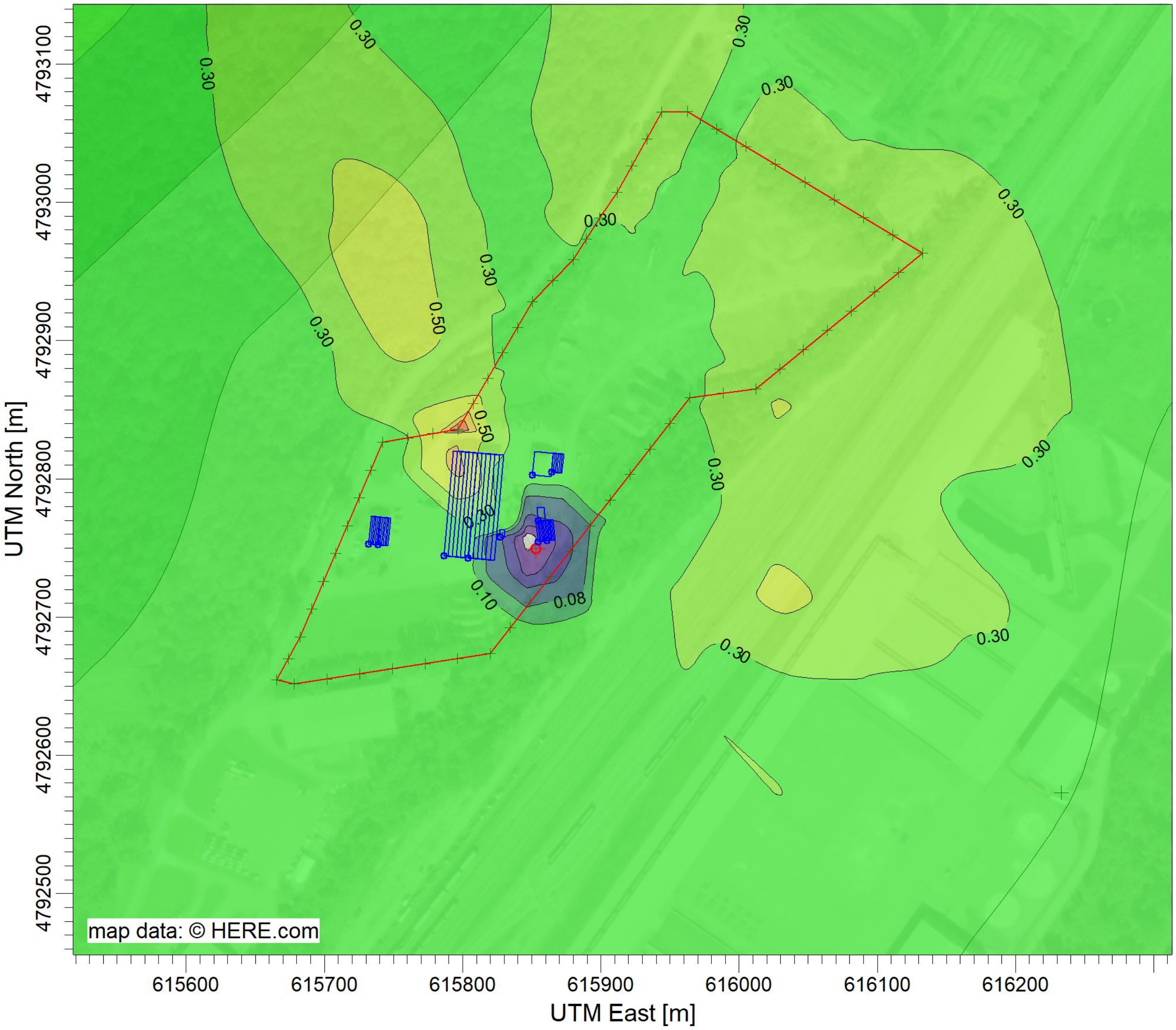
9/1/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

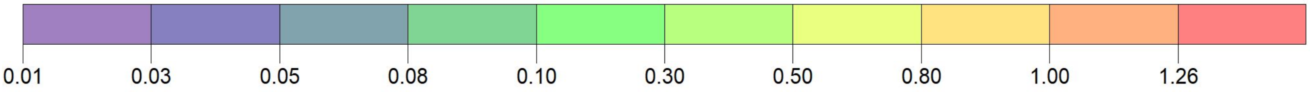
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.26 [ug/m^3] at (615796.68, 4792835.91)



COMMENTS:

Air Dispersion Results

Hydrogen Fluoride (CAS No. 7664-39-3) based on conversion of all Fluoride within PFAS compounds to HF.

SOURCES:

1

COMPANY NAME:

C.T. MALE ASSOCIATES

RECEPTORS:

4001

MODELER:

C.T. MALE STAFF

OUTPUT TYPE:

Concentration

SCALE:

1:5,000

0 0.1 km

MAX:

1.26 ug/m^3

DATE:

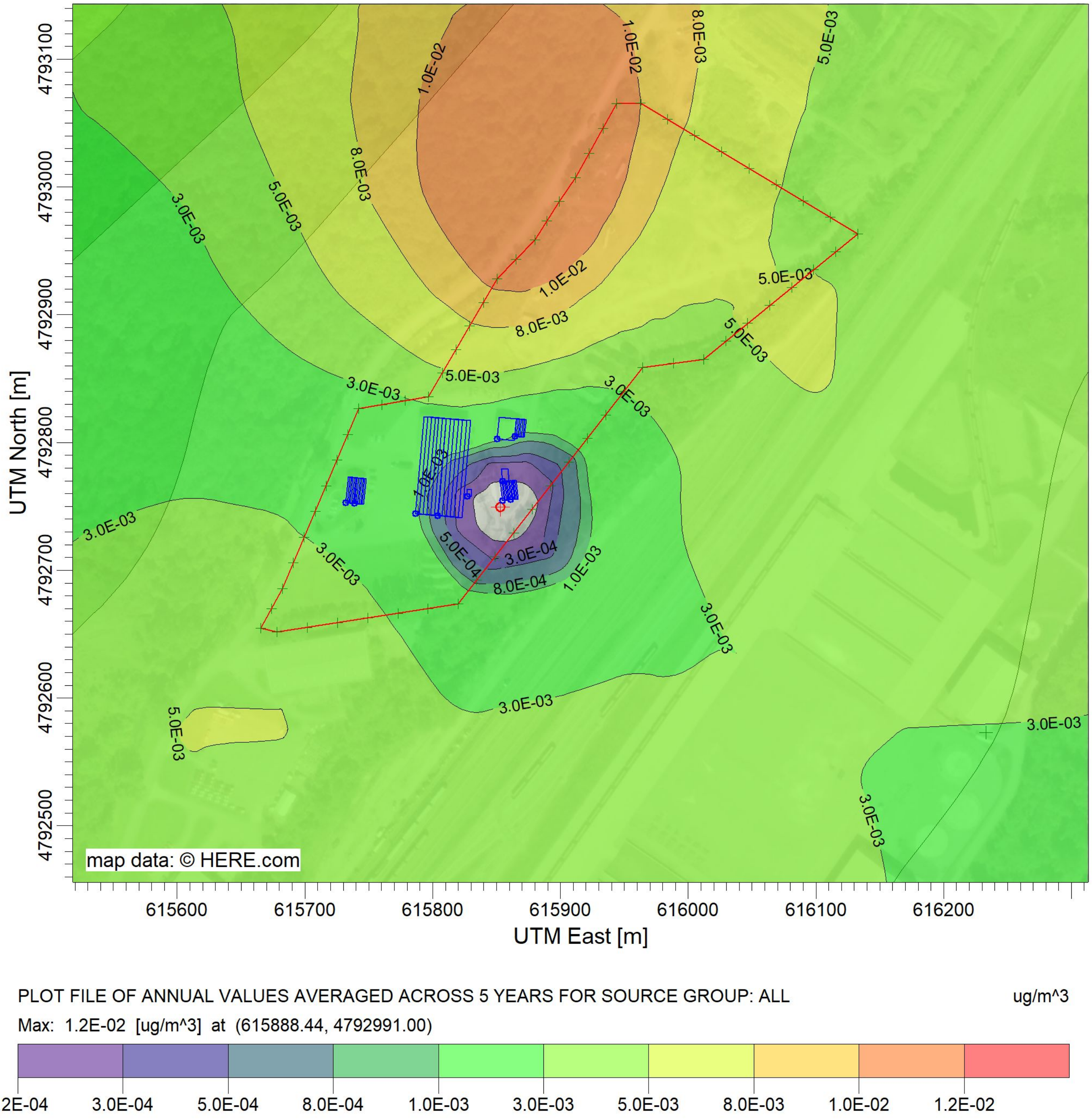
9/14/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.2E-02 [ug/m^3] at (615888.44, 4792991.00)

COMMENTS:

Air Dispersion Results

Hydrogen Fluoride (CAS No. 7664-39-3) based on conversion of all Fluoride within PFAS compounds to HF.

SOURCES:
1

COMPANY NAME:
C.T. MALE ASSOCIATES

RECEPTORS:
4001

MODELER:
C.T. MALE STAFF

OUTPUT TYPE:
Concentration

SCALE: 1:5,000

0 0.1 km

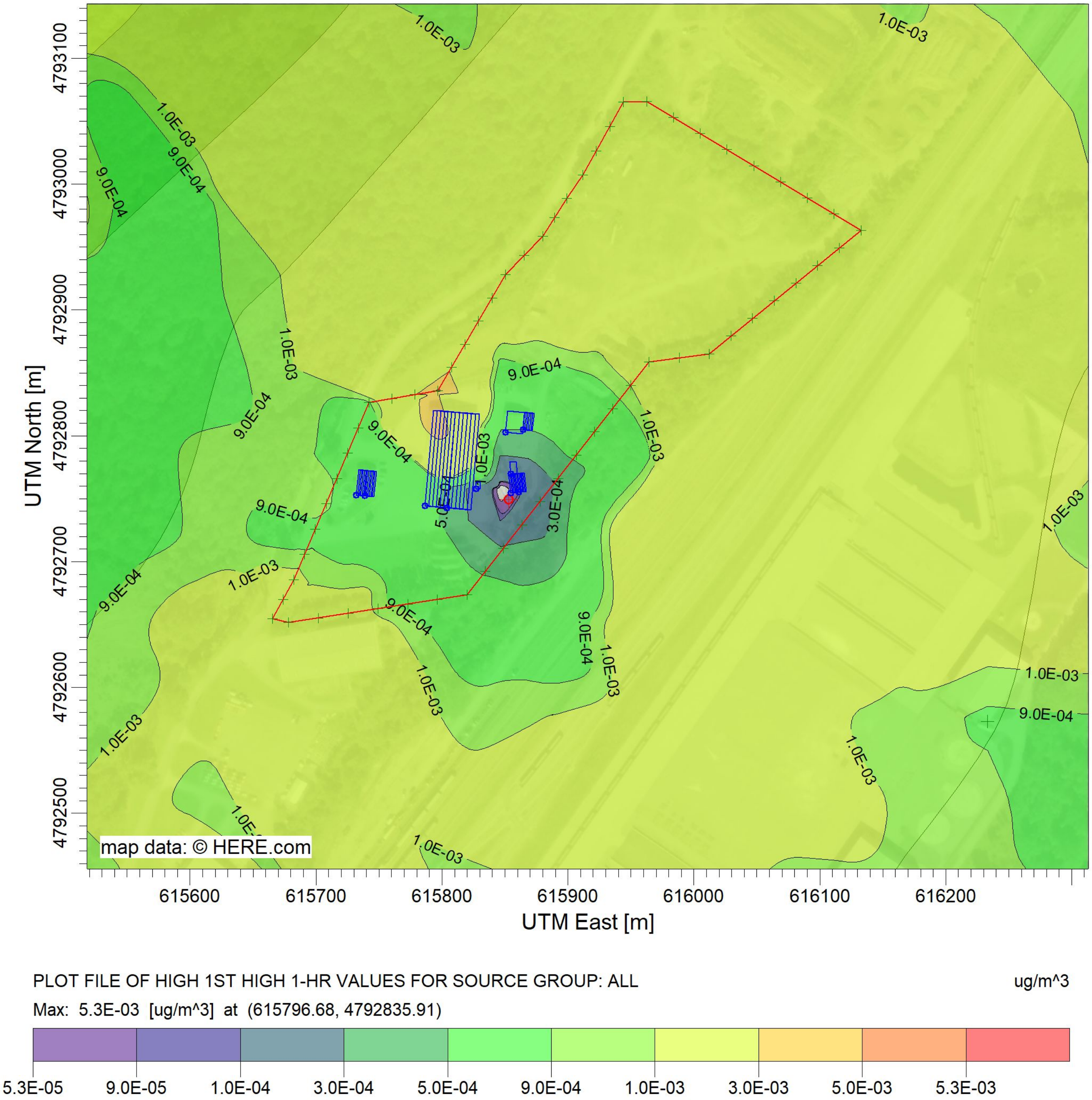
MAX:
1.2E-02 ug/m^3

DATE:
9/14/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration



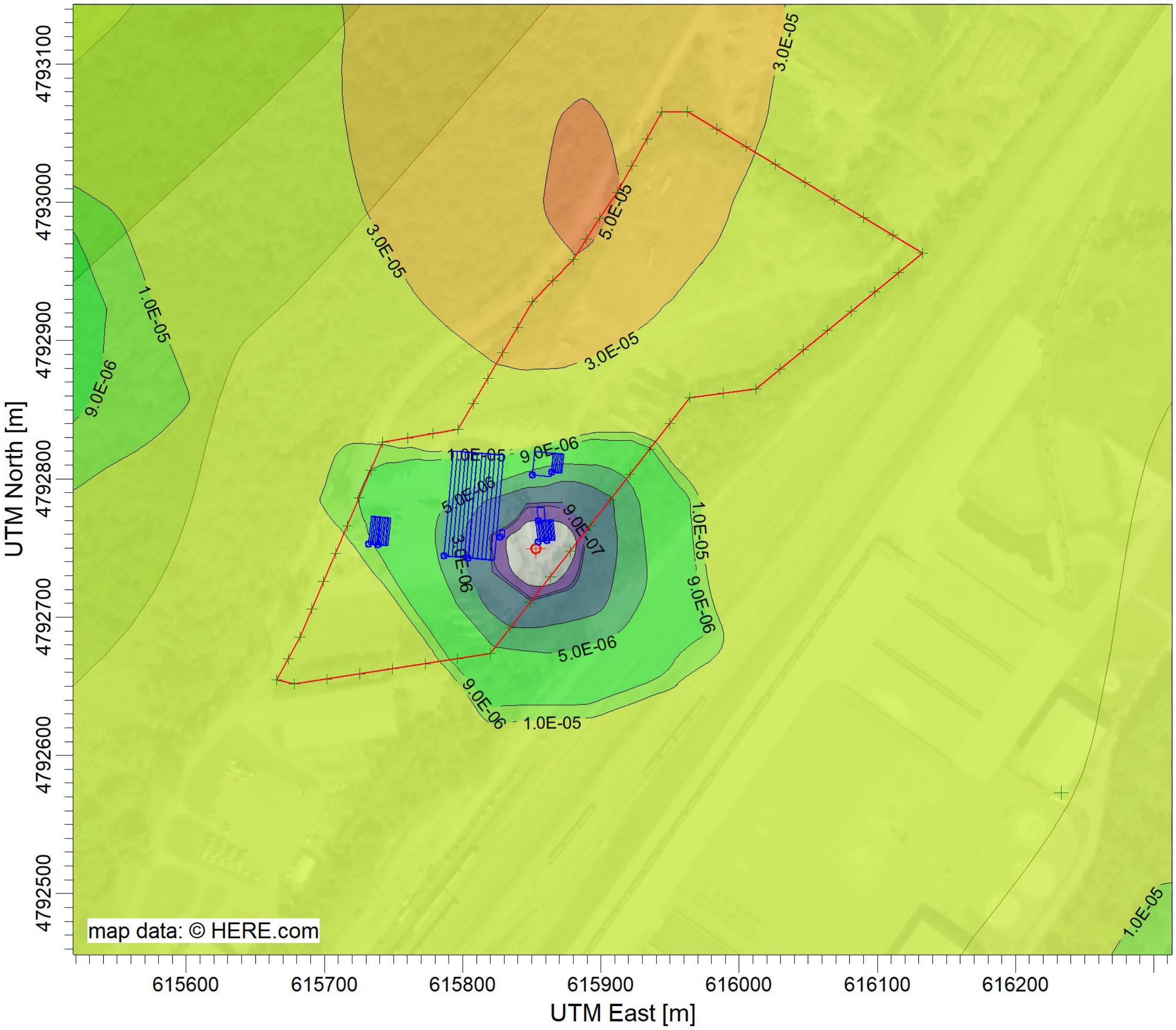
PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

Max: 5.3E-03 [ug/m^3] at (615796.68, 4792835.91)

COMMENTS: Air Dispersion Results Carbon Tetrafluoride (CAS No. 75-73-0) calculated emission rate based on literature (see reference in air modeling report)	SOURCES: **1**	COMPANY NAME: **C.T. MALE ASSOCIATES**	
	RECEPTORS: **4001**	MODELER: **C.T. MALE STAFF**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 0.1 km	
	MAX: **5.3E-03 ug/m^3**	DATE: **9/14/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 5.2E-05 [ug/m^3] at (615888.44, 4792991.00)

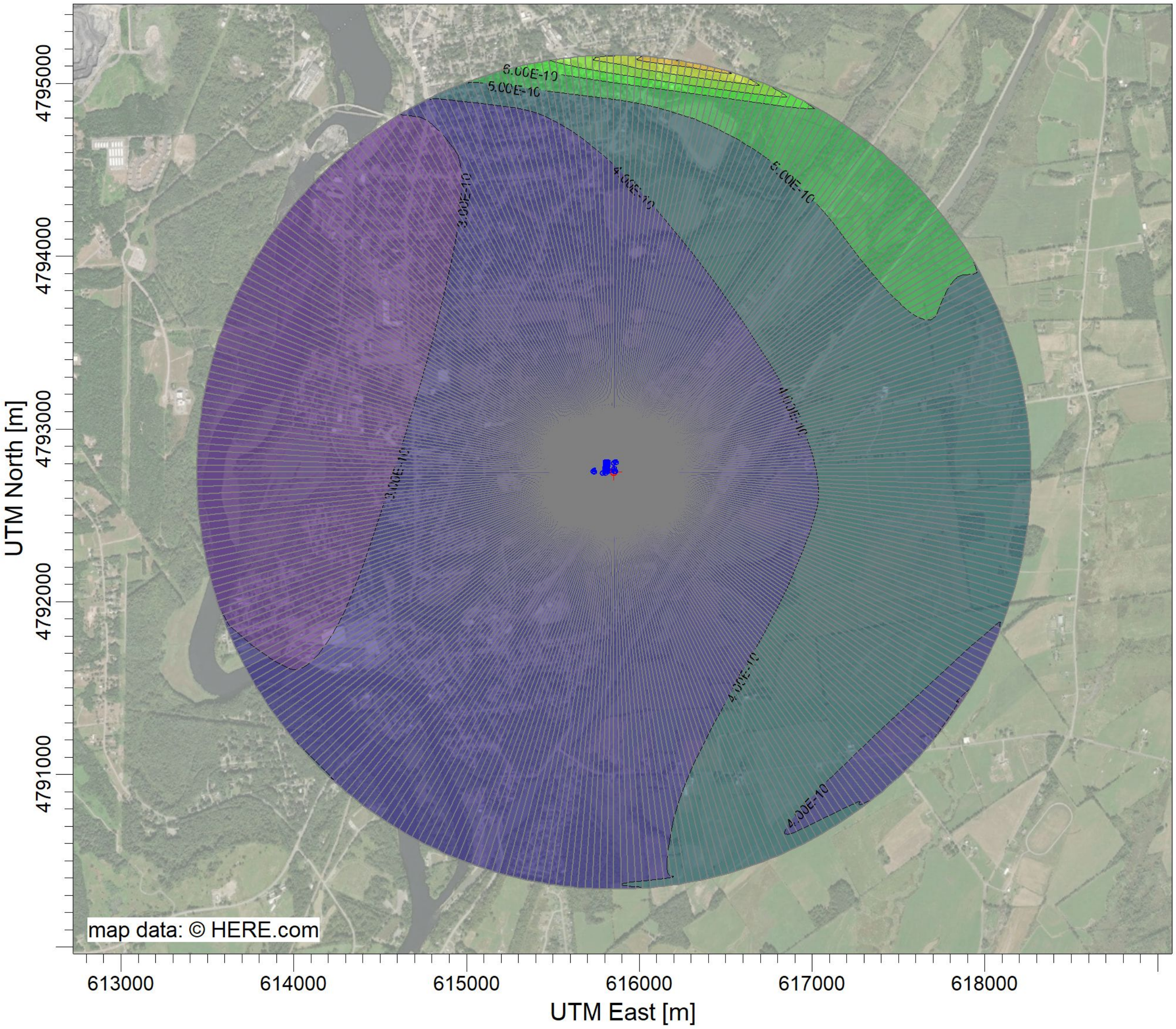
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟧	🟧	🟥
5.2E-07	9.0E-07	1.0E-06	3.0E-06	5.0E-06	9.0E-06	1.0E-05	3.0E-05	5.0E-05	5.2E-05

COMMENTS: Air Dispersion Results Carbon Tetrafluoride (CAS No. 75-73-0) calculated emission rate based on literature (see reference in air modeling report)	SOURCES: **1**	COMPANY NAME: **C.T. MALE ASSOCIATES**	
	RECEPTORS: **4001**	MODELER: **C.T. MALE STAFF**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 0.1 km	
	MAX: **5.2E-05 ug/m^3**	DATE: **9/14/2023**	PROJECT NO.: **22.2756**

AERMOD View - Lakes Environmental Software C:\Data\Lakes\CEFE2023 - All Runs\CF4\CF4.isc

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE - At 1.5 mile Endpoint



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 1.01E-09 [g/m^2] at (616272.09, 4795126.91)

🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥
1.34E-10	3.00E-10	4.00E-10	5.00E-10	6.00E-10	7.00E-10	8.00E-10	9.00E-10	1.00E-09	1.01E-09

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. MALE ASSOCIATES

RECEPTORS:
360

MODELER:
C.T. MALE STAFF

OUTPUT TYPE:
Total Depos.

SCALE: 1:40,000

0 1 km

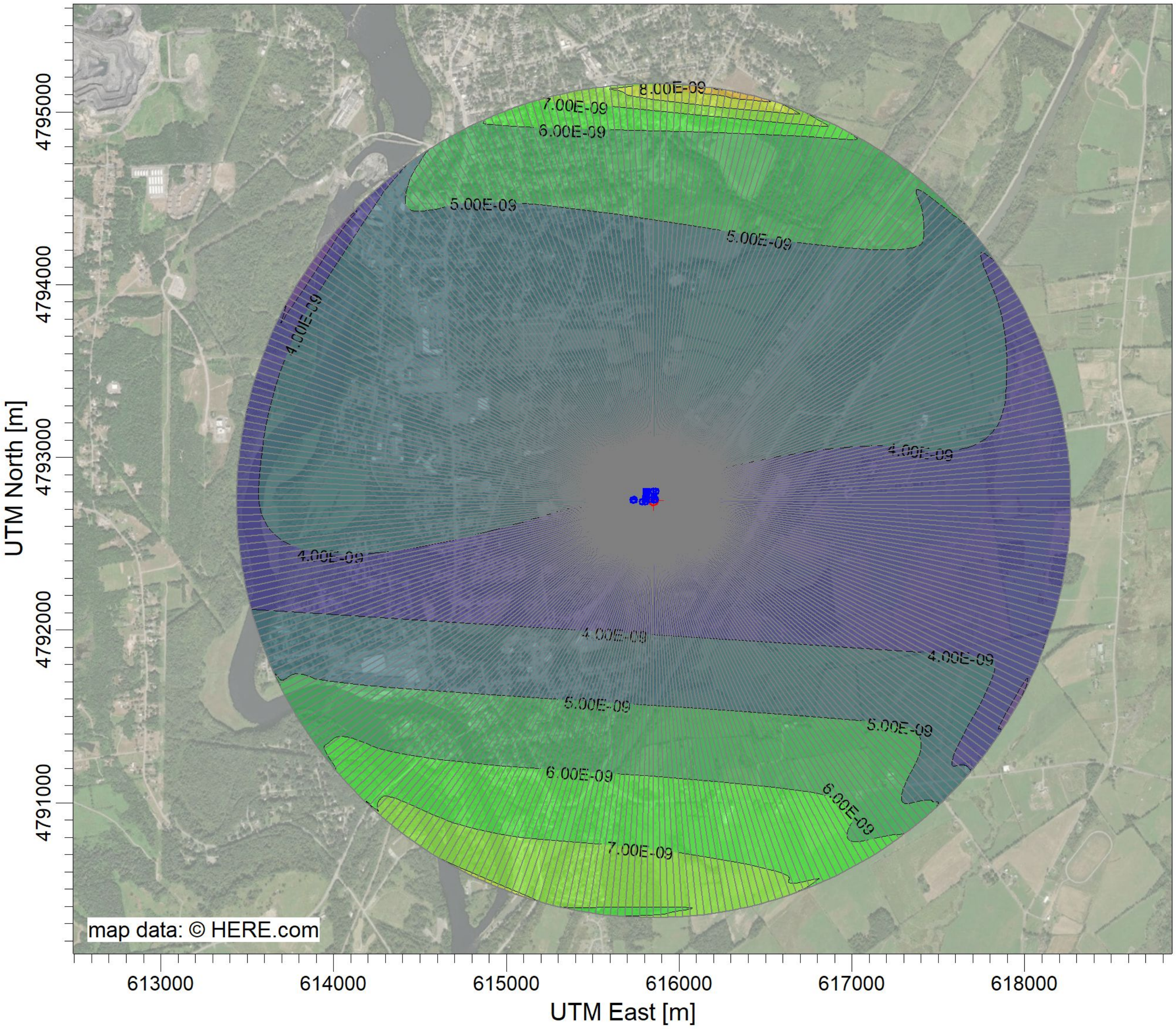
MAX:
1.01E-09 g/m^2

DATE:
9/12/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE - At 1.5 mile Endpoint



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

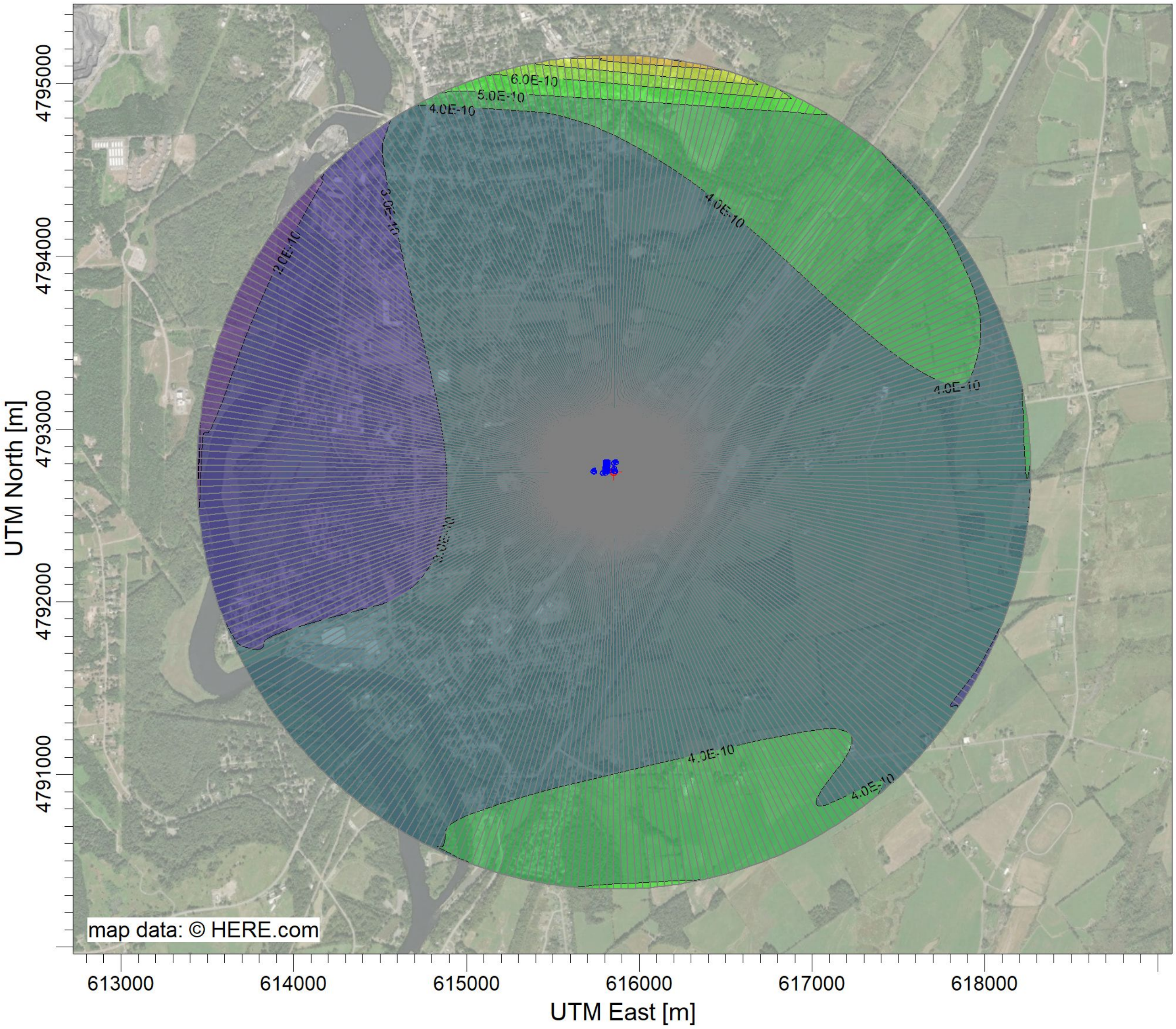
Max: 1.04E-08 [g/m^2] at (616313.51, 4795119.23)

2.25E-09	3.00E-09	4.00E-09	5.00E-09	6.00E-09	7.00E-09	8.00E-09	9.00E-09	1.00E-08	1.04E-08
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥

COMMENTS: Method 2 Analysis for PM-2.5 to Represent PFAS Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **360**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:40,000 0 1 km	
	MAX: **1.04E-08 g/m^2**	DATE: **4/18/2024**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE - At 1.5 mile Endpoint



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

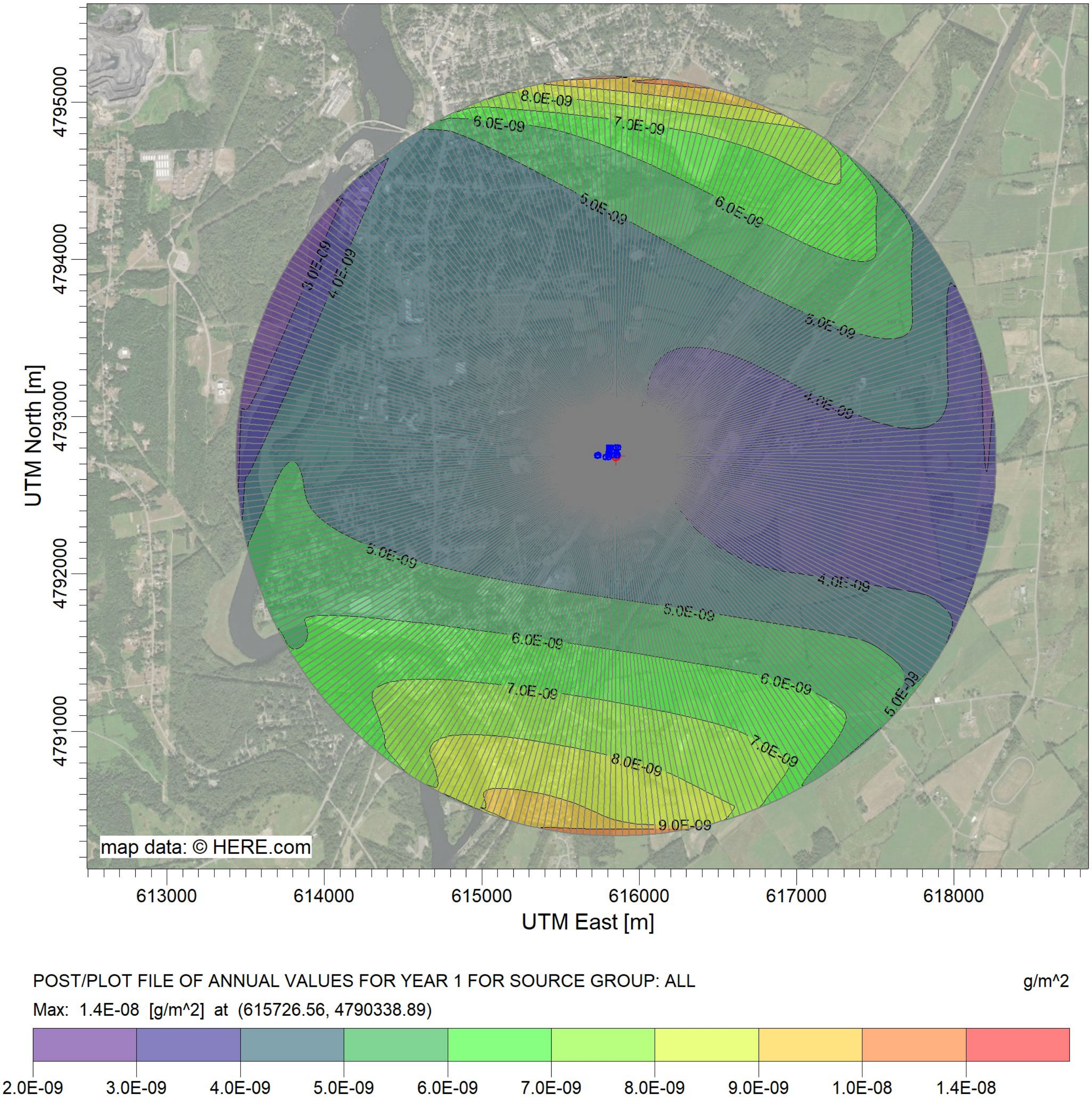
Max: 9.1E-10 [g/m^2] at (616272.09, 4795126.91)

1.3E-10	2.0E-10	3.0E-10	4.0E-10	5.0E-10	6.0E-10	7.0E-10	8.0E-10	9.0E-10	9.1E-10

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. MALE ASSOCIATES**	
	RECEPTORS: **360**	MODELER: **C.T. MALE STAFF**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:40,000 0 1 km	
	MAX: **9.1E-10 g/m^2**	DATE: **9/12/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.90% PFAS DRE - At 1.5 mile Endpoint



COMMENTS:

Method 2 Analysis for PM-2.5 to Represent PFAS

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

360

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE:

1:40,000

0 1 km

MAX:

1.4E-08 g/m^2

DATE:

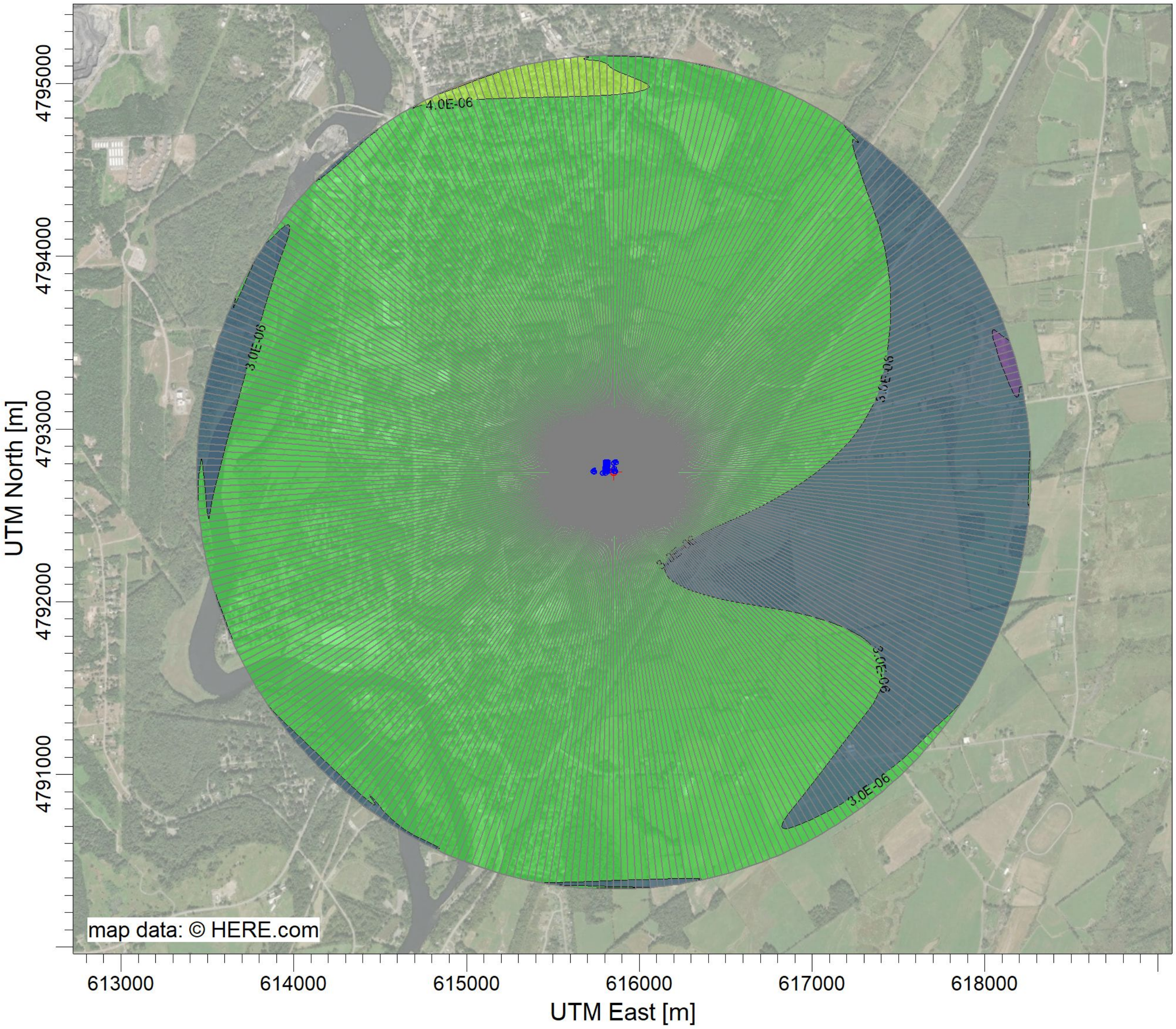
4/18/2024

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE - At 1.5 mile Endpoint



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 5.4E-06 [ug/m^3] at (614987.80, 4795003.24)

1.7E-06	2.0E-06	3.0E-06	4.0E-06	5.0E-06	5.4E-06
🟪	🟦	🟩	🟩	🟧	🟥

COMMENTS:

Air Dispersion Results

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. MALE ASSOCIATES

RECEPTORS:
360

MODELER:
C.T. MALE STAFF

OUTPUT TYPE:
Concentration

SCALE: 1:40,000

0 1 km

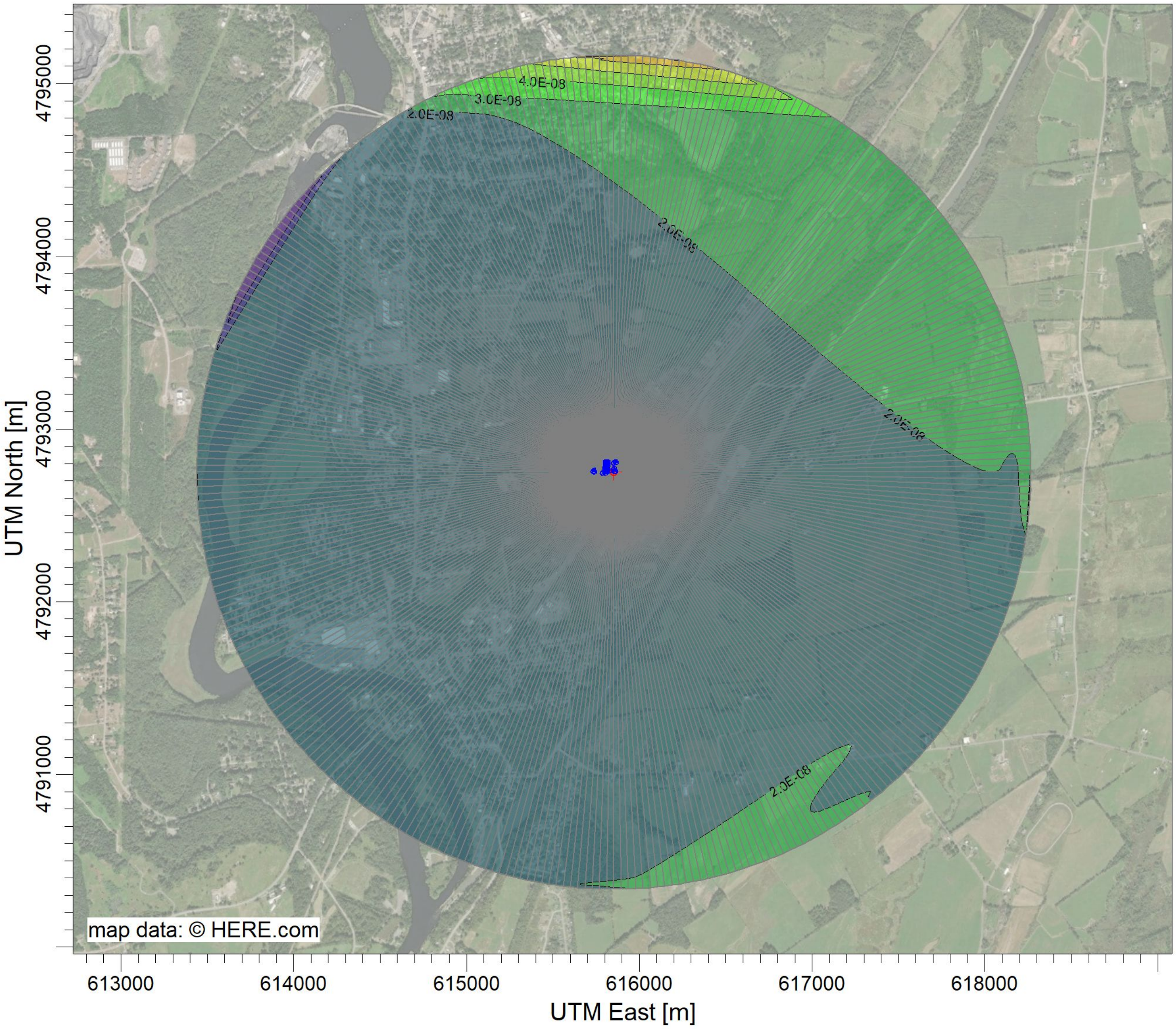
MAX:
5.4E-06 ug/m^3

DATE:
9/12/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFASE DRE - At 1.5 mile Endpoint



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 7.1E-08 [ug/m^3] at (616230.53, 4795133.86)

🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥
7.0E-09	9.0E-09	1.0E-08	2.0E-08	3.0E-08	4.0E-08	5.0E-08	6.0E-08	7.0E-08	7.1E-08

COMMENTS:

Air Dispersion Results

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. MALE ASSOCIATES

RECEPTORS:

360

MODELER:

C.T. MALE STAFF

OUTPUT TYPE:

Concentration

SCALE: 1:40,000

0 1 km

MAX:

7.1E-08 ug/m^3

DATE:

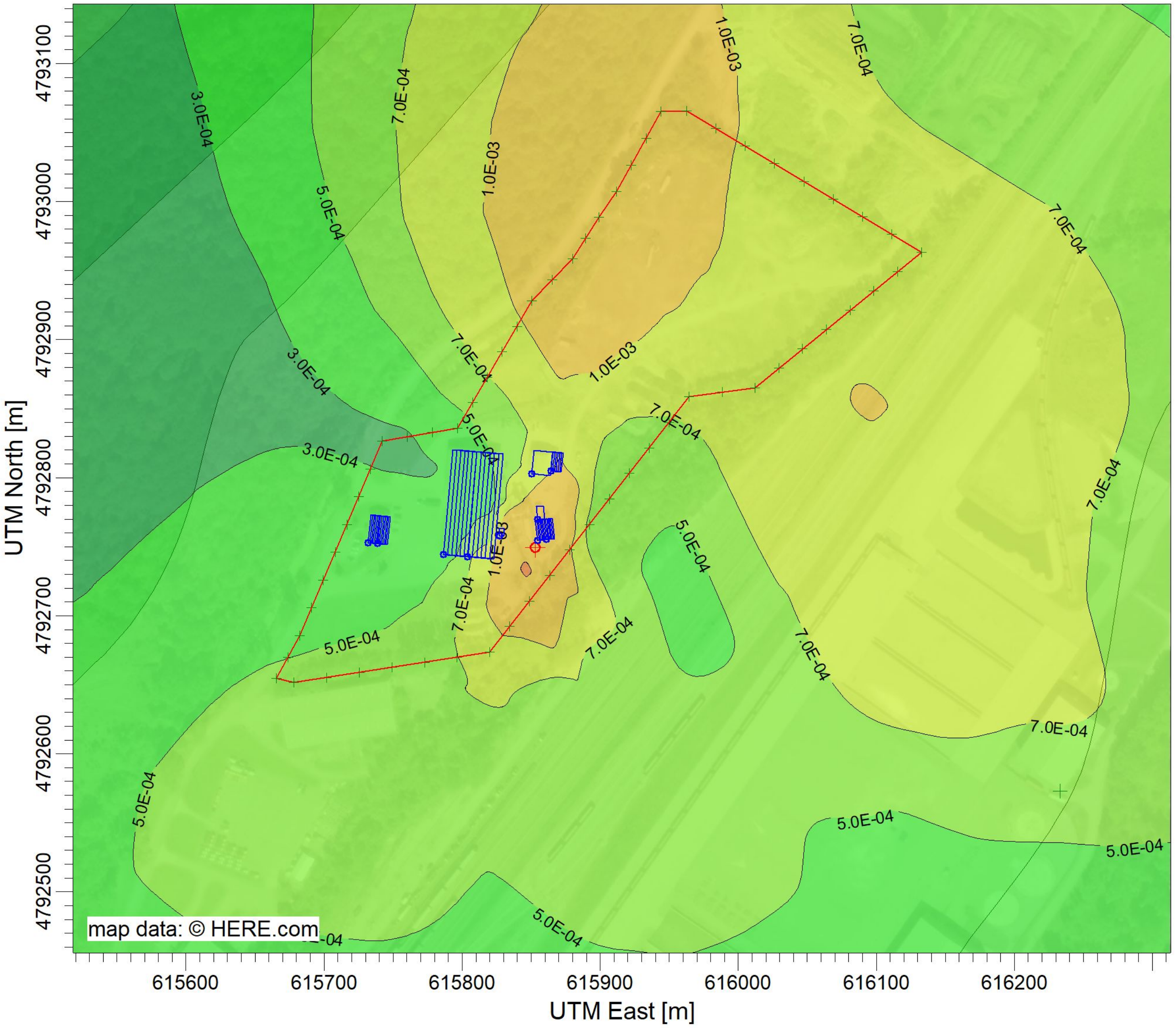
9/12/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Annual Average Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 3.4E-03 [g/m^2] at (615846.24, 4792732.92)

3.4E-05 5.0E-05 7.0E-05 1.0E-04 3.0E-04 5.0E-04 7.0E-04 1.0E-03 3.0E-03 3.4E-03

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

"Representative" PFAS at 0.1 g/s

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:

3.4E-03 g/m^2

DATE:

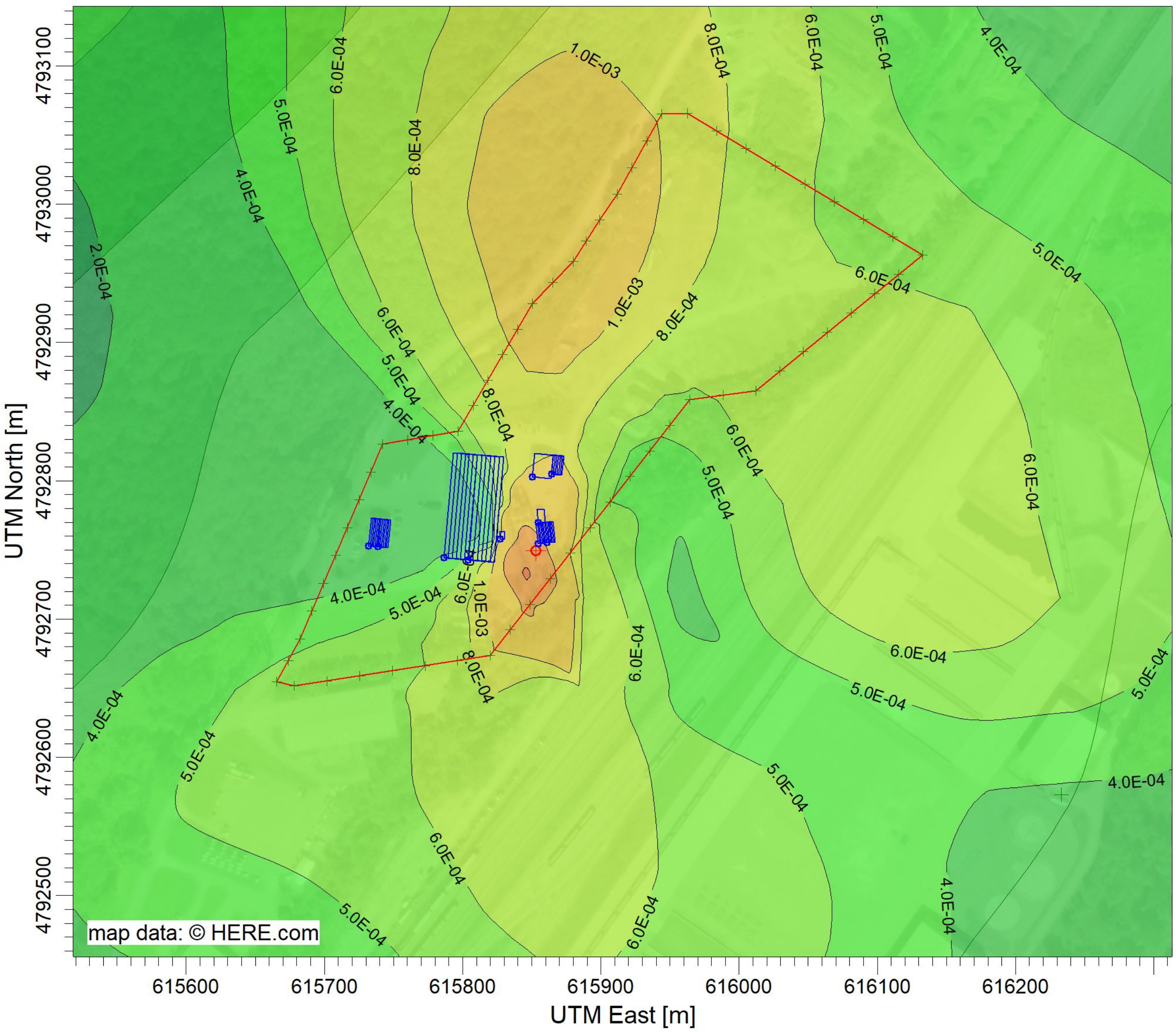
8/29/2023

PROJECT NO.:

22.2756

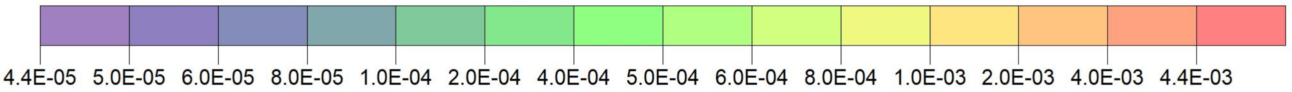
PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Annual Average Deposition Based on 99.90% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 4.4E-03 [g/m^2] at (615846.24, 4792732.92)

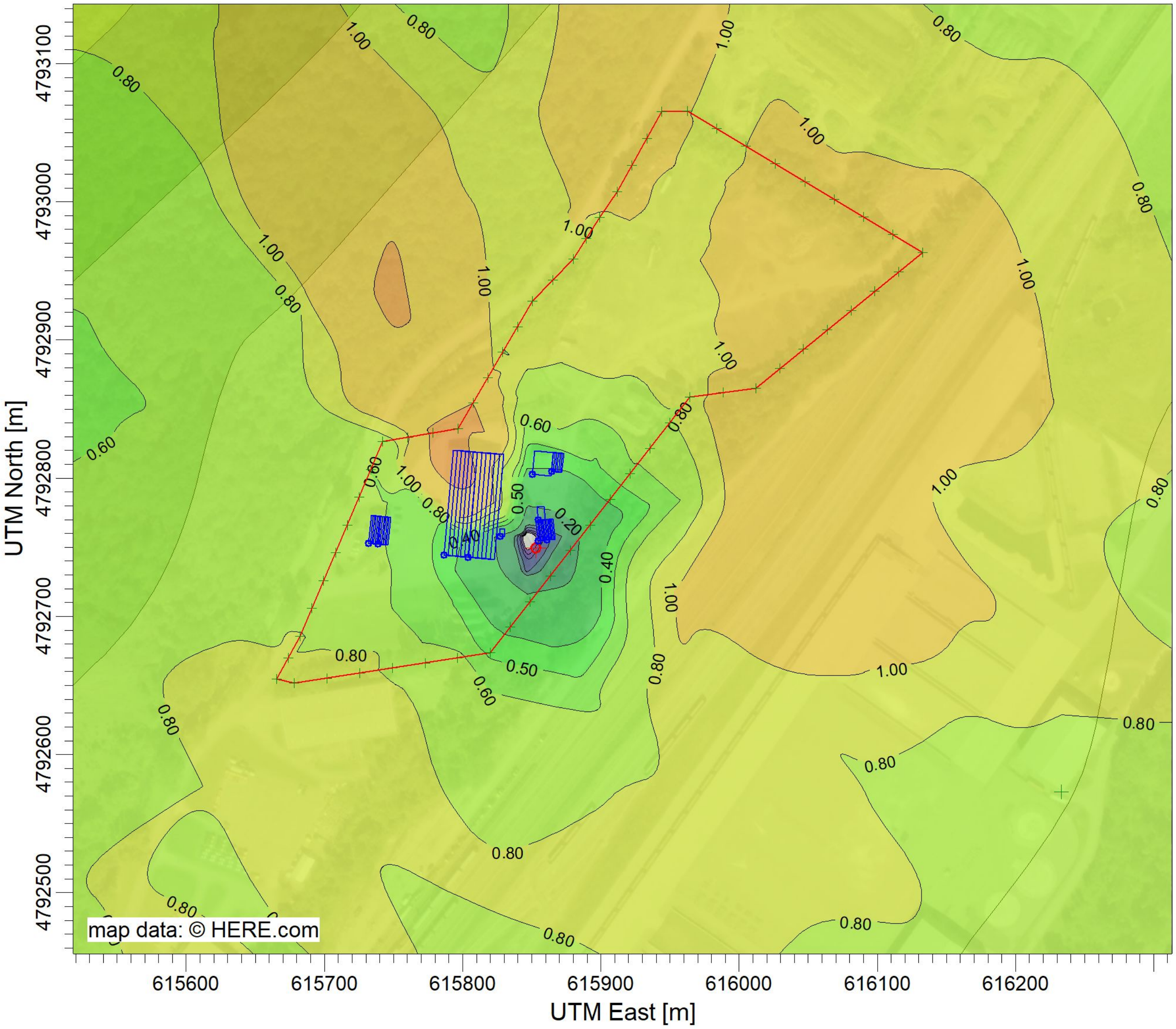


COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS "Representative" PFAS at 0.1 g/s	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **4.4E-03 g/m^2**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

AERMOD View - Lakes Environmental Software C:\Data\Lakes\CEFE2023 - All Runs\CEFE2023\CEFE2023.isc

PROJECT TITLE:

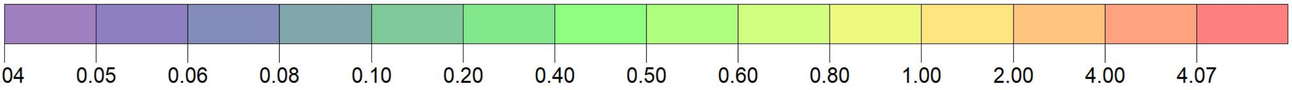
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

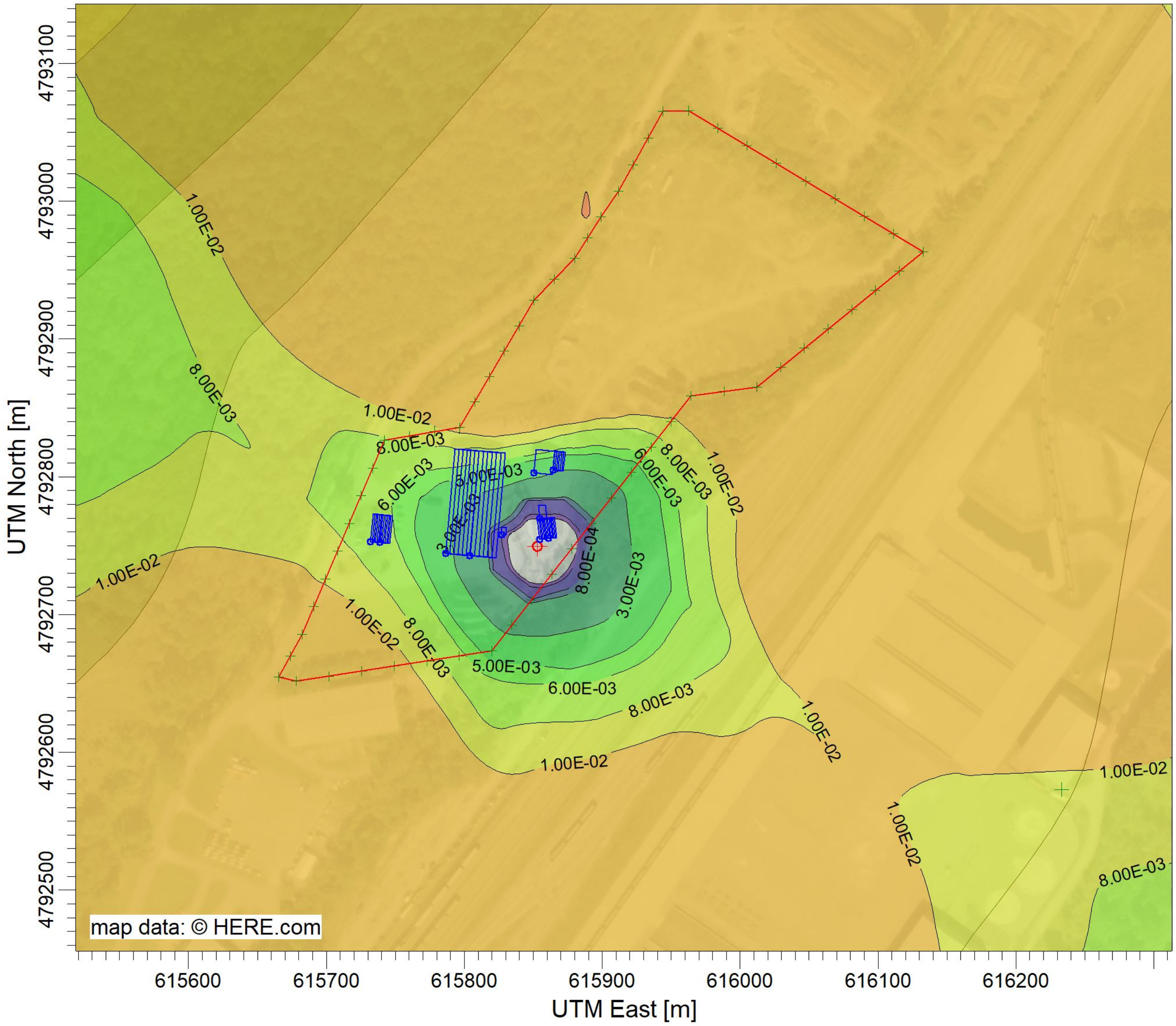
Max: 4.07 [ug/m^3] at (615796.68, 4792835.91)



COMMENTS: Air Dispersion Results "Representative" PFAS at 0.1 g/s	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 ▬ 0.1 km	
	MAX: **4.07 ug/m^3**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.90% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

ug/m^3

Max: 4.02E-02 [ug/m^3] at (615888.44, 4792991.00)

4.00E-04 5.00E-04 8.00E-04 1.00E-03 3.00E-03 5.00E-03 6.00E-03 8.00E-03 1.00E-02 4.00E-02 4.02E-02

COMMENTS: Air Dispersion Results "Representative" PFAS at 0.1 g/s	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 0.1 km	
	MAX: **4.02E-02 ug/m^3**	DATE: **8/29/2023**	PROJECT NO.: **22.2756**

Attachment B

Summary of Dispersion and Deposition Modeling Results and Graphical Representations of Output at 99.99% Destruction Efficiency

C.T. Male Associates

Clean Earth Fort Edward, NY Site
Air Deposition Modeling Results
C.T. Male Project No.: 22.2756

Summary of Modeling Results at
99.99% Destruction Efficiency

Compound	CAS#	Soil Concentration (in ppb)	Emission Rate based on 99.99% DRE (in g/s)	Deposition Results (in g/m^2)[1]				Dispersion Results (in ug/m^3)		File Name
				Low Year Maximum	Low Year	High Year Maximum	High Year	Maximum Hourly	Maximum Annual	
Perfluorobutane Sulfonate (PFBS)	375-73-5	0.085	6.42589E-11	2.17166E-12	4 of 5	2.83866E-12	5 of 5	2.61465E-09	2.58227E-11	PFBS9999
Perfluorooctanoic acid (PFOA)	335-67-1	4.482	3.38833E-09	1.14510E-10	4 of 5	1.49681E-10	5 of 5	1.37869E-07	1.36161E-09	PFOA9999
Perfluorononanoic acid (PFNA)	375-95-1	2.061	1.55809E-09	5.26564E-11	4 of 5	6.88292E-11	5 of 5	6.33975E-08	6.26124E-10	PFNA9999
Perfluorohexanesulfonic acid (PFHxS)	335-46-4	0.220	1.66E-10	5.62077E-12	4 of 5	7.34712E-12	5 of 5	6.76733E-09	6.68352E-11	PFHS9999
Perfluorooctanesulfonic acid (PFOS)	1763-23-1	58.793	4.44E-08	1.50210E-09	4 of 5	1.96345E-09	5 of 5	1.80851E-06	1.78611E-08	PFOS9999
Sum of all PFAS Compounds[2]	N/A	89.485	6.76495E-08	2.28625E-09	4 of 5	2.98844E-09	5 of 5	2.75261E-06	2.71852E-08	PFAS9999
Hydrogen Fluoride (HF)[3]	7664-39-3	N/A	3.08737E-02	N/A[5]				1.25623	1.24067E-02	HF
Carbon Tetrafluoride (CF$_4$)[4]	75-73-0	N/A	1.29685E-04					5.27681E-03	5.21146E-05	CF4
"Representative" PFAS at 0.1 g/s	N/A	N/A	0.1	3.37955E-03	4 of 5	4.41754E-03	5 of 5	4.06893	4.01854E-02	CEFE2023

[1] - Results based on 5 years of climate data with AERMOD generating annual depostion. Results show the highest and lowest individual year per model run.

[2] - Sum of all sampled PFAS compounds.

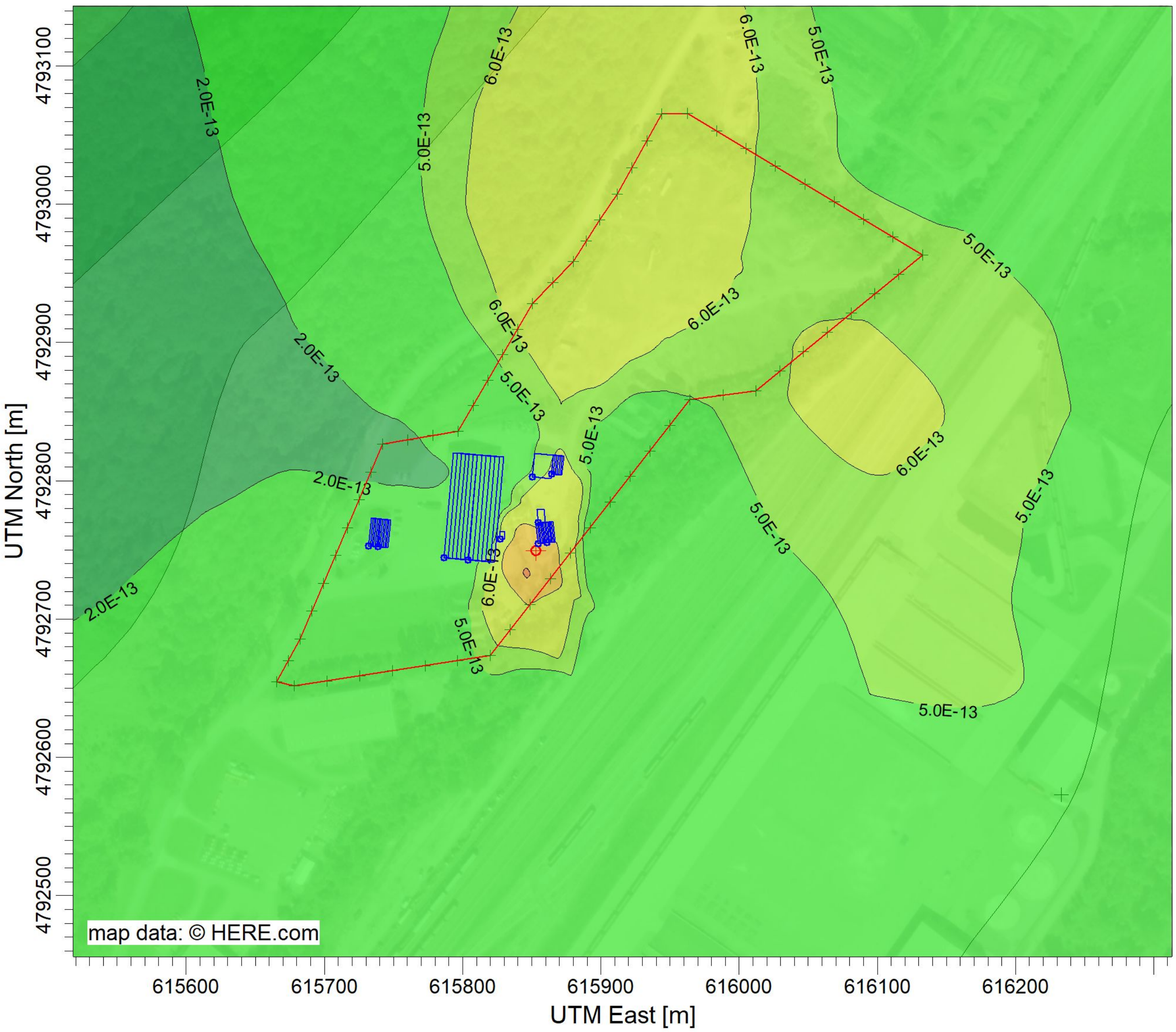
[3] - Calculated emission rate based on conversion of all fluorine within PFAS compounds to hydrofluoric acid.

[4] - Calculated emission rate based on the following article:
Jonathan D. Krug, Paul M. Lemieux, Chun-Wai Lee, Jeffrey V. Ryan, Peter H. Kariher, Erin P. Shields, Lindsay C. Wickersham, Martin K. Denison, Kevin A. Davis, David A. Swensen, R. Preston Burnette, Jost O.L.
Wendt & William P. Linak (2022) Combustion of C1 and C2 PFAS: Kinetic modeling and experiments, Journal of the Air & Waste Management Association, 72:3, 256-270, DOI:

[5] - Compound does not behave as a particulate therefore deposition modeling is not applicable.

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 2.2E-12 [g/m^2] at (615846.24, 4792732.92)

2.2E-14 5.0E-14 6.0E-14 1.0E-13 2.0E-13 5.0E-13 6.0E-13 1.0E-12 2.0E-12 2.2E-12

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:

2.2E-12 g/m^2

DATE:

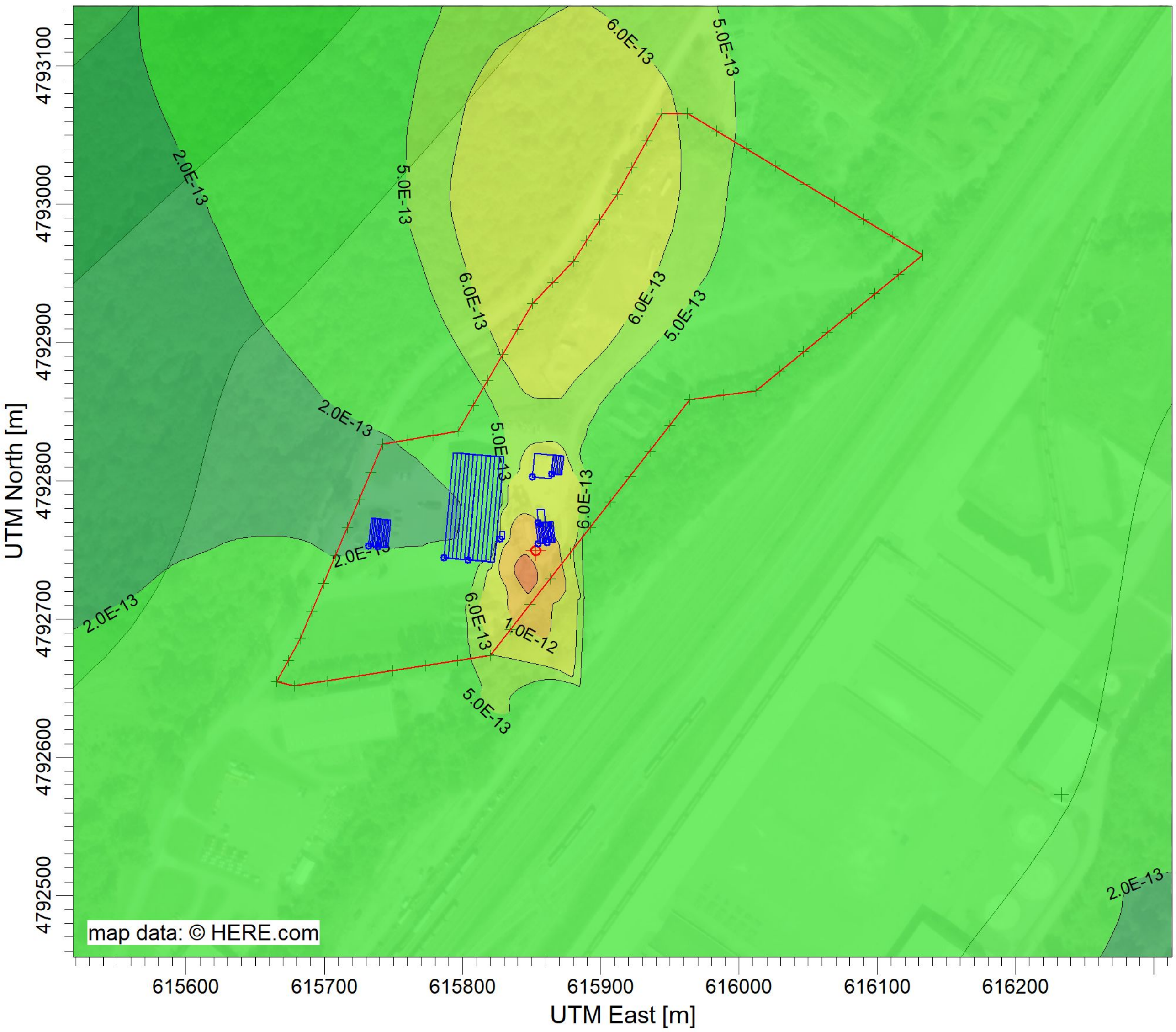
8/30/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

g/m^2

Max: 2.8E-12 [g/m^2] at (615846.24, 4792732.92)

2.8E-14 5.0E-14 6.0E-14 1.0E-13 2.0E-13 5.0E-13 6.0E-13 1.0E-12 2.0E-12 2.8E-12

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:

2.8E-12 g/m^2

DATE:

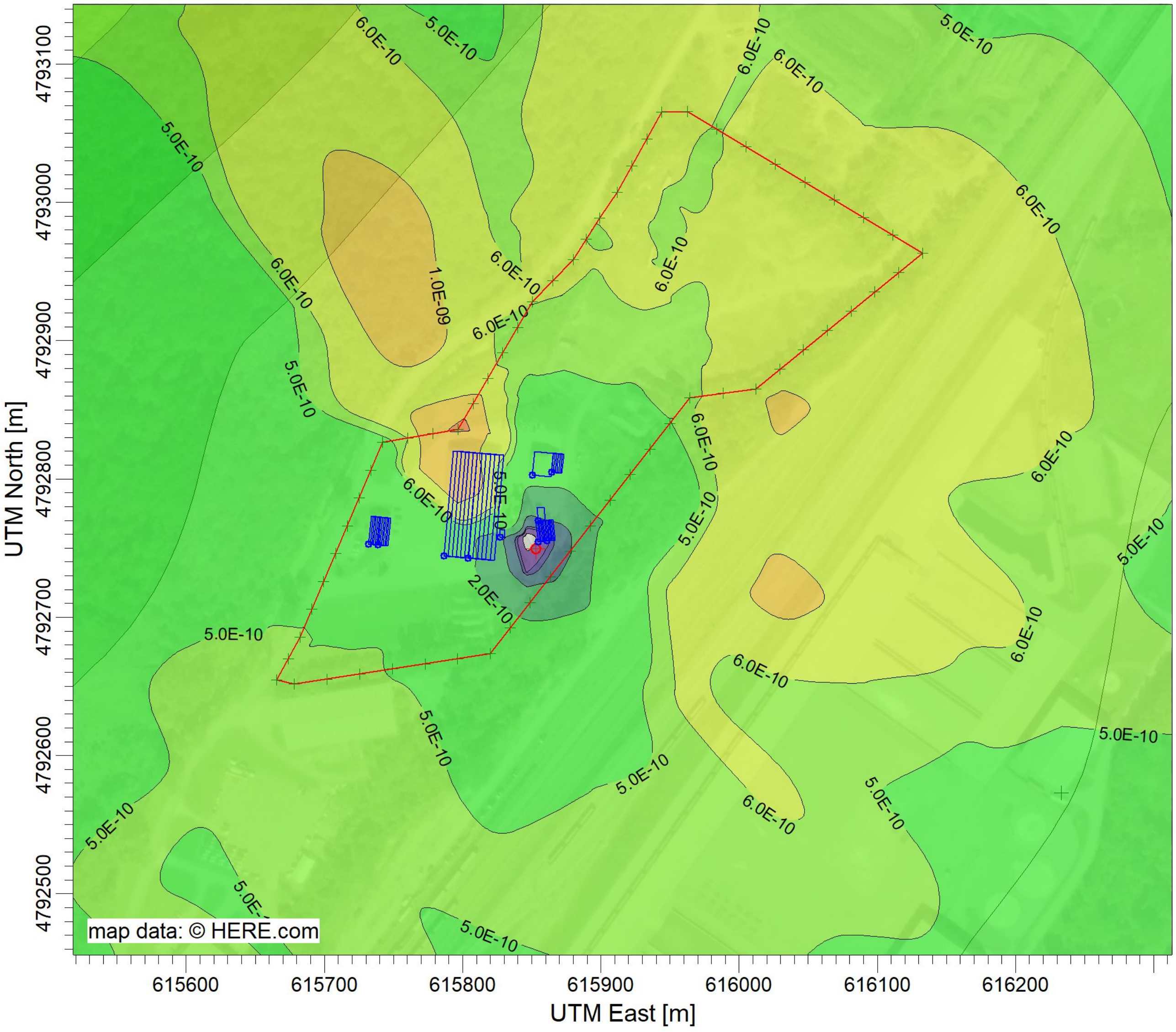
8/30/2023

PROJECT NO.:

22.2756

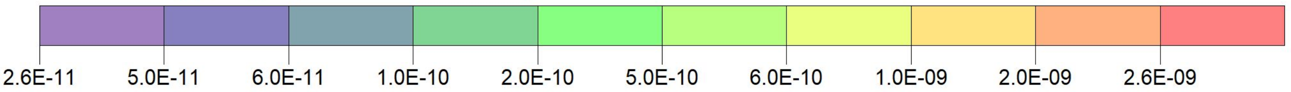
PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL ug/m^3

Max: 2.6E-09 [ug/m^3] at (615796.68, 4792835.91)

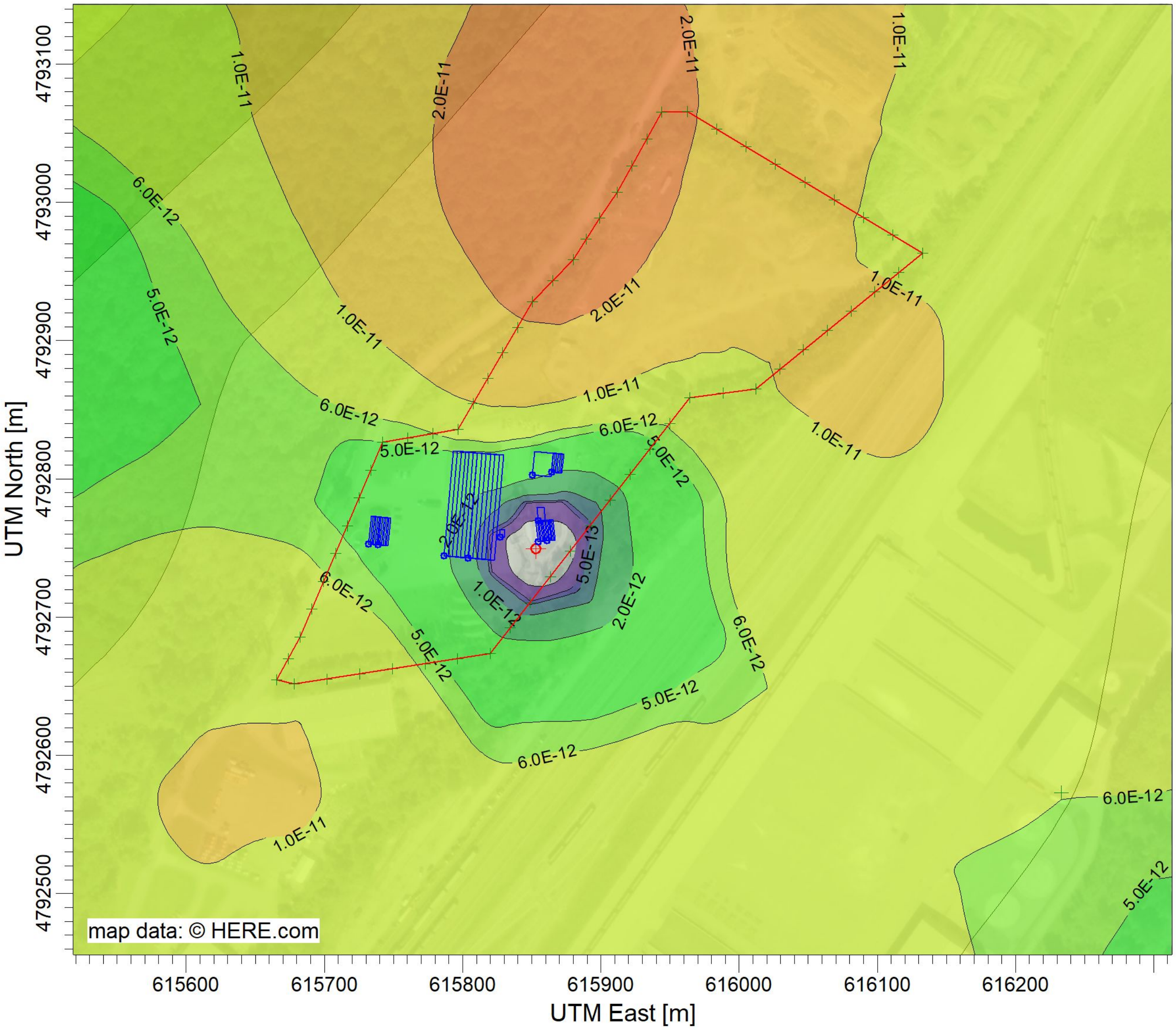


COMMENTS: Air Dispersion Results Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 ▬ 0.1 km
	MAX: **2.6E-09 ug/m^3**	DATE: **8/30/2023**

PROJECT NO.: **22.2756**

PROJECT TITLE:

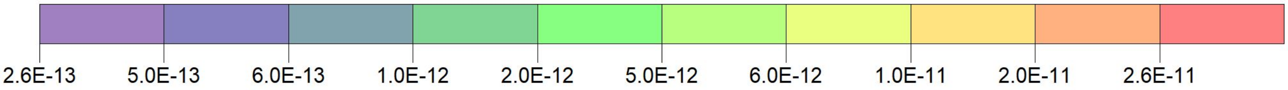
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

ug/m^3

Max: 2.6E-11 [ug/m^3] at (615888.44, 4792991.00)



COMMENTS:

Air Dispersion Results

Perfluorobutane Sulfonate (CAS No. 375-73-5) with Incoming Soil Concentration to Facility at 0.085 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE: 1:5,000

0 0.1 km

MAX:

2.6E-11 ug/m^3

DATE:

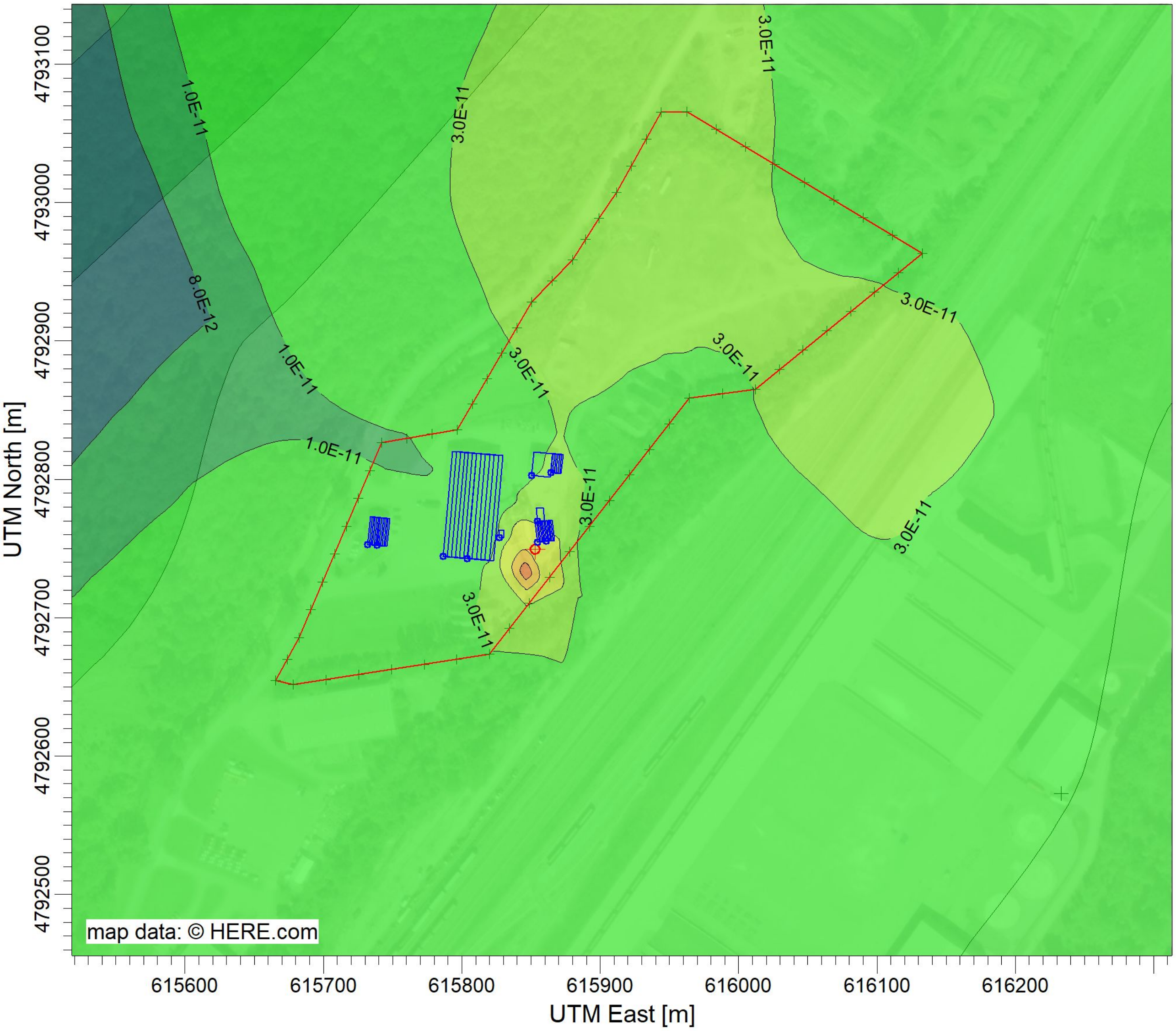
8/30/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

Max: 1.1E-10 [g/m^2] at (615846.24, 4792732.92)

🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥
1.1E-12	3.0E-12	5.0E-12	8.0E-12	1.0E-11	3.0E-11	5.0E-11	8.0E-11	1.0E-10	1.1E-10

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg

SOURCES: **1**

COMPANY NAME: **C.T. Male Associates**

RECEPTORS: **4001**

MODELER: **C.T. Male Staff**

OUTPUT TYPE: **Total Depos.**

SCALE: 1:5,000

0 0.1 km

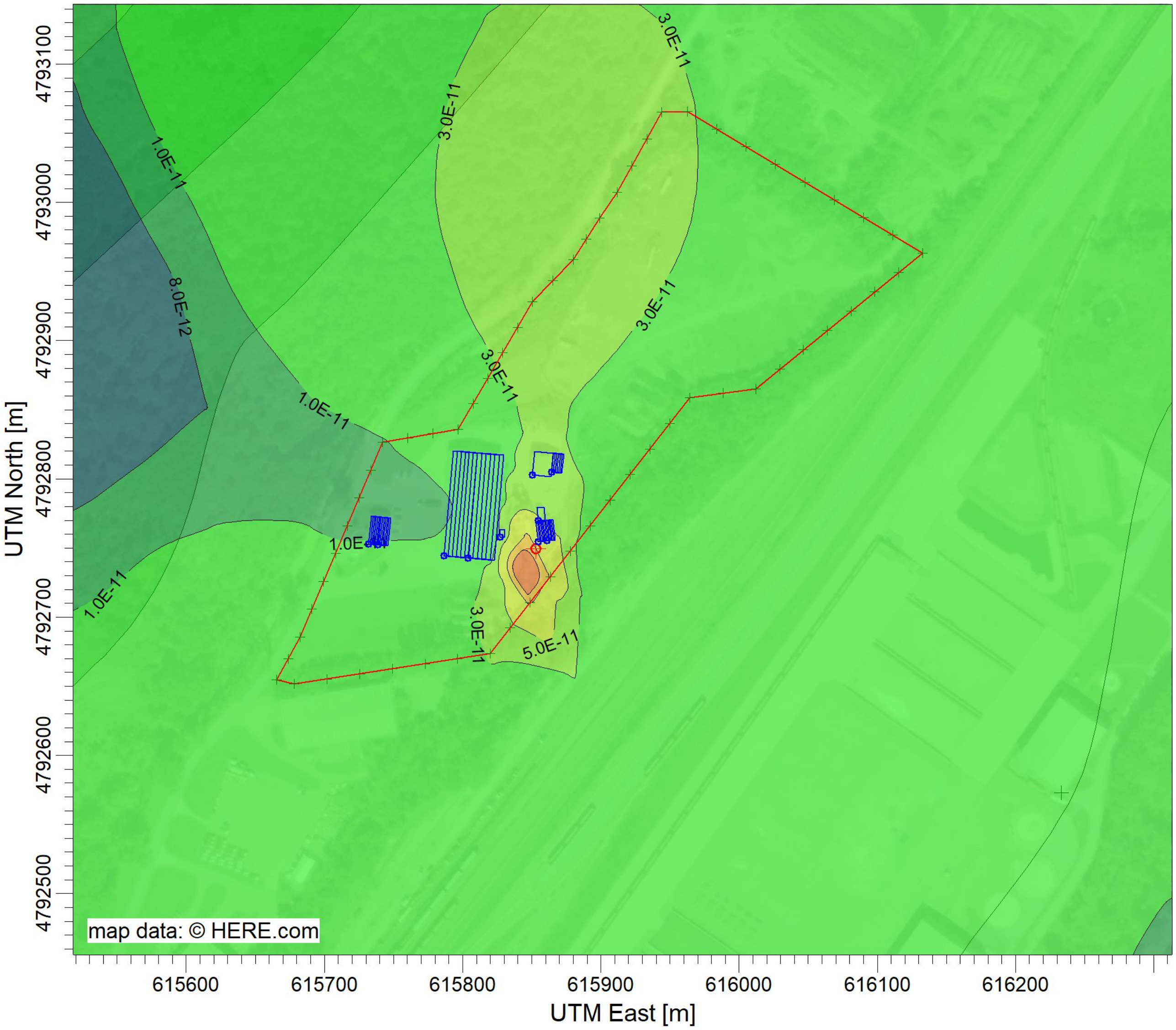
MAX: **1.1E-10 g/m^2**

DATE: **8/30/2023**

PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

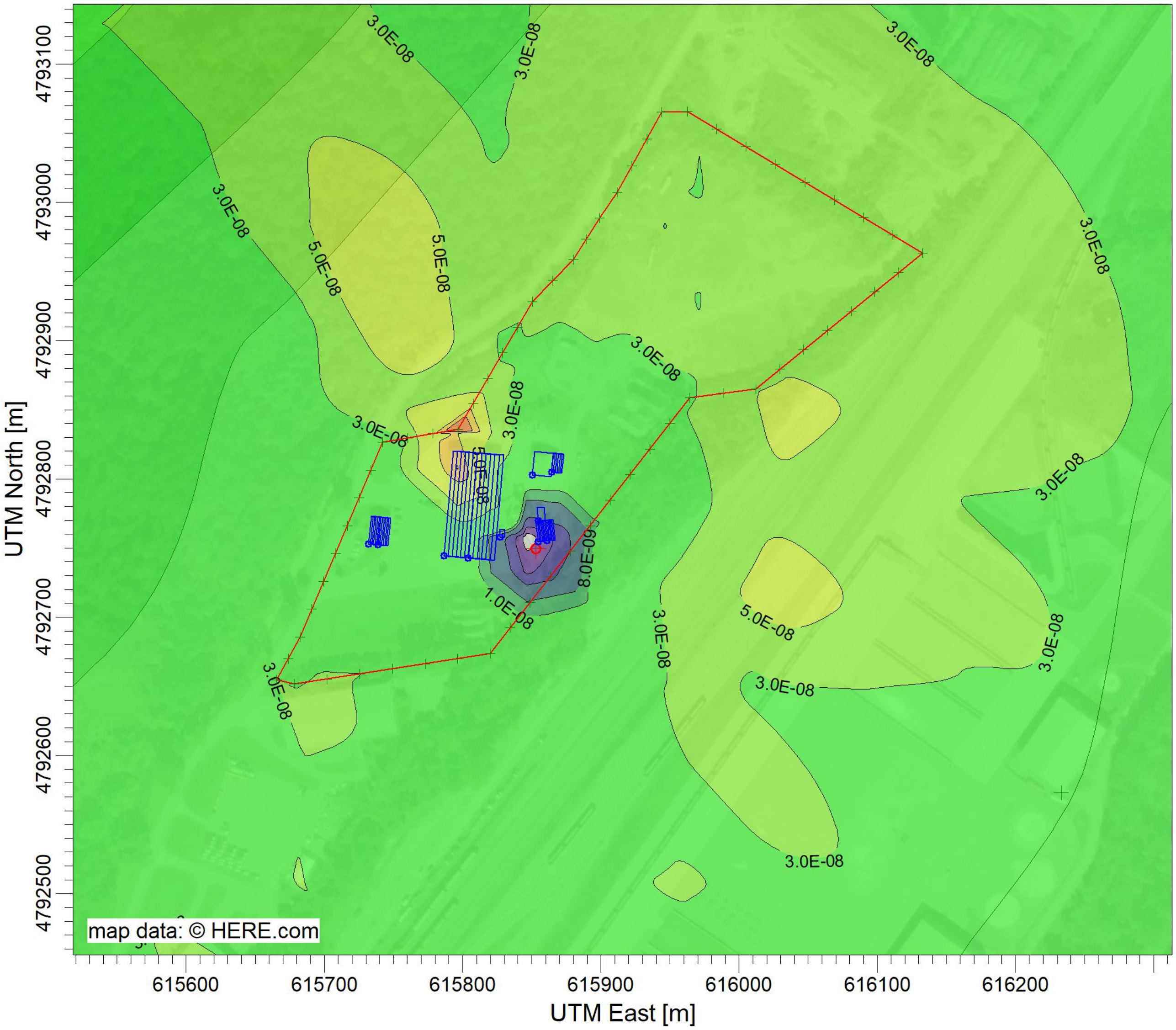
Max: 1.5E-10 [g/m^2] at (615846.24, 4792732.92)

1.5E-12 3.0E-12 5.0E-12 8.0E-12 1.0E-11 3.0E-11 5.0E-11 8.0E-11 1.0E-10 1.5E-10

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **1.5E-10 g/m^2**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.4E-07 [ug/m^3] at (615796.68, 4792835.91)

1.4E-09	3.0E-09	5.0E-09	8.0E-09	1.0E-08	3.0E-08	5.0E-08	8.0E-08	1.0E-07	1.4E-07
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥

COMMENTS:

Air Dispersion Results

Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE:

1:5,000

0 0.1 km

MAX:

1.4E-07 ug/m^3

DATE:

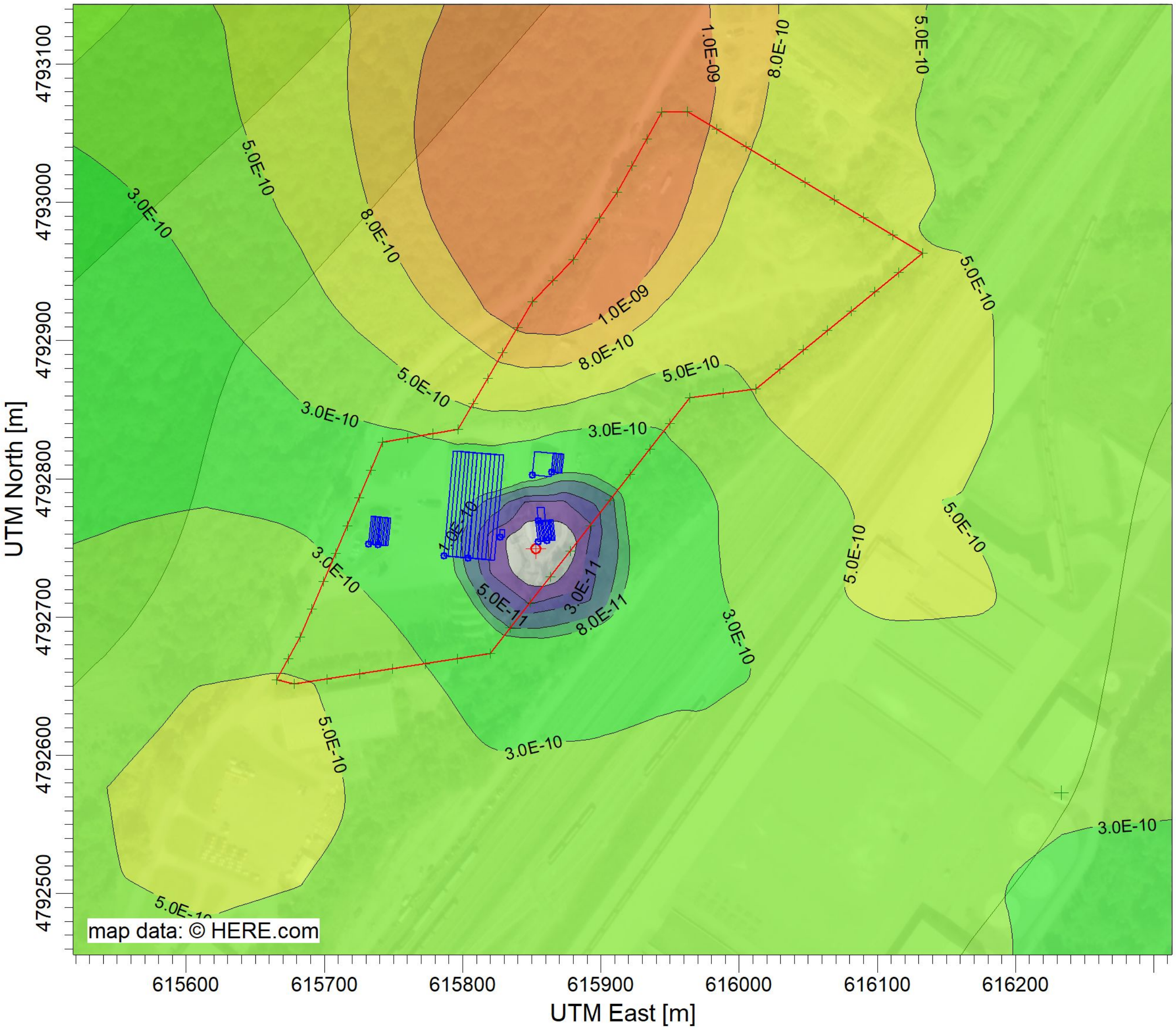
8/30/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

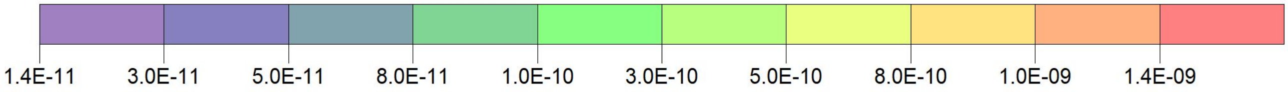
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.4E-09 [ug/m^3] at (615888.44, 4792991.00)



COMMENTS:

Air Dispersion Results

Perfluorooctanoic Acid (CAS No. 335-67-1) with Incoming Soil Concentration to Facility at 4.482 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE: 1:5,000

0 0.1 km

MAX:

1.4E-09 ug/m^3

DATE:

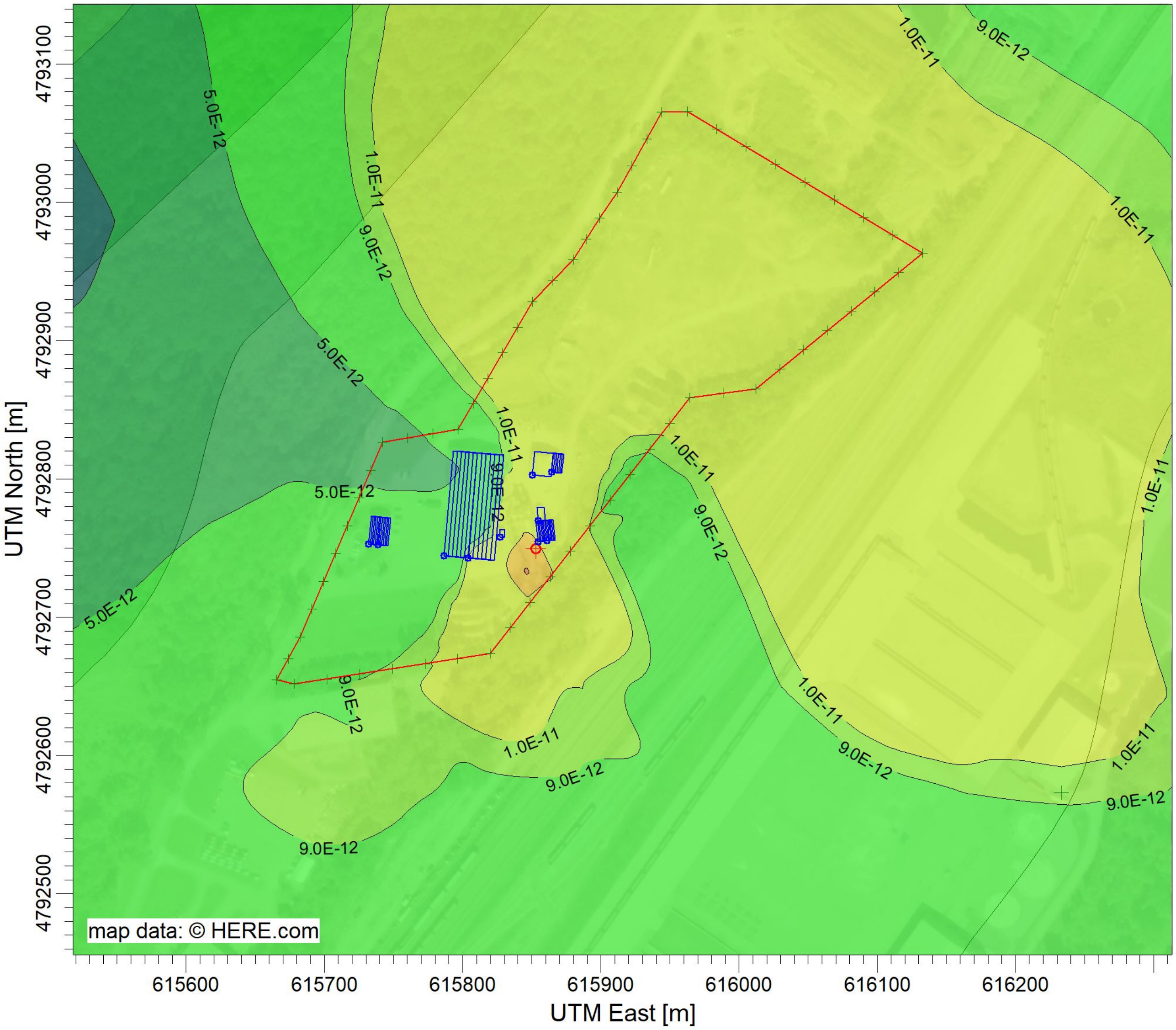
8/30/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

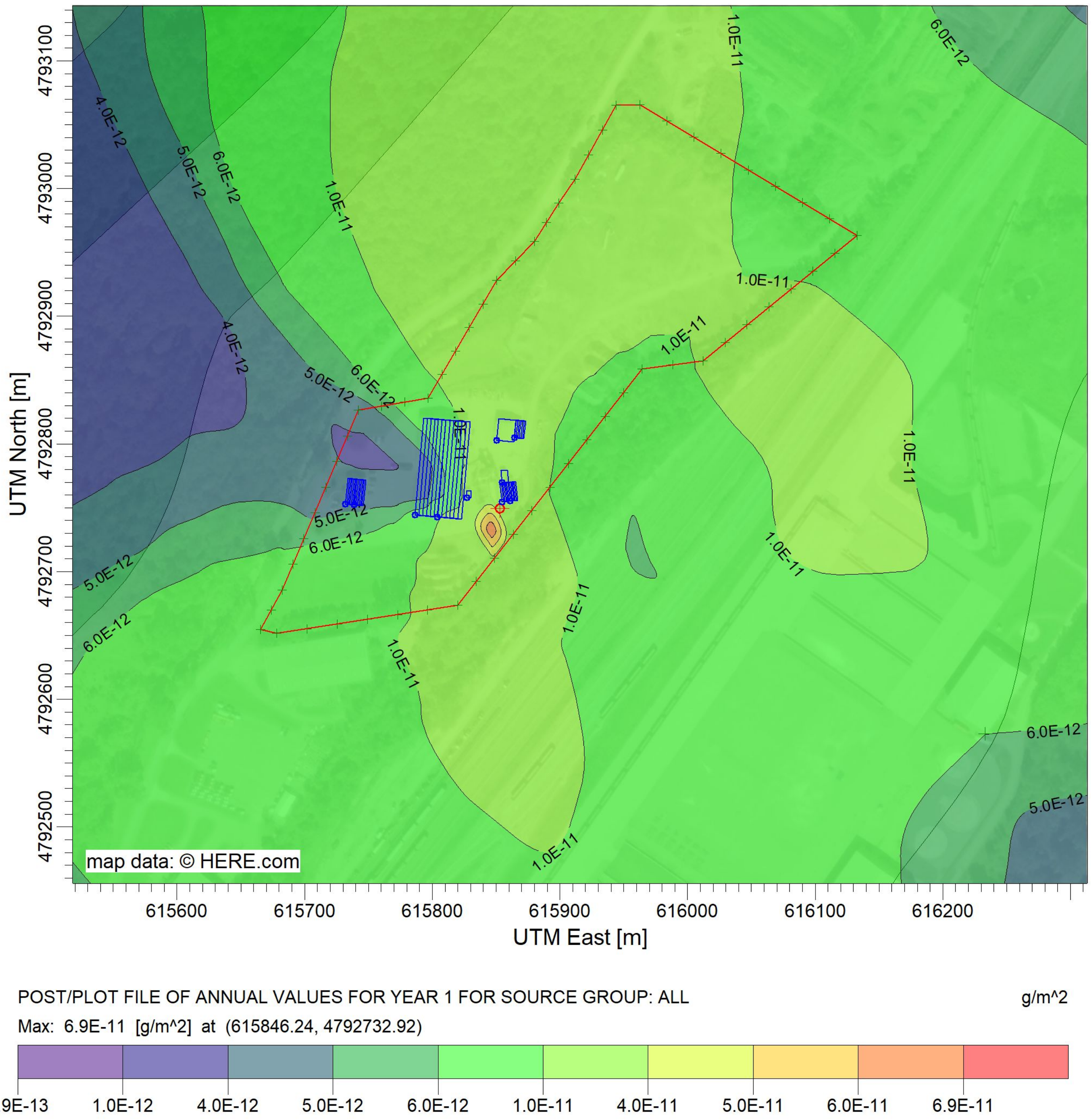
Max: 5.3E-11 [g/m^2] at (615846.24, 4792732.92)

5.3E-13	9.0E-13	1.0E-12	3.0E-12	5.0E-12	9.0E-12	1.0E-11	3.0E-11	5.0E-11	5.3E-11

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km
	MAX: **5.3E-11 g/m^2**	DATE: **8/30/2023**
		PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

Max: 6.9E-11 [g/m^2] at (615846.24, 4792732.92)

COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE: 1:5,000

0 0.1 km

MAX:

6.9E-11 g/m^2

DATE:

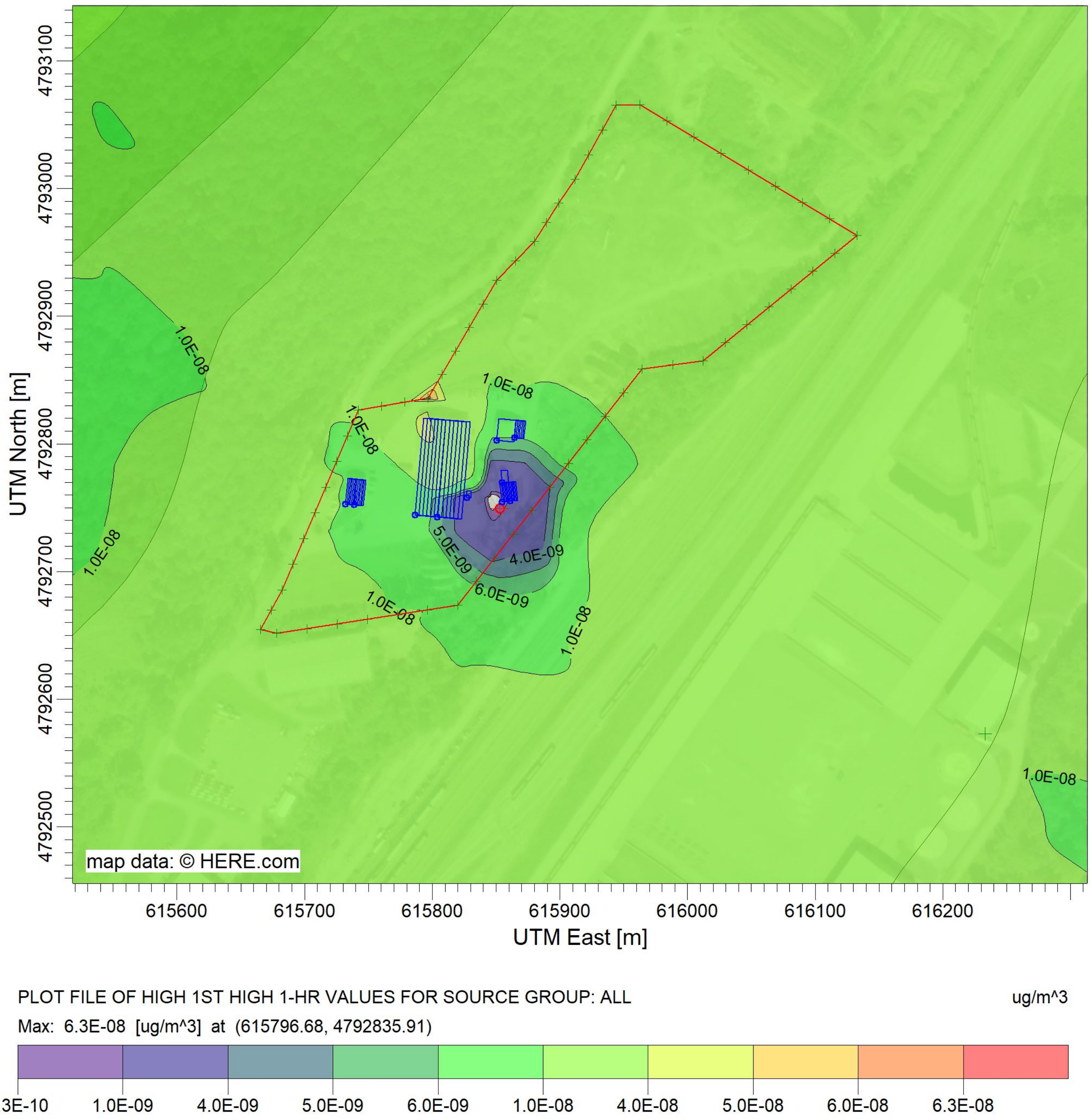
8/30/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

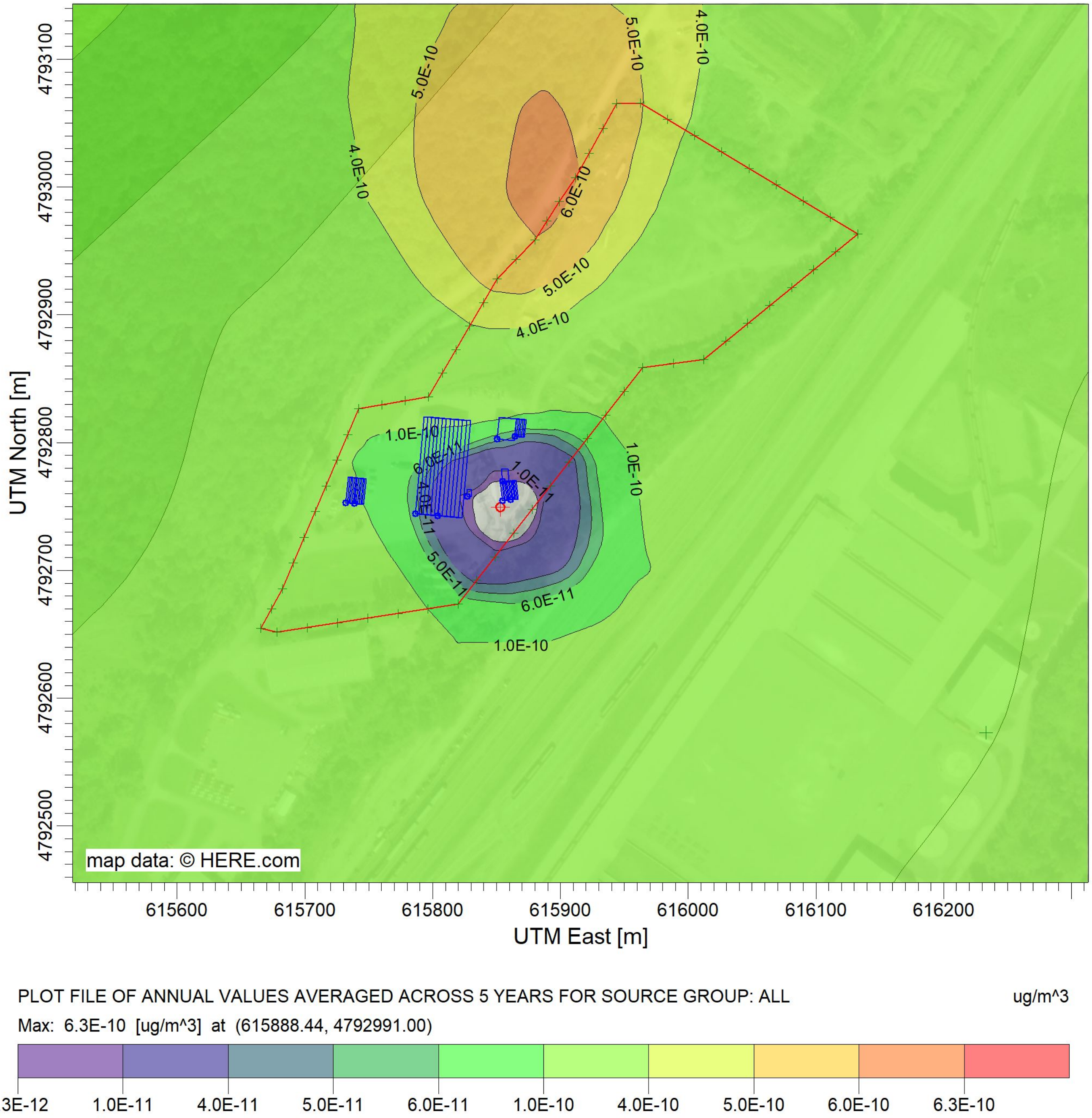
ug/m^3

Max: 6.3E-08 [ug/m^3] at (615796.68, 4792835.91)

COMMENTS: Air Dispersion Results Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 ▬ 0.1 km	
	MAX: **6.3E-08 ug/m^3**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

Max: 6.3E-10 [ug/m^3] at (615888.44, 4792991.00)

COMMENTS:

Air Dispersion Results

Perfluorononanoic Acid (CAS No. 375-95-1) with Incoming Soil Concentration to Facility at 2.061 ug/kg

SOURCES:
1

COMPANY NAME:
C.T. Male Associates

RECEPTORS:
4001

MODELER:
C.T. Male Staff

OUTPUT TYPE:
Concentration

SCALE: 1:5,000

0 0.1 km

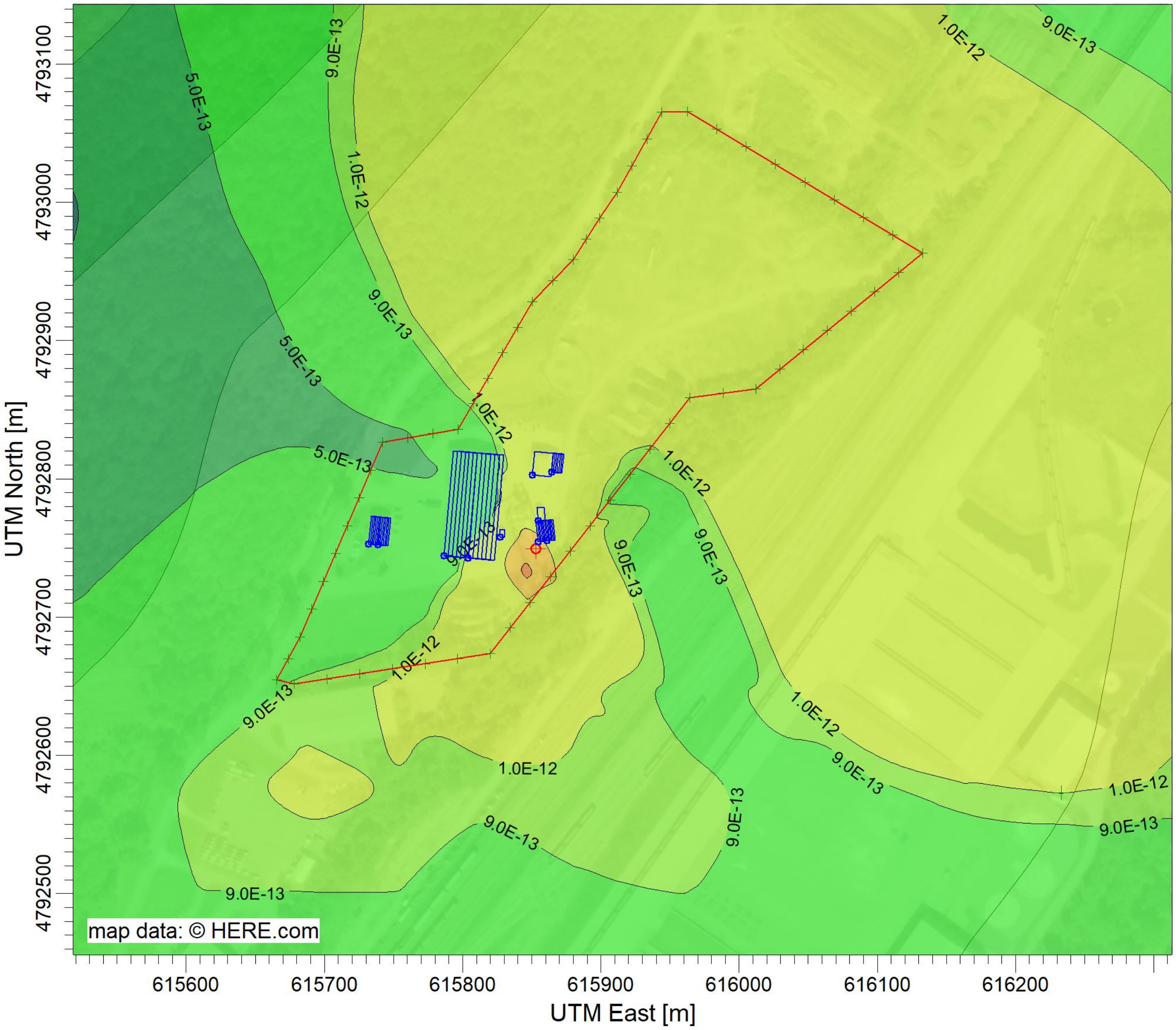
MAX:
6.3E-10 ug/m^3

DATE:
8/30/2023

PROJECT NO.:
22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

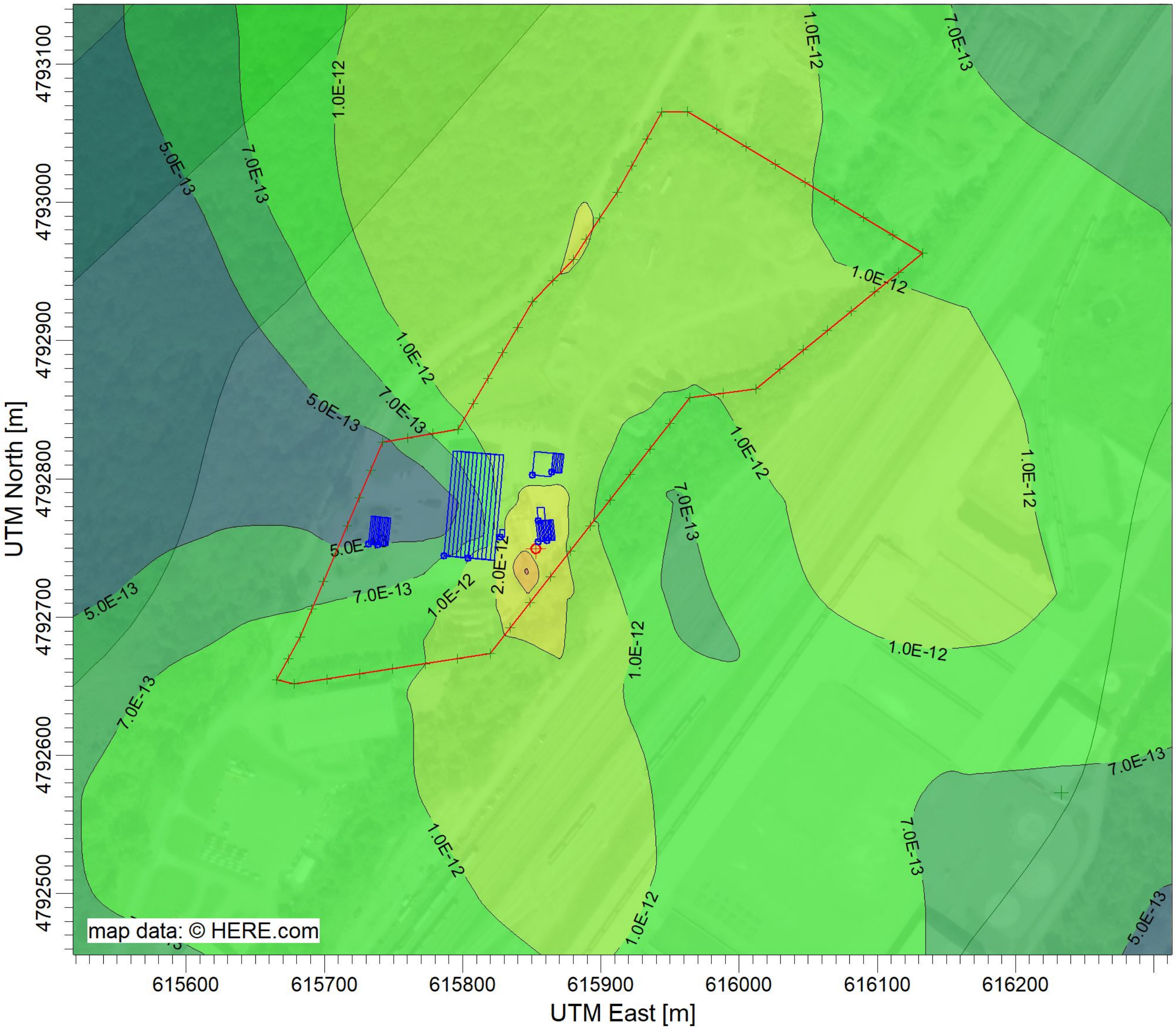
Max: 5.6E-12 [g/m^2] at (615846.24, 4792732.92)

5.6E-14 9.0E-14 1.0E-13 3.0E-13 5.0E-13 9.0E-13 1.0E-12 3.0E-12 5.0E-12 5.6E-12

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **5.6E-12 g/m^2**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

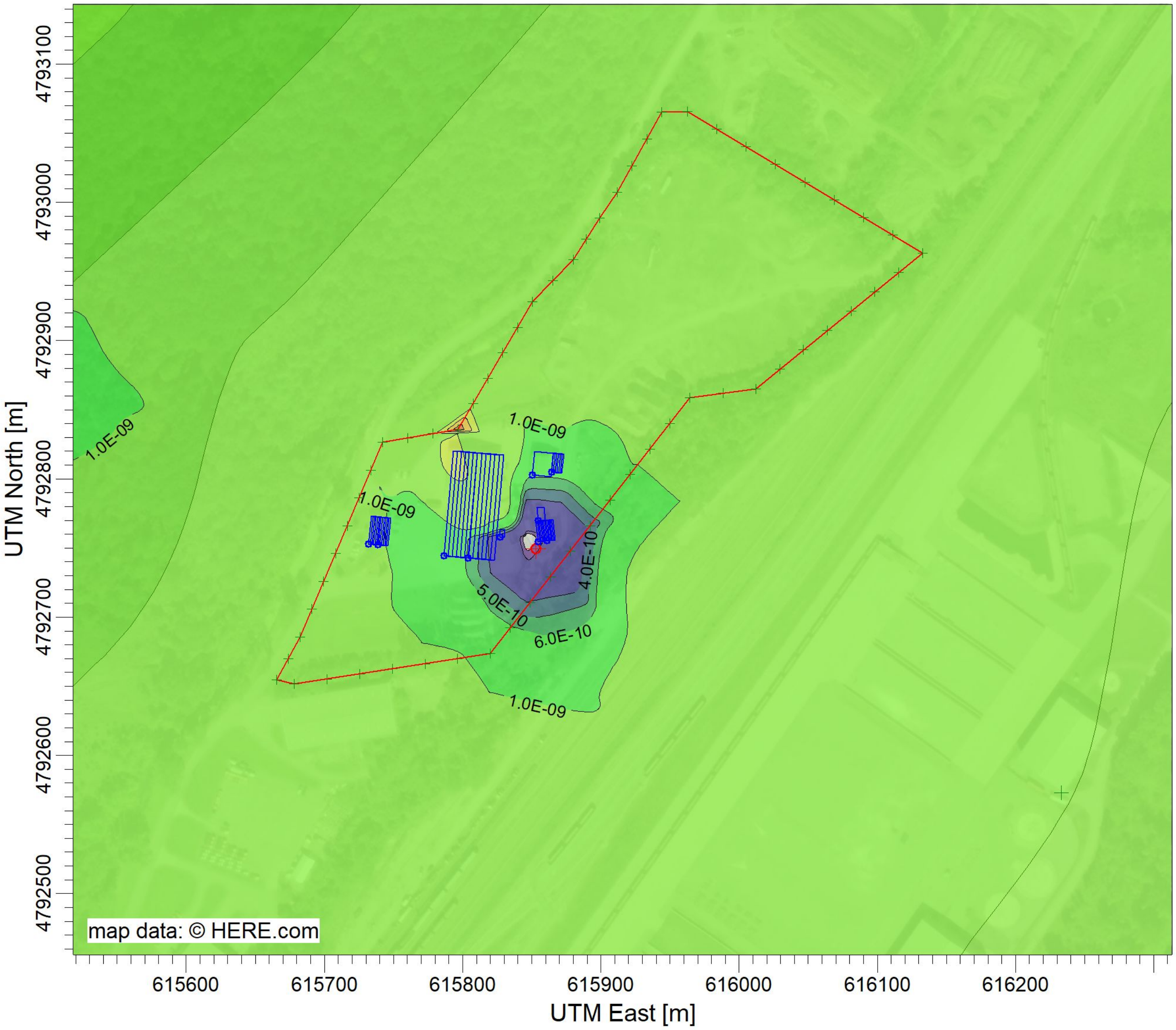
Max: 7.3E-12 [g/m^2] at (615846.24, 4792732.92)

7.3E-14	1.0E-13	2.0E-13	5.0E-13	7.0E-13	1.0E-12	2.0E-12	5.0E-12	7.0E-12	7.3E-12

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. MALE ASSOCIATES**	
	RECEPTORS: **4001**	MODELER: **C.T. MALE STAFF**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **7.3E-12 g/m^2**	DATE: **12/19/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 6.8E-09 [ug/m^3] at (615796.68, 4792835.91)

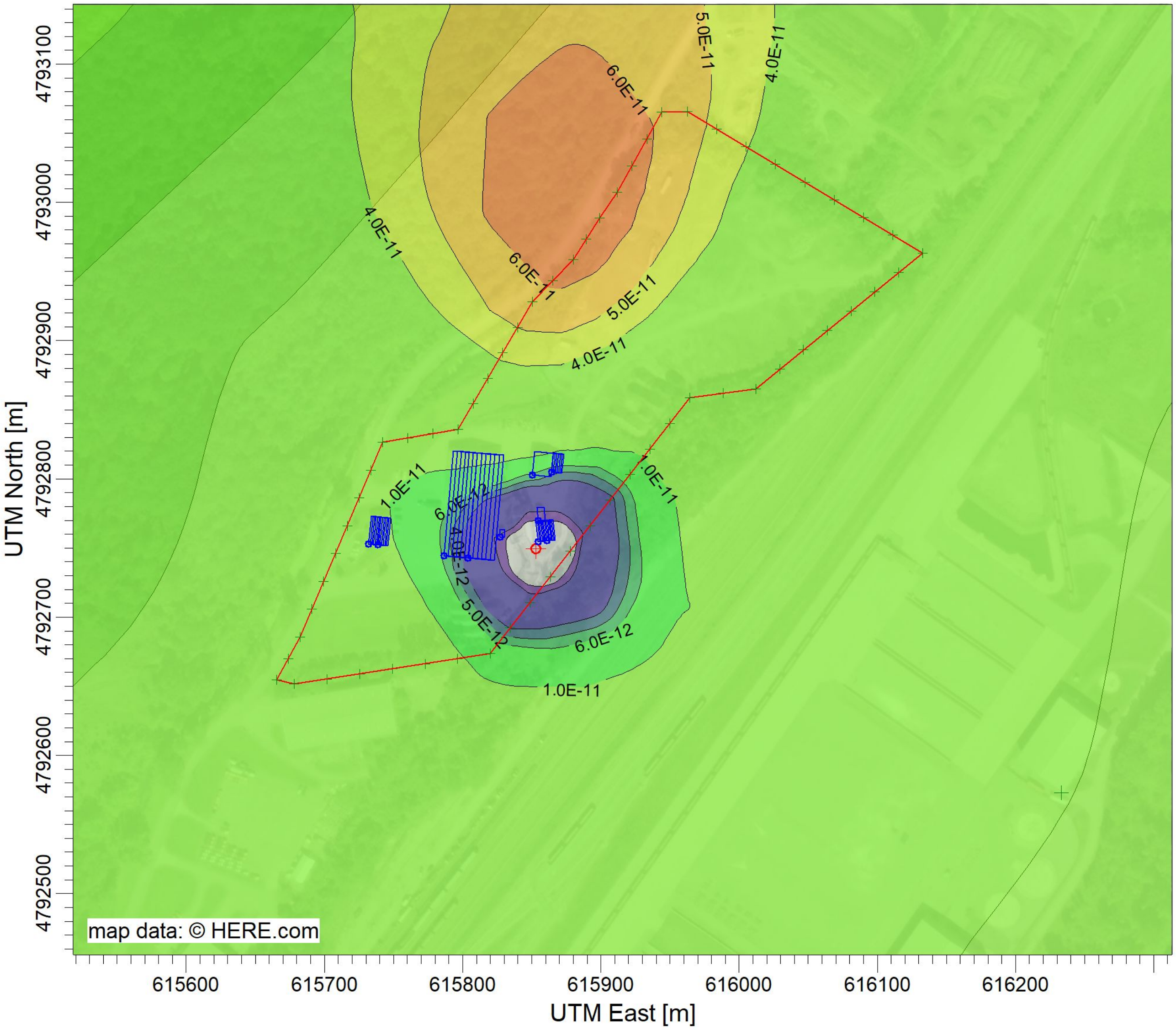
🟪	🟪	🟦	🟩	🟩	🟩	🟨	🟨	🟧	🟥

6.8E-11 1.0E-10 4.0E-10 5.0E-10 6.0E-10 1.0E-09 4.0E-09 5.0E-09 6.0E-09 6.8E-09

COMMENTS: Air Dispersion Results Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 ▬ 0.1 km	
	MAX: **6.8E-09 ug/m^3**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL ug/m^3

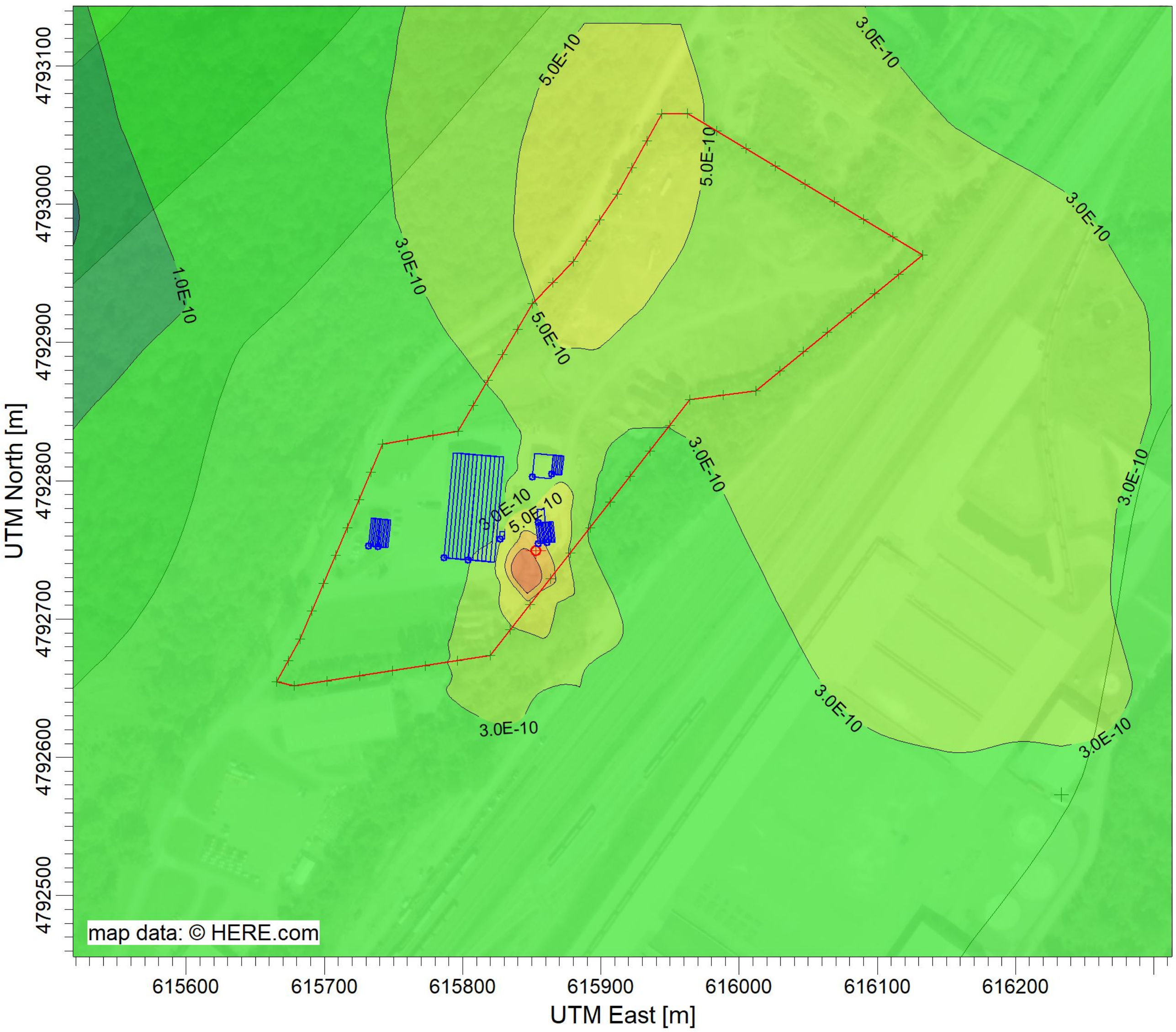
Max: 6.7E-11 [ug/m^3] at (615888.44, 4792991.00)

6.7E-13 1.0E-12 4.0E-12 5.0E-12 6.0E-12 1.0E-11 4.0E-11 5.0E-11 6.0E-11 6.7E-11

COMMENTS: Air Dispersion Results Perfluorohexanesulfonic Acid (CAS No. 335-46-4) with Incoming Soil Concentration to Facility at 0.220 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 ▬ 0.1 km	
	MAX: **6.7E-11 ug/m^3**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

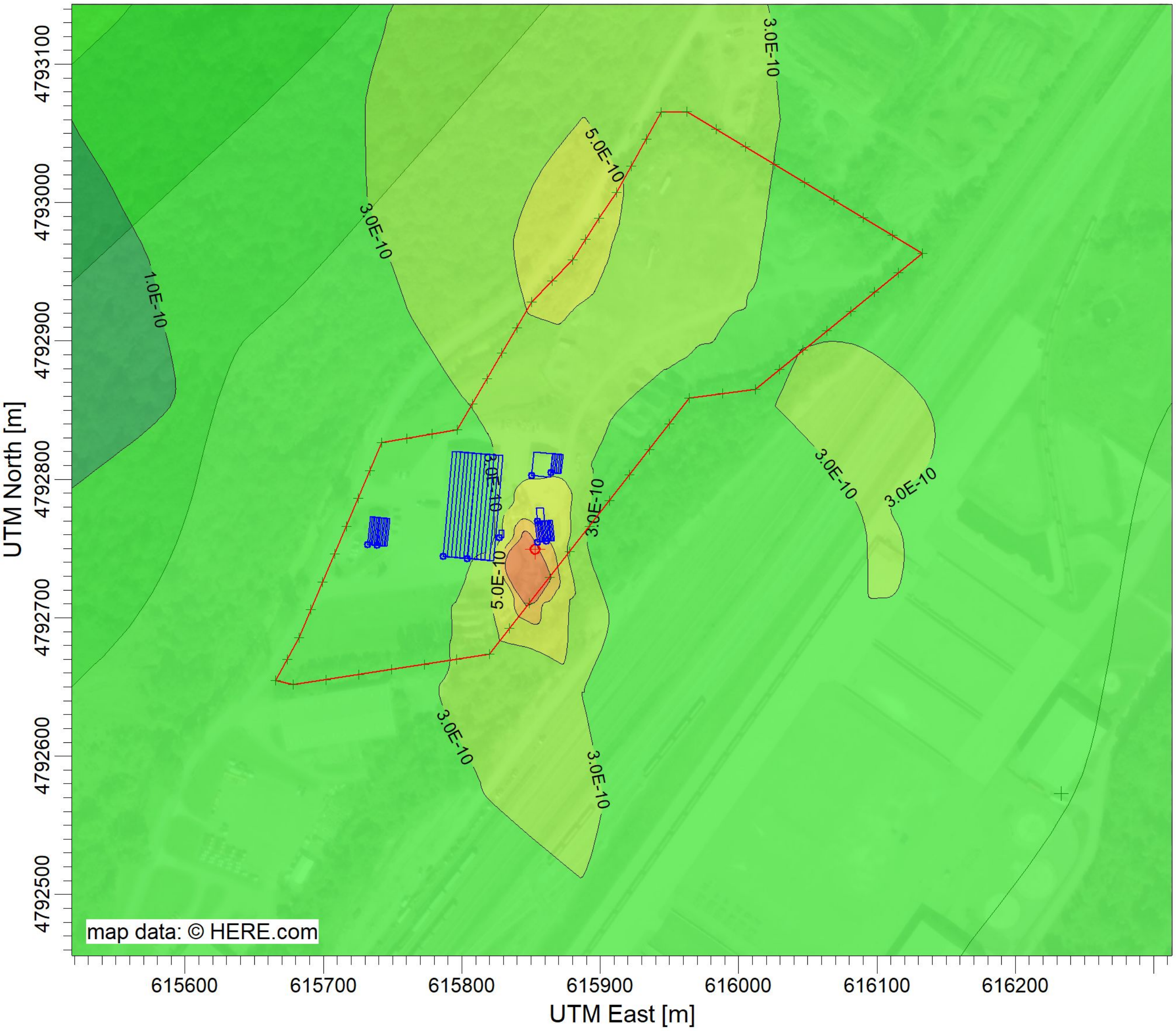
Max: 1.5E-09 [g/m^2] at (615846.24, 4792732.92)

1.5E-11 | 3.0E-11 | 5.0E-11 | 8.0E-11 | 1.0E-10 | 3.0E-10 | 5.0E-10 | 8.0E-10 | 1.0E-09 | 1.5E-09

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **1.5E-09 g/m^2**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

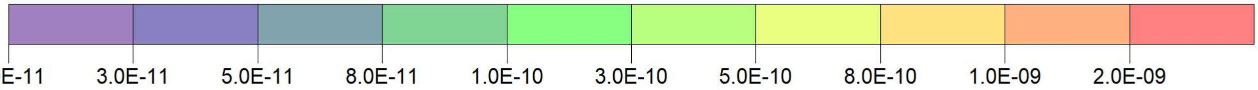
PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

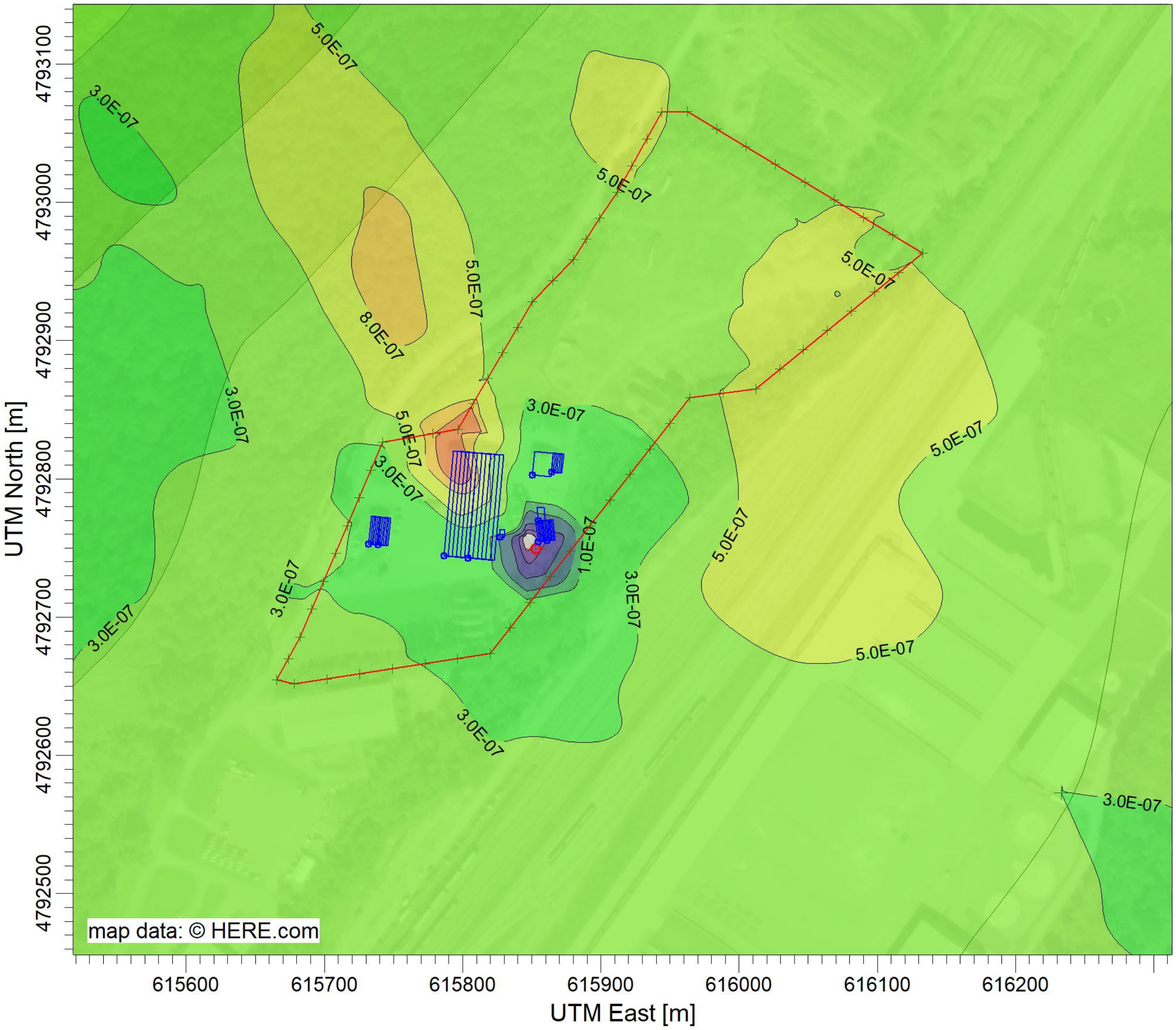
Max: 2.0E-09 [g/m^2] at (615846.24, 4792732.92)



COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km
	MAX: **2.0E-09 g/m^2**	DATE: **8/30/2023**
		PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 1.8E-06 [ug/m^3] at (615796.68, 4792835.91)

🟪	🟪	⬛	🟩	🟩	🟩	🟨	🟨	🟧	🟥

1.8E-08 3.0E-08 5.0E-08 8.0E-08 1.0E-07 3.0E-07 5.0E-07 8.0E-07 1.0E-06 1.8E-06

COMMENTS:

Air Dispersion Results

Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE: 1:5,000

0 0.1 km

MAX:

1.8E-06 ug/m^3

DATE:

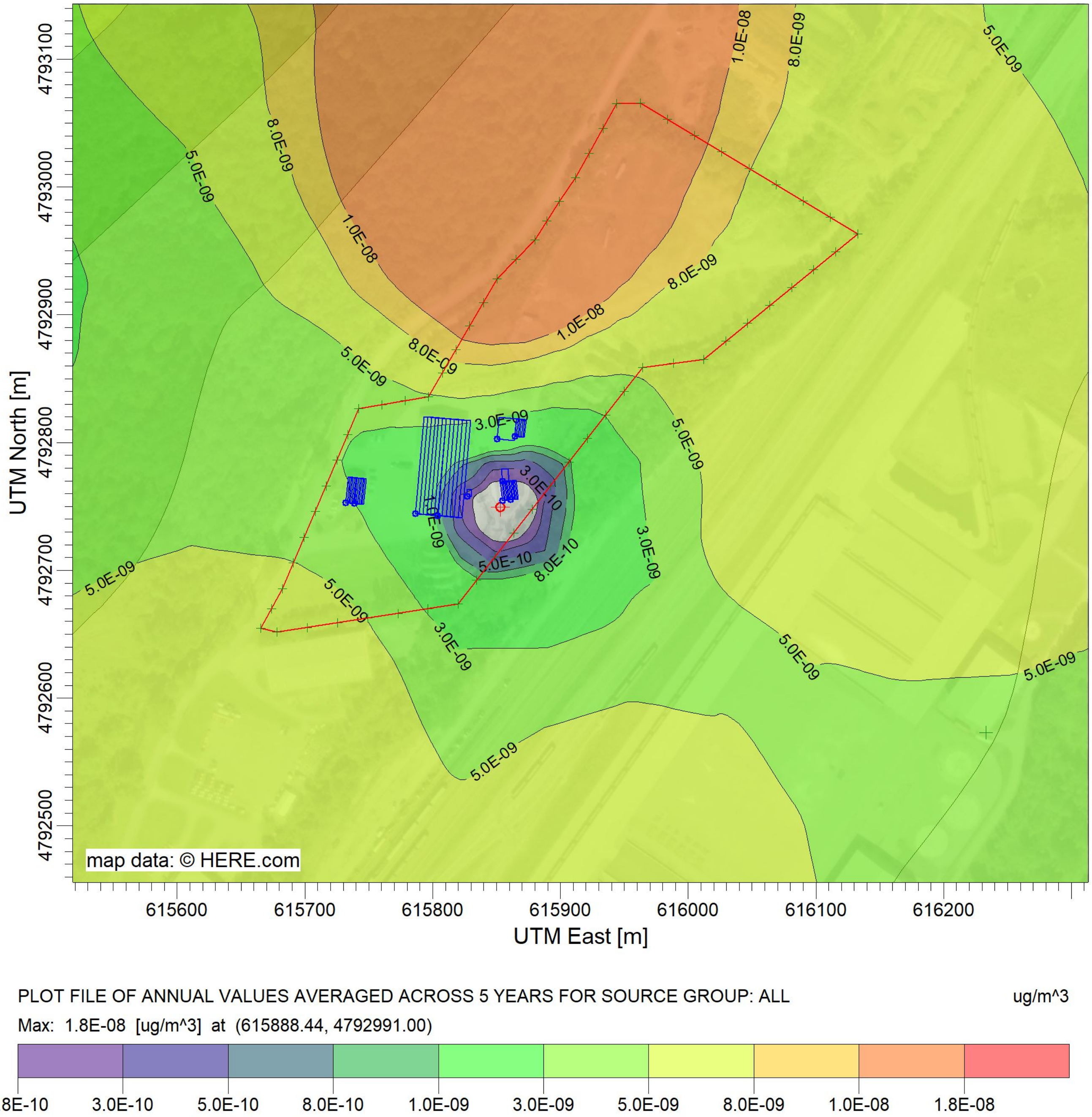
8/30/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.99% PFAS DRE



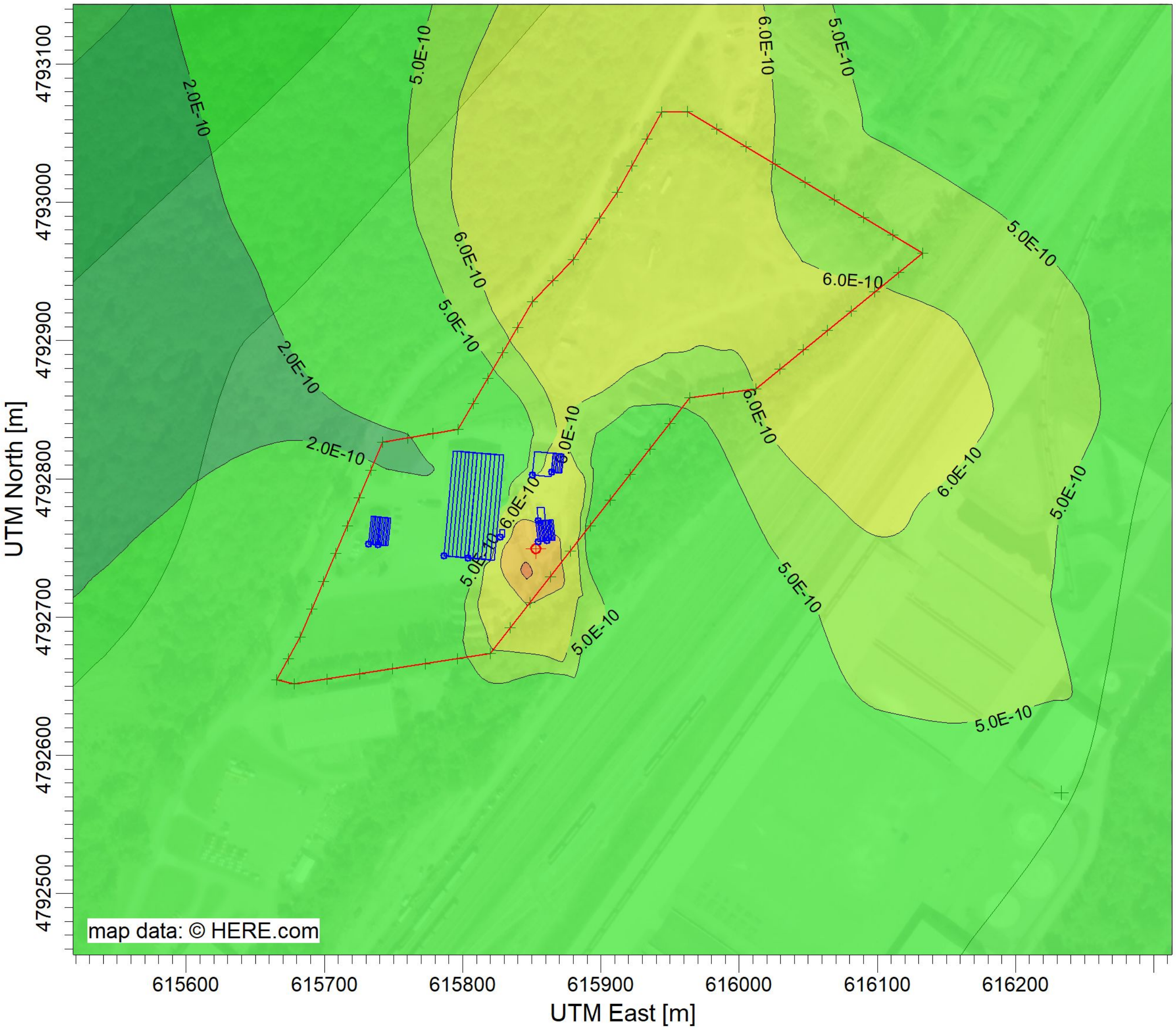
PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

Max: 1.8E-08 [ug/m^3] at (615888.44, 4792991.00)

COMMENTS: Air Dispersion Results Perfluorooctanesulfonic Acid (CAS No. 1763-23-1) with Incoming Soil Concentration to Facility at 58.793 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 0.1 km	
	MAX: **1.8E-08 ug/m^3**	DATE: **8/30/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

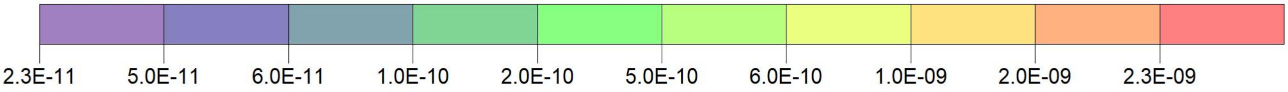
Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 4 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL

g/m^2

Max: 2.3E-09 [g/m^2] at (615846.24, 4792732.92)



COMMENTS:

Method 1 Analysis for PM-10 to Represent PFAS

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Total Depos.

SCALE:

1:5,000

0 0.1 km

MAX:

2.3E-09 g/m^2

DATE:

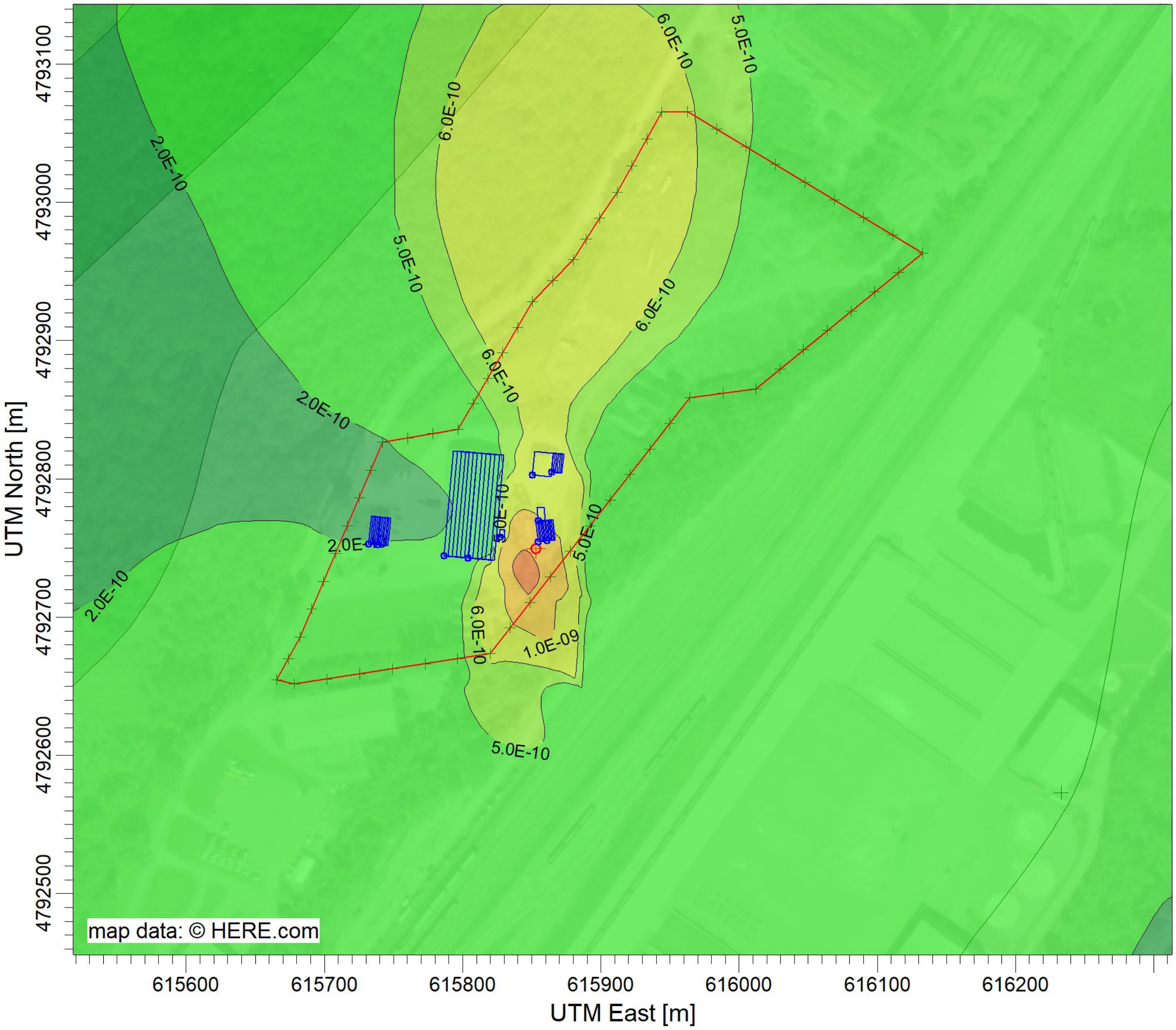
9/1/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Year 5 of 5 - Average Annual Deposition Based on 99.99% PFAS DRE



POST/PLOT FILE OF ANNUAL VALUES FOR YEAR 1 FOR SOURCE GROUP: ALL g/m^2

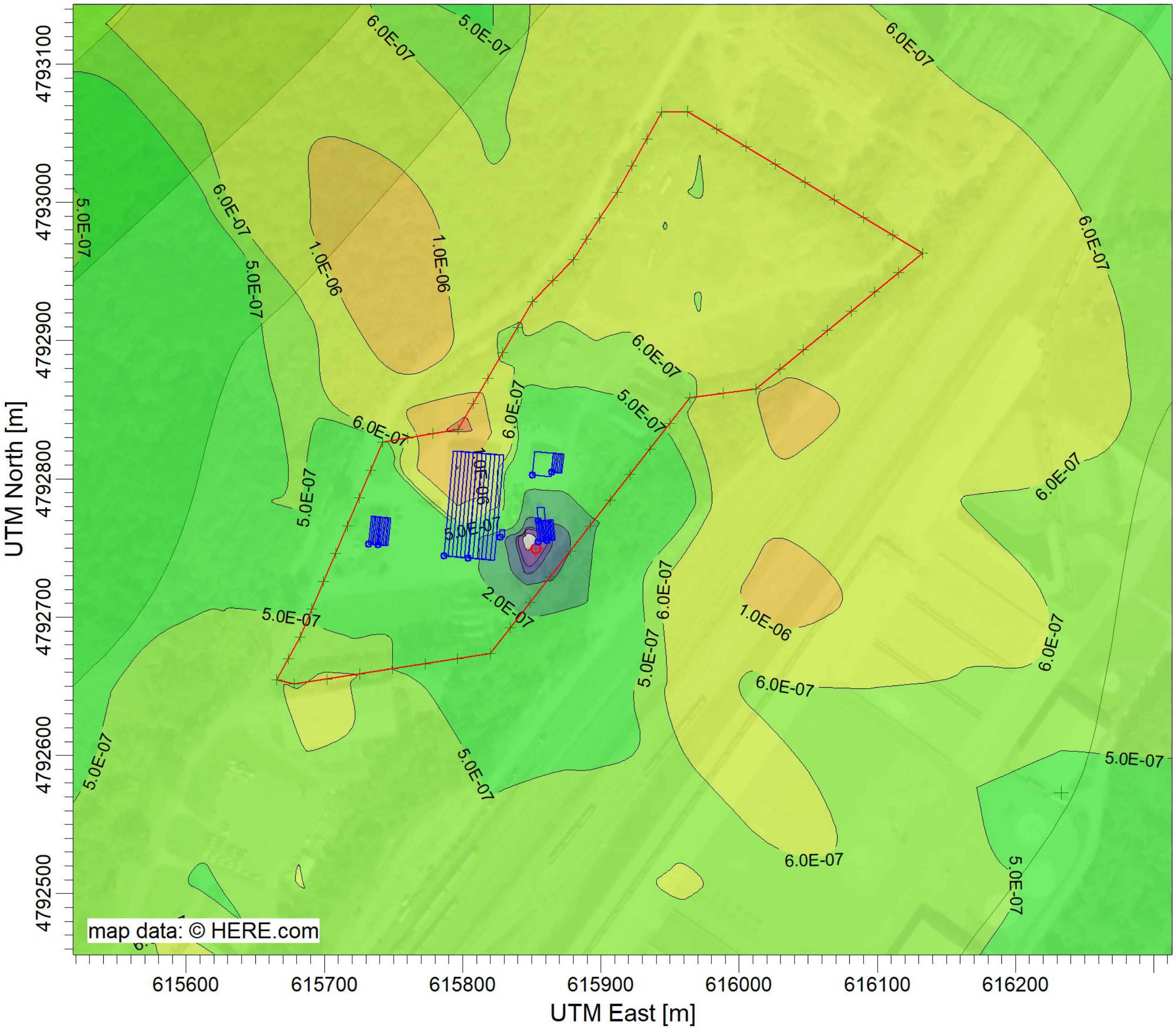
Max: 3.0E-09 [g/m^2] at (615846.24, 4792732.92)

3.0E-11 5.0E-11 6.0E-11 1.0E-10 2.0E-10 5.0E-10 6.0E-10 1.0E-09 2.0E-09 3.0E-09

COMMENTS: Method 1 Analysis for PM-10 to Represent PFAS Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Total Depos.**	SCALE: 1:5,000 0 0.1 km	
	MAX: **3.0E-09 g/m^2**	DATE: **9/1/2023**	PROJECT NO.: **22.2756**

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Hourly Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: ALL

ug/m^3

Max: 2.8E-06 [ug/m^3] at (615796.68, 4792835.91)

2.8E-08 5.0E-08 6.0E-08 1.0E-07 2.0E-07 5.0E-07 6.0E-07 1.0E-06 2.0E-06 2.8E-06

COMMENTS:

Air Dispersion Results

Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg

SOURCES:

1

COMPANY NAME:

C.T. Male Associates

RECEPTORS:

4001

MODELER:

C.T. Male Staff

OUTPUT TYPE:

Concentration

SCALE: 1:5,000

0 0.1 km

MAX:

2.8E-06 ug/m^3

DATE:

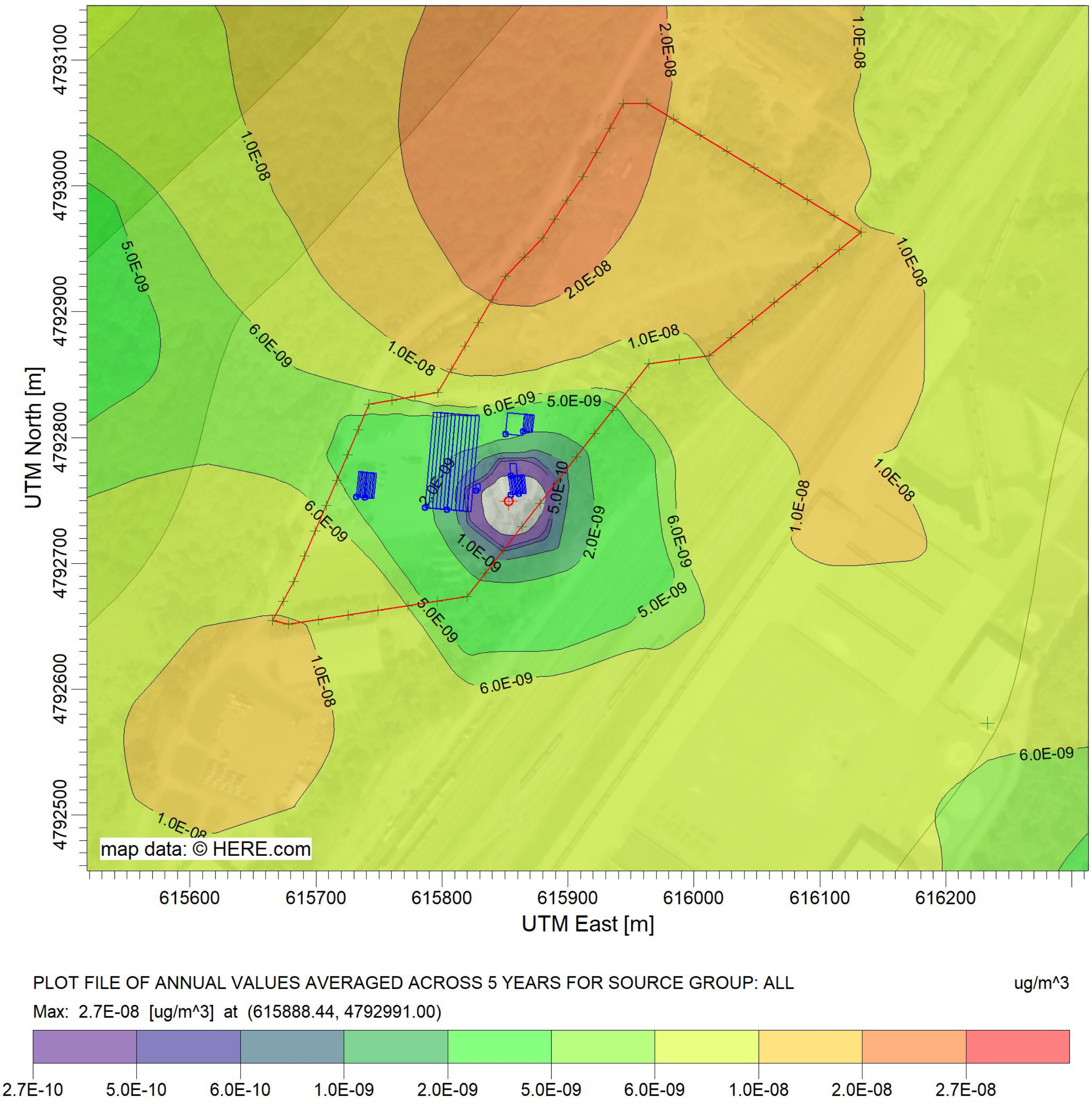
9/1/2023

PROJECT NO.:

22.2756

PROJECT TITLE:

Air Dispersion and Deposition Modeling - Clean Earth Fort Edward, NY Site
Maximum Annual Dispersion Concentration Based on 99.99% PFAS DRE



PLOT FILE OF ANNUAL VALUES AVERAGED ACROSS 5 YEARS FOR SOURCE GROUP: ALL

Max: 2.7E-08 [ug/m^3] at (615888.44, 4792991.00)

COMMENTS: Air Dispersion Results Sum of All PFAS Compounds with Incoming Soil Concentration to Facility at 89.485 ug/kg	SOURCES: **1**	COMPANY NAME: **C.T. Male Associates**	
	RECEPTORS: **4001**	MODELER: **C.T. Male Staff**	
	OUTPUT TYPE: **Concentration**	SCALE: 1:5,000 0 ▬ 0.1 km	
	MAX: **2.7E-08 ug/m^3**	DATE: **9/1/2023**	PROJECT NO.: **22.2756**

Attachment C

NYSDOH Prepared "Summary of Toxicological Assessment for Carbon Tetrafluoride in Support of the Development of an AGC and SGC for the NYSDEC"

Bureau of Toxic Substance Assessment
Division of Environmental Health Assessment
Center for Environmental Health
October 2023

Summary of the Toxicological Assessment of Carbon Tetrafluoride in Support of the Development of an Annual Guideline Concentration (AGC) and Short-term Guideline Concentration (SGC) for the NYS Department of Environmental Conservation (NYS DEC)

1. Executive Summary of Recommended Annual Guideline Concentration

At the request of the NYS DEC's Division of Air Resources, the New York State Department of Health's (NYS DOH) Bureau of Toxic Substance Assessment (BTSA) evaluated the toxicity of carbon tetrafluoride in support of the development of an AGC. As described in the bulleted summaries below, the NYS DOH searched for acute, subchronic and chronic toxicity information from authoritative bodies and the scientific literature. The toxicological database for carbon tetrafluoride was found to be very limited and inadequate to derive an AGC. Chemical-specific toxicity data sufficient to evaluate the potential for portal-of-entry effects (including irritation at the site of contact) and/or systemic effects from acute, subchronic or chronic exposures (via oral and inhalation routes of exposure) were not available for carbon tetrafluoride. Thus, NYS DOH evaluated the toxicity of structurally similar chemicals to derive an AGC for carbon tetrafluoride by inference to structurally similar chemicals for which toxicity information is available. This approach is permitted under the NYS DEC (2021) guidelines for the derivation of AGCs, which states: "if information about a chemical is limited, structure activity relationships for chemicals of close or similar structure will be used to calculate an interim AGC." Therefore, the NYS DOH recommends an AGC for carbon tetrafluoride of 0.33 milligrams per cubic meter (mg/m^3) based upon the toxicity of two structurally similar analogues (i.e., trichlorofluoromethane and dichlorodifluoromethane). Since chemical-specific toxicity information on carbon tetrafluoride was found to be insufficient to inform whether the health effects of carbon tetrafluoride are likely to be portal-of-entry, systemic or both, carbon tetrafluoride is being treated as a Category 3 gas based on toxicity studies for the two selected analogues (trichlorofluoromethane and dichlorodifluoromethane), which demonstrate that the predominant toxicological effects from inhalation exposure to these two chemicals are systemic effects. Inhalation toxicity values from authoritative bodies are available for these two chemicals and are based on noncancer health effects from inhalation exposures in animals and humans. The NYS DOH used these inhalation toxicity values, along with the application of uncertainty factors to account for less than lifetime exposures in the critical studies to derive the recommended AGC for carbon tetrafluoride. Based on the uncertainties and limitations presented by the absence of chemical-specific toxicity information for carbon tetrafluoride, the NYS DOH supports the adoption of 0.33 mg/m^3 as an interim AGC value, which could change if new and adequate chemical-specific toxicity data become available.

2. Search Criteria Used to Evaluate the Toxicity of Carbon Tetrafluoride

To evaluate whether an AGC and/or SGC could be derived based on chemical-specific toxicity information on carbon tetrafluoride, internet searches were performed for the following six key areas of information:

1) Physical-chemical properties
2) Basic information on chemical use and manufacturing

3) Chronic and subchronic toxicity values (including oral and inhalation cancer and noncancer toxicity values)
4) Toxicity studies from the scientific literature (acute, subchronic and chronic studies for oral and inhalation routes of exposure)
5) Other toxicity information (e.g., pharmacokinetics and mode-of-action (MOA) for toxicity)
6) Occupational exposure limits

3. Physical-Chemical Properties and Chemical Use of Carbon Tetrafluoride

Carbon tetrafluoride is a colorless, odorless, nonflammable gas that is used as a refrigerant (PubChem, 2023). Carbon tetrafluoride is also a stable combustion byproduct that can be emitted into air via the incineration of fluorine-containing waste (Lohmann et al., 2020). Carbon tetrafluoride can also be emitted into air through industrial activities, such as aluminum production (US EPA and IAI, 2008). Additional information on the physical-chemical properties of carbon tetrafluoride is provided in Appendix B (Table B – 1).

4. Toxicity Information on Carbon Tetrafluoride

The available information on the toxicity of carbon tetrafluoride is very limited. Chronic and subchronic toxicity values from authoritative bodies are not available. In addition, chronic or subchronic carbon tetrafluoride toxicity studies by the inhalation or oral routes of exposure were not found. The toxicological database on carbon tetrafluoride is inadequate to derive toxicity values[1] based on cancer or noncancer long term health effects, and thus, is inadequate to derive an AGC using chemical-specific information.

NYS DEC (2021) uses acute toxicity data (e.g., lethality data) for toxicity classification of air contaminants and uses occupational exposure limits to derive AGC/SGC values in the absence of chronic toxicity values. While BTSA has not derived health-based guidance values for evaluating acute occupational exposures in the past, in order to assess the overall completeness of the toxicological database for carbon tetrafluoride, acute toxicity studies (inhalation and oral routes of exposure) and occupational exposure limits were included in the search criteria.

Fluorine-based occupational exposure limits for carbon tetrafluoride from European countries (NIOSH, 2023) were found (Appendix B, Table B - 2). However, occupational exposure limits for carbon tetrafluoride are not available from the authoritative bodies that are preferred by NYS DEC (2021) for AGC/SGC development (e.g., American Conference of Governmental Industrial Hygienists (ACGIH)).

Information on the acute toxicity of carbon tetrafluoride is very limited. An acute exposure study is available in the scientific literature (Makowski et al., 2022). However, this study does not use a traditional study design for acute toxicity testing (US EPA, 1998). Rats were exposed via inhalation to normobaric air, hyperbaric air, or a hyperbaric mixture containing a high concentration of carbon tetrafluoride (i.e., 79% carbon tetrafluoride, 21% oxygen) for 30 minutes per day for 5 days. Statistically significant effects on bodyweight were reported in females exposed to hyperbaric carbon tetrafluoride, but the authors reported that these bodyweights were within the normal range reported in the scientific literature. The lowest published lethal concentration is 895,000 parts per million per 15 minutes in rats via inhalation exposure (NIOSH, 2023). The available

---

[1] Both inhalation and oral toxicity values were considered based on the potential use of route-to-route extrapolation for health effects that are systemic (i.e., not point-of-contact).

information, while limited, suggests low acute toxicity.[2] However, the available information on the acute toxicity of carbon tetrafluoride is limited and insufficient to derive a chemical-specific SGC.

5. Identification of Structurally Similar Carbon Tetrafluoride Analogues

Given that the available chemical-specific information on carbon tetrafluoride was insufficient to derive an AGC (which was the focus of this assessment), the next phase of the assessment was to identify possible carbon tetrafluoride analogues to evaluate the chronic and subchronic toxicity of structurally similar compounds. Use of toxicity data on structurally similar compounds for inference to the potential toxicity of carbon tetrafluoride, in the absence of chemical-specific information, is permitted under NYS DEC (2021) guidelines for the derivation of AGCs.

Online tools, including ChemIDPlus[3] (NLM, 2022), Integrated Chemical Environment (NTP, 2022) and the Comptox Dashboard (US EPA, 2022)[4], were used to identify structurally similar analogues to carbon tetrafluoride. Structurally similar analogues meeting criteria of greater than or equal to 80% similarity, 0.8 similarity threshold or 0.8 Tanimoto score are included in Appendix B (Table B – 3). While disparate similarity metrics cannot be directly compared, higher values (on scales of 0 to 100% or 0 to 1) generally indicate higher levels of structural similarity to carbon tetrafluoride. Table 1 includes structural similarity scores from Appendix B (Table B – 3) for a subset of structurally similar carbon tetrafluoride analogues for which inhalation toxicity values are available.

6. Method for Obtaining Toxicity Information on Structurally Similar Carbon Tetrafluoride Analogues

The online tools for quantitatively assessing structural similarity to carbon tetrafluoride provided approximately 20 structurally similar analogues for consideration (Appendix B, Table B - 3). For these chemicals, online searches were performed for the six key areas of information listed in Section 2 (e.g., physical chemical properties, acute, subchronic and chronic toxicity values, scientific literature on acute, subchronic and chronic toxicity).

To streamline the process for obtaining toxicity information on structurally similar analogues, initial searches were performed using the Comptox Dashboard (US EPA, 2022), which provided available toxicity values. Moreover, consistent with NYS DEC (2021) guidance, toxicity values derived by US EPA were prioritized in this

---

[2] Two additional studies were found that evaluate the health effects of exposure in mice to different pressures of gases and gas mixtures (Clarke et al, 1978; Daniels et al., 1979). However, these studies could not be used to assess acute inhalation toxicity as they do not utilize a traditional acute toxicity study design (US EPA, 1998), there were co-exposures to gas mixtures, and air concentrations of carbon tetrafluoride were not reported. Exposure metrics were reported as measures of pressure in these studies (i.e., in atmosphere (ATM) or pounds per square inch (PSI)).

[3] The ChemIDPlus (NLM, 2022) is no longer active as of 2023. The ChemIDPlus database is now part of PubChem. However, the chemical similarity tool in PubChem (NLM, 2023) differs from and provides a different suite of chemicals than ChemIDPlus. The PubChem tool provides less useful analogues than the original ChemIDPlus similarity results and were not considered in this assessment.

[4] Structurally similar compounds were retrieved from the Comptox Dashboard using the “Chemical Details” tab in the carbon tetrafluoride chemical profile. The Comptox Dashboard GenRA tool was also used to determine whether the ToxRef (*in vivo* data) and ToxCast (*in vitro* data) databases could provide suitable analogues for assessment using the automated read-across feature in the Comptox Dashboard GenRA tool. However, the chemicals retrieved via GenRA using *in vivo* data filters (i.e., ToxRef) generally had lower structural similarity based on toxprint and morgan fingerprints (e.g., < 0.5 jaccard similarity for most analogues). Thus, while GenRA was performed as part of this assessment, it ultimately was not used for surrogate selection given the emphasis on identifying chemicals with a high level of structural similarity to carbon tetrafluoride as a means of inferring and predicting toxicity.

assessment for screening of carbon tetrafluoride analogues. The Comptox Dashboard was also used to screen and identify toxicity studies on carbon tetrafluoride analogues via the PubMed Abstract Sifter (US EPA, 2022).

ChemIDPlus (NLM, 2022) and PubChem (NLM, 2023) chemical databases were used to obtain general information on chemical structure, use, physical chemical properties, and acute toxicity information on structurally similar analogues. While additional internet searches were performed, as needed, this hierarchal approach to sourcing and prioritizing toxicity information was implemented given the large number of chemicals that were screened and evaluated in this assessment.

7. **Toxicity Information on Structurally Similar Carbon Tetrafluoride Analogues**

There was limited toxicity information available on most of the identified surrogates. Only three of the approximately 20 structurally similar chemicals (i.e., trichlorofluoromethane, dichlorodifluoromethane and carbon tetrachloride) had available toxicity values that could be used to derive an AGC. Table 1 shows the available cancer and noncancer inhalation toxicity that were found on the three surrogates. However, as described in previous sections, chemical-specific toxicity information on carbon tetrafluoride is insufficient to evaluate carcinogenicity or to support a biological rationale for assessing carbon tetrafluoride carcinogenicity using chemical correlation. Therefore, while searches were performed for information on both cancer and noncancer toxicity of carbon tetrafluoride analogues, noncancer toxicity was prioritized for consideration in the development of a potential AGC.

Of the three analogues, carbon tetrachloride had the most extensive toxicity database. For example, US EPA Integrated Risk Information System (IRIS) derived cancer and noncancer toxicity values for carbon tetrachloride based on oral and inhalation exposure (US EPA IRIS, 2010). Additional inhalation toxicity values were also identified via the Comptox Dashboard (US EPA, 2022) from authoritative bodies such as the Agency for Toxic Substances and Disease Registry (ATSDR, 2005, 2023) and California Office of Environmental Health Hazard Assessment (CA OEHHA, 2008, 2023). By comparison, the toxicity databases were limited for trichlorofluoromethane and dichlorodifluoromethane. For example, oral reference doses for each chemical were derived by US EPA IRIS. However, inhalation toxicity and the potential for carcinogenicity were not assessed under the IRIS program. US EPA derived subchronic reference concentrations (RfCs) under US EPA's Superfund program (i.e., provisional peer-reviewed toxicity values (PPRTV)). However, US EPA did not derive chronic RfCs for trichlorofluoromethane and dichlorodifluoromethane, and determined that there was "inadequate information to assess the carcinogenic potential" of these chemicals.

Table 1 below includes summaries of available inhalation toxicity values for trichlorofluoromethane, dichlorodifluoromethane and carbon tetrachloride from US EPA and other authoritative bodies (e.g., CA OEHHA, Danish Ministry of the Environment (DME), ATSDR and the Michigan Department of Environmental Quality (DEQ)). The toxicity values derived by US EPA, CA OEHHA, ATSDR and the Michigan DEQ are based on extra-respiratory (systemic) effects in animals or humans, and involve application of physiologically based pharmacokinetic (PBPK) modeling or dosimetric adjustment factors for Category 3 gases to calculate human equivalent concentrations (HECs). These methods are consistent with currently accepted risk assessment practices for deriving RfCs.[5] However, the DME did not calculate HECs to derive RfCs and instead used

---

[5] US EPA guidance for deriving RfCs (US EPA, 1994, 2012) recommends inhalation dosimetry to extrapolate from inhalation exposure levels in animals to inhalation exposures in humans. In the absence of physiologically based pharmacokinetic (PBPK) models for

uncertainty factors to account for pharmacokinetic and pharmacodynamic differences between animals and humans.

---

extrapolating between animals and humans, the default recommended approach for application of inhalation dosimetry considers physical-chemical properties as determinants of chemical uptake into the respiratory system (US EPA, 1994, 2012). Category 1 gas characteristics include high solubility in water and/or rapid irreversible reactivity. Category 1 gases do not accumulate in blood and elicit site of contact effects at the portal of entry. Category 2 gases have moderate solubility in water, may be rapidly reversibly reactive or moderately to slowly irreversibly metabolized in the respiratory tract. Category 2 gases have the potential for accumulation in blood and effects may be systemic or at the portal of entry. Category 3 gases have low water solubility, are relatively unreactive in surface liquid and tissue, can accumulate in blood, and have systemic toxicity.

Table 1. Available Inhalation Toxicity Values for Structurally Similar Carbon Tetrafluoride Analogues Identified via Quantitative Structural Similarity Assessment Tools[A,B]

Chemical Name/ CAS Number	Toxicity Value	Source	Study Details	POD/DAF	Toxicity Endpoint	Uncertainty Factors
Analogues (listed in the order of most to least structurally similar to carbon tetrafluoride)						
Trichlorofluoromethane (Freon 11) 75-69-4 *95% structural similarity to carbon tetrafluoride	1 mg/m^3 Subchronic p-RfC	US EPA, 2009; provisional peer-reviewed toxicity Value (PPRTV)	Single exposure concentration study; 5620 mg/m^3 in humans exposed via inhalation 8 hour/day, 5 days/week, for 2 to 4 weeks	LOEL$_{ADJ}$ = 1338 mg/m^3	Small decrements in cognitive performance in humans	1000 UF$_L$ = 10 UF$_H$ = 10 UF$_D$ = 10
	570 mg/m^3 Health-based quality criterion in air	DME, 2014	Single exposure concentration study; Guinea pigs, rats and dogs exposed continuously to 57,000 mg/m^3 for 90 days.	NOEL = 57,000 mg/m^3 An HEC was not calculated; Applied UF approach[C]	No adverse effects reported	100 UF$_A$ = 10 UF$_H$ = 10
	0.13 mg/m^3 Initial Threshold Screening Level (ITSL)	Michigan DEQ, 2019a	Adopted US EPA (2009) PPRTV (See above) with application of additional uncertainty factor			10,000 UF$_L$ = 10 UF$_H$ = 10 UF$_D$ = 10 UF$_S$ = 10
Dichlorodifluoromethane (Freon 12) 75-71-8 *95% structural similarity to carbon tetrafluoride	1 mg/m^3 Subchronic p-RfC; Chronic screening level[D]	US EPA, 2010; PPRTV	Single exposure concentration study; 0 or 4,136 mg/m^3 for 8 hours/day, 5 days/week for 6 weeks in guinea pigs, rabbits, dogs, and monkeys	LOEL$_{ADJ[HEC]}$ = 985 mg/m^3 DAF = 1 (Category 3 Gas)	Decreased bodyweight gain in guinea pigs, rabbits, dogs, and monkeys	1000 UF$_A$ = 3 UF$_H$ = 10 UF$_L$ = 10 UF$_D$ = 3
	14 mg/m^3 Health-based quality criterion in air	DME, 2014	90 day continuous exposure in guinea-pigs showed to single concentration of 4,100 mg/m^3	LOEL = 4,100 mg/m^3 An HEC was not calculated; Applied UF approach[C]	Fatty infiltration and necrosis in the liver	100 UF$_A$ = 10 UF$_H$ = 10
	0.33 mg/m^3 ITSL	Michigan DEQ, 2019b	Adopted US EPA (2010) PPRTV (See above) with application of additional uncertainty factor[E]			3000 UF$_A$ = 3 UF$_H$ = 10 UF$_L$ = 10 UF$_S$ = 10
Carbon tetrachloride (Freon 10) 56-23-5 *88% structural similarity to carbon tetrafluoride	0.1 mg/m^3 RfC	US EPA IRIS, 2010	Whole body exposure in rats to 0, 31.5, 157, or 786 mg/m^3 (99.8% pure) vapor for 6 hours/day, 5 days/ week for 104 weeks	BMCL$_{10[HEC]}$ = 14.3 mg/m^3 *A human PBPK model was used to obtain HEC (Category 3 gas)	Fatty changes in the liver	100 UF$_A$ = 3 UF$_H$ = 10 UF$_D$ = 3

Chemical Name/ CAS Number	Toxicity Value	Source	Study Details	POD/DAF	Toxicity Endpoint	Uncertainty Factors
	6×10^{-6} per mcg/m^3 Unit Risk[F]		BDF1 mice exposed to carbon tetrachloride vapor for 104 weeks (6 hours/ day, 5 days/week)	LEC_{10}, lower 95% bound on exposure at 10% extra risk - 1.78×10^4 mcg/m^3	Increased incidence in adrenal gland tumors	Not applicable
	0.04 mg/m^3 Chronic Reference Exposure Level	CA OEHHA (2008, 2023)	Guinea pigs exposed to 0, 5, 10, 25, 50, 100, 200 and 400 ppm (0, 37, 74, 186, 372, 744, 1487, 2974 mg/m^3) carbon tetrachloride for varying duration. At the LOEL (37 p mg/m^3) exposure was for 7 hours/day, 5 days/week for 7.3 months.	$LOEL_{ADJ[HEC]}$ = 10.7 mg/m^3 RGDR = 1.7 (Category 3 gas)	Increase in liver weight and liver lipid content	300 UF_A = 3 UF_H = 10 UF_L = 3 UF_S = 3
	4.2×10^{-5} per mcg/m^3 Unit Risk	CA OEHHA (2011, 2023)	Based on cross-route extrapolation from an oral cancer potency factor derived by US EPA in 1984.		Increased incidence in liver tumors in mice	Not applicable
	0.19 mg/m^3 (0.03 ppm) Inhalation Minimal Risk Level	ATSDR, 2005	Whole body exposure to e (>99% pure) to 0, 5, 25, or 125 ppm (0, 37, 186, 930 mg/m^3) carbon tetrachloride for 6 hours/day, 5 days/week for 104 weeks. LOEL = 186 mg/m^3	$NOEL_{ADJ[HEC]}$ = 0.9 ppm (6.7 mg/m^3) DAF = 1 (Category 3 gas)	increased liver weight, serum enzymes, and liver histopathology (fatty change, granulation, foci, deposition of ceroid, fibrosis, and cirrhosis)	30 UF_A = 3 UF_H = 10

[A] Table Definitions: ADJ (adjusted for continuous exposure), BMCL (benchmark concentration lower bound), DAF (dosimetric adjustment factor), HEC (human equivalent concentration), LOEL (lowest-observed-effect-level), NOEL (no-observed-effect-level), POD (point-of-departure), p-RfC (provisional reference concentrations), RfC (reference concentration), RGDR (Regional Gas Dose Ratio), UF_A (interspecies uncertainty factor), UF_D (database uncertainty factor), UF_H (intraspecies uncertainty factor) UF_L (LOEL-to-NOEL uncertainty factor), UF_S (uncertainty factor for less than lifetime exposure).

[B] As described in Section 5, structural similarity scores for carbon tetrafluoride analogues come from online tools, including ChemIDPlus[6] (NLM, 2022), Integrated Chemical Environment (NTP, 2022) and the Comptox Dashboard (US EPA, 2022). Higher structural similarity scores (on scales of 0 to 100% or 0 to 1) generally indicate higher levels of structural similarity to carbon tetrafluoride. Table 1 includes the subset of carbon tetrafluoride analogues for which inhalation toxicity values were found. The full list of structurally similar analogues meeting criteria of greater than or equal to 80% similarity, 0.8 similarity threshold or 0.8 Tanimoto score can be found in Appendix B (Table B – 3).

[C] Current US EPA guidance for deriving RfCs (US EPA, 1994) recommends the use of mathematical models (i.e., physiologically based pharmacokinetic modeling (PBPK)) or dosimetric adjustment factors (DAFs) to extrapolate from inhalation exposure levels in animals to inhalation exposures to humans. In the absence of available PBPK models for extrapolating between animals and humans, the default recommended approach for application of DAFs considers the physical-chemical properties of chemicals (i.e., whether chemicals are particles or gases) and pharmacokinetics (i.e., whether chemicals are reactive at the site of contact (Category 1 gases), absorbed and distributed systemically and elicit systemic effects (Category 3 gases), or both (Category 2 gases)) in order to calculate human equivalent concentrations (HECs) from inhalation exposure levels in animals. US EPA used a DAF to calculate an HEC for dichlorodifluoromethane from animal inhalation exposure levels and did not use a DAF for trichlorofluoromethane as the POD was based on human health effects. However, DME (2014) used the uncertainty factor approach to account for both pharmacokinetic and pharmacodynamic differences between animals and humans (i.e., applied a total uncertainty factor of 10 for interspecies extrapolation) in toxicity value derivations.

---

[6] The ChemIDPlus (NLM, 2022) is no longer active as of 2023. The ChemIDPlus database is now part of PubChem. However, the chemical similarity tool in PubChem (NLM, 2023) differs from and provides a different suite of chemicals than ChemIDPlus. The PubChem tool provides less useful analogues than the original ChemIDPlus similarity results and were not considered in this assessment.

[D] US EPA (2010) did not derive a chronic RfC for dichlorodifluoromethane. However, US EPA indicated that a “screening level” chronic RfC of 0.1 mg/m^3 could be derived by using an additional UF of 10 for chronic-to-subchronic extrapolation, which would result in a total UF 10,000. According to current risk assessment practices for deriving an RfC, total uncertainty factors (i.e., for extrapolation from a LOEL to a NOEL, from a subchronic to lifetime study, and for intra- and interspecies extrapolation) are typically limited to a maximum of 3000, even when there are four areas of uncertainty being addressed through application of uncertainty factors.

[E] Michigan DEQ (2019b) also calculated a screening chronic provisional value of 0.1 mg/m^3 using a total UF of 10,000.

[F] 10^{-6} Cancer Risk Level = 0.17 mcg/m^3 (0.00017 mg/m^3)

8. Comparison of Carbon Tetrafluoride Analogues

8.1. Comparison of Toxicity Values

Of the three structurally similar analogues for which toxicity values were found (Table 1), trichlorofluoromethane and dichlorodifluoromethane had the highest structural similarity to carbon tetrafluoride (both with about 95% structural similarity). The structural similarity between carbon tetrachloride and carbon tetrafluoride was lower (about 88%). However, the toxicity of carbon tetrachloride is well characterized compared to the other two analogues, and carbon tetrachloride has the lowest inhalation toxicity value from US EPA[7] (Table 1) of the three analogues. In addition, the US EPA IRIS (2010) RfC derivation for carbon tetrachloride (0.1 mg/m^3) includes several favorable attributes, such as use of a lifetime-exposure toxicity study in rodents, benchmark dose modeling to estimate a point-of-departure (POD), and pharmacokinetic modeling to obtain a human equivalent concentration (instead of use of default dosimetry calculations). US EPA IRIS (2010) assigned a medium overall confidence in their RfC assessment, high confidence in the selected key study, and medium confidence in the toxicity database for carbon tetrachloride.

By contrast, the US EPA derivations for trichlorofluoromethane and dichlorodifluoromethane (subchronic provisional RfCs of 1 mg/m^3 for each chemical) are limited in that they are both subchronic toxicity values and are based on lowest-observed-effect levels (LOELs) from short-term, single exposure studies (Table 1). The RfC for trichlorofluoromethane is based on health effects in humans (i.e., cognitive effects in humans exposed via inhalation to 5620 mg/m^3 trichlorofluoromethane for 8 hours per day, 5 days per week, for up to 4 weeks (Stewart et al., 1975, 1978, reviewed in US EPA, 2009)). PODs based on health effects in humans are generally preferred to use of health effects in animals for derivation of inhalation toxicity values. However, US EPA (2009) also applied a database uncertainty factor of 10 due to the limited availability of inhalation toxicity studies on trichlorofluoromethane (e.g., lack of reproductive, developmental, and comprehensive neurobehavioral toxicity studies). US EPA (2009) assigned a low overall confidence in the provisional subchronic RfC for trichlorofluoromethane, medium-to-low confidence in the selected key study, and low confidence in the toxicity database.

The provisional RfC for dichlorodifluoromethane is based on short-term health effects in laboratory animals. The LOEL selected as the POD based on toxicity in animals is lower than the no-observed-effect level (NOEL) of 1,179 mg/m^3) reported in a study of humans exposed via inhalation to a single concentration for 8 hours per day, 5 days per week for up to 4 weeks (Stewart et al., 1978, reviewed in US EPA, 2010). The US EPA provisional RfC for dichlorodifluoromethane includes a database uncertainty factor of 3 for lack of reproductive and developmental toxicity. US EPA did not apply a full database uncertainty factor of 10, in part, due to the presence of one chronic duration inhalation study of dichlorodifluoromethane in rodents (Maltoni et al., 1988). This study examined the carcinogenicity of dichlorodifluoromethane and reported no treatment related differences in tumor incidence in the organs and systems of rats and mice examined in the study (e.g., brain, mammary glands, blood). However, this study reported limited information on noncancer toxicity (US EPA, 2010). The only noncancer findings reported in the study were that effects on bodyweight were not observed in rats and mice. Thus, the US EPA (2010) considered the highest exposure concentration tested in this study to be a NOEL (2,976 mg/m^3). It should be noted that the NOEL from the Maltoni et al. (1988) study is

---

[7] Consistent with NYS DEC (2021) guidance, toxicity values derived by US EPA were prioritized in this assessment for screening of carbon tetrafluoride analogues.

much higher than the POD of 985 mg/m^3 selected as the basis of US EPA's subchronic provisional RfC for dichlorodifluoromethane. US EPA (2010) assigned a low overall confidence in the provisional subchronic RfC, low confidence in the selected key study, and low-to-medium confidence in the toxicity database.

With respect to the two fluorinated structurally similar analogues, the US EPA provisional RfC derivations for trichlorofluoromethane and dichlorofluoromethane are of similar quality, with similar strengths and weaknesses. Thus, for trichlorofluoromethane and dichlorofluoromethane a strong rationale for choosing one chemical and corresponding toxicity value over the other as a potential basis of an AGC for carbon tetrafluoride was not apparent. Therefore, it was concluded at this stage in the assessment that additional information was needed on the three analogues (carbon tetrachloride, trichlorofluoromethane and dichlorodifluoromethane) in order to determine whether a biological rationale could be formulated to inform surrogate selection based on factors such as pharmacokinetics and modes-of-action for toxicity. Surrogate selection for use in deriving an AGC for carbon tetrafluoride is covered in subsequent sections of this document (Sections 8.2, 9.1, 9.2, 10, 11.1 and 11.2). These sections consider additional supporting information and provide a scientific rationale for recommending an approach to deriving an AGC for carbon tetrafluoride.

8.2. Chemical Property Considerations

In comparing the toxicity of carbon tetrachloride, trichlorofluoromethane and dichlorodifluoromethane, physical-chemical properties (Appendix B, Table B - 1), including chemical makeup, were also considered. For example, the low boiling points of the three analogues (Appendix B, Table B - 1) indicate that they are volatile organic chemicals. In terms of chemical makeup, while the analogues are all fully halogenated methanes, carbon tetrachloride and carbon tetrafluoride differ in chemical composition given that the former is fully chlorinated and the latter is a fully fluorinated. Toxicity comparisons between groups of chemicals with similar halogen makeup is a common practice in human health risk assessment (e.g., per- and polyfluoroalkyl substances (PFAS), polychlorinated dibenzo-*p*-dioxins, polybrominated diphenyl ethers, polychlorinated biphenyls). However, evidence to support a rationale for assuming similar toxicity between chemicals with dissimilar halogen makeup, such as fully chlorinated and fully fluorinated chemicals, was not found. The presence or absence of fluorine could also play an important role in chemical attributes. For example, the carbon-fluorine covalent bond is considered the strongest in organic chemistry, and has a low reactivity due to factors such as the electronegativity of fluorine, the polarity of the bond, and poor accessibility to the bonded fluorine atom's valence electrons (Chan et al., 2011). In addition, information on fully fluorinated chemicals, such as PFAS, indicates that some fluorinated chemicals have high thermal and chemical stability, are persistent in the environment, and do not readily undergo biological transformation (Langenbach and Wilson, 2021). Thus, the dissimilarities in halogen makeup between carbon tetrachloride and carbon tetrafluoride reduced the confidence in the use of a precautionary principal approach at this stage of the assessment (i.e., selection of carbon tetrachloride, the chemical with the lowest RfC and most robust toxicity database, as the basis of an AGC for carbon tetrafluoride).

9. Structurally Related Fluorinated Chemicals

9.1. Identification of Related Fluorinated Chemicals

Since there was limited toxicity information on the approximately 20 chemical analogues initially identified by the structural similarity tools, the assessment of potential carbon tetrafluoride analogues was widened to include additional fluorinated compounds (e.g., partially halogenated methanes and haloalkanes identified in authoritative body documents on chlorofluorocarbons, chemicals identified in other online structural assessment tools (e.g., the free ChemMine tool (Backman et al., 2022) and through professional judgement). This additional screening was performed to address important limitations in the assessment due to compounding uncertainties presented by both the absence of chemical-specific toxicity data on carbon tetrafluoride and the limited toxicity databases on the inhalation toxicity of structurally similar compounds as a whole and for trichlorofluoromethane and dichlorodifluoromethane, specifically. While the additional screening of fluorinated chemicals was not exhaustive, it provided additional related chemicals for consideration (e.g., 20 to 30 additional chemicals).

Any chemicals that had carbon chains of greater than 2 carbons or that had carbon-to-carbon double bonds were excluded from screening as the focus of this part of the assessment was to find chemicals with potential structural and functional similarities to carbon tetrafluoride. The remaining related fluorinated chemicals were screened for chronic or subchronic toxicity values, with an emphasis on inhalation toxicity values (Section 9.2). If other relevant toxicity information were readily available (e.g., pharmacokinetics or MOA), the information was captured in the assessment.

9.2. Toxicity Screening of Related Fluorinated Chemicals

The same search method for obtaining toxicity information described in Section 6 was used to identify toxicity values for screening of related chemicals. These searches of more than 20 related chemicals yielded 10 additional chronic and subchronic inhalation toxicity values for eight fluorinated chemicals (halomethanes and haloalkanes) for consideration. The available toxicity values for these additional compounds (Table 2) were generally higher than the ones found for the three structurally similar analogues evaluated in this assessment (Table 1). While the toxicity databases for the additional chemicals were limited, the additional data on fluorinated halomethanes and haloalkanes were not suggestive of high noncancer toxicity. Had the available toxicity data for these compounds demonstrated higher toxicity than the initial three analogues identified by structural similarity, application of the precautionary principal to select carbon tetrachloride as the surrogate chemical for use in deriving an AGC could have been reconsidered at this stage in the assessment. However, since this was not the case, the two fluorinated analogues from the initial structural similarity assessment (i.e., trichlorofluoromethane and dichlorodifluoromethane) remained options for deriving an AGC for carbon tetrafluoride. Thus, the screening of these additional related fluorinated compounds served to increase the confidence in the selection of the two partially fluorinated structurally similar carbon tetrafluoride analogues.

Table 2. Available Inhalation Toxicity Values for Chemicals that are Structurally Related to Carbon Tetrafluoride[A,B]

Chemical Name/ CAS Number	Toxicity Value	Source	Study Details	POD/DAF	Toxicity Endpoint	Uncertainty Factors
Dichlorofluoromethane (Freon 21) 75-43-4	0.13 mg/m^3 Health-based quality criterion in air	DME, 2014	Rats exposed via inhalation to 213, 640 or 2130 mg/m^3 (6 hours/day, 5 days/week, for 90 days). LOEL = 213 mg/m^3	$LOEL_{ADJ}$= 38 mg/m^3 An HEC was not calculated; Applied UF approach[C]	Histopathological changes in the liver	300 UF_A = 10 UF_H = 10 UF_L = 3
Chlorodifluoromethane (Freon 22) 75-45-6	50 mg/m^3 RfC	US EPA IRIS, 1993	Whole-body exposure to 0, 3540, 35,370, or 176,800 mg/m^3 for 5 hours/day, 5 days/week, for up to 118 weeks (females) or 131 weeks (males). LOEL = 176,800 mg/m^3	$NOEL_{ADJ[HEC]}$ = 5260 mg/m^3 DAF = 1	Increased kidney, adrenal and pituitary weights in rats.	100 UF_A = 3 UF_H = 10 UF_D = 3
2-Chloro-1,1,1-trifluoroethane (Freon 133a) 75-88-7	2.1 mg/m^3 Health-based quality criterion in air	DME, 2014	Inhalation exposure to rat dams (2,500 mg/m^3 for 6 hours/day on gestation days 6 to 15), which corresponds to 625 mg/m^3 after adjusting for continuous exposure. Documentation of study details is limited.	$LOEL_{ADJ}$ = 625 mg/m^3 An HEC was not calculated; Applied UF approach[C].	Developmental toxicity at concentrations that did not cause maternal toxicity	300 UF_A = 10 UF_H = 10 UF_L = 3
1,1,1,2-Tetrafluoroethane (Freon 134a) 811-97-2	80 mg/m^3 RfC	US EPA IRIS, 1995a	Rats whole-body exposed 0, 10,400, 41,700, and 208,600 mg/m^3 for 6 hours/day, 5 days/week. Duration adjusted concentrations = 1860, 7450, or 37,250 mg/m^3 LOEL = 37,250 mg/m^3	$BMC_{10[ADJ]}$ = 8200 mg/m^3 DAF = 1 (Category 3 Gas)	Leydig cell hyperplasia	100 UF_A = 3 UF_H = 10 UF_D = 3
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) 76-13-1	5 mg/m^3 Chronic p-RfC	US EPA, 2016; PPRTV	cross-sectional study of workers exposed via inhalation for an average of 2.77 years. LOEL = 19,160 mg/m^3	$NOEL_{ADJ}$ = 1440 mg/m^3	Slight impairment of psychomotor performance reported in two male volunteers for 1.5 hours	300 UF_H = 10 UF_S= 10 UF_D = 3
	50 mg/m^3 Subchronic p-RfC					30 UF_H = 10 UF_D = 3
	109 mg/m^3 Health-based quality criterion in air	DME, 2014	2-year inhalation study in rats exposed 5 days/week to 15,300 mg/m^3 and 76,600 mg/^{3}. LOEL = 76,600 mg/m^3	$NOEL_{ADJ}$= 10,900 mg/m^3 An HEC was not calculated; Applied UF approach[C]	Decreased body weight	100 UF_A = 10 UF_H = 10
1,1,1-Trifluoroethane (Freon 143a) 420-46-2	20 mg/m^3 Chronic p-RfC	US EPA 2015; PPRTV	3–8-weeks-old rats exposed via inhalation (whole-body) to 0, 2,000, 10,000, or 40,000 ppm (0, 6,874, 34,370, and 137,500 mg/m^3) 6 hours/day, 5 days/week, for 90 days.	$NOEL_{ADJ[HEC]}$ = 24,550 mg/m^3 DAF = 1 (Category 3 Gas)	No effects reported at highest concentration	1000 UF_A = 3 UF_H = 10 UF_D = 3 UF_S = 10
	200 mg/m^3			$NOEL_{ADJ[HEC]}$ = 24,550 mg/m^3		100 UF_A = 3

Chemical Name/ CAS Number	Toxicity Value	Source	Study Details	POD/DAF	Toxicity Endpoint	Uncertainty Factors
	Subchronic p-RfC			DAF = 1 (Category 3 Gas)		UF_H = 10 UF_D = 3
1-Chloro-1,1-difluoroethane (Freon 142b) 75-68-3	50 mg/m^3 RfC	US EPA IRIS, 1995b	Rats were exposed via whole-body inhalation exposure for 6 hours/day, 5 days/week for 104 weeks to 0, 1000, 10,000, or 20,000 ppm (4110, 41,100, or 82,200 mg/m^3). NOEL corresponds to the highest concentration tested.	$NOEL_{ADJ[HEC]}$ = 14,710 mg/m^3 DAF = 1 (Category 3 Gas)	No effects reported at the highest concentration	300 UF_A = 3 UF_H = 10 UF_D = 10

[A] Per the search methodology of this assessment, this Table provides inhalation toxicity values derived by US EPA, if available, or toxicity values from other authoritative bodies when toxicity values from US EPA were not found.

[B] Table Definitions**:** ADJ (adjusted), BMC (benchmark concentration), DAF (dosimetric adjustment factor), HEC (human equivalent concentration), LOEL (lowest-observed-effect-level), NOEL (no-observed-effect-level), POD (point-of-departure), p-RfC (provisional reference concentrations), RfC (reference concentration), UF_A (interspecies uncertainty factor), UF_D (database uncertainty factor), UF_H (intraspecies uncertainty factor) UF_L (LOEL-to-NOEL uncertainty factor), UF_S (uncertainty factor for less than lifetime exposure)

[C] Current US EPA guidance for deriving RfCs (US EPA, 1994) recommends the use of mathematical models (i.e., physiologically based pharmacokinetic modeling (PBPK) or dosimetric adjustment factors (DAFs) to extrapolate from inhalation exposure levels in animals to inhalation exposures to humans. In the absence of available PBPK models for extrapolating between animals and humans, the default recommended approach for application of DAFs considers the physical-chemical properties of chemicals (i.e., whether chemicals are particles or gases) and pharmacokinetics (i.e., whether chemicals are reactive at the site of contact (Category 1 gases), absorbed and distributed systemically and elicit systemic effects (Category 3 gases), or both (Category 2 gases)). in order to calculate human equivalent concentrations (HECs) from inhalation exposure levels in animals. US EPA used a DAF to calculate an HEC for dichlorodifluoromethane from animal inhalation exposure levels and did not use a DAF for trichlorofluoromethane as the POD was based on human health effects. However, DME (2014) used the uncertainty factor approach to account for both pharmacokinetic and pharmacodynamic differences between animals and humans (i.e., applied a total uncertainty factor of 10 for interspecies extrapolation) in toxicity value derivations.

[D] ECETOC (2008) summarized a gestational study with a lower LOEL in rats (1,400 mg/m^3). Female Sprague-Dawley rats were exposed to 280, 1,400, 2,800 mg/m^3 for 6 hours/day, 5 days/week on gestation days 6 through 15. Slight increases in extra ribs were reported at 1,400 and 2,800 mg/m^3 (Coate, 1977). ECETOC (2008) also summarized additional findings from Coate et al. (1977), which reported an even lower LOEL for effects in male Sprague-Dawley rats exposed for 6 hours/day 5 days/week to 0, 280, 1,400 or 2,800 mg/m^3 chlorofluoromethane for 13 weeks. Relative spleen weights were significantly lower than the control in all exposed groups (i.e., LOEL of 280 mg/m^3) and reproductive effects (i.e., decreased relative testis weight and hypospermatogenesis) occurred at the highest level of exposure.

10. Summary of Information on MOA for Noncancer Toxicity of Carbon Tetrafluoride and Analogues

Since chemical correlation analyses can be informed by both structural and functional similarities, the final phase of the assessment included consideration of available information on the MOA for noncancer toxicity as well as pharmacokinetics (i.e., absorption, distribution, metabolism, excretion) of carbon tetrafluoride and the three structurally similar analogues (trichlorofluoromethane, dichlorodifluoromethane and carbon tetrachloride). The assessment was also informed by any relevant information found for the related fluorinated compounds identified for screening. The purpose of this was to explore potential biological rationales for structurally similar analogue selection. The following bullets summarize the key findings of this phase of the assessment.

- There are no studies available on the pharmacokinetics or chronic and subchronic toxicity of carbon tetrafluoride. While it is unknown whether carbon tetrafluoride is metabolized following inhalation exposure, a study of energetic parameters associated with carbon tetrafluoride molecular bonds and information on other related chemicals, suggests that carbon-fluorine bonds may be less prone to biological transformation than carbon bonds with other halogens (Koski et al., 1997; Yin et al., 1995).
- The hypothesized MOA for the noncancer liver effects of carbon tetrachloride involves the production of highly reactive chlorinated metabolites, which occurs through reductive dehalogenation via cytochrome P-450.[8] However, since carbon tetrafluoride is fully fluorinated, even if metabolized by reductive dehalogenation via cytochrome P-450, it would be unlikely for the metabolites to be chlorinated free radicals like those produced during the metabolism of carbon tetrachloride. As noted in the bullet above, studies on carbon tetrafluoride metabolism were not found. However, a study of chemical properties (energetic parameters such as bond strength and vertical electron affinity) suggests that metabolism of carbon tetrafluoride and free radical production may be unlikely (Koski et al., 1997).
- According to US EPA (2009), available data suggest little or no metabolism of inhaled trichlorofluoromethane. Most of the compound is rapidly eliminated unchanged via exhaled air and only traces of radioactivity are recovered in the urine or feces (from exposure to radiolabeled trichlorofluoromethane). An *in vitro* study suggests that rat liver microsomes could dechlorinate trichlorofluoromethane to a fluorinated metabolite (dichlorofluoromethane). However, there are currently no *in vivo* data to support this finding. Studies on dichlorodifluoromethane also suggest little to no metabolism following inhalation exposures (WHO, 1990).

---

[8] Carbon tetrachloride is metabolized via a cytochrome P-450 pathway, which includes reductive dehalogenation (reductive cleavage of one carbon-chloride bond) and formation of the trichloromethyl radical. The trichloromethyl radical can undergo anaerobic or aerobic transformation to other chlorine containing intermediates. Regarding the potential MOA for noncancer effects, US EPA IRIS[11] stated the following: "liver metabolism rate was selected as the primary dose metric for liver effects, based on evidence that metabolism of carbon tetrachloride via CYP2E1 to highly reactive free radical metabolites plays a crucial role in its MOA in producing liver toxicity (described in Section 4.5). The primary reactive metabolites that are thought to participate in carbon tetrachloride toxicity are the trichloromethyl radical ($\cdot CCl_3$) and the trichloromethyl peroxy radical ($O\text{-}OCCl_3$), although other reactive species may also contribute to a lesser extent (e.g., dichlorocarbene, $:CCl_2$)."

11. Derivation of an AGC for Carbon Tetrafluoride

11.1. Uncertainties and Limitations of the Assessment

Traditional toxicological assessments rely heavily on chemical-specific toxicity studies on the chemical of interest. However, when such data are not available, a risk assessment can be performed using structural activity relationships and read-across to infer the toxicity of a chemical lacking toxicity data by drawing comparisons to a structurally similar chemical with a more robust toxicological database (Health Canada, 2022; OECD, 2023). While this approach fulfills data needs when chemical-specific toxicity data are lacking, assessing and outlining of uncertainties is a key step in the selection of analogues and the implementation of a weight-of-evidence approach (Health Canada, 2022; Schultz et al., 2015).

The assessment of the toxicity of carbon tetrafluoride and structurally similar analogues has three main areas of uncertainty.

1) As described in Section 4, there was no information available on the chronic or subchronic toxicity of carbon tetrafluoride in an online search of the toxicological literature. Given that toxicity data were lacking, there was insufficient information to evaluate MOA or to assess whether the effects of carbon tetrafluoride are likely to be systemic or point-of-contact based on chemical specific information. Appendix A provides additional information on the potential for carbon tetrafluoride to elicit point-of-contact and/or systemic effects based on toxicity information for structurally similar analogues.
2) Carbon tetrachloride and its toxicologically active metabolites do not contain any fluorines. Thus, while the toxicity database for carbon tetrachloride is more robust than other analogues considered in this assessment, there is no strong biological rationale to suggest similar toxicity or similar toxicity pathways for carbon tetrafluoride and carbon tetrachloride, despite the chemicals having similar structures, since they don't share similar chemical makeup (i.e., the chemicals do not contain any common halogens). Therefore, carbon tetrachloride was not selected as the basis of an AGC due to uncertainties related to chemical properties and considerations related to MOA.
3) With respect to the two fluorinated structurally similar analogues (trichlorofluoromethane and dichlorodifluoromethane), the overall databases on inhalation toxicity as well as the critical studies used to derive provisional RfCs are limited. The provisional RfC derivation corresponding to the lowest LOEL for dichlorodifluoromethane (i.e., the US EPA (2010) subchronic RfC of 1 mg/m^3) is based on short-term exposure in animals (6 weeks) and a total uncertainty factor of 1000 across four areas of uncertainty (Table 1). The provisional RfC derivation corresponding to the lowest LOEL for trichlorofluoromethane (i.e., the US EPA (2009) subchronic RfC of 1 mg/m^3) is based on a short-term exposure in humans (2 to 4 weeks) and has a total uncertainty factor of 1000 based on three areas of uncertainty (Table 1).

With respect to the third point, some of the uncertainties associated with the limited inhalation toxicity databases on trichlorofluoromethane and dichlorodifluoromethane were reduced through the additional screening of structurally related fluorinated chemicals (e.g., partially fluorinated halomethanes and haloalkanes). These structurally related fluorinated chemicals were not captured in the structural similarity assessment. However, some of these chemicals, in addition to being structurally related to carbon tetrafluoride, have similar industrial use as refrigerants. As a whole, the available inhalation toxicity values for these chemicals did not demonstrate a high level of toxicity. With the exception of dichlorofluoromethane, all seven of the other structurally related chemicals had inhalation toxicity values that are higher than the RfCs derived by US EPA for trichlorofluoromethane and dichlorodifluoromethane. The DME (2014) derived an inhalation toxicity value of 0.13 mg/m^3 for dichlorofluoromethane based on histopathological effects in the liver of rats following repeated inhalation exposure (i.e., 213, 640 or 2130 mg/m^3 dichlorofluoromethane for 6 hours per day, 5 days per week, for 90 days). Effects were reported at the lowest level of exposure, which corresponds to 38 mg/m^3 when adjusted for continuous exposure. The DME applied a total uncertainty factor of 300 (i.e., 10 for interspecies extrapolation, 10 for intraspecies extrapolation and 3 for use of a LOEL). The LOEL in the DME derivation for dichlorofluoromethane is lower than the LOELs selected as the POD for trichlorofluoromethane and dichlorodifluoromethane in the US EPA derivations of provisional subchronic RfCs (i.e., LOELs of 1338 and 985 mg/m^3, respectively). However, US EPA applied total uncertainty factors of 1000 in the derivations for both trichlorofluoromethane and dichlorodifluoromethane (Table 1). Therefore, the provisional subchronic RfCs for trichlorofluoromethane and dichlorodifluoromethane (1 mg/m^3 for both chemicals) are 38-fold lower than the LOEL of 38 mg/m^3 for dichlorofluoromethane. Therefore, screening of additional fluorinated chemicals (described in Section 9 and Table 2), increased overall confidence in the assessment of structurally similar carbon tetrafluoride analogues and the potential selection of trichlorofluoromethane and/or dichlorodifluoromethane as the basis of an AGC for carbon tetrafluoride.

11.2. Surrogate Selection and AGC Recommendations

Both trichlorofluoromethane and dichlorodifluoromethane are selected as surrogates for evaluating the toxicity of carbon tetrafluoride given that a biological rationale for selecting one analogue over the other was not apparent based on an assessment of the toxicity and pharmacokinetics of the chemicals (See Sections 7, 8 and 10). In addition, the strengths and weaknesses of the respective US EPA provisional subchronic RfC derivations for trichlorofluoromethane and dichlorodifluoromethane were similar. Therefore, the approach for derivation of an AGC based on structural activity relationships is to use the subchronic RfCs for the two fluorinated analogues (1 mg/m^3 each for trichlorofluoromethane and dichlorodifluoromethane, Table 1) and increase the total uncertainty factor from 1000 to 3000, which is typically the maximum total uncertainty factor that can be applied to a derivation of an RfC across 4 areas of uncertainty.[9] The increase in total uncertainty factors addresses the use of subchronic toxicity endpoints in the derivation and would yield an AGC of 0.33 mg/m^3 for carbon tetrafluoride. Given the selection of trichlorofluoromethane and dichlorodifluoromethane as surrogates, carbon tetrafluoride is being treated as a Category 3 gas based on the systemic effects of the surrogates in the absence of chemical-specific toxicity data on carbon tetrafluoride (see Appendix A for additional details). The PODs used in the US EPA provisional RfC derivations for trichlorofluoromethane and dichlorodifluoromethane are based on extrarespiratory effects (e.g., cognitive effects in humans and effects on bodyweight gain in laboratory animals, respectively). In addition, for both analogues, the most reliable evidence of toxicity from inhalation exposure correspond to systemic effects.

Evidence to support the derivation of an AGC of 0.33 mg/m^3 for carbon tetrafluoride also comes from the screening of several structurally related fluorinated chemicals. The results of the screening collectively suggest that an AGC of 0.33 mg/m^3 for carbon tetrafluoride would be adequately protective of noncancer health effects if the toxicity of carbon tetrafluoride is similar to that of other fluorinated halomethanes or fluorinated

---

[9] According to current risk assessment practices for deriving an RfC, total uncertainty factors are typically limited to a maximum of 3000, even when there are four areas of uncertainty being addressed through application of uncertainty factors.

haloethanes (Tables 1 and 2). Of the inhalation toxicity value derivations for structurally related chemicals (Table 2), the POD corresponding to the lowest LOEL is 38 mg/m^3 for dichlorofluoromethane. The AGC of 0.33 mg/m^3 is about 115-fold lower than this effect level.

The recommended approach for deriving an AGC for carbon tetrafluoride of 0.33 mg/m^3 is also supported by mechanistic information, which suggests that trichlorofluoromethane and dichlorodifluoromethane are not metabolized or metabolized to a small degree. While the MOAs for these chemicals are not known, it seems possible that toxicity could be resulting from the parent compounds, which both contain fluorine atoms. However, given the technical limitations of the assessment presented by data gaps in the available toxicity information on carbon tetrafluoride and the selected surrogates, the AGC should be reconsidered by NYS DEC if studies on the toxicity of carbon tetrafluoride become available in the future and suggest a different degree of toxicity that is not addressed by the current assessment.

12. References

ACGIH (American Conference of Governmental Industrial Hygienists). 2023. Carbon Tetrafluoride. Available online at: https://www.acgih.org/carbon-tetrachloride/

ATSDR (Agency for Toxic Substances and Disease Registry). 2005. Toxicological Profile for Carbon Tetrachloride. Available online at: https://www.atsdr.cdc.gov/toxprofiles/tp30.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2023. Minimal Risk Levels (MRLs) for Hazardous Substances. Available online at: https://wwwn.cdc.gov/tsp/MRLS/mrlslisting.aspx

Backman TW, Cao Y, Girke T. 2022. ChemMine Tools. Available online at: https://chemminetools.ucr.edu/about/

CA OEHHA (California Office of Environmental Health Hazard Assessment). 2008. Technical Supporting Document for Noncancer RELs, Appendix D3. Available online at: https://oehha.ca.gov/media/downloads/crnr/appendixd3final.pdf

CA OEHHA (California Office of Environmental Health Hazard Assessment). 2011. Appendix B: Chemical-Specific Summaries of the Information Used to Derive Unit Risk and Cancer Potency Values. Available online at: https://oehha.ca.gov/air/crnr/technical-support-document-cancer-potency-factors-2009

CA OEHHA (California Office of Environmental Health Hazard Assessment). 2023. Carbon Tetrachloride. Available online at: https://oehha.ca.gov/chemicals/carbon-tetrachloride

Chan PWY, Yakunin AF, Edwards EA, Pai EF. 2011. Mapping the Reaction Coordinates of Enzymatic Defluorination. J Am Chem Soc. 133(19):7461-7468.

Clarke RF, Daniels S, Harrison CB, Jordan MJ, Paton WD, Smith EB, Smith RA. 1978. Potency of mixtures of general anaesthetic agents. Br J Anaesth. 50(10):979-83.

Clayton, JW. 1966. The mammalian toxicology of organic compounds containing fluorine. Hand Exp Pharmakol. 20:459–500.Coate WB. 1977. 90-day inhalation toxicity study in albino rats, Genetron 31. Unpublished final report No. 165-178. Hazleton Laboratories America, Vienna, Virginia, USA. Allied Chemical, Morristown, New Jersey, USA.

Daniels S, Paton WD, Smith EB. 1979. The effects of some hydrophobic gases on the pulmonary surfactant system.Br J Pharmacol. 65(2):229-235.

DME (Danish Ministry of the Environment). 2014. Chlorofluorocarbons: CFC-11, CFC-12, CFC-113, HCFC-21, HCFC-31, HCFC-133a. Available online at: https://www2.mst.dk/Udgiv/publications/2014/04/978-87-93178-40-3.pdf

ECETOC (European Centre for Ecotoxicology and Toxicology of Chemicals). 2008. Toxicity of Possible Impurities and By-products in Fluorocarbon Products. Available online at: https://www.ecetoc.org/wp-content/uploads/2021/10/ECETOC-TR-103.pdf

Health Canada. 2022. Use of analogues and read-across in risk assessment. Available online at: https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/analogues-read-across-risk-assessment.html

Jenkins LJ, Jones RA, Coon RA, Siegel J. 1970. Repeated and continuous exposures of laboratory animals to trichlorofluoromethane. Toxicol Appl Pharmacol. 16:133−142.

Koski et al. 1997. Potential Toxicity of CF(3)X Halocarbons. In Vitro Toxicology. 10(4):455-457.

Langenbach B and Wilson M. 2021. Per- and Polyfluoroalkyl Substances (PFAS): Significance and Considerations within the Regulatory Framework of the USA. Int J Environ Res Public Health. 18: 11142.

Leuschner F, Neumann RW, Hubscher F. 1983. Report on subacute toxicological studies with several fluorocarbons in rats and dogs by inhalation. Arzneim. Forsch. 33(10):1475−1476.

Lohmann R, Cousins IT, DeWitt JC, Glüge J, et al. 2020. Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS? Environ Sci Technol. 20: 12820-12828.

Makowski MS, Sproul C, Swartz C, Everitt JI, Knaus DA, Wilbur JC, Moon RE. 2022. Safety evaluation of carbon tetrafluoride as an inert hyperbaric breathing gas in Sprague-Dawley rats. Toxicol Appl Pharmacol. 444:116023.

Maltoni C, Lefemine G, Tovoli D, Perino G. 1988. Long-term carcinogenicity bioassays on three chlorofluorocarbons (trichlorofluoromethane, FC11; dichlorodifluoromethane, FC12; chlorodifluoromethane, FC22) administered by inhalation to Sprague-Dawley rats and Swiss mice. Ann NY Acad Sci. 534:261-82.

Michigan DEQ (Michigan Department of Environmental Quality). 2019a. Screening Level Update for Trichlorofluoromethane [Interoffice Communication] . Available online at: https://www.egle.state.mi.us/aps/downloads/ATSL/75-69-4/75-69-4_1hr_annual_ITSL.pdf

Michigan DEQ (Michigan Department of Environmental Quality). 2019b. Screening Level Update for Dichlorodifluoromethane [Interoffice Communication] . Available online at: https://www.egle.state.mi.us/aps/downloads/ATSL/75-71-8/75-71-8_8hr_annual_ITSL.pdf

NIOSH (National Institute for Occupational Safety and Health). 2022. Registry of Toxic Effects of Chemical Substances (RTECS). Carbon tetrafluoride. Available online at: https://www.cdc.gov/niosh-rtecs/FG4B12C0.html.

NIOSH (National Institute of Occupational Safety and Health). 1994a. Immediately Dangerous to Life or Health Concentrations (IDLH). Dichlorodifluoromethane. Available online at: https://www.cdc.gov/niosh/index.htm

NIOSH (National Institute of Occupational Safety and Health). 1994b. Immediately Dangerous to Life or Health Concentrations (IDLH). Fluorotrichloromethane. Available online at: https://www.cdc.gov/niosh/index.htm

NIOSH (National Institute of Occupational Safety and Health). 1994c. Immediately Dangerous to Life or Health Concentrations (IDLH). Fluorotrichloromethane. Available online at: https://www.cdc.gov/niosh/index.htm

NIOSH (National Institute of Occupational Safety and Health). 2023. Carbon Tetrafluoride. Available online at: https://www.cdc.gov/niosh-rtecs/FG4B12C0.html

NLM (National Library of Medicine). 2022. ChemIDPlus (searchable chemical database). Available online at: https://pubchem.ncbi.nlm.nih.gov/source/ChemIDplus

NLM (National Library of Medicine). 2023. PubChem (open chemistry database). Available online at: https://pubchem.ncbi.nlm.nih.gov/

NTP (National Toxicology Program). 2022. Integrated Chemical Environment (chemical database). Available online at: https://ice.ntp.niehs.nih.gov/

NYS DEC (New York State Department of Environmental Conservation). 2021. DAR-1 Guidelines for the Evaluation and Control of Ambient Air Contaminants Under 6NYCRR Part 212. https://www.dec.ny.gov/docs/air_pdf/dar1.pdf

OECD (Organisation for Economic Co-operation and Development). 2023. Grouping of Chemicals: Chemical Categories and Read-Across. Available online at: https://www.oecd.org/chemicalsafety/risk-assessment/groupingofchemicalschemicalcategoriesandread-across.htm

OSHA (Occupational Health and Safety Administration). 2015. Shipyard Employment Hazards during the Repair and Maintenance of Refrigeration Systems on Vessels. Available online at: https://www.osha.gov/sites/default/files/publications/OSHA3836.pdf

Prendergast JA, Jones RA, Jenkins LJ Jr, Siegel J. 1967. Effects on experimental animals of long-term inhalation of trichloroethylene, carbon tetrachloride, 1,1,1-trichloroethane, dichlorodifluoromethane, and 1,1-dichloroethylene. Toxicol Appl Pharmacol. 10(2):270-89.

PubChem. 2023. Carbon Tetrafluoride. Available online at: https://pubchem.ncbi.nlm.nih.gov/compound/6393

Schultz TW, Amcoff P, Berggren E, et al. 2015. A strategy for structuring and reporting a read-across prediction of toxicity. Regul Toxicol Pharmacol. 72(3):586-601. doi:10.1016/j.yrtph.2015.05.016.

Stewart RD, Baretta ED, Herrmann AA et al. 1975. Acute and repetitive human exposure to fluorotrichloromethane. The Medical College of Wisconsin, Department of Environmental Medicine.

Stewart RD, Newton PE, Baretta ED et al. 1978. Physiological response to aerosol propellants. Environ. Health Perspect. 26:275−285.

US APHC (U.S. Army Public Health Command). 2013. Technical Guide 230 Environmental Health Risk Assessment and Chemical Exposure Guidelines for Deployed Military Personnel. Available online at: https://phc.amedd.army.mil/PHC%20Resource%20Library/TG230-DeploymentEHRA-and-MEGs-2013-Revision.pdf

US DOE (United States Department of Energy). 2022. PAC Database Revision 29. https://edms3.energy.gov/pac/Search/Reports/573

US DOE (United States Department of Energy). 2022. Protection Action Criteria Tables. Available online at: https://edms3.energy.gov/pac/docs/Revision_29A_Table3.pdf

US EPA (United States Environmental Protection Agency). 1994. Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. Available online at: https://www.epa.gov/risk/methods-derivation-inhalation-reference-concentrations-and-application-inhalation-dosimetry

US EPA (United States Environmental Protection Agency). 1998. Health Effects Test Guidelines OPPTS 870.1300 Acute Inhalation Toxicity. Available online at: https://www.epa.gov/test-guidelines-pesticides-and-toxic-substances/series-870-health-effects-test-guidelines

US EPA (United States Environmental Protection Agency). 2009. Provisional Peer-Reviewed Toxicity Values for Trichlorofluoromethane (CASRN 75-69-4). Available online at: https://cfpub.epa.gov/ncea/pprtv/documents/Trichlorofluoromethane.pdf

US EPA (United States Environmental Protection Agency). 2010. Provisional Peer-Reviewed Toxicity Values for Dichlorodifluoromethane (CASRN 75-71-8). Available online at: https://cfpub.epa.gov/ncea/pprtv/documents/Dichlorodifluoromethane.pdf

US EPA (United States Environmental Protection Agency). 2012. Advances in Inhalation Gas Dosimetry for Derivation of a Reference Concentration (RfC) and Use in Risk Assessment. Available online at: https://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=244650#tab-3

US EPA (United States Environmental Protection Agency). 2016. Provisional Peer-Reviewed Toxicity Values for 1,1,2-Trichloro-1,2,2-trifluoroethane (CASRN 76-13-1). Available online at: https://cfpub.epa.gov/ncea/pprtv/documents/Trichloro122trifluoroethane112.pdf

US EPA (United States Environmental Protection Agency). 2022. Comptox Dashboard. Available online at: https://comptox.epa.gov/dashboard/

US EPA (United States Environmental Protection Agency).2015. Provisional Peer-Reviewed Toxicity Values for 1,1,1-Trifluoroethane (CASRN 420-46-2). Available online at: https://hhpprtv.ornl.gov/issue_papers/Trifluoroethane111.pdf

US EPA and IAI (United States Environmental Protection Agency and International Aluminum Institute. 2008. Protocol for Measurement of Tetrafluoromethane (CF$_4$) and Hexafluoroethane (C$_2$F$_6$) Emissions from Primary Aluminum Production. Available online at: https://www.epa.gov/sites/default/files/2016-02/documents/measureprotocol.pdf

US EPA IRIS (United States Environmental Protection Agency Integrated Risk Information System). 2010. Carbon tetrachloride. CASRN 56-23-5. DTXSID8020250. Available online at: https://iris.epa.gov/ChemicalLanding/&substance_nmbr=20

US EPA IRIS (United States Environmental Protection Agency Integrated Risk Information System). 1987a. Trichlorofluoromethane. CASRN 75-69-4. DTXSID5021384 Available online at: https://iris.epa.gov/ChemicalLanding/&substance_nmbr=120

US EPA IRIS (United States Environmental Protection Agency Integrated Risk Information System). 1987b. Dichlorodifluoromethane. CASRN 75-71-8. DTXSID6020436Available online at: https://iris.epa.gov/ChemicalLanding/&substance_nmbr=40

US EPA IRIS (United States Environmental Protection Agency Integrated Risk Information System). 1993. Chlorodifluoromethane. CASRN 75-45-6. DTXSID6020301. Available online at: https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=657

US EPA IRIS (United States Environmental Protection Agency Integrated Risk Information System). 1995a. 1,1,1,2-Tetrafluoroethane. CASRN 811-97-2. DTXSID1021324. Available online at: https://iris.epa.gov/ChemicalLanding/&substance_nmbr=656

US EPA IRIS (United States Environmental Protection Agency Integrated Risk Information System). 1995b. 1-Chloro-1,1-difluoroethane. CASRN 75-68-3. DTXSID9023960. Available online at: https://iris.epa.gov/ChemicalLanding/&substance_nmbr=661#:~:text=1%2DChloro%2D1%2C1%2Ddifluoroethane

WHO (World Health Organization). 1990. Environmental Health Criteria 113. Fully halogenated chlorofluorocarbons. Available online at: https://apps.who.int/iris/bitstream/handle/10665/39345/9241571136-eng.pdf?sequence=1

Yin H, Anders MW, Korzekwa KR, et al. 1995. Designing safer chemicals: predicting the rates of metabolism of halogenated alkanes. Proc Natl Acad Sci. 92 (24): 11076-11080.

Appendix A: Supplemental Information

A.1. Summary of Toxicity Information Relevant to the Assessment of Portal-of-Entry versus Systemic Effects of Carbon Tetrafluoride

The literature review on carbon tetrafluoride included a search for both oral and inhalation toxicity studies (acute, subchronic and chronic). However, chemical-specific toxicity data to evaluate the potential for portal-of-entry effects (including irritation at the site of contact), first pass liver effects, and systemic effects from acute oral or inhalation studies are not available for carbon tetrafluoride.

In the absence of chemical specific toxicity studies that provide evidence as to whether the toxicological effects of carbon tetrafluoride are portal-of-entry and/or systemic, carbon tetrafluoride is being treated as a Category 3 gas based on the available toxicity information on carbon tetrafluoride analogues (i.e., trichlorofluoromethane and dichlorodifluoromethane). The points-of-departure (PODs) used by US EPA (2009, 2010) to derive subchronic reference concentrations (RfCs) for trichlorofluoromethane and dichlorodifluoromethane correspond to extrarespiratory effects following inhalation exposures (e.g., cognitive effects in humans and effects on bodyweight gain in laboratory animals, respectively). In addition, for both compounds, the most reliable evidence of toxicity from inhalation exposure correspond to systemic effects (see Section A.3 below for more information).

A.2. Odor Thresholds for Carbon Tetrafluoride and Selected Surrogates

Carbon tetrafluoride is a colorless, odorless gas. An odor threshold was not found in PubChem[3] or via online searches of authoritative body information.

Dichlorodifluoromethane, one of the selected carbon tetrafluoride surrogates, is a colorless gas with an ether-like odor at extremely high concentrations. An odor threshold was not listed for dichlorodifluoromethane in PubChem. However, a fact sheet from the Occupational Safety and Health Administration indicates that 1000 parts per million (ppm) is a “normal range of odor threshold” for halocarbons, including dichlorodifluoromethane (OSHA, 2015). Thus, for dichlorodifluoromethane, this corresponds to an air concentration of 4,950 mg/m^3.

Trichlorofluoromethane, the other selected surrogate, is a colorless to water-white, nearly odorless liquid or gas. It has an odor threshold of 200,000 ppm (1.1 x 10^6 mg/m^3) in PubChem (NLM, 2023).

A.3. Additional Details on Respiratory and Liver Effects for Dichlorodifluoromethane and Trichlorofluoromethane Reported in US EPA (2009, 2010)

A.3.1 Trichlorofluoromethane

The POD selected by US EPA (2009) for use in deriving a subchronic RfC for trichlorofluoromethane corresponds to a lowest-observed-effect-level (LOEL) for cognitive effects in humans. Thus, a dosimetric adjustment factor was not needed for the derivation. However, evidence of toxicity in laboratory animals suggests that trichlorofluoromethane is also a Category 3 gas.

The only other LOEL from inhalation exposure identified in the US EPA (2009) assessment comes from a 90-day study of continuous exposure (0 or 5620 mg/m^3) trichlorofluoromethane in several species of laboratory animals (Jenkins et al., 1970; reviewed in US EPA, 2009). Nonspecific inflammatory changes in the lungs of all tested species and mild vacuolar changes in the liver of guinea pigs were reported. However, details on severity or incidence of effects were not provided. The study authors concluded that these findings were not related to exposure. US EPA (2009) did not include these effects in the selection of a LOEL for trichlorofluoromethane. US EPA (2009) identified renal effects in dogs as the LOEL corresponding to this study and considered the same exposure level (5620 mg/m^3) to be a NOEL for other animal species examined in this study.

The same authors (Jenkins et al., 1970; reviewed in US EPA, 2009) performed a subchronic study of intermittent inhalation exposure to trichlorofluoromethane (0 or 56,200 mg/m^3 for 8 hours/day, 5 days/week, for 6 weeks) and reported a variety of histopathological effects (e.g., mild discoloration, characterized as a darkening of the tissue, of the liver in rats and guinea pigs, and nonspecific inflammatory changes of the lungs in guinea pigs, rats, and monkeys (incidences not reported)). However, the authors did not consider any of these histopathological findings to be related to exposure. whether there were study quality issues. However, even if these histopathological changes were considered to be related to exposure, the exposure concentration is much higher than the LOEL for systemic effects in dogs.

In a 90-day study of male and female rats exposed to trichlorofluoromethane (0 or 56,200 mg/m^3 for 6 hours/day, 7 days/week), a variety of toxicity endpoints were evaluated, including liver and lung toxicity (Leuschner et al., 1983; reviewed in US EPA, 2009)[1]. However, adverse health effects were not reported in this study.

Effects that could be consistent with site of contact toxicity (e.g., edema and emphysema in the lungs) were reported in a short-term inhalation study (Clayton, 1966; reviewed in US EPA, 2009). A variety of other effects from histological examination were also reported (e.g., vacuolation of cells in the liver). However, study limitations (e.g., there was only a single exposure concentration of 67,416 mg/m^3 tested in the study, the sample size was three, and there were no control animals used in the study) preclude use of these findings to evaluate the toxicity of trichlorofluoromethane or carbon tetrafluoride by proxy.

The US EPA Integrated Risk Information System (US EPA IRIS, 1987a) has a reference dose for trichlorofluoromethane that is based on mortality and histopathological effects on the heart and lungs of rats exposed via gavage for 78 weeks.

A.3.2 Dichlorodifluoromethane

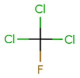
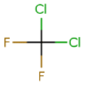
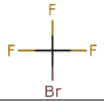
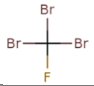
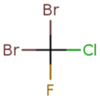
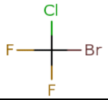
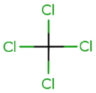
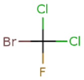
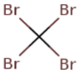
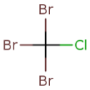
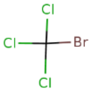
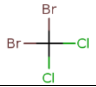
Subchronic inhalation studies on dichlorodifluoromethane reported histopathological effects in the lungs of both controls and treated animals (Leuschner et al., 1983; Prendergast et al., 1967; reviewed in US EPA, 2010), and thus, do not provide conclusive evidence of effects at the site of contact.

Focal necrosis and fatty infiltration of the liver were reported in a subchronic inhalation study of dichlorodifluoromethane in guinea pigs (Predergast et al., 1967; reviewed in US EPA, 2010). However, liver effects were not observed in any of the other animal species tested. In addition, a subchronic inhalation study of rats and dogs that included a detailed examination of liver toxicity showed no effects on the liver at exposures of up to 12,375 mg/m^3 (Leuschner et al., 1983; reviewed in US EPA, 2010)[2]. Due to potential differences in species sensitivity to liver effects from inhalation exposure to dichlorodifluoromethane, US EPA (2010) did not consider liver toxicity to be a critical effect of inhalation exposure.

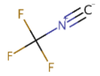
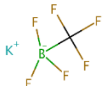
The POD used in the derivation of US EPA's (2010) subchronic RfC for dichlorodifluoromethane corresponds to reduced bodyweight gain in inhalation exposure studies in laboratory animals. The same critical effect was used as POD by US EPA (2010) and US EPA IRIS (1987b) to derive subchronic and chronic reference doses, respectively, for dichlorodifluoromethane based on oral exposure studies in laboratory animals.

Appendix B: Supplemental Tables

Table B - 1. Physical-Chemical Properties of Carbon Tetrafluoride and Analogues from ChemIDPlus[a]

Analogue	Structure	Melting Point (°Celsius)	Boiling Point (°Celsius)	log P (octanol-water)	Water Solubility[b] (mg/L)	Vapor Pressure[b] (mm Hg)	Henry's Law Constant[b] (atm-m^3/mole)	Atmospheric OH Rate Constant[b] (cm^3/molecule-sec)
Carbon Tetrafluoride		-184	-128.00	1.18	--	18.80	5.15	4.00E-16
Chlorotrifluoromethane (Freon-13)		-181	-81.40	1.65	90.00	21400	1.38	7.00E-16
Trichloromonofluoromethane (Freon-11)		-111	23.70	2.53	1100.00	803	0.10	5.00E-16
Dichlorodifluoromethane (Freon-12		-158	-29.80	2.16	280.00	4850	0.34	4.00E-16
Dibromodifluoromethane (Freon 12-B2)		-110	25.00	1.99	313.00	820	0.03	5.90E-16
Bromotrifluoromethane (Freon 13-B1)		-172	-57.80	1.86	320.00	12200	0.50	1.00E-16
Tribromofluoromethane		-73.6	108	2.4	--	--	--	0.0
Dibromochlorofluoromethane		--	80.3	2.31	--	--	--	2.31
Bromochlorodifluoromethane (Freon 12B1)		-160	-3.70	1.90	277.00	2070	0.09	1.00E-15
Carbon tetrachloride (Freon 10)		-23	76.80	2.83	793.00	115	0.03	1.20E-16
Bromodichlorofluoromethane		-106	52	--	--	--	--	--
Tetrabromomethane		90.1	189.5	3.42	240.00	--	4.91E-04	0.0
Tribromochloromethane		55	158.5	2.71	--	--	--	0.0
Bromotrichloromethane		-5.7	105	2.53	869	39	3.71E-04	0.0
Dibromodichloromethane		38.00	150.2	2.62	--	--	--	0.0
Trifluoroiodomethane (Freon 13T1)		--	-22.5	2.01	--	--	--	5.2E-14

Appendix B: Supplemental Tables

Analogue	Structure	Melting Point (°Celsius)	Boiling Point (°Celsius)	log P (octanol-water)	Water Solubility[b] (mg/L)	Vapor Pressure[b] (mm Hg)	Henry's Law Constant[b] (atm-m³/mole)	Atmospheric OH Rate Constant[b] (cm³/molecule-sec)
Trifluoromethylisocyanide		--	--	--	--	--	--	--
(Trifluoromethyl)silane		--	--	--	--	--	--	--
Potassium trifluoro(trifluoromethyl)borate(1-)		--	--	--	--	--	--	--
Trifluoromethane[c]		-155.18	-82.0	0.64	4.09E+03	3.53E+04	--	--

[a] Analogues are listed non-alphabetically based on structural similarity (see Supplementary Table 3).

[b] At 25 degrees Celsius.

[c] Values obtained from PubChem (NLM, 2023).

Appendix B: Supplemental Tables

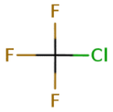
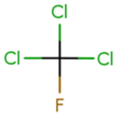
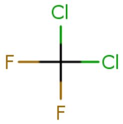
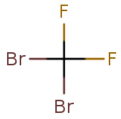
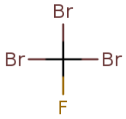
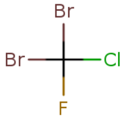
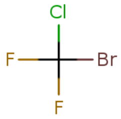
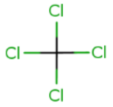
Table B - 2. Available Occupational Exposure Limits for Structurally Similar Carbon Tetrafluoride Analogues

Chemical	Occupational Exposure Limit	Source/Reference
Carbon tetrafluoride*	time-weighted average 2.5 mg(F)/m^3	Occupational Exposure Limits listed in a fact sheet from the National Institute of Occupational Safety and Health (NIOSH, 2022) for Australia, Belgium, and Hungary
	short term exposure limit 10 mg(F)/m^3	
	3000 mg/m^3	Short-term Occupational Exposure Limits listed in NIOSH (2022) for Russia
Trichlorofluoromethane	1,000 ppm (5,600 mg/m^3)	NIOSH Recommended Exposure Limit (REL) Ceiling, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) Time-weighted Average (TWA) and ACGIH Threshold Limit Value (TLV) Ceiling (NIOSH, 1994b)
Dichlorodifluoromethane	1,000 ppm (4,950 mg/m^3)	NIOSH REL TWA, OSHA PEL TWA and ACGIH TLV TWA (NIOSH, 1994a)
Carbon tetrachloride	ACGIH TLV TWA: 5 ppm (31 mg/m^3) ACGIH Short-term Exposure Limit (STEL): 10 ppm (63 mg/m^3) NIOSH REL: 2 ppm (12.6 mg/m^3) 60-minute STEL; OSHA PEL: 10 ppm (74.4 mg/m^3) TWA, 25 ppm (ceiling) (185.9 mg/m^3), 200 ppm (1487.3 mg/m^3) 5-min maximum peak in any 4 hours	(ACGIH, 2023; NIOSH, 1994c)

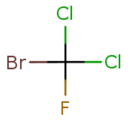
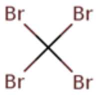
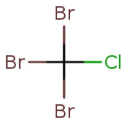
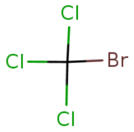
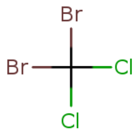
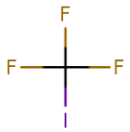
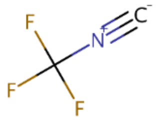
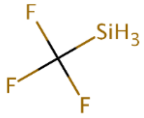
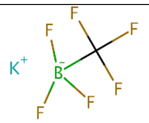
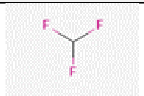
*The US Department of Energy (2022) and the US Department of Defense (US APHC, 2013) have short-term air guidelines for carbon tetrafluoride (i.e., Protective Action Criteria (PAC) and Military Exposure Guidelines (MEG), respectively). However, the derivation details for these values were not found online. In addition, NYS DEC (2021) guidance lists authoritative body sources for deriving AGCs and SGCs and does not include PACs or MEGs.

Appendix B: Supplemental Tables

Table B - 3. Carbon Tetrafluoride Analogues and Similarity Metrics

Structural Analogues	RN	Structure	Molecular Weight	Similarity to Tetrafluoromethane (by % or Tanimoto Coefficient)[a]
Chemical of Interest: Carbon tetrafluoride	75-73-0		88.003	--
Analogues Identified via ChemIDPlus (NLM, 2022)				
Chlorotrifluoromethane (Freon-13)	75-72-9		104.458	97.5309% similar
Trichlorofluoromethane (Freon-11)	75-69-4		137.368	95.1807% similar
Dichlorodifluoromethane (Freon-12)	75-71-8		120.913	95.1807% similar
Dibromodifluoromethane (Freon 12-B2)	75-61-6		209.815	91.8605% similar
Bromotrifluoromethane (Freon 13B1)	75-63-8		148.909	91.8605% similar
Tribromofluoromethane-	353-54-8		270.721	91.8605% similar
Dibromochlorofluoromethane	353-55-9		226.27	89.7727% similar
Bromochlorodifluoromethane (Freon 12B1)	353-59-3		165.364	89.7727% similar
Carbon tetrachloride (Freon 10)	56-23-5		181.819	87.7778% similar

Appendix B: Supplemental Tables

Structural Analogues	RN	Structure	Molecular Weight	Similarity to Tetrafluoromethane (by % or Tanimoto Coefficient)[a]
Bromodichlorofluoromethane	353-58-2		181.819	87.7778% similar
Tetrabromomethane	558-13-4		331.627	84.8837% similar
Tribromochloromethane	594-15-0		287.176	82.9545% similar
Bromotrichloromethane	75-62-7		198.274	81.1111% similar
Dibromodichloromethane	594-18-3		242.725	81.1111% similar
Analogues Identified via Integrated Chemical Environment (NTP, 2022)				
Trifluoroiodomethane (Freon 13T1)	2314-97-8		195.905	0.882353 (Tanimoto coefficient)
Trifluoromethylisocyanide	105879-13-8		95.02	0.833333 (Tanimoto coefficient)
(Trifluoromethyl)silane	10112-11-5		97.091	0.823529 (Tanimoto coefficient)
Potassium trifluoro(trifluoromethyl)borate(1-)	42298-15-7		175.91	0.823529 (Tanimoto coefficient)
Analogues Identified via the Comptox Dashboard (US EPA, 2022)				
Trifluoromethane	75-46-7		70.014	0.833333313 (similarity threshold)

[a] Structurally similar chemicals are characterized using online tools from ChemIDPlus, the Integrated Chemical Environment, and the Comptox Dashboard. Chemicals are grouped based on both similarity metric and online tool so that chemicals with common similarity metrics can be compared.

Attachment C
PFAS Boiling Point Tables

Appendix G – PFAS Analyte List

Group	Chemical Name	Abbreviation	CAS Number
Perfluoroalkyl sulfonic acids	Perfluorobutanesulfonic acid	PFBS	375-73-5
	Perfluoropentanesulfonic acid	PFPeS	2706-91-4
	Perfluorohexanesulfonic acid	PFHxS	355-46-4
	Perfluoroheptanesulfonic acid	PFHpS	375-92-8
	Perfluorooctanesulfonic acid	PFOS	1763-23-1
	Perfluorononanesulfonic acid	PFNS	68259-12-1
	Perfluorodecanesulfonic acid	PFDS	335-77-3
	Perfluorododecanesulfonic acid	PFDoS	79780-39-5
Perfluoroalkyl carboxylic acids	Perfluorobutanoic acid	PFBA	375-22-4
	Perfluoropentanoic acid	PFPeA	2706-90-3
	Perfluorohexanoic acid	PFHxA	307-24-4
	Perfluoroheptanoic acid	PFHpA	375-85-9
	Perfluorooctanoic acid	PFOA	335-67-1
	Perfluorononanoic acid	PFNA	375-95-1
	Perfluorodecanoic acid	PFDA	335-76-2
	Perfluoroundecanoic acid	PFUnA	2058-94-8
	Perfluorododecanoic acid	PFDoA	307-55-1
	Perfluorotridecanoic acid	PFTrDA	72629-94-8
	Perfluorotetradecanoic acid	PFTeDA	376-06-7
Per- and Polyfluoroether carboxylic acids	Hexafluoropropylene oxide dimer acid	HFPO-DA	13252-13-6
	4,8-Dioxa-3H-perfluorononanoic acid	ADONA	919005-14-4
	Perfluoro-3-methoxypropanoic acid	PFMPA	377-73-1
	Perfluoro-4-methoxybutanoic acid	PFMBA	863090-89-5
	Nonafluoro-3,6-dioxaheptanoic acid	NFDHA	151772-58-6
Fluorotelomer sulfonic acids	4:2 Fluorotelomer sulfonic acid	4:2-FTS	757124-72-4
	6:2 Fluorotelomer sulfonic acid	6:2-FTS	27619-97-2
	8:2 Fluorotelomer sulfonic acid	8:2-FTS	39108-34-4
Fluorotelomer carboxylic acids	3:3 Fluorotelomer carboxylic acid	3:3 FTCA	356-02-5
	5:3 Fluorotelomer carboxylic acid	5:3 FTCA	914637-49-3
	7:3 Fluorotelomer carboxylic acid	7:3 FTCA	812-70-4
Perfluorooctane sulfonamides	Perfluorooctane sulfonamide	PFOSA	754-91-6
	N-methylperfluorooctane sulfonamide	NMeFOSA	31506-32-8
	N-ethylperfluorooctane sulfonamide	NEtFOSA	4151-50-2
Perfluorooctane sulfonamidoacetic acids	N-methylperfluorooctane sulfonamidoacetic acid	N-MeFOSAA	2355-31-9
	N-ethylperfluorooctane sulfonamidoacetic acid	N-EtFOSAA	2991-50-6
Perfluorooctane sulfonamide ethanols	N-methylperfluorooctane sulfonamidoethanol	MeFOSE	24448-09-7
	N-ethylperfluorooctane sulfonamidoethanol	EtFOSE	1691-99-2

Group	Chemical Name	Abbreviation	CAS Number
Ether sulfonic acids	9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (F-53B Major)	9Cl-PF3ONS	756426-58-1
	11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (F-53B Minor)	11Cl-PF3OUdS	763051-92-9
	Perfluoro(2-ethoxyethane) sulfonic acid	PFEESA	113507-82-7

Boiling Points for Select PFAS- Standard 1633 List (Eurofins)

PFAS Name (§)	Molecular Formula	CAS No.	Boiling Point (T_b, ^oC)	Boiling Point (T_b, ^oF)
Perfluorobutanoic acid	C_3F_7COOH	375-22-4	120	248
			121	249.8
			121.8	251.24
Perfluoropentanoic acid	C_4F_9COOH	2706-90-3	139	282.2
			140	284
Perfluorohexanoic acid	$C_5F_{11}COOH$	307-24-4	157	314.6
			136	276.8
			168	334.4
			157	314.6
			168	334.4
Perfluoroheptanoic acid	$C_6F_{13}COOH$	375-85-9	175	347
			175	347
			185	365
Perfluorooctanoic acid	$C_7F_{15}COOH$	335-67-1	188	370.4
			189	372.2
			189	372.2
			189	372.2
			204	399.2
Perfluorononanoic acid	$C_8F_{17}COOH$	375-95-1	218	424.4
			218	424.4
			222	431.6
Perfluorodecanoic acid	$C_9F_{19}COOH$	335-76-2	218	424.4
			219	426.2
			218	424.4
			219	426.2
			239	462.2
Perfluoroundecanoic acid	$C_{10}F_{21}COOH$	2058-94-8	160	320
			238.4	461.12
			256	492.8
			238	460.4
Perfluorododecanoic acid	$C_{11}F_{23}COOH$	307-55-1	249	480.2
			249	480.2
			272	521.6
Perfluorotridecanoic acid	$C_{12}F_{25}COOH$	72629-94-8		501.8
			261	
Perfluorotetradecanoic acid	$C_{13}F_{27}COOH$	376-06-7	270	518
				573.8
			301	
Perfluorobutane sulfonic acid	$C_4F_9SO_3H$	375-73-5	198	388.4
			211	411.8
			214	417.2
Perfluoropentane sulfonic acid	$C_5F_{11}SO_3H$	2706-91-4	225	437
			225	437
			225	437
Perfluorohexane sulfonic acid	$C_6F_{13}SO_3H$	355-46-4	238.5	461.3
			452	845.6
			238	460.4
Perfluoroheptane sulfonic acid	$C_7F_{15}SO_3H$	375-92-8	226	438.8
Perfluorooctane sulfonic acid	$C_8F_{17}SO_3H$	1763-23-1	249	480.2
			249	480.2
			244	471.2
Perfluorononane sulfonic acid	$C_9F_{19}SO_3H$	68259-12-1	251	483.8
Perfluorodecane sulfonic acid	$C_{10}F_{21}SO_3H$	335-77-3	255	491
5:3 Fluorotelomer carboxylic acid	C F (CH) COOH	914637-49-3		390.2

5:3 Fluorotelomer carboxylic acid	$C_5F_{11}(CH_2)_2COOH$	914637-49-3	199	
4:2 Fluorotelomer sulfonic acid	$C_4F_9(CH_2)_2SO_3H$	757124-72-4	216	420.8
6:2 Fluorotelomer sulfonic acid	$C_6F_{13}(CH_2)_2SO_3H$	27619-97-2	258	496.4
8:2 Fluorotelomer sulfonic acid	$C_8F_{17}(CH_2)_2SO_3H$	39108-34-4	265	509
Perfluorooctane sulfonamide	$C_8F_{17}SO_2NH_2$	754-91-6	227	440.6
N-Methyl perfluorooctane sulfonamide	$C_8F_{17}SO_2NHCH_3$	31506-32-8	227	440.6
N-Ethyl perfluorooctane sulfonamide	$C_8F_{17}SO_2NHCH_2CH_3$	4151-50-2	196	384.8
			110	230
			407	764.6
			247	476.6
N-Methyl perfluorooctane sulfonamidoethanol	$C_8F_{17}SO_2N(CH_3)(CH_2)_2OH$	24448-09-7	300	572
			150	302
N-Ethyl perfluorooctane sulfonamidoethanol	$C_8F_{17}SO_2N(C_2H_5)(CH_2)_2OH$	1691-99-2	118	244.4
			317	602.6
N-Methyl perfluorooctane sulfonamido acetic acid	$C_8F_{17}SOON(CH_3)CH_2CO_2H$	2355-31-9	327	620.6
N-Ethyl perfluorooctane sulfonamido acetic acid	$C_8F_{17}SOON(C_2H_5)CH_2CO_2H$	2991-50-6	343	649.4
Hexafluoropropylene oxide dimer acid	$C_3F_7O(CF_2)_2COOH$	13252-13-6	145	293
			129	264.2
Perfluoro-3-methoxypropanoic acid	$CF_3O(CF_2)_2COOH$	377-73-1	147	296.6
Perfluoro-4-methoxybutanoic acid	$CF_3O(CF_2)_3COOH$	863090-89-5	158	316.4
Perfluoro-3,6-dioxaheptanoic acid	$CF_3O(CF_2)_2OCF_2COOH$	151772-58-6	186	366.8
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	$Cl(CF_2)_8O(CF_2)_2SO_3H$	763051-92-9	224	435.2
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	$Cl(CF_2)_6O(CF_2)_2SO_3H$	756426-58-1	217	422.6
Perfluoro(2-ethoxyethane)sulfonic acid	$C_2F_5O(CF_2)_2SO_3H$	113507-82-7	217	422.6
4,8-dioxa-3H-perfluorononanoic acid	$CF_3O(CF_2)_3OC_2HF_3COOH$	919005-14-4	228	442.4
			183.3	361.94
Perfluorododecanesulfonic Acid PFDoS	C12F25SO3H	79780-39-5		
3:3 FTCA	C6H5F7O	356-02-5	78	172.4
7:3 FTCA	C8H3F13O2	812-70-4	194.8	382.64
			229.8	445.64
			264.8	508.64

Boiling Points for Select PFAS- Extended List (Eurofins 1633 Extended List)

PFAS Name (§)	Molecular Formula	CAS No.	Boiling Point (T_b, ^{o}C)	Boiling Point (T_b, $_o$Cύ
Perfluorobutanoic acid	C_3F_7COOH	375-22-4	120	248
			121	249.8
			121.8	251.24
Perfluoropentanoic acid	C_4F_9COOH	2706-90-3	139	282.2
			140	284
Perfluorohexanoic acid	$C_5F_{11}COOH$	307-24-4	157	314.6
			136	276.8
			168	334.4
			157	314.6
			168	334.4
Perfluoroheptanoic acid	$C_6F_{13}COOH$	375-85-9	175	347
			175	347
			185	365
Perfluorooctanoic acid	$C_7F_{15}COOH$	335-67-1	188	370.4
			189	372.2
			189	372.2
			189	372.2
			204	399.2
Perfluorononanoic acid	$C_8F_{17}COOH$	375-95-1	218	424.4
			218	424.4
			222	431.6
Perfluorodecanoic acid	$C_9F_{19}COOH$	335-76-2	218	424.4
			219	426.2
			218	424.4
			219	426.2
			239	462.2
Perfluoroundecanoic acid	$C_{10}F_{21}COOH$	2058-94-8	160	320
			238.4	461.12
			256	492.8
			238	460.4
Perfluorododecanoic acid	$C_{11}F_{23}COOH$	307-55-1	249	480.2
			249	480.2
			272	521.6
Perfluorotridecanoic acid	$C_{12}F_{25}COOH$	72629-94-8		501.8
			261	
Perfluorotetradecanoic acid	$C_{13}F_{27}COOH$	376-06-7	270	518
				573.8
			301	
Perfluorobutane sulfonic acid	$C_4F_9SO_3H$	375-73-5	198	388.4
			211	411.8
			214	417.2
Perfluoropentane sulfonic acid	$C_5F_{11}SO_3H$	2706-91-4	225	437
			225	437
			225	437
Perfluorohexane sulfonic acid	$C_6F_{13}SO_3H$	355-46-4	238.5	461.3
			452	845.6
			238	460.4
Perfluoroheptane sulfonic acid	$C_7F_{15}SO_3H$	375-92-8	226	438.8
Perfluorooctane sulfonic acid	$C_8F_{17}SO_3H$	1763-23-1	249	480.2
			249	480.2
			244	471.2
Perfluorononane sulfonic acid	$C_9F_{19}SO_3H$	68259-12-1	251	483.8
Perfluorodecane sulfonic acid	$C_{10}F_{21}SO_3H$	335-77-3	255	491
5:3 Fluorotelomer carboxylic acid	$C_5F_{11}(CH_2)_2COOH$	914637-49-3		390.2
			199	

6:2 Fluorotelomer carboxylic acid	$C_6F_{13}CH_2COOH$	53826-12-3	193	379.4
4:2 Fluorotelomer sulfonic acid	$C_4F_9(CH_2)_2SO_3H$	757124-72-4	216	420.8
6:2 Fluorotelomer sulfonic acid	$C_6F_{13}(CH_2)_2SO_3H$	27619-97-2	258	496.4
8:2 Fluorotelomer sulfonic acid	$C_8F_{17}(CH_2)_2SO_3H$	39108-34-4	265	509
10:2 Fluorotelomer sulfonic acid	$C_{10}F_{21}(CH_2)_2SO_3H$	120226-60-0	220	428
Perfluorooctane sulfonamide	$C_8F_{17}SO_2NH_2$	754-91-6	227	440.6
N-Methyl perfluorooctane sulfonamide	$C_8F_{17}SO_2NHCH_3$	31506-32-8	227	440.6
N-Ethyl perfluorooctane sulfonamide	$C_8F_{17}SO_2NHCH_2CH_3$	4151-50-2	196	384.8
			110	230
			407	764.6
			247	476.6
N-Methyl perfluorooctane sulfonamidoethanol	$C_8F_{17}SO_2N(CH_3)(CH_2)_2OH$	24448-09-7	300	572
			150	302
N-Ethyl perfluorooctane sulfonamidoethanol	$C_8F_{17}SO_2N(C_2H_5)(CH_2)_2OH$	1691-99-2	118	244.4
			317	602.6
N-Methyl perfluorooctane sulfonamido acetic acid	$C_8F_{17}SOON(CH_3)CH_2CO_2H$	2355-31-9	327	620.6
N-Ethyl perfluorooctane sulfonamido acetic acid	$C_8F_{17}SOON(C_2H_5)CH_2CO_2H$	2991-50-6	343	649.4
Hexafluoropropylene oxide dimer acid	$C_3F_7O(CF_2)_2COOH$	13252-13-6	145	293
			129	264.2
Perfluoro-3-methoxypropanoic acid	$CF_3O(CF_2)_2COOH$	377-73-1	147	296.6
Perfluoro-4-methoxybutanoic acid	$CF_3O(CF_2)_3COOH$	863090-89-5	158	316.4
Perfluoro-3,6-dioxaheptanoic acid	$CF_3O(CF_2)_2OCF_2COOH$	151772-58-6	186	366.8
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	$Cl(CF_2)_8O(CF_2)_2SO_3H$	763051-92-9	224	435.2
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	$Cl(CF_2)_6O(CF_2)_2SO_3H$	756426-58-1	217	422.6
Perfluoro(2-ethoxyethane)sulfonic acid	$C_2F_5O(CF_2)_2SO_3H$	113507-82-7	217	422.6
4,8-dioxa-3H-perfluorononanoic acid	$CF_3O(CF_2)_3OC_2HF_3COOH$	919005-14-4	228	442.4
			183.3	361.94
Perfluoro-n-hexdecanoic Acid (PFHxDA)	C16HF31COOH	67905-19-5	211	411.8
Perfluoro-n-octadecanoic Acid (PFODA)	C17F35COOH / C18HF35O	16517-11-6	235	455
Perfluorododecanesulfonic Acid (PFDoS)	C12HF25O3S	79780-39-5		
3:3 FTCA	C6H5F7O	356-02-5	78	172.4
7:3 FTCA	C8H3F13O2	812-70-4	194.8	382.64
			229.8	445.64
			264.8	508.64
6:2 FTUCA	C8H2F12O2	70887-88-6	215.5	419.9
8:2 FTCA	C10H3F17O2	27854-31-5	260.4	500.72
8:2 FTUCA	C10H2F16O2	70887-84-2	169.4	336.92
			209.4	408.92
			249.4	480.92
10:2 FTCA	C12H3F21O2	53826-13-4	221	429.8
			256	492.8
			291	555.8
10:2 FTUCA	C12H2F20O2	70887-94-4	201.5	394.7
			241.5	466.7
			281.5	538.7
PFECHS	C8HF15O3S	133201-07-7		
PFPrS	C3F7SO3H	423-41-6	196	
PFPrA	CF3CF2CO2H	422-64-0	97	
PFMOAA	C3HF5O3	674-13-5	109.3	228.74
PFECA G	C7HF13O3	801212-59-9	183.5	362.3
PFO4DA	C6HF11O6	39492-90-5	181.9	359.42
PFO3OA	C5HF9O5	39492-89-2	179.3	354.74
PFO2HxA	C4HF7O4	39492-88-1	139.3	282.74
R-EVE	C8H2F12O5	2416366-22-6	386.6	727.88
NVHOS	C4H2F8O4S	1132933-86-8		
Hydro-EVE Acid	C8H2F14O4	773804-62-9	186.9	368.42
EVE Acid	C8HF13O4	69087-46-3	182.64	360.752
PFO5DA	C7HF13O7	39492-91-6	179.3	354.74
PMPA	C4HF7O3	13140-29-9	121.5	250.7

PEPA	C5HF9O3	267239-61-2	156.6	313.88
MTP	C4H4F4O3	93449-21-9	200.6	393.08
PS Acid	C7HF13O5S	29311-67-9	216.4	421.52
Hydro-PS Acid	C7H2F14O5S	749836-20-2	220.6	429.08
R-PSDA	C7H2F12O6S	2416366-18-0		
Hydrolyzed PSDA	C7H3F11O7S	2416366-19-1		
R-PSDCA	C6H2F12O4S	2416366-21-5		

Boiling Point References:

b) Product – Chemical Profile for Treatments Containing Perfluoroalkyl or Polyfluoroalkyl Substances for Use on Converted Textiles or Leathers NOVEMBER 2019 • DISCUSSION DRAFT
  - https://dtsc.ca.gov/wp-content/uploads/sites/31/2019/11/Product-Chemical-Profile-for-Treatments-with-PFASs.pdf
    - ” Most PFASs are solid at room temperature. Notable exceptions include 6:2 FTOH and 4:2 FTOH, which exist as a liquid at room temperature, and 8:2 FTOH, which exists as a solid but can sublimate and volatilize at room temperature (Concawe 2016). The boiling points of PFASs are similar to those of the homologous hydrocarbons (i.e., molecules with the same structure but only carbon-hydrogen bonds instead of carbon-fluorine bonds), except for perfluoroethers and perfluoroketones, which boil at significantly lower temperatures compared to their hydrocarbon homologues due to lower intermolecular forces (Ceretta 2013).”

c) Additional information relating to the draft risk management evaluation on long-chain perfluorocarboxylic acids, their salts and related compounds
  - https://consult.defra.gov.uk/pops-and-chemicals-in-waste-team/poprc-evaluation-2023/supporting_documents/Document%203.2_Additional%20information%20on%20LC%20PFCAs.pdf
    - C21 PFCA Boiling Point of 361.3°C

d) Reference provided by Pace Analytical:
  - https://www.chemicalbook.com/ProductChemicalPropertiesCB8342100_EN.htm

e) Interstate Technology and Regulatory Council PFAS Boiling Point Table
  - Section 4: Physical and Chemical Properties Table 4-1 Excel File
    - https://pfas-1.itrcweb.org/#1_3

Attachment D
Table 2

Table 2
AERMOD Modeling Summary

Contaminant	Max Hourly Dispersion Concentration	SGC	% of SGC	Max Annual Dispersion Concentration	AGC	% of AGC
	All values in ug/m3					
Total Sampled PFAS (99.9% DRE, full receptor grid)	**2.75E-05**	**N/A**	**N/A**	**2.72E-07**	**0.0053**[1]	**0.005%**
Total Sampled PFAS (99.9% DRE, 1.5 mile endpoint)	**5.39E-06**	**N/A**	**N/A**	**7.08E-08**	**0.0053**[1]	**0.001%**
Hydrogen Fluoride (HF)	**1.26**	**5.6**	**23%**	**0.0124**	**0.071**	**17%**
Carbon Tetrafluoride (CF4)	**5.28E-03**	**N/A**	**N/A**	**5.21E-05**	**0.33**[2]	**0.02%**

1 – Individual AGC for PFOA

2 – NYSDOH recommended AGC, not formally accepted by the NYSDEC

Attachment E
ESMI email to NYSDEC requesting clarification on the PPP requirement

Martin, Robert R

From: Martin, Robert R
Sent: Thursday, April 11, 2024 3:42 PM
To: Magee, Beth A (DEC)
Cc: Wood, Kevin (DEC); White, Katelyn M (DEC); Zeng, Yuan (DEC); Patel, Yasmini M (DEC); Love, Aaron A (DEC); Burns, Erin (DEC); Rance, Averil B
Subject: RE: :EXTERNAL: RE: ESMI of New York RD&D Permit Submittal; PFAS Contaminated Soil

Good Afternoon Beth. ESMI of New York (ESMI) is seeking clarification regarding the issued Notice of Incomplete Application (dated 3/14/24). Specifically, Item #7 of the document which requires ESMI to prepare a Public Participation Plan (PPP) pursuant to DEC Commissioner Policy 29 (DEC CP 29). ESMI is applying for a limited (time and soil mass limited) Research, Development, and Demonstration Permit (RDD) at a permitted solid waste treatment facility that holds an air resources permit.

DEC CP 29 specifically states that the PPP policy "… shall apply to applications for major projects and major modifications…" ((CP 29 (V)(A)) and that "… this policy shall not apply to permit applications for minor modifications…" (CP 29 (V)(A)(2)). Finally, DEC CP 29 defines "major project" as "any action requiring a permit identified in section 621.2 of title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York (6 NYCRR Part 621.2), which is not specifically defined as minor." ((CP 29 (III)(A)(5)).

As referenced in the "major project" definition above, 6 NYCRR Part 621.2 specifically states that a Research, Development, and Demonstration Projects is designated as a minor project (6 CRR Part 621.2 (s), 6 CRR Part 621.4 (g)(2-3) and (m)(2)(5); 621.4 (g) is referenced in noting the permit does not meet the definition of "major permit"). Additionally, under 6 CRR 360.18, an RD&D permit is a limited permit by its very nature. 360.18(c) notes that "an activity whose primary purpose is to process commercial quantities of waste." Is prohibited. Per ESMI's submittal, the requested timeframe for treatment is approximately two weeks with a soil mass of up to 5,000-tons. The timeframe and tonnage noted in the submittal were identified to "… effectively address the research objectives." (6 CRR 360.18 (d)(3)). ESMI intends to again demonstrate that soil can be treated to meet current State soil cleanup guidance objectives and demonstrate that emissions can be controlled to designated levels acceptable to the State.

Based on the above, ESMI believe that a PPP for this particular permit is not required. We look forward to your response and learning how DEC CP 29 is applied to various projects.

Should you have any questions, or require additional information, please let me know.

Thank you
Rob

Robert Martin
Technical Director - PFAS

CleanEarth™

M +1.518.681.6759 O 518.747.5500
rmartin@cleanearthinc.com
www.cleanearthinc.com

304 Towpath Ln, Fort Edward, NY 12828

icare
think safety. act safely

From: Magee, Beth A (DEC) <beth.magee@dec.ny.gov>
Sent: Friday, March 15, 2024 2:11 PM
To: Martin, Robert R <rmartin@cleanearthinc.com>
Cc: Wood, Kevin (DEC) <kevin.wood@dec.ny.gov>; White, Katelyn M (DEC) <katelyn.white@dec.ny.gov>; Zeng, Yuan (DEC) <yuan.zeng@dec.ny.gov>; Patel, Yasmini M (DEC) <yasmini.patel@dec.ny.gov>; Love, Aaron A (DEC) <Aaron.Love@dec.ny.gov>; Burns, Erin (DEC) <erin.burns@dec.ny.gov>
Subject: :EXTERNAL: RE: ESMI of New York RD&D Permit Submittal; PFAS Contaminated Soil

Hi Rob.

Department staff have reviewed the referenced application and found it to be incomplete. Please see the attached which outlines the additional information needed and feel free to contact us with any questions.

Take care,

Beth A. Magee
Deputy Regional Permit Administrator, Division of Environmental Permits

New York State Department of Environmental Conservation
232 Golf Course Road, Warrensburg, NY 12885
P: (518) 623-1283 | F: (518) 623-3603 | beth.magee@dec.ny.gov
www.dec.ny.gov | | |

From: Martin, Robert R <rmartin@harsco.com>
Sent: Friday, December 29, 2023 4:03 PM
To: Wood, Kevin (DEC) <kevin.wood@dec.ny.gov>; Sierzenga, Paul M (DEC) <paul.sierzenga@dec.ny.gov>
Cc: White, Katelyn M (DEC) <katelyn.white@dec.ny.gov>; Patel, Yasmini M (DEC) <yasmini.patel@dec.ny.gov>; Magee, Beth A (DEC) <beth.magee@dec.ny.gov>
Subject: ESMI of New York RD&D Permit Submittal; PFAS Contaminated Soil

Good Afternoon. ESMI is submitting the attached 360.18 and 201-1.16 RD&D Permit submittal for the treated of PFAS contaminated soil at the Fort Edward Facility.

Once you have received the document, could you please let me know so that I can make internal notifications. If you have any questions, or require additional information, please let me know.

We look forward to engaging with the State in developing scientific data that will support both parties goals moving forward.

Talk to you soon.
Rob

Robert Martin
Technical Director - PFAS

CleanEarth™

M 518.681.6759 O 518.747.5500
rmartin@harsco.com
www.cleanearthinc.com
304 Towpath Ln, Fort Edward, NY 12828

icare
think safety. act safely