State of Wisconsin
Department of Natural Resources
PO Box 7921, Madison WI 53707-7921
dnr.wi.gov

Technical Assistance, Environmental Liability Clarification or Post-Closure Modification Request

Notice: Use this form to request **a written response (on agency letterhead)** from the Department of Natural Resources (DNR) regarding technical assistance, a post-closure change to a site, a specialized agreement or liability clarification for Property with known or suspected environmental contamination. A fee will be required as is authorized by s. 292.55, Wis. Stats., and NR 749, Wis. Adm. Code., unless noted in the instructions below. Personal information collected will be used for administrative purposes and may be provided to requesters to the extent required by Wisconsin's Open Records law [ss. 19.31 - 19.39, Wis. Stats.].

Definitions

"Property" refers to the subject Property that is perceived to have been or has been impacted by the discharge of hazardous substances.

"Liability Clarification" refers to a written determination by the Department provided in response to a request made on this form. The response clarifies whether a person is or may become liable for the environmental contamination of a Property, as provided in s. 292.55, Wis. Stats.

"Technical Assistance" refers to the Department's assistance or comments on the planning and implementation of an environmental investigation or environmental cleanup on a Property in response to a request made on this form as provided in s. 292.55, Wis. Stats.

"Post-closure modification" refers to changes to Property boundaries and/or continuing obligations for Properties or sites that received closure letters for which continuing obligations have been applied or where contamination remains. Many, but not all, of these sites are included on the GIS Registry layer of RR Sites Map to provide public notice of residual contamination and continuing obligations.

Select the Correct Form

This from should be used to request the following from the DNR:

- Technical Assistance
- Liability Clarification
- Post-Closure Modifications
- Specialized Agreements (tax cancellation, negotiated agreements, etc.)

Do not use this form if one of the following applies:

- Request for an **off-site liability exemption or clarification** for Property that has been or is perceived to be contaminated by one or more hazardous substances that originated on another Property containing the source of the contamination. Use DNR's Off-Site Liability Exemption and Liability Clarification Application Form 4400-201.
- Submittal of an Environmental Assessment for the **Lender Liability Exemption**, s 292.21, Wis. Stats., **if no response or review by DNR is requested**. Use the Lender Liability Exemption Environmental Assessment Tracking Form 4400-196.
- Request for an **exemption to develop on a historic fill site** or licensed landfill. Use DNR's Form 4400-226 or 4400-226A.
- **Request for closure** for Property where the investigation and cleanup actions are completed. Use DNR's Case Closure - GIS Registry Form 4400-202.

All forms, publications and additional information are available on the internet at: dnr.wi.gov/topic/Brownfields/Pubs.html.

Instructions

1. Complete sections 1, 2, 6 and 7 for all requests. Be sure to provide adequate and complete information.
2. Select the type of assistance requested: Section 3 for technical assistance or post-closure modifications, Section 4 for a written determination or clarification of environmental liabilities; or Section 5 for a specialized agreement.
3. Include the fee payment that is listed in Section 3, 4, or 5, unless you are a "Voluntary Party" enrolled in the Voluntary Party Liability Exemption Program **and** the questions in Section 2 direct otherwise. Information on to whom and where to send the fee is found in Section 8 of this form.
4. Send the completed request, supporting materials and the fee to the appropriate DNR regional office where the Property is located.

   See the map on the last page of this form. A paper copy of the signed form and all reports and supporting materials shall be sent with an electronic copy of the form and supporting materials on a compact disk. For electronic document submittal requirements see: http://dnr.wi.gov/files/PDF/pubs/rr/RR690.pdf"

The time required for DNR's determination varies depending on the complexity of the site, and the clarity and completeness of the request and supporting documentation.

Section 1. Contact and Recipient Information

Requester Information

This is the person requesting technical assistance or a post-closure modification review, that his or her liability be clarified or a specialized agreement and is identified as the requester in Section 7. DNR will address its response letter to this person.

Last Name	First	MI	Organization/ Business Name		
Wahl	Scott		Tyco Fire Products LP		
Mailing Address			**City**	**State**	**ZIP Code**
2700 Industrial Parkway South			Marinette	WI	54143
Phone # (include area code)	**Fax # (include area code)**		**Email**		

The requester listed above: (select all that apply)

- [x] Is currently the owner
- [ ] Is considering selling the Property
- [ ] Is renting or leasing the Property
- [ ] Is considering acquiring the Property
- [ ] Is a lender with a mortgagee interest in the Property
- [ ] Other. Explain the status of the Property with respect to the applicant:

Contact Information (to be contacted with questions about this request)

- [ ] Select if same as requester

Contact Last Name	First	MI	Organization/ Business Name		
Verburg	Ben		Arcadis		
Mailing Address			**City**	**State**	**ZIP Code**
126 N Jefferson Street, Suite 400			Milwaukee	WI	53202
Phone # (include area code)	**Fax # (include area code)**		**Email**		
(414) 276-7742			Ben.Verburg@arcadis.com		

Environmental Consultant (if applicable)

Contact Last Name	First	MI	Organization/ Business Name		
Verburg	Ben		Arcadis		
Mailing Address			**City**	**State**	**ZIP Code**
126 N Jefferson Street, Suite 400			Milwaukee	WI	53202
Phone # (include area code)	**Fax # (include area code)**		**Email**		
(414) 276-7742			Ben.Verburg@arcadis.com		

Section 2. Property Information

Property Name			FID No. (if known)		
Tyco Fire Technology Center - PFCs			438005590		
BRRTS No. (if known)		**Parcel Identification Number**			
0238580694					
Street Address		**City**		**State**	**ZIP Code**
2700 Industrial Parkway South		Marinette		WI	54143
County	**Municipality where the Property is located**		**Property is composed of:**		**Property Size Acres**
Marinette	◯ City ◯ Town ◯ Village of Marinette		◯ Single tax parcel ◯ Multiple tax parcels		380

1. Is a response needed by a specific date? (e.g., Property closing date) Note: Most requests are completed within 60 days. Please plan accordingly.

   (●) No ( ) Yes

   Date requested by: ________________

   Reason:

   ____

2. Is the "Requester" enrolled as a Voluntary Party in the Voluntary Party Liability Exemption (VPLE) program?

   (●) No. **Include the fee that is required for your request in Section 3, 4 or 5.**

   ( ) Yes. **Do not include a separate fee.** This request will be billed separately through the VPLE Program.

Fill out the information in Section 3, 4 or 5 which corresponds with the type of request:
Section 3. Technical Assistance or Post-Closure Modifications;
Section 4. Liability Clarification; or Section 5. Specialized Agreement.

Section 3. Request for Technical Assistance or Post-Closure Modification

Select the type of technical assistance requested: [**Numbers in brackets are for WI DNR Use]**

- [ ] No Further Action Letter (NFA) (Immediate Actions) - NR 708.09, [183] - **Include a fee of $350.** Use for a written response to an immediate action after a discharge of a hazardous substance occurs. Generally, these are for a one-time spill event.
- [ ] Review of Site Investigation Work Plan - NR 716.09, [135] - **Include a fee of $700.**
- [ ] Review of Site Investigation Report - NR 716.15, [137] - **Include a fee of $1050.**
- [ ] Approval of a Site-Specific Soil Cleanup Standard - NR 720.10 or 12, [67] - **Include a fee of $1050.**
- [ ] Review of a Remedial Action Options Report - NR 722.13, [143] - **Include a fee of $1050.**
- [ ] Review of a Remedial Action Design Report - NR 724.09, [148] - **Include a fee of $1050.**
- [ ] Review of a Remedial Action Documentation Report - NR 724.15, [152] - **Include a fee of $350**
- [ ] Review of a Long-term Monitoring Plan - NR 724.17, [25] - **Include a fee of $425.**
- [ ] Review of an Operation and Maintenance Plan - NR 724.13, [192] - **Include a fee of $425.**

Other Technical Assistance - s. 292.55, Wis. Stats. [97] (For request to build on an abandoned landfill use Form 4400-226)

- [ ] Schedule a Technical Assistance Meeting - **Include a fee of $700.**
- [ ] Hazardous Waste Determination - **Include a fee of $700.**
- [x] Other Technical Assistance - **Include a fee of $700.** Explain your request in an attachment.

Post-Closure Modifications - NR 727, [181]

- [ ] Post-Closure Modifications: Modification to Property boundaries and/or continuing obligations of a closed site or Property; sites may be on the GIS Registry. This also includes removal of a site or Property from the GIS Registry. **Include a fee of $1050, and:**
  - [ ] Include a fee of $300 for sites with residual soil contamination; and
  - [ ] Include a fee of $350 for sites with residual groundwater contamination, monitoring wells or for vapor intrusion continuing obligations.

  Attach a description of the changes you are proposing, and documentation as to why the changes are needed (if the change to a Property, site or continuing obligation will result in revised maps, maintenance plans or photographs, those documents may be submitted later in the approval process, on a case-by-case basis).

Skip Sections 4 and 5 if the technical assistance you are requesting is listed above and complete Sections 6 and 7 of this for

Section 6. Other Information Submitted

Identify all materials that are included with this request.

Send both a paper copy of the signed form and all reports and supporting materials, and an electronic copy of the form and all reports, including Environmental Site Assessment Reports, and supporting materials on a compact disk.

Include one copy of any document from any state agency files that you want the Department to review as part of this request. The person submitting this request is responsible for contacting other state agencies to obtain appropriate reports or information.

- [ ] Phase I Environmental Site Assessment Report - Date: ________________
- [ ] Phase II Environmental Site Assessment Report - Date: ________________

- [ ] Legal Description of Property (required for all liability requests and specialized agreements)
- [ ] Map of the Property (required for all liability requests and specialized agreements)

Analytical results of the following sampled media: Select all that apply and include date of collection.

- [ ] Groundwater
- [ ] Soil
- [ ] Sediment
- [ ] Other medium - Describe:

Date of Collection:

- [ ] A copy of the closure letter and submittal materials
- [ ] Draft tax cancellation agreement
- [ ] Draft agreement for assignment of tax foreclosure judgment
- [x] Other report(s) or information - Describe: Air Deposition Evaluation Report

For Property with newly identified discharges of hazardous substances only: Has a notification of a discharge of a hazardous substance been sent to the DNR as required by s. NR 706.05(1)(b), Wis. Adm. Code?

- ◯ Yes - Date (if known):
- ◯ No

Note: The Notification for Hazardous Substance Discharge (non-emergency) form is available at: dnr.wi.gov/files/PDF/forms/4400/4400-225.pdf.

Section 7. Certification by the Person who completed this form

- [ ] I am the person submitting this request (requester)
- [x] I prepared this request for: Scott Wahl
  Requester Name

I certify that I am familiar with the information submitted on this request, and that the information on and included with this request is true, accurate and complete to the best of my knowledge. I also certify I have the legal authority and the applicant's permission to make this request.

Signature	6/8/2020 Date Signed
Project Environmental Scientist Title	(414) 276-7742 Telephone Number (include area code)

Section 8. DNR Contacts and Addresses for Request Submittals

Send or deliver one paper copy and one electronic copy on a compact disk of the completed request, supporting materials, and fee to the region where the property is located to the address below. Contact a DNR regional brownfields specialist with any questions about this form or a specific situation involving a contaminated property. For electronic document submittal requirements see: http://dnr.wi.gov/files/PDF/pubs/rr/RR690.pdf.

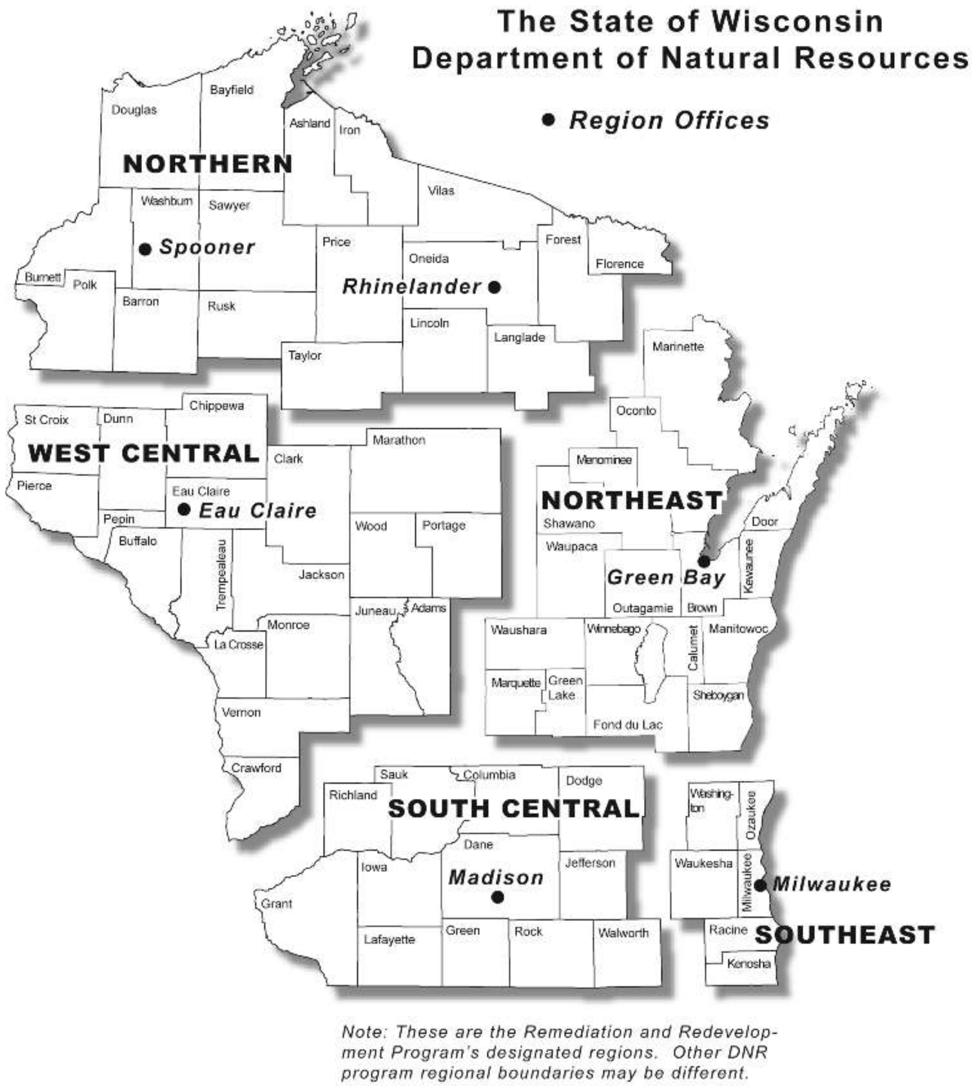
DNR NORTHERN REGION
Attn: RR Program Assistant
Department of Natural Resources
223 E Steinfest Rd Antigo, WI 54409

DNR NORTHEAST REGION
Attn: RR Program Assistant
Department of Natural Resources
2984 Shawano Avenue
Green Bay WI 54313

DNR SOUTH CENTRAL REGION
Attn: RR Program Assistant
Department of Natural Resources
3911 Fish Hatchery Road
Fitchburg WI 53711

DNR SOUTHEAST REGION
Attn: RR Program Assistant
Department of Natural Resources
2300 North Martin Luther King Drive
Milwaukee WI 53212

DNR WEST CENTRAL REGION
Attn: RR Program Assistant
Department of Natural Resources
1300 Clairemont Ave.
Eau Claire WI 54702



DNR Use Only			
Date Received	Date Assigned	BRRTS Activity Code	BRRTS No. (if used)
DNR Reviewer	Comments		
Fee Enclosed? ◯ Yes ◯ No	Fee Amount $	Date Additional Information Requested	Date Requested for DNR Response Letter
Date Approved	Final Determination		

Tyco Fire Products LP

AERIAL DEPOSITION EVALUATION REPORT

Tyco Fire Technology Center

Marinette, Wisconsin

BRRTS No. 02-38-580694

June 2020

FTC AERIAL DEPOSITION EVALUATION REPORT

Tyco Fire Technology Center
Marinette, Wisconsin
BRRTS No. 02-38-580694

Prepared for:

Tyco Fire Products LP

2700 Industrial Parkway South

Marinette, Wisconsin 54143

Prepared by:

Arcadis U.S., Inc.

126 North Jefferson Street

Suite 400

Milwaukee

Wisconsin 53202

Tel 414 276 7742

Fax 414 276 7603

Our Ref.:

30015294

Date:

June 8, 2020

Erika Houtz, PhD
Senior Engineer

Ben Verburg, PE
Project Manager

Michael Bedard
Project Lead

CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

%	percent
µg/kg	micrograms per kilogram
AFFF	Aqueous Film Forming Foam
Arcadis	Arcadis U.S., Inc.
g/cm^3	grams per cubic centimeter
ng/L	nanograms per liter
OTA	Outdoor Testing/Training Area
PFAS	per- and polyfluoroalkyl substances
PFCA	perfluoroalkyl carboxylate
PFHxS	perfluorohexane sulfonate
PFOA	perfluorooctanoic acid/ perfluorooctanoate
PFOS	perfluorooctane sulfonic acid/ perfluorooctane sulfonate
ppt	parts per trillion
R&D	research and development
Report	Aerial Deposition Evaluation Report
Site	Tyco Fire Technology Center
Tyco	Tyco Fire Products LP
USEPA	United States Environmental Protection Agency
WDNR	Wisconsin Department of Natural Resources

EXECUTIVE SUMMARY

The Tyco Fire Technology Center (Site) located in Marinette, Wisconsin is a fire suppressant training, testing, research, and development facility. This Aerial Deposition Evaluation Report (Report) presents an evaluation of the potential for aerial releases of Site-related per- and poly-fluoroalkyl substances (PFAS) to impact offsite soil and groundwater. This Report concludes that Site activities, data collected to date, and air modeling do not support that aerial deposition of PFAS constitutes an important transport mechanism.

Aqueous film-forming foams (AFFF) have been used at the Site as part of research and development (R&D), quality control, and firefighting training activities. PFAS such as perfluorooctanoic acid (PFOA) and/or perfluorooctanesulfonic acid (PFOS) have been present in various formulations of AFFF. PFAS have been detected in groundwater samples collected at the Site and in samples collected from offsite drinking water and groundwater monitoring wells. Outdoor releases of AFFF occurred at the Site as part of the Outdoor Testing/Training Area (OTA) activities; however, AFFF has not been sprayed outdoors at the OTA since November 2017.

A multiple lines of evidence approach was used to evaluate the potential for aerial releases and transport of PFAS via aerial deposition to impact offsite soil and groundwater. The lines of evidence evaluated, and key observations and conclusions from these evaluations, include the following:

- Potential aerial release mechanisms:
  - PFAS are not manufactured at the Tyco facility in Marinette, Wisconsin. There are no stack emissions at the Site. Indoor facility operations related to PFAS are not sources of aerial emissions.
  - Outdoor firefighter training and product testing occurred at the Site. Foam migration resulting from this activity was further explored as a potential source of aerial deposition of PFAS. Anecdotal observations from Tyco employees note that pieces of foam were occasionally observed to drift away from the OTA during fire training exercises.
  - Thus, the only potential air release mechanism from the facility is historical foam migration from the OTA, including historical activities at the Hydraulics Laboratory.
- Physical-chemical characteristics of the PFAS present in AFFF used or tested at the Site:
  - The PFAS found in AFFF contain charged functional groups (e.g., negatively charged functional groups like sulfonate), which are integral to their functionality as surfactants in AFFF. The charged nature of these chemicals inhibits their volatilization out of solution.
  - The PFAS found in AFFF have a tendency to remain in the aqueous phase or at the air-water interface of bubbles and follow the same migration pathways as water.
  - Because of their chemical characteristics, aerial migration of PFAS relevant to AFFF would occur in association with aerosol particles, not in the gas phase.
- PFAS soil data:

  - Soil samples have been collected from the Site in and around the OTA. Limited excavation and removal of piping and subsurface concrete foundations has occurred within the OTA, but not the surrounding soils. Investigation soil samples were not collected in areas where excavation has occurred.
  - The highest detections of PFAS in surficial soil occur within the fire training portion of the OTA, near known discharge and testing points, and along surface water runoff routes.
  - Soil detections are variable with direction and do not follow the pattern of predominant wind directions indicated by the wind rose collected from the nearby Menominee-Marinette Twin County Airport.
  - Multiple soil samples collected within 150 feet of the OTA and the R&D testing facility contain PFOS and PFOA concentrations that are within an order of magnitude or less of the concentrations observed in literature reported background soils. The decrease in PFAS concentrations from the source of foam application to concentrations within an order of magnitude of background in a short distance from the OTA support the conceptual site model that AFFF application of foam on the OTA is the primary source and infiltration at the application area and surface runoff are the primary pathways. The decrease in PFAS concentrations in surficial soils do not support that aerial transport and deposition off the OTA was a common transport pathway. These data provide strong evidence that foam migration will not cause substantial PFAS impacts to soil outside of the Site.
  - Collectively, the soil data do not support that foam migration from outdoor training and testing activities or unexpected PFAS emissions from the facility indoor operations are an important source of PFAS impacts immediately adjacent to the major outdoor release areas.
- PFAS groundwater data:
  - The PFAS mixture observed in groundwater samples collected from the Site and in the downgradient plume is consistently PFOA or perfluorohexanoic acid (PFHxA) dominant. The variability in the AFFF used at the Site over time did not result in a variable PFAS mixture in groundwater.
  - Where the PFAS mixture in groundwater deviated from the characteristic Site signature, PFAS impacts were lower than a benchmark value of 20 nanograms per liter (ng/L, or parts per trillion [ppt]) in groundwater.
  - Groundwater samples collected at the perimeter of the Site that are not downgradient of the OTA and are not connected by surface water features do not contain PFOS or PFOA concentrations above 20 ng/L. These samples suggest that in the absence of hydraulic connectivity within the Site, other PFAS transport mechanisms such as aerial deposition are insufficient to result in impacts above the 20 ng/L benchmark value.
  - The distribution of PFAS in groundwater that is so far understood to be connected to the Site is consistent with hydraulically driven transport pathways, not aerial deposition.
- Air modeling:

- Air modeling was conducted using the modeling software AERMOD to understand AFFF transport as a function of distance using local meteorological data from the Menominee-Marinette Twin County Airport and foam release scenarios typical of releases that occurred during testing and training at the OTA and the Hydraulics Laboratory. Total deposition over a 5-year period was modeled.
- While the wind directions are variable, the net effect of long-term testing at the OTA is a radial pattern of deposition, with deposition contours that extend slightly further from the release point in prevailing wind directions to the northeast and southeast.
- Under the modeling scenario where foam traveled the farthest distances (i.e., the lower density foam modeling scenario), there is a 99.9% reduction of PFAS deposition within 1500 feet of the OTA, which falls entirely within the Site boundaries. Groundwater samples collected at the southwestern and northwestern perimeter of the Site outside of the 99.9% deposition contour do not contain PFOS and PFOA above 20 ng/L.
- Most of the PFAS deposition occurred in near proximity of the point of release (i.e., 90% within 125 feet of the release locations). These modeling results agree with the soil data collected a short distance outside the OTA, in which PFOS and PFOA soil concentrations decrease to within an order of magnitude of literature-reported background concentrations in directions that are not along surface water flow pathways.

These lines of evidence, individually and synthesized together, do not support that an aerial transport pathway has carried sufficient quantities of PFAS off the Site to cause PFOS and PFOA concentrations in groundwater above 20 ng/L. Furthermore, the data collected to date and the aerial modeling both indicate that any substantial aerial impacts would have occurred within onsite areas that have already been investigated. Therefore, expansion of the Site investigation area for the purposes of evaluating aerial deposition is not warranted.

1 INTRODUCTION

This Aerial Deposition Evaluation Report (Report) has been prepared by Arcadis U.S., Inc. (Arcadis) on behalf of Tyco Fire Products LP (Tyco). The Ansul Fire Technology Center (Site) is located at 2700 Industrial Parkway, Marinette, Wisconsin. The Site is a fire suppressant training, testing, and research and development (R&D) facility that was constructed in the early 1960s. The Site encompasses approximately 380 acres with approximately 9 acres used as the Outdoor Testing/Training Area (OTA) and R&D and quality testing activities. The area of the Site outside the central campus comprises over 300 acres of undeveloped forest and wetlands. Tyco and Arcadis have conducted per- and polyfluoroalkyl substances (PFAS) investigation work within the City of Marinette and the Town of Peshtigo since 2016. This Report reviews the potential for aerial releases of Site-related PFAS to impact offsite soil and groundwater and concludes that Site activities and data collected to date do not support that aerial deposition of PFAS is an important transport offsite transport mechanism of PFAS.

The OTA includes the Firefighting School area (where firefighting scenarios are simulated) and the R&D area (where product testing occurs). The training area is an open gravel lot containing concrete and clay pads and steel pans, some with “props” where a contained fire is started and extinguished with the various products to test the performance of the fire suppression products. The OTA also includes the Hydraulics Laboratory (Building 105), where foam performance tests were conducted outdoors. There are various buildings at the Site where other R&D, quality control, and fire training activities are conducted indoors. The remaining area of the Site is used for light manufacturing, warehousing, office or classroom activities, parking, or is undeveloped. An overall Site diagram showing the locations of the areas and buildings is provided in Figure 1.

Aqueous film-forming foams (AFFF) sold by Tyco and/or others have been used at the Site as part of R&D, quality control, and firefighting training activities. PFAS such as PFOA and/or PFOS and their precursors have been present in various formulations of AFFF. PFAS have been detected in groundwater samples collected at the Site and in offsite drinking water samples and groundwater monitoring wells. The PFAS present in AFFF are non-volatile and no manufacturing with corresponding stack emissions have occurred at the Site. Outdoor releases of AFFF occurred at the Site as part of the OTA testing and training activities; however, AFFF has not been sprayed outdoors at the OTA since November 2017.

In 2016 the United States Environmental Protection Agency (USEPA) established a health advisory level of 70 ng/L for PFOS and PFOA combined in drinking water to offer a margin of protection to everyone, including the most sensitive populations, based on a life-time exposure to PFOA and PFOS from drinking water (USEPA 2016). In addition, the USEPA has determined that consumer products and food are a large source of exposure to these chemicals. In June 2019, the Wisconsin Department of Health Services recommended a groundwater enforcement standard of 20 ng/L for PFOA and PFOS, individually and combined. The 20 ng/L value is a potential future groundwater standard and is included as a benchmark value in this Report for discussion purposes. Humans that may be exposed to PFAS via ingestion of groundwater with concentrations of 20 ng/L or more PFOS and PFOA are the major receptors of concern in the Site investigation to date and future planned monitoring activities.

A multiple lines of evidence approach was used to evaluate the potential for aerial releases to impact offsite soil and groundwater:

1. An evaluation of the physical-chemical characteristics of the PFAS present in AFFF used or tested at the Site and their implications for aerial migration of these chemicals.
2. A review of operations at the Site, including foam testing and fire training exercises, to evaluate the potential for aerial releases of PFAS.
3. An evaluation of existing soil and groundwater data collected on and offsite.
4. Air modeling of foam deposition away from the Site to understand AFFF transport as a function of distance within the local meteorological context.

2 BACKGROUND ON AFFF

AFFF is a Class B foam used to suppress hydrocarbon fuel-based fires. AFFF formulations consist of water, an organic solvent such as diethylene glycol butyl ether, up to 5 percent (%) hydrocarbon surfactants, and 1% to 3% PFAS, by weight (Moody and Field 2000). Before use, AFFF is designed to be diluted with water to a 1%, 3%, or 6% mixture by weight, depending on the specific product. The PFAS in AFFF lower the air-water surface tension of the foam, and, in combination with the hydrocarbon surfactants lowering the fuel-water interfacial tension, enable efficient spreading of a thin film of the foam over the fuel source. PFAS are very thermally stable and do not appreciably degrade under the temperatures of hydrocarbon fires.

2.1 PFAS Chemistry in AFFF

The types of PFAS found in AFFF formulations vary both by year of production and manufacturer (Place and Field 2012; Houtz et al. 2013; D'Agostino et al. 2013). Some of the AFFF manufactured in the 1960s reportedly contained perfluoroalkyl carboxylates (PFCAs) like PFOA (Prevedouros et al. 2006). Until 2001, some types of AFFF formulations contained high concentrations of perfluoroalkyl sulfonates such as PFOS that were produced using electrochemical fluorination processes. These types of AFFF also contained a high percentage of short-chain "C6" precursors (i.e., contain six consecutive fluorinated carbons), which form perfluorohexane sulfonate (PFHxS) following environmental transformation (Houtz et al. 2013). Other AFFF formulations used PFAS manufactured by fluorotelomerization; these PFAS have been predominantly of a 6:2 fluorotelomer structure; although, older formulations also contained a high percentage (i.e., >15% of the total mass of PFAS content) of 8:2 fluorotelomer compounds (Place and Field 2012; Houtz et al. 2013). The telomer compounds can form PFCAs containing an equal or fewer number of fluorinated carbons in the environment. In recent years, military and governmental entities in Australia and the United States have prioritized the procurement of AFFF that does not contain any long-chain PFAS and many manufacturers have modified the PFAS chemistry in their products to meet these requirements.

2.2 AFFF-Derived PFAS Transport

The primary PFAS constituents in AFFF are surfactants by design and carry one or more positive or negative charges (Place & Field 2012; D'Agostino et al. 2013). The anionic (i.e., negatively charged) PFAS only take on a neutral character at extremely acidic pH. These molecular charges mean that the PFAS cannot volatilize into the gas phase. The PFAS constituents are dissolved in AFFF and will migrate with the foam. At unlined fire training areas and in emergency response, PFAS will seep into subsurface soil and groundwater, runoff to neighboring surface water and sediments, or remain on surficial soil as foam dries in place. PFAS can also seep into concrete (Baduel et al. 2015).

Only one study out of the relatively large body of AFFF literature has thus far indicated the potential for PFAS from AFFF to enter the vapor phase (Roth et al. 2020). This study measured PFAS using two different analytical methods in air following agitation of AFFF under simulated laboratory conditions in an enclosed chamber. Notably, each analytical method detected some PFAS in air, but the two techniques gave conflicting results about which PFAS were present. The results could not unequivocally determine whether the PFAS were present within aerosols or as a vapor.

AFFF can blow away from the point of release, spreading the footprint of PFAS impacts. At one fire training area where AFFF was used for more than 20 years, PFOS concentrations in surface soils declined from 34,000 micrograms per kilogram (µg/kg) at the center of the fire training area to less than 500 µg/kg within 500 feet, suggesting aerial transport was limited at this location (McGuire et al. 2014). A similar decline in soil PFAS concentrations with distance is observed at the Site OTA (Section 5.1) and is supported by modeling of air deposition at the Site, which demonstrates that aerial deposition declines by 90% within 125 feet of the release (Section 6).

3 LOCAL WIND CONDITIONS

Wind speed and direction is collected approximately 3.5 miles north of the Site at the Menominee-Marinette Twin County Airport, reported at 10 meters above the ground. This airport wind monitoring is assumed to be representative of conditions at the Site.

The average hourly wind speed at Menominee-Marinette Twin County Airport experiences significant seasonal variation over the course of the year (Figure 2). As described on weatherspark.com, highest wind speeds occur from late September to the beginning of May, with average wind speeds of more than 10.5 miles per hour. The windiest day of the year is typically in mid-January, with an average hourly wind speed of 12.7 miles per hour. The lowest wind speeds last from the beginning of May to late September. The calmest day of the year is typically mid-July, with an average hourly wind speed of 8.3 miles per hour. Fire schools and other outdoor AFFF testing historically occurred during summer, the calmest part of the year (Section 4.2.1). Outdoor foam testing at the Hydraulics Laboratory (Building 105) occurred year-round, weather permitting. Testing was suspended during freezing temperature conditions, and for seasonal holidays.

The predominant average hourly wind direction at Menominee-Marinette Twin County Airport (Station IDs: 726487, 94896) varies throughout the year; a wind rose from June, July, and August 2015 to 2019 is plotted in Figure 3, obtained from data collected by the National Oceanographic and Atmospheric Agency at ftp://ftp.ncdc.noaa.gov/pub/data/noaa/. The direction of the longest spoke shows the direction the wind is blowing from with the greatest frequency. During fire schools and other outdoor AFFF testing that occurred during summertime (Section 4.2.1), the wind is most often from the southwest and northwest towards Green Bay (Figure 3). The least predominant wind direction during historical outdoor AFFF testing for fire schools is from the northeast. Winds from years prior to the 2015 to 2019 period have a similar pattern.

4 SITE OPERATIONS AND RELEVANCE TO AERIAL EMISSIONS

This section discusses Site operations and their relevance to PFAS aerial emissions. PFAS were not manufactured at the Site and AFFF formulations were not blended at the Site. There are no stack emissions at the Site. Facility operations include testing, training, R&D, light manufacturing, warehousing, and office/classroom space.

4.1 Indoor Facility Operations

This subsection discusses facility operations and buildings where PFAS products were handled. With the exception of the four buildings discussed below, PFAS-containing products are not handled in the remaining buildings onsite. These remaining buildings are used for manufacturing, warehousing, office, or classroom activities. Building numbers are labeled on Figure 1.

4.1.1 Engineering Laboratory

The Engineering Laboratory (Building 102) was constructed in approximately 1962, with various additions over time. A range of laboratory scale R&D and quality control activities on AFFF products have occurred inside this building, including laboratory scale foam formulation development, small scale fire testing, physical and chemical parameter testing, and equipment testing and calibration (Tyco 2018). The fire testing consists of a one square foot fire test in a ventilated hood that uses heptane, acetone, or isopropanol fuel. There is a 15 second burn period prior to application of a one-liter foam solution (i.e., diluted to product specifications) over 90 seconds. The annual number of these tests conducted has ranged from 1500 to 5000 tests. The products tested are primarily Tyco AFFF products; although in approximately 1988, Tyco began providing third-party laboratory testing services for its foam products as well as foam agents manufactured by others. There are no significant air emissions, including potential PFAS air emissions, from this building.

4.1.2 Fire Test Houses

The first Fire Test House (Building 107) was constructed in approximately 1970 and has been used for indoor fire testing, including, but not exclusively foam and foam sprinkler testing. A second Fire Test House (Building 127) was added in approximately 2016 for the same activities. Typically six fires per day per test house for 50 weeks a year are conducted with common application rates of 2 to 3 gallons per minute of AFFF solution for three to five minutes. Based on facility testing data, maximum temperatures in the range of 140 to 300 degrees centigrade are reached during test fires prior to application of AFFF and temperatures remain above 100 degrees centigrade for two to six minutes. Ceiling and wall temperatures peak at approximately 150 degrees centigrade. The fires are rapidly cooled and quenched once AFFF is applied. Smoke from test fires exits the building through a roof opening. The spent AFFF solution is contained within the building. The fire test houses are not believed to be a source of PFAS air emissions.

4.1.3 Cold Storage

The Cold Storage Building (Building 115) was constructed in approximately 1976 and has been used for foam testing activities, including test enclosure extinguishment testing of non-AFFF material and nozzle testing of AFFF (Tyco 2018). All AFFF releases were confined indoors. There is no designated venting for the test fires, and any spent foam remained indoors. There are no significant air emissions, including potential PFAS air emissions, from this building.

4.1.4 Conclusions

Based on the indoor facility operations, there are no significant aerial release mechanisms for PFAS.

4.2 Outdoor Facility Operations

This subsection discusses activities in the OTA and Hydraulics Laboratory (Building 105). PFAS releases have occurred in these areas as described below.

4.2.1 Outdoor Testing/Training Area

The OTA was constructed in approximately 1961 and has been used to conduct testing, demonstrations, and training on a range of fire suppressants (both dry chemical and foam-containing products).

The OTA consists of various concrete and clay pads and steel pans, some with “props” where a contained fire would be started and extinguished with the various products to test the performance of the fire suppression products. The testing of foam products began in the early 1960s.

Training and demonstration activities also occurred at the OTA, although PFAS-containing foam, including AFFF, has not been used outdoors since 2017. Fire training and testing activities at the OTA historically occurred during a three-month period in the summer between the beginning of June and the end of August during the day (Monday to Friday, 7 AM to 5 PM, local time). The Site previously hosted fire schools and foam schools to train employees and customers on fire suppression techniques. Roughly 10 to 20 fire schools were scheduled per year prior to 2017 with one foam demonstration per school. For the foam schools, approximately two were scheduled per year with two foam demonstrations per school, and an additional three to four foam schools with two foam demonstrations were also conducted for specific applications (Tyco 2018). The fire schools appear to have occurred prior to the 1980s, and it is presently believed that the foam schools may have started at the Site after the late 1990s (Tyco 2018).

The typical fire training exercise was a person standing on the ground, using fire suppression equipment to spray AFFF to extinguish a fire. In most cases, foam was dispersed by a person standing at ground level; however, foam was also released at higher elevations less frequently when extinguishing fires on small structures.

Anecdotal observations from Tyco employees indicate that foam was occasionally observed to drift away from the OTA during fire training exercises.

It is believed that there was another outdoor testing area that was referred to as the Marine testing area located between Buildings 110 and 115 and that it had been dismantled (Tyco 2018). This area is approximately 300 feet west of the current OTA. After a reasonable and good faith inquiry, information to document the time period and uses of the Marine testing area was not found (Tyco 2018). As this area is close to the OTA, the evaluation of potential foam aerial release from the OTA will be adequate to also evaluate potential foam aerial releases from the Marine testing area.

4.2.2 Hydraulics Laboratory

The Hydraulics Laboratory (Building 105) was constructed in approximately 1985 and is in the northwest corner of the OTA. It consists of a building with various tanks, pumps, and nozzles where foam concentrate is mixed with water and used to conduct performance testing of foam systems (proportioning and hardware). It has an outdoor paved foam monitor pad that is sloped to direct drainage of water/foam mixture back into the building into a collection system. Outdoor testing at this location occurred most of year except during extreme cold and during seasonal holidays and ceased in 2017. Testing frequency varied over the years, but in the years leading up to 2017, testing typically occurred daily.

4.2.3 Conclusions

The OTA, including the Hydraulics Laboratory operations, resulted in outdoor liquid releases of AFFF containing PFAS. Anecdotal observations from Tyco employees indicate that foam was occasionally observed to drift away from the OTA during fire training or testing exercises. The potential for OTA and Hydraulics Laboratory operations to serve as a source of aerial deposition of PFAS to surrounding offsite areas is further explored in the following sections of this report.

5 OBSERVATIONS FROM EXISTING DATA

Since 2016, Tyco has been conducting PFAS investigations on and offsite in soil, groundwater, surface water, and private drinking wells. Table 1 summarizes relevant Site PFAS data summaries and Site Investigation Reports submitted to Wisconsin Department of Natural Resources (WDNR).

Table 1. Site Investigation Reports and Data Summaries Previously Submitted to WDNR

Report Title	Submission Date
2016 Investigation Report (Ansul Fire Technology Center Site)	November 2016
Site Investigation Report (Tyco Fire Technology Center – PFCs)	September 2018
Data Summary Report (Tyco Fire Technology Center)	March 2019
Data Summary Report - Supplemental Site Investigation (Tyco Fire Technology Center)	December 2019
Data Summary Report – Heath Lane Area Site Investigation	January 2020
Southern Area Groundwater Evaluation Report	March 2020
Conceptual Site Model (Tyco Fire Technology Center)	May 2020
Interim Site Investigation Report (Tyco Fire Technology Center)	May 2020

Onsite surficial soil samples and on and offsite groundwater samples analyzed for PFAS inform an understanding of potential aerial deposition from the Site. The PFAS analytes that were measured and their corresponding acronyms are described in Table 2. Not all PFAS analytes in Table 2 were measured in all samples; more recent investigations have included a longer list of analytes than earlier investigations.

Table 2. PFAS Analytes Included in Soil and Groundwater Investigations

Analyte	Acronym
Perfluorobutanoic acid	PFBA
Perfluoropentanoic acid	PFPeA
Perfluorohexanoic acid	PFHxA
Perfluoroheptanoic acid	PFHpA
Perfluorooctanoic acid	PFOA
Perfluorononanoic acid	PFNA
Perfluorodecanoic acid	PFDA
Perfluoroundecanoic acid	PFUnA
Perfluorododecanoic acid	PFDoA
Perfluorotridecanoic acid	PFTrDA
Perfluorotetradecanoic acid	PFTeDA
Perfluorobutanesulfonic acid	PFBS
Perfluorohexanesulfonic acid	PFHxS
Perfluoroheptanesulfonic acid	PFHpS
Perfluorooctanesulfonic acid	PFOS
Perfluorodecane sulfonic acid	PFDS
6:2 Fluorotelomer sulfonic acid	6:2 FTS
8:2 Fluorotelomer sulfonic acid	8:2 FTS
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA
Perfluorooctane sulfonamide	FOSA

Note: The analyte list **changed over time and not all samples were analyzed for all analytes.**

5.1 Soil Data

PFAS soil results from soil collected within the top 2 feet at the Site are presented in Figures 4 and 5. The top 2 feet are considered most relevant to soil impacts resulting from aerial releases. All soil data collected to date has been within the OTA or within approximately 300 feet of the OTA.

Excavation of 4,800 cubic yards of soil, 100 cubic yards of concrete, and piping within the OTA was conducted to remove petroleum impacts in 2006 (Earth Tech 2007); the excavated materials were landfilled offsite. These excavated locations represent a small portion of the OTA. PFAS soil sampling did not occur in any excavated locations.

Soil samples were bracketed into groups based on combined PFOS and PFOA detections (Figure 4). The groupings are not based on any regulatory targets, but grouped approximately by order of magnitude of concentration:

- >1000 µg/kg (yellow);
- <1000 and >100 µg/kg (blue);

- >10 and <100 µg/kg (orange);
- >5 and < 10 µg/kg (purple); and
- <5 µg/kg (green).

Several observations can be made from the PFAS soil data as it relates to the potential for aerial PFAS emissions and deposition at the Site:

- Combined PFOS and PFOA concentrations greater than 100 µg/kg (i.e., the two highest concentration groups) are concentrated in the following locations that are associated with historical AFFF outdoor releases or their surface water runoff pathways (blue and yellow circles within **Error! Reference source not found.**4):
  - Within the fire training portion of the OTA (e.g., locations SS-135 and SS-105);
  - Along the Hydraulics Laboratory paved foam monitoring pad (near samples locations FTC-71, FTC-72, FTC-77);
  - Along depressions that convey surface water runoff to the southwest of the FTA (near sample SS-133) and the northeast of the OTA (SS-122, SS-139).
- In many locations within 150 feet or less of the OTA, the combined PFOS and PFOA concentrations are below 10 µg/kg, three or more orders of magnitude lower than the highest detections (e.g., samples located at SS-123, SS-124, SS-130, SS-134, SS-115, SS-116, SS-119 represented by green and purple dots on Figure 4). The decrease in concentrations in a short distance support the observation in the previous bullet, that PFAS concentrations are primarily a result of AFFF application to quench fires on the OTA pad and surface water runoff pathways. The gradient in soil concentrations are not consistent with aerial transport of foam and deposition of foam in the vicinity of the OTA.
- Wind direction is variable at the Site (Section 3). The predominant wind directions during historical summertime training at the OTA are from the southwest and northwest towards Green Bay, and the least common wind direction is from the northeast to the southwest (Section 3; Figure 3). The pattern of soil detections around the OTA do not follow the predominant wind directions indicated by the wind rose (Figure 3):
  - In all directions around the OTA, the pattern of soil PFAS detections is variable.
  - Low concentration samples that contain less than 10 µg/kg PFOS and PFOA are observed in the predominant wind directions along the southeast and northeast perimeter of the OTA (e.g., SS-119, SS-120, SS-116, SS-115, SS-134).
  - Low concentration samples that contain less than 10 µg/kg PFOS and PFOA are also observed in the least predominant wind directions along the southwest and northwest perimeter of the OTA (e.g., FTC-83, SS-130, SS-123, SS-138).
- The concentrations of PFAS in soil range over four orders of magnitude without a clear concentration gradient (Figures 4 and 5A-B). These results corroborate the absence of an aerial emissions source at the Site, which would result in a decline in concentrations with distance from the point of release.

As indicated above, the higher soil detections coincide with the locations of historical AFFF outdoor releases or their surface water runoff pathways.

- The PFAS mixture observed in soil samples is highly variable (Figure 5A-B). These results corroborate the absence of an aerial emissions source at the Site, which would result in a more consistent pattern of PFAS compound distribution.
- Median background levels of PFOS and PFOA in soil reported in the peer reviewed literature range from approximately 0.4 to 1.9 µg/kg PFOS and 0.5 to 2.4 µg/kg PFOA, depending on degree of urbanization (Table 3). Less than 150 feet outside of the OTA in all compass directions (i.e., SS-123, SS-124, SS-138 and SS-127 to the north/northwest, SS-119 and SS-120 to the north/northeast, SS-130 to the west, SS-115 and SS-116 to the east, and SS-134 to the southeast) there are soil samples that are within an order of magnitude or less of these literature reported background levels (Table 3). The decrease in PFAS concentrations from the source of foam application to concentrations within an order of magnitude of background in a short distance from the OTA support the conceptual site model that AFFF application of foam on the OTA is the primary source and infiltration at the application area and surface runoff are the primary pathways. The decrease in PFAS concentrations do not support that aerial transport and deposition off the OTA was a common transport pathway. These data provide strong evidence that foam migration will not cause substantial PFAS impacts to soil outside of the Site.

Table 3. Review of Median Soil PFOS and PFOA Background Concentrations in Published Literature

Compound	Pristine North America Soils (µg/kg) (Rankin et al. 2016)	Global Urban Soils (µg/kg) (Strynar et al. 2012)	Statewide Survey of Vermont Soils (µg/kg) (Zhu et al. 2019)
PFOS	0.39	1.88	0.40
PFOA	0.54	2.42	0.68

Overall, the soil PFAS data reflect locations of known surface releases and surface water migration pathways of AFFF. They furthermore do not support foam migration or other aerial release as a major source of PFAS impacts to soil within the Site or outside of the Site.

5.2 Groundwater Data

Groundwater PFAS sampling locations and detections of PFOS and PFOA are plotted on Figure 6. The average PFAS mixture detected at groundwater sampling locations onsite and potentially associated with the Site are shown on Figures 7 and 8. The maximum PFAS concentrations detected at the same groundwater sampling locations are shown on Figure 9A-C. Note that the analyte list measured in groundwater changed over time; it was expanded to include more analytes. The minimum analyte list includes: PFOA, PFOS, PFNA, PFHpA, PFBS, and PFHxS. NEtFOSAA, NMeFOSAA, PFDA, PFDoA, PFHxA, PFTeA, PFTrA, and PFUdA. These were measured in approximately 70% of groundwater samples and are included in the PFAS mixture analysis in Figures 7 through 9. Because PFBA, PFPeA, PFOSA, 6:2 FtS, 8:2 FtS, PFHpS, and PFDS were measured in fewer than 4% of groundwater samples, they are excluded from the PFAS mixture analysis in Figures 7 through 9.

Several observations can be made from the PFAS groundwater data as it relates to the potential for aerial PFAS emissions and migration at the Site:

- The groundwater onsite and potentially associated with the Site contain a very similar PFAS mixture that is dominated by PFOA (green bars) or in some samples PFHxA (yellow bars) (Figure 7 and Figure 8).
    - Location SB-30 is the only location that contains more than 20 ng/L PFOS and PFOA that is not PFOA and/or PFHxA dominant.
    - Where the PFAS mixture deviates from the characteristic mixture of PFAS associated with the Site, the combined PFOS and PFOA concentration is less than 20 ng/L PFOS and PFOA. Although there is no assumption that foam migration is responsible for the alternative mixtures observed, if it were the source of the PFAS detections, it is not resulting in impacts to groundwater greater than the benchmark value of 20 ng/L.
- Groundwater collected at the southwest perimeter of the Site at location VAP-16 was non-detect for PFOS and PFOA (Figure 6). In groundwater collected at the northwest perimeter of the Site at VAP-22, PFOA was the only PFAS detected, and it was only detected in one interval at a concentration less than 20 ng/L (Figure 6). These locations are not downgradient of the OTA and are not connected by surface water features. These samples suggest that in the absence of hydraulic connectivity within the Site, other PFAS transport mechanisms such as aerial deposition are not common enough and/or do not carry sufficient mass to result in impacts above the 20 ng/L benchmark value.

The spatial distribution of onsite and offsite PFAS concentrations in groundwater, which will be discussed in greater detail in the forthcoming Site Conceptual Model Report, is consistent with a source area release and groundwater and surface water transport (Figure 6). The spatial distribution of PFAS concentrations, including groundwater at the perimeter of the Site that contains less than 20 ng/L PFOS and PFOA, does not support that aerial deposition of PFAS was common enough or carried enough mass to constitute an important transport mechanism for PFAS at the Site.

6 AIR MODELING OF FOAM MIGRATION FROM OTA

Air dispersion modeling can be used to provide an estimate of foam particle transport at defined distances downwind; therefore, an air deposition modeling analysis was conducted to estimate the deposition of AFFF particles from historical outdoor release areas as a function of distance in all directions from the Site. Estimating the total mass of deposition from the Site was beyond the scope of the modeling.

There is not a widely accepted air model for estimating foam transport. Air particle transport models were reviewed for their ability to mimic foam transport. The American Meteorological Society and United States Environmental Protection Agency (USEPA) Model Improvement Committee oversees development of state-of-the-art modeling concepts to USEPA's air quality models. This committee oversaw the development of AERMOD. The air dispersion model AERMOD (version 19191) was used for air dispersion and particle deposition modeling.

6.1 Air Model Setup

Inputs into the model include the emission source locations (i.e., the OTA and the Hydraulics Laboratory), emission source type, emission rate, meteorological data (including wind direction), the receptor grid, and modeling time periods.

6.1.1 Foam Release Assumptions

There are two outdoor areas where AFFF was used (Section 4.2): the OTA and the Hydraulics Laboratory. Releases were assumed to occur at both of these locations, with additional detail on the release assumptions described below.

Meteorological data, from 2015 to 2019, used to model deposition from these releases was constrained to the fire training and fire testing time periods described in Section 4.2.1. The fire suppression equipment was treated as a point source releasing foam at a specified elevation. It was assumed that 75%, 20%, and 5% of the foam was released at 1.2 m (to mimic a person standing on the ground using fire suppression equipment), 2.5 m (to mimic elevated foam release for extinguishing fires on small structures), and 5 m (to mimic elevated foam release for extinguishing fires on small structures), respectively, to approximate the range of fire training and testing activities that occurred as part of fire schools and foam testing at the OTA. Model parameters such as release height and frequency were based on discussions with facility operations personnel. The training and testing events were also intermittent, as described in Section 4.2.1. Based on a total of approximately 30 fire training and testing events per summer and an assumed 10-minute duration of testing, 100 minutes of outdoor foam release per month was estimated at the OTA. These events were represented as a *volume* source type in AERMOD to represent a release of foam. A *unitized* emission rate was used to represent the potential source emissions. A unitized emission rate is valid here because the purpose of the analysis is to determine foam deposition with distance from the source.

The second outdoor foam use area was adjacent to the Hydraulics Laboratory (Building 105) (Section 4.2.2). For the purposes of this modeling, testing was assumed to occur 11 months a year, 5 days a week between January 21 and December 21 (i.e., there was no testing between December 21 and January 21) for a total of 25 minutes a day between the hours 7 AM and 5 PM, local time. Meteorological data used to model deposition from these releases was constrained to these time periods. Testing frequency varied over the years, but in the years leading up to 2017, testing typically occurred daily. It was estimated that foam was dispersed at 1.2 m and 2.5 m above the ground, 60% and 40%, respectively. Similar to training and testing activities at the OTA, each testing event was represented as a *volume source type* in AERMOD, and a *unitized* emission rate was used to represent the potential source emissions.

6.1.2 Particle Size Assumptions

As described in Section 6, the model estimates particle air dispersion and deposition. It was assumed that foam was a particle for air modeling purposes. The density of the particles and the particle size distribution were both inputs for deposition modeling. Undiluted AFFF has a density similar to water, approximately 1 gram per cubic centimeter (g/cm^3). On deployment, AFFF is mixed with water and aerated to form foam. The resulting expansion factor increases the volume by approximately 2 to 10, thereby reducing density to 0.1 to 0.5 g/m^3 (Ansul 2013; Chemguard 2019). The model evaluated foam releases consisting of two different densities (0.1 g/m^3 and 0.5 g/m^3).

It was assumed that bubble size is equal to particle size. The model treated the foam particles as individual bubbles. AFFF is engineered to be cohesive, enabling layers of foam to interlock to extinguish the flames. The bubbles with greatest transport or dispersal potential are small individual bubbles. Estimates of the particle size distribution, or bubble size, were based on a peer-reviewed publication by Kennedy et al., which tested the dynamics of bubble coarsening in an AFFF concentrate that is designed to be used in a 3% mixture with water (2015). The bubble sizes of the AFFF material varied over a large range of sizes and also depended upon length of time after release. The bubble size distribution in the 30-second time frame after release was chosen because it contained the smallest bubble sizes. In the air model, smaller particles travel farther then larger particles.

6.1.3 Receptor Grid and Meteorological Inputs

A receptor grid is used in the model to define discrete locations to calculate air deposition. Approximately 7500 locations were used to calculate potential foam deposition points from each source. The model incorporates the topography of the area, obtained from United States Geological Survey National Elevation Dataset (NED), using the AERMOD terrain processor AERMAP.

The model used meteorological data from 2015 to 2019 from the nearby Menominee - Marinette Twin County Airport (Station IDs: 726487, 94896). The AERMOD-ready meteorological data were processed by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) and are representative of the area. The model computed the total potential deposition from both sources (the OTA and the Hydraulics Laboratory) over the modeled period for a foam density of 0.1 g/cm^3 and a foam density of 0.5 g/cm^3.

6.1.4 Uncertainties Associated with the Air Modelling

The air modeling results are built on the assumptions discussed above. Additional uncertainties are worth noting.

The effects of specific weather conditions (e.g., humidity and temperature) encountered during individual foam releases cannot be incorporated in the model.

Wind conditions at the Site may vary from those at the Menominee - Marinette Twin County Airport, whose meteorological data was used as inputs to the model. As discussed in Section 3, the wind direction at Menominee-Marinette Twin County Airport varies throughout the year. The modeling incorporates this variability. Thus, while wind conditions at the Site may vary from the Menominee - Marinette Twin County Airport, the variability in wind direction at the airport provides a modeling evaluation of all possible wind directions. As cited in Frost et al. 2014, the EPA Guideline on Air Quality Models states that uncertainty in wind direction by 5–10 degrees can affect short term predictions by 20–70% (Code of Federal Regulations, title 40, section 51). This uncertainty was addressed by looking at total deposition over a 5-year period (2015 to 2019).

The effects of the tree barrier surrounding the OTA and other obstructions to air transport have not been accounted for in the modeling but would likely affect aerial deposition by reducing the transport distance.

The bubble size distribution within a release of foam may vary from model inputs. AFFF bubble size increases over time after formation of the foam (Kennedy et al. 2015). The air modeling used the smallest bubble size from Kennedy et al. (2015) because in the air model, the bubbles with greatest transport distance or dispersal potential are small individual bubbles. The increase in bubble size over time occurs by small bubbles merging into a larger bubble (Kennedy et al. 2015). It should not be assumed that bubble size is the same as mass. While bubble size increases with time, liquid drains out of the foam over time (Kennedy et al. 2015). The thickness of the lamellar films is difficult to measure and not well understood (Kennedy et al. 2015). Thus, it cannot be assumed that smaller bubbles have less mass than larger bubbles. The relationship between bubble size and mass is unknown.

Finally, the model does not have the capability to estimate airborne deposition or transport of larger pieces of foam that are aggregates of many bubbles.

6.2 Air Model Results

The air model results are shown on Figures 10 and 11 for bubbles with a density of 0.1 and 0.5 g/cm^3, respectively. The stars on Figures 10 and 11 are the locations of the two sources (i.e., the OTA and Hydraulics Laboratory).

Figure 10 presents a summary of the total deposition of 0.1 g/cm^3 foam particles. The contours show the reduction in total deposition from each source. For example, the outermost contour of 0.1% represents a 99.9% reduction in foam deposition. The largest contour interval of 10% can be seen on the inset of Figure 10. The 10% line indicates that deposition declines by 90% within approximately 125 ft of the release locations. The shapes of the contours are the result of daily weather variability.

Figure 11 presents a summary of the total deposition for 0.5 g/cm^3 foam particles. The results are similar to those in Figure 10, but each contour is closer to the release locations, reflecting the fact that denser particles settle out faster. A review of the air modeling in Figures 10 and 11 demonstrates the following:

- While the wind directions are variable, the net effect of long-term testing at the OTA is a radial pattern of deposition, with deposition contours that extend slightly further from the release point in prevailing wind directions to the northeast and southeast.
- Under the modeling scenario where foam traveled the farthest distances (i.e., the lower density foam modeling scenario), there is a 99.9% reduction of PFAS deposition within 1500 feet of the OTA, which falls entirely within the Site boundaries.
    - These modeling results agree with PFAS data measured in groundwater samples collected at the southwestern and northwestern perimeter of the Site outside of the 99.9% deposition contour (i.e., VAP-16 and VAP-22; Figure 6 and Section 5.2). These samples are not hydraulically connected to the releases at the Site and did not contain PFOS and PFOA above 20 ng/L, suggesting that aerial transport from the OTA was insufficient to result in groundwater impacts above 20 ng/L PFOS and PFOA at these perimeter locations.
- Most of the PFAS deposition occurred in near proximity of the point of release (i.e., 90% within 125 feet of the release locations).

- These modeling results agree with the soil data collected a short distance outside the OTA, in which PFAS concentrations decrease to within an order of magnitude of background in directions that are not surface water flow pathways (Figure 4 and Section 5.1).

7 SUMMARY

A multiple lines of evidence approach was used to evaluate the potential for aerial releases and transport of PFAS via aerial deposition to impact offsite soil and groundwater. These lines of evidence, individually and synthesized together, do not support that an aerial transport pathway was an important PFAS transport mechanism at the Site. The lines of evidence evaluated, and key observations and conclusions from these evaluations, include the following:

1. Evaluation of potential aerial release mechanisms.

   PFAS are not manufactured at the Tyco facility and there are no stack emissions at the Site. Indoor facility operations related to PFAS are not sources of aerial emissions. Outdoor firefighter training and product testing occurred at the Site and anecdotal observations from Tyco employees note that pieces of foam were occasionally observed to drift away from the OTA during fire training exercises. The only potential air release mechanism from the Site is historical foam migration from the OTA and Hydraulics Laboratory.

2. Evaluation of the physical-chemical characteristics of the PFAS present in AFFF used or tested at the Site.
   The PFAS found in AFFF contain charged functional groups (e.g., negatively charged functional groups like sulfonates), which are integral to their functionality as surfactants in AFFF. The charged nature of these chemicals inhibits their volatilization out of solution. PFAS are thermally stable and do not appreciably degrade under the temperatures of hydrocarbon fires. Once a fire is suppressed, the PFAS constituents will migrate with the foam, either dissolved in the liquid or arranged at the air water interface of the foam bubbles. As a result of these chemical features, aerial migration of PFAS relevant to AFFF would occur in association with liquid aerosol particles, not in the gas phase.

3. Evaluation of PFAS soil data.

   Soil samples have been collected within the Site in and immediately adjacent to the OTA. Investigation soil samples were not collected in the limited areas where excavation has occurred. The highest detections of PFAS in surficial soil occur within the fire training portion of the OTA, near known discharge and testing points, and along surface water runoff routes. Soil detections are variable and do not follow the pattern of predominant wind directions indicated by the wind rose collected from the nearby Menominee-Marinette Twin County Airport. Multiple soil samples within 150 feet of the OTA and the R&D testing facility contain PFOS and PFOA levels that are within an order of magnitude or less of the levels observed in literature reported background soils. The decrease in PFAS concentrations from the source of foam application to concentrations within an order of magnitude of background in a short distance from the OTA support the conceptual site model that AFFF application of foam on the OTA is the primary source and infiltration at the application area and surface runoff are the primary pathways. The decrease in PFAS concentrations do not support that aerial transport was a common transport pathway. Collectively, the soil data do not support that foam migration or unexpected PFAS emissions from the facility indoor operations are an aerial source of PFAS impacts to soil.

4. Evaluation of PFAS groundwater data.
   The PFAS mixture in groundwater samples collected within the Site and in the downgradient plume is consistently PFOA or PFHxA dominant. Where the PFAS mixture in groundwater deviates from the characteristic Site signature, PFOS and PFOA impacts were lower than 20 ng/L. Groundwater samples collected at the perimeter of the Site that are not downgradient of the OTA and are not connected by surface water features do not contain PFOS or PFOA above 20 ng/L. The spatial distribution of PFAS concentrations in groundwater appear to be the result of a source area release with subsequent groundwater and surface water transport and not the result of aerial deposition.

5. Air modeling.
   Air modeling was conducted to understand AFFF transport as a function of distance using local meteorological data and foam release scenarios typical of releases that occurred during testing and training at the OTA and the Hydraulics Laboratory. Most of the PFAS deposition occurred in near proximity of the point of release (i.e., 90% within 125 feet of the release locations). Under the modeling scenario where foam traveled the farthest distances (i.e., the lower density foam modeling scenario), there is a 99.9% reduction of PFAS deposition within 1500 feet of the OTA. Both soil and groundwater PFAS data collected onsite agree with the extent of PFAS deposition suggested by the air model.

These lines of evidence, individually and synthesized together, do not support that an aerial transport pathway has carried sufficient PFAS off the Site to cause PFOS and PFOA concentrations in groundwater above 20 ng/L. Furthermore, the data collected to date and the aerial modeling both indicate that any substantial aerial impacts would occur within onsite areas that have already been investigated. Therefore, expansion of the Site investigation area for the purposes of evaluating aerial deposition is not warranted.

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LEGEND:

OUTDOOR TESTING/TRAINING AREA

0 225 450

GRAPHIC SCALE IN FEET

NOTES:

1. IMAGERY SOURCE: 4/27/2016, DIGITALGLOBE, VIVID - USA.

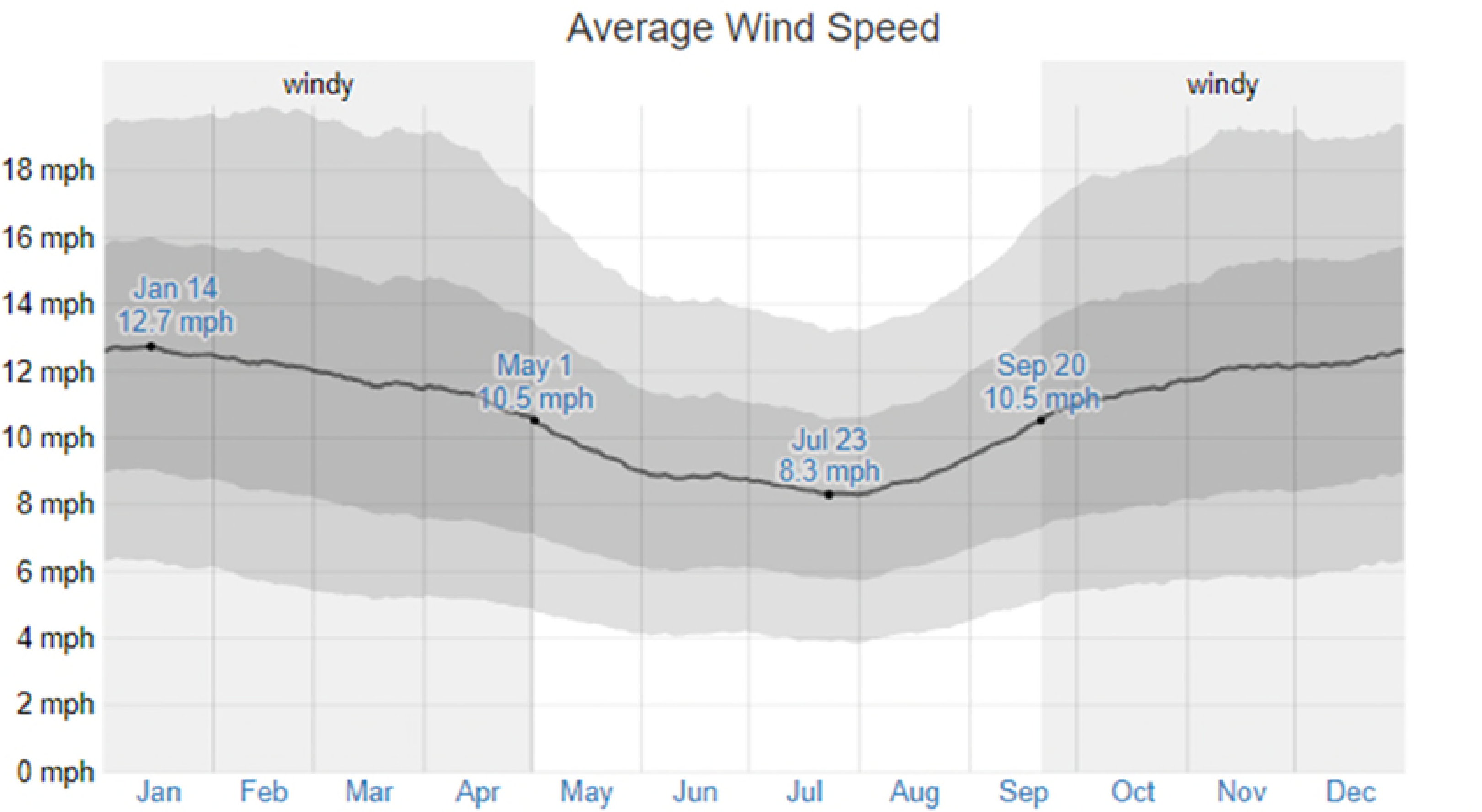
TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

OUTDOOR TESTING/TRAINING AREA

ARCADIS

FIGURE 1

City: Minneapolis/Citrix Div/Group: IMDVC Created By: Last Saved By: msmiller
TYCO Marinette, WI
Z:\GISProjects_ENV\TYCO_Marinette_WI\MXD\2020-05\05142020\CSM\Figure 2 Outdoor_Training_Area.mxd 5/18/2020 1:56:56 PM



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Note:
Data obtained at https://weatherspark.com/y/146527/Average-Weather-at-Menominee-Marinette-Twin-County-Airport-Michigan United-States-Year-Round.

TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

AVERAGE WIND SPEED (MILES PER HOUR) AT MENOMINEE-MARINETTE TWIN COUNTY AIRPORT

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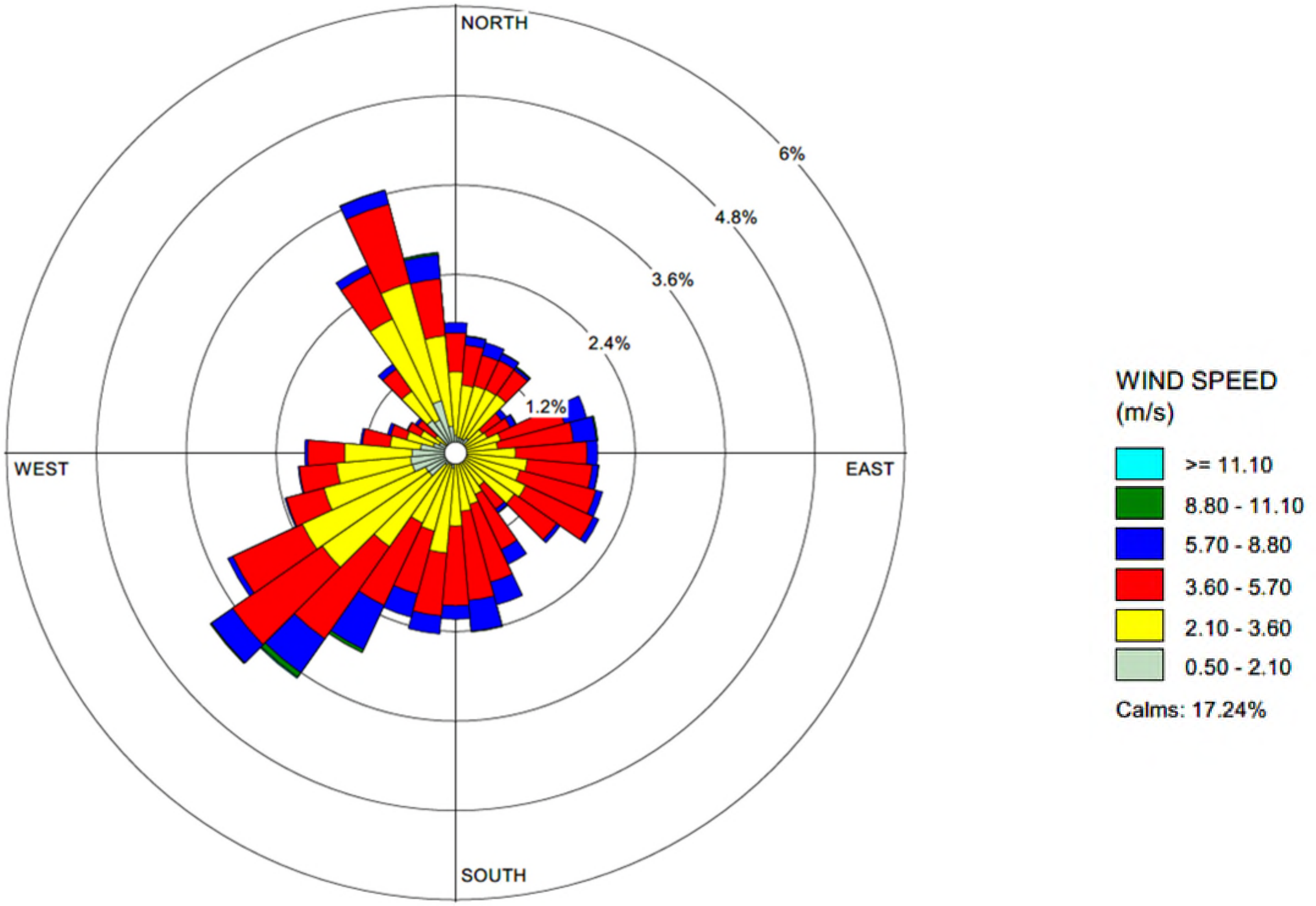
FIGURE
2



Note:
Data obtained at ftp://ftp.ncdc.noaa.gov/pub/data/noaa/. Note: 1 m/s = 2.2 mph.

TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

WIND ROSE FROM JUNE, JULY, AND AUGUST 2015 TO 2019 AT MENOMINEE-MARINETTE TWIN COUNTY AIRPORT

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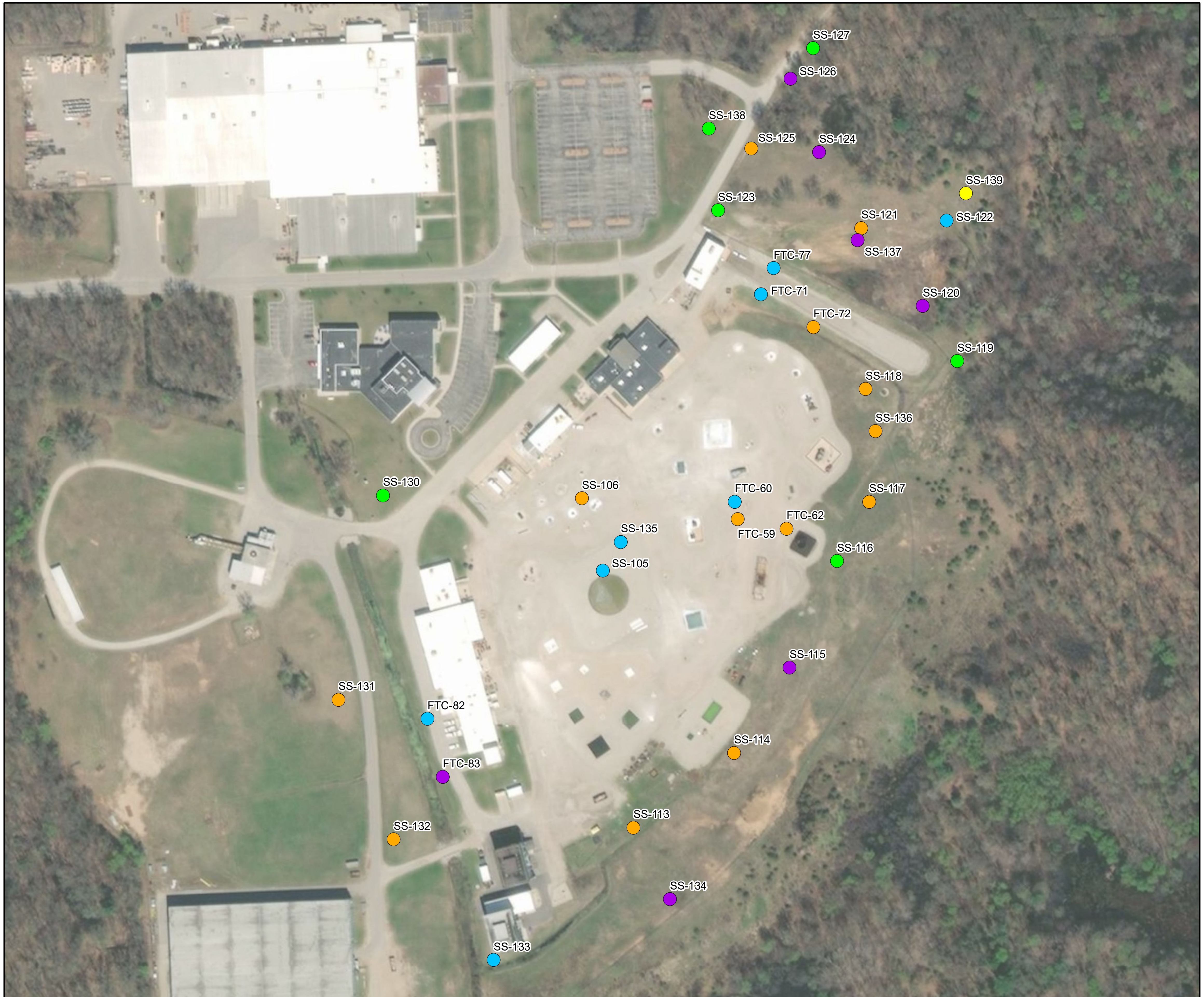
FIGURE
3



Legend

COMBINED PFOS AND PFOA CONCENTRATION IN SHALLOW SOIL SAMPLE LOCATIONS

- ND - 5 µg/kg
- 5 - 10 µg/kg
- 10 - 100 µg/kg
- 100 - 1,000 µg/kg
- >1,000 µg/kg

NOTES:

1. IMAGERY SOURCE: 4/27/2016, DIGITALGLOBE, VIVID - USA.
2. PFOA = PERFLUOROCTANOIC ACID
PFOS = PERFLUOROOCTANE SULFONIC ACID
3. ug/kg = MICROGRAMS PER KILOGRAM
4. ND = NON-DETECT

0 150 300

GRAPHIC SCALE IN FEET

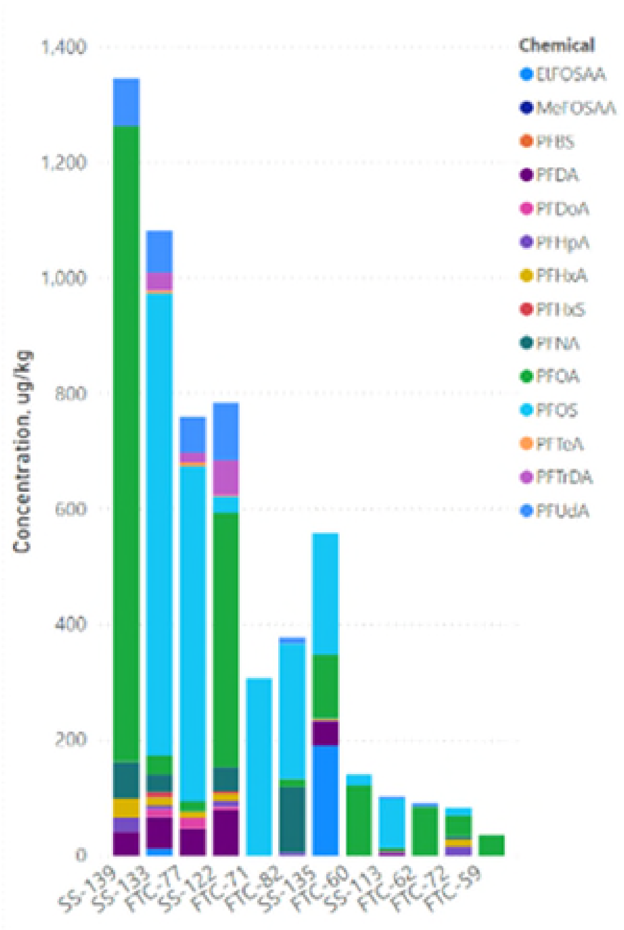
TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN

SHALLOW SOIL INVESTIGATION LOCATIONS

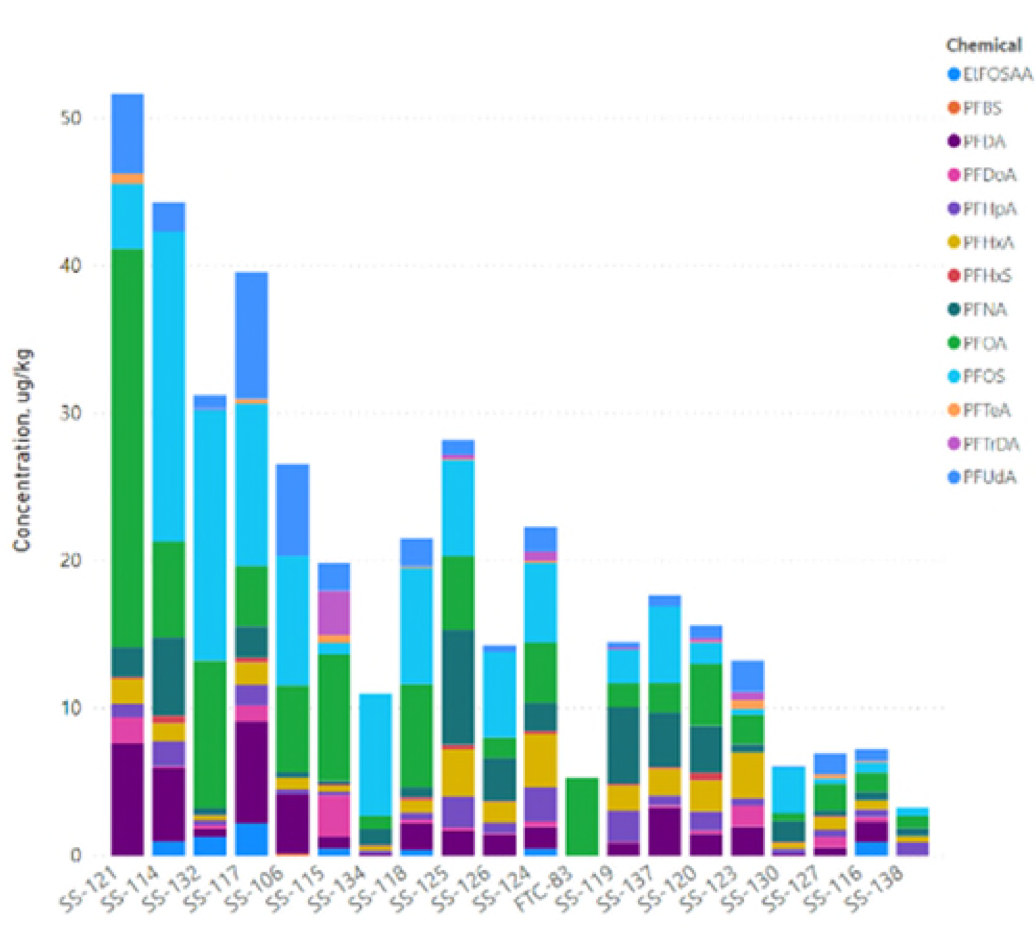
ARCADIS

FIGURE 4

City: Minneapolis/Citrix Div/Group: IMDVC Created By: Last Saved By: msmiller
TYCO Marinette, WI
Z:\GISProjects_ENV\TYCO_Marinette_WI\MXD\2020-05\05142020\CSM\SampleLocationsColorCode.mxd 5/18/2020 2:05:03 PM



A



B

Note:
A and B are on two different y-axis scales

TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

PFAS SOIL RESULTS IN THE TOP 2 FEET OF SOIL AT THE OTA

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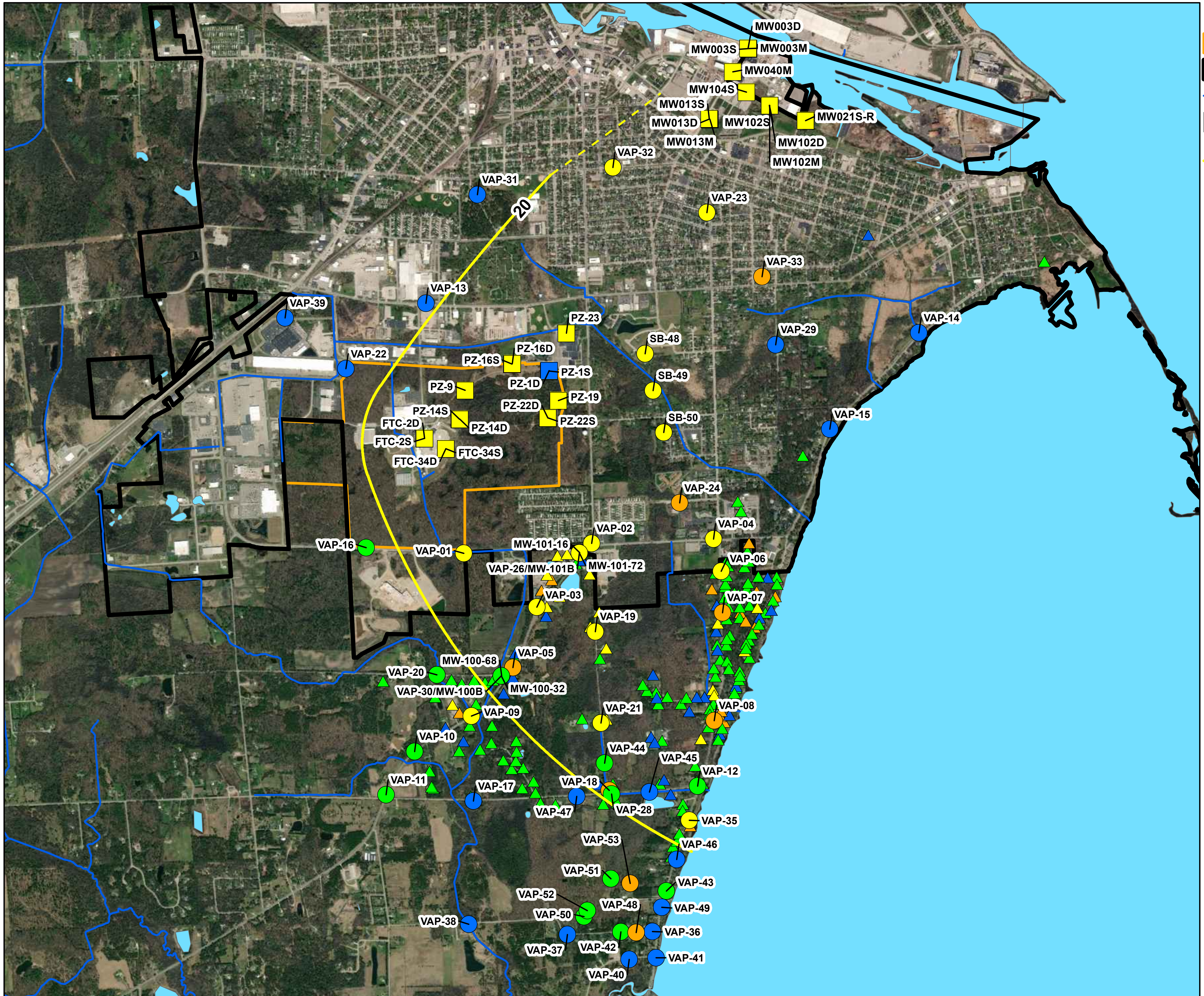
FIGURE
5



LEGEND:

- APPROXIMATE SITE PROPERTY BOUNDARY
- APPROXIMATE MARINETTE CITY BOUNDARY
- DITCH/STREAM
- WATERBODY
- APPROXIMATE WESTERN EXTENT OF GROUNDWATER WHERE COMBINED PFOS AND PFOA DETECTED ABOVE 20 ppt AND POTENTIALLY ASSOCIATED WITH THE FTC OR STANTON STREET SITES (DASHED WHERE INFERRED)

TOTAL PFOS AND PFOA IN GROUNDWATER

VAP BORING (MAX RESULT AT ANY SAMPLE DEPTH)

- ND - 2 ppt
- 2 - 20 ppt
- 20 - 70 ppt
- >70 ppt

MONITORING WELL SAMPLE RESULT (AUGUST 2019)

- ND - 2 ppt
- 2 - 20 ppt
- 20 - 70 ppt
- >70 ppt

RESIDENTIAL WELL SAMPLING RESULT (SPRING 2019)

- ND - 2 ppt
- 2 - 20 ppt
- 20 - 70 ppt
- >70 ppt

NOTES:

1. FIGURE PROVIDES REPRESENTATIVE ONSITE DATA AND DOES NOT REFLECT A COMPREHENSIVE DATASET FOR THE FTC SITE
2. RESIDENTIAL WELL LOCATIONS ARE APPROXIMATE
3. ppt = PARTS PER TRILLION
   PFOA = PERFLUOROOCTANOIC ACID
   PFOS = PERFLUOROOCTANESULFONIC ACID
   VAP = VERTICAL AQUIFER PROFILE
   FTC = FIRE TRAINING CENTER
4. SERVICE LAYER CREDITS: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY

0 1,200 2,400

GRAPHIC SCALE IN FEET

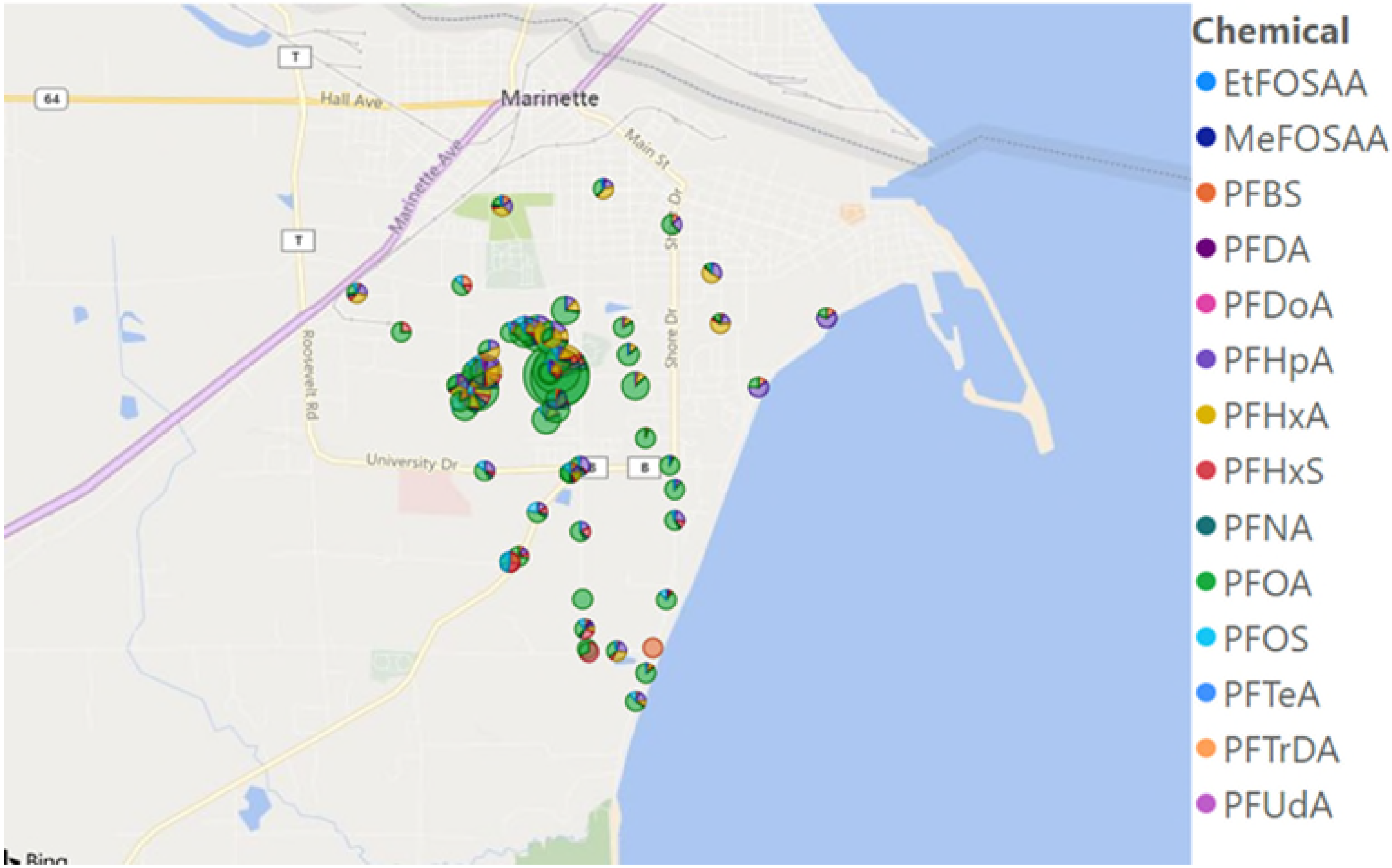
TYCO FIRE PRODUCTS LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

DETECTIONS OF PFOA AND PFOS IN GROUNDWATER

ARCADIS

FIGURE 6

City: Minneapolis/Citrix Div/Group: IMDVC Created By: Last Saved By: msmiller
TYCO Marinette, WI
Z:\GISProjects_ENV\TYCO_Marinette_WI\MXD\2020-05\05142020\CSM\Figure_6_VAP_HeatMap.mxd 5/15/2020 1:42:44 PM



Notes:
Bubble size is related to the magnitude of the PFAS impacts in that location.
For locations with data from multiple vertical intervals, the maximum detection per PFAS compound was used.

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MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

PFAS GROUNDWATER SAMPLING LOCATIONS WITH DETECTIONS ONSITE AND POTENTIALLY ASSOCIATED WITH SITE

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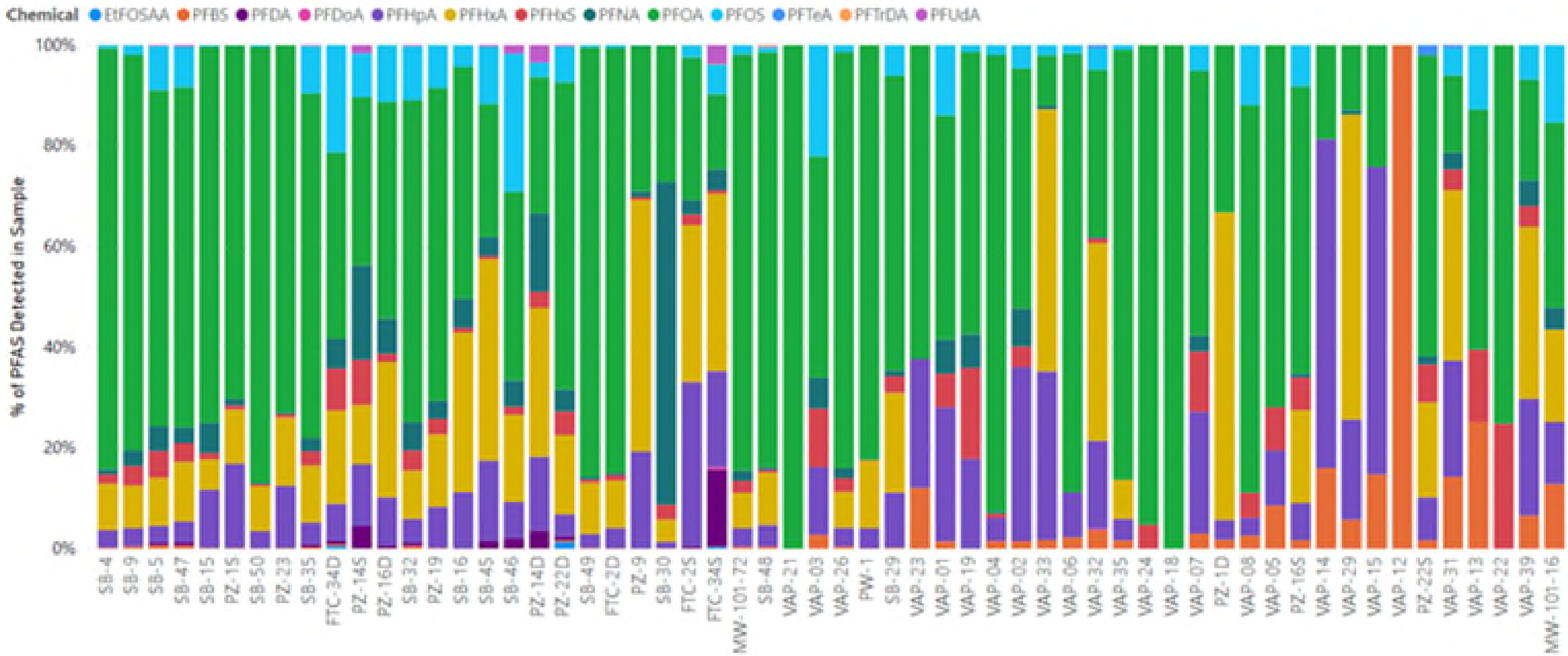
FIGURE
7



Note:
For locations with data from multiple vertical intervals, the maximum detection per PFAS compound was used.

TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

MIXTURE OF MAXIMUM PFAS DETECTIONS AT GROUNDWATER SAMPLING LOCATIONS ONSITE AND POTENTIALLY ASSOCIATED WITH SITE

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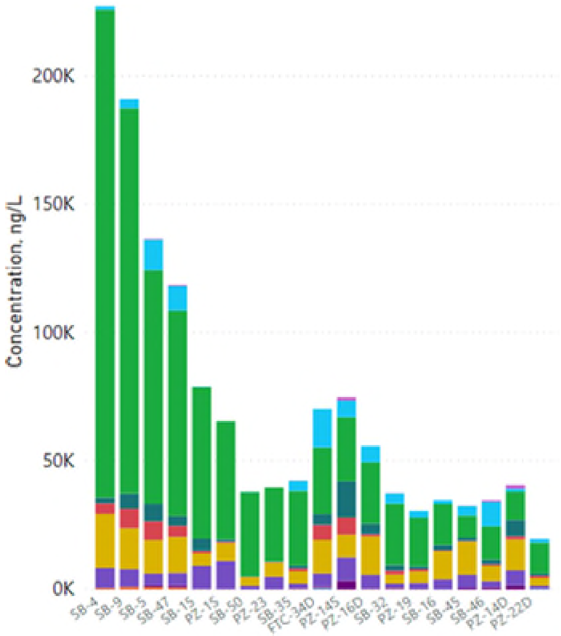
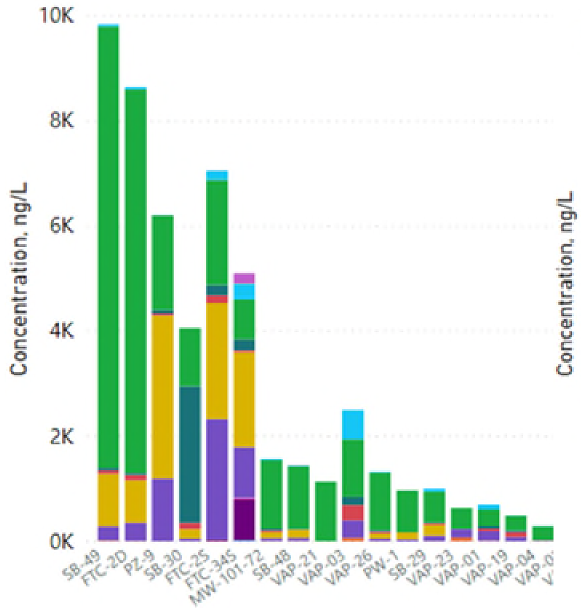
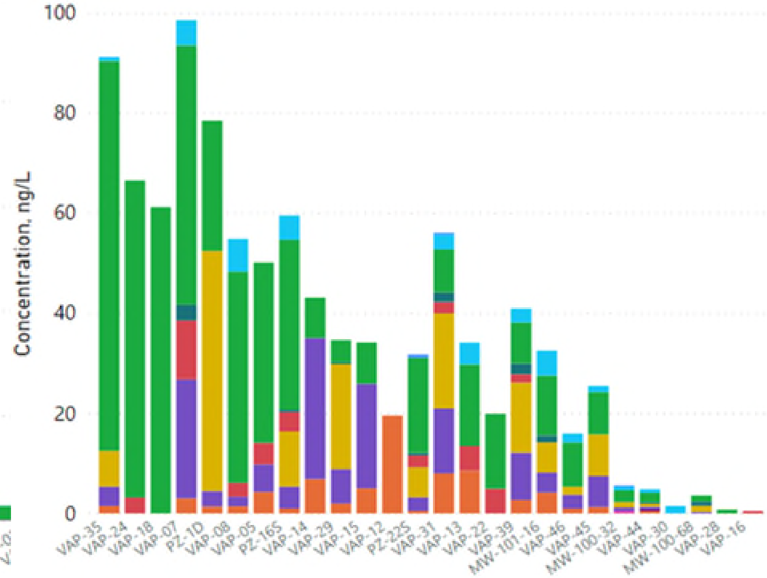
FIGURE
8



A



B



C

Note:
For locations with data from multiple vertical intervals, the maximum detection per PFAS compound was used.
Figures A through C each have a different y-axis scale.

TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

MAXIMUM PFAS DETECTIONS AT GROUNDWATER SAMPLING LOCATIONS ONSITE AND POTENTIALLY ASSOCIATED WITH THE SITE

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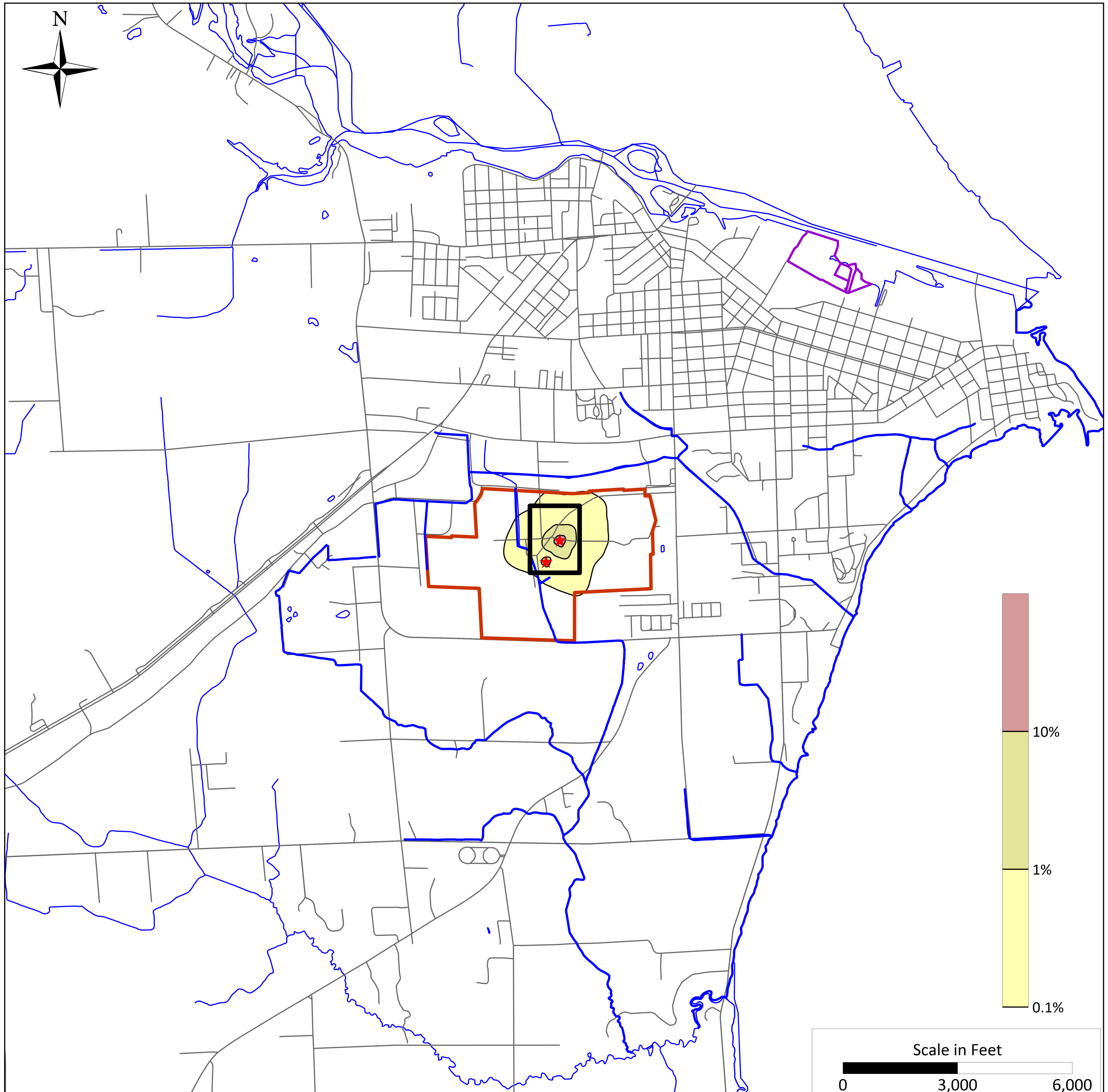
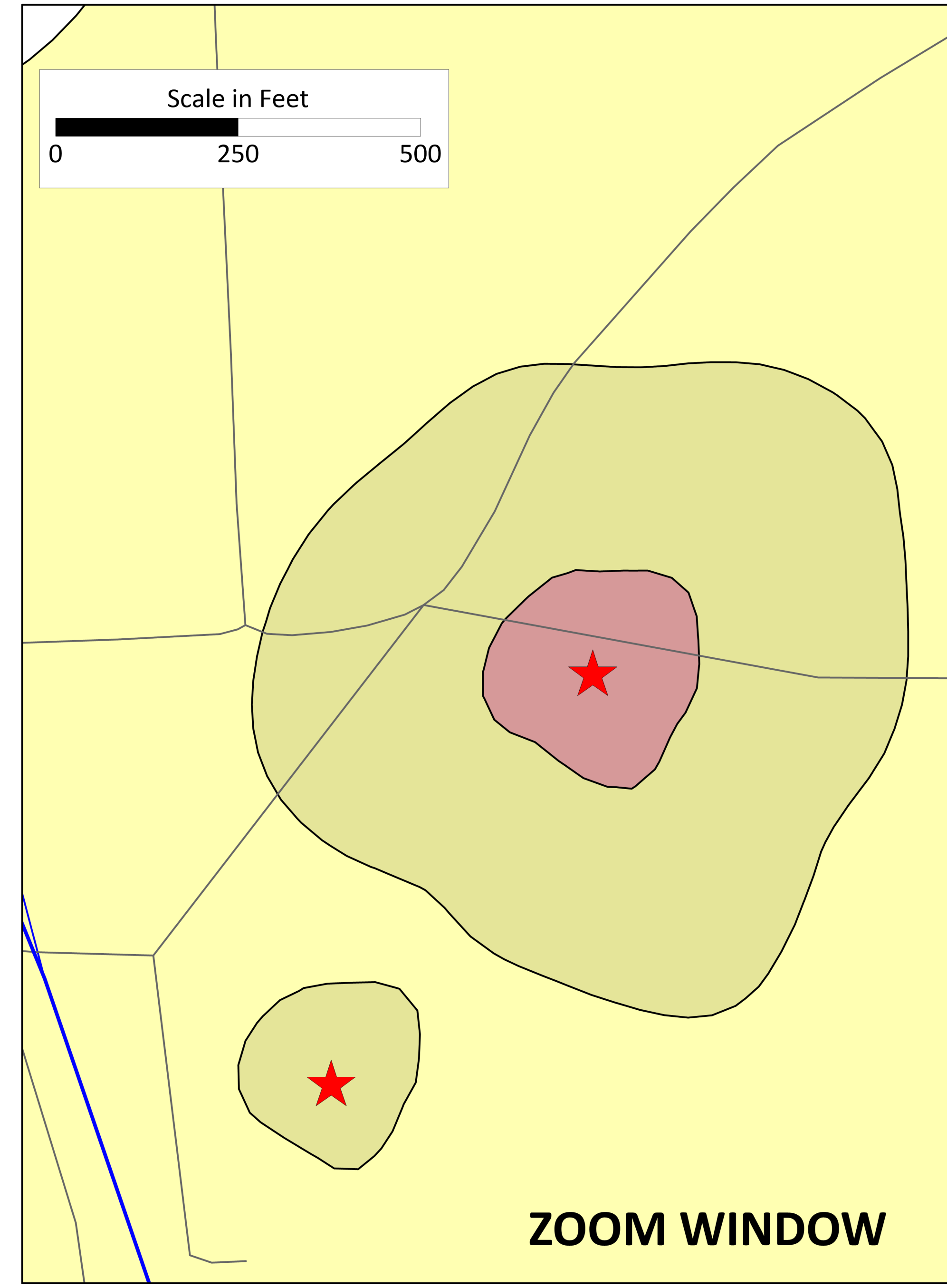
FIGURE
9A-C





LEGEND

A contour level of 10% indicates the total deposition of foam has declined by 90% from the source, while 0.1% indicates a 99.9% reduction.

The "stars" identify the locations of foam release

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MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

PARTICLE DEPOSITION (%) OF FOAM WITH A DENSITY OF 0.1 g/cm^3

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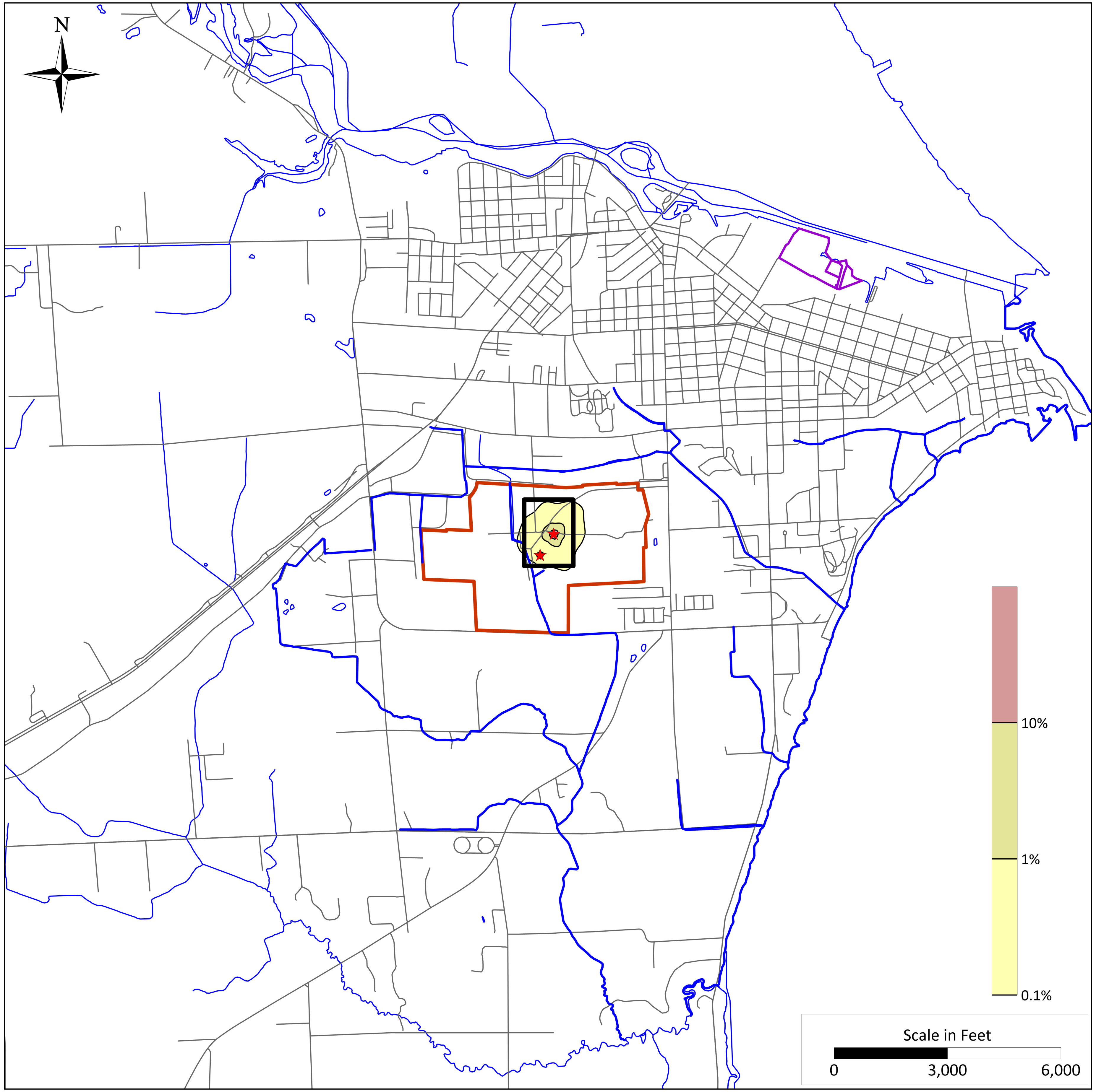
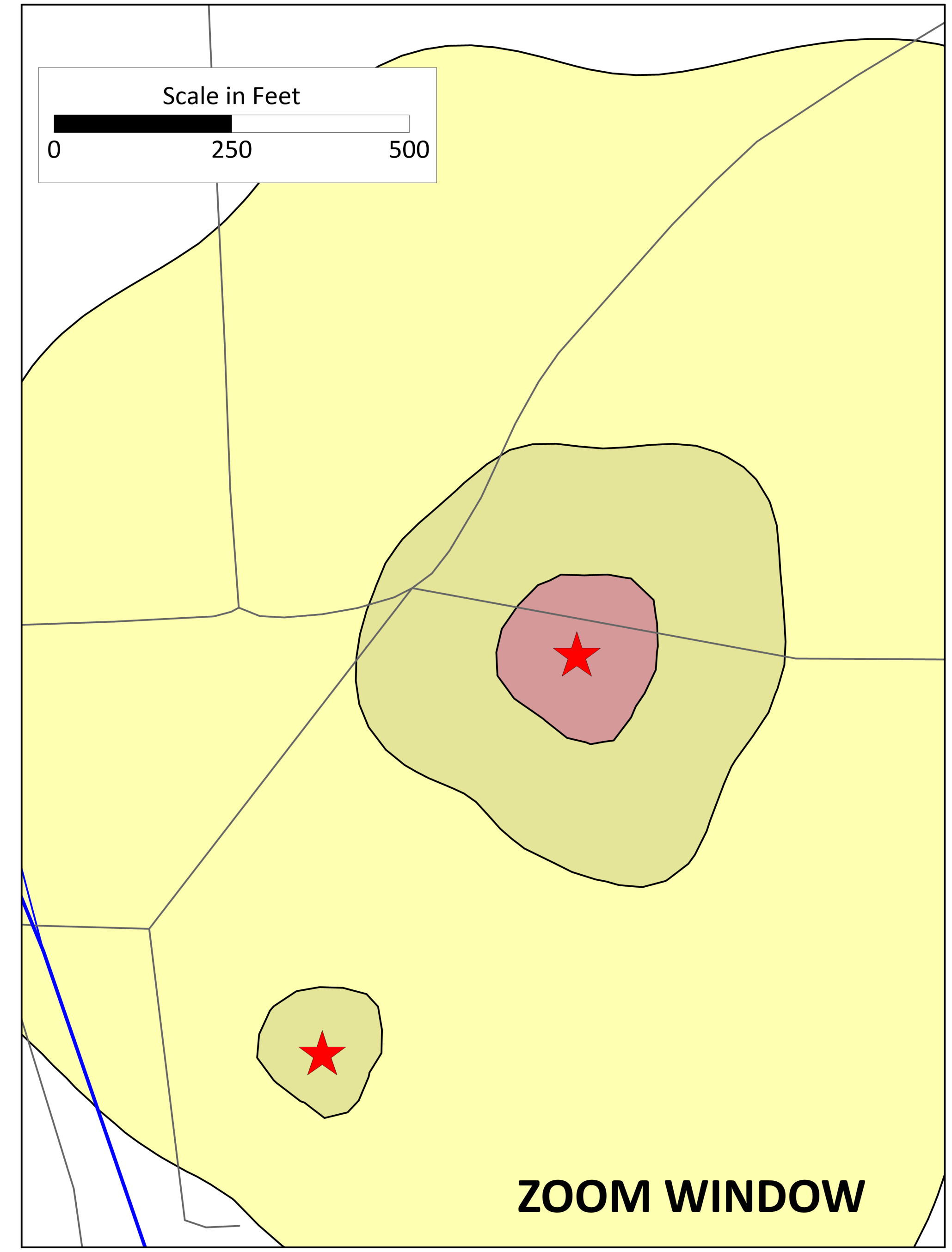
FIGURE
10





LEGEND

A contour level of 10% indicates the total deposition of foam has declined by 90% from the source, while 0.1% indicates a 99.9% reduction..

The "stars" identify the locations of foam release

TYCO FIRE PRODUCTS, LP
MARINETTE, WISCONSIN
AERIAL DEPOSITION EVALUATION REPORT

PARTICLE DEPOSITION (%) OF
FOAM WITH A DENSITY OF 0.5 g/cm^3

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FIGURE
11

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