FINAL

SITE INSPECTION REPORT

SITE INSPECTION OF AQUEOUS FILM FORMING FOAM (AFFF) RELEASE AREAS ENVIRONMENTAL PROGRAMS WORLDWIDE

AIR FORCE PLANT #3
TULSA, OKLAHOMA

Prepared for:
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Joint Base San Antonio – Lackland, Texas

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Oneida Total Integrated Enterprises

Contract FA8903-16-D-0027
Task Order 0004

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ACRONYMS

AFCEC	Air Force Civil Engineer Center
AFFF	Aqueous Film Forming Foam
AFP#3	Air Force Plant #3
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
amsl	above mean sea level
API	Amec Foster Wheeler Programs, Inc.
bgs	below ground surface
BRAC	Base Realignment and Closure
btoc	below top of casing
CoC	Chain-of-Custody
DL	detection level
DoD	Department of Defense
DPT	direct push technology
DW	Drinking Water
EC	Emerging Contaminant
ELLE	Eurofins Lancaster Laboratories Environmental
FTA	fire training area
FTS	fluorotelomer sulfonate
HA	Health Advisory
HDPE	high-density polyethylene
HGL	HydroGeoLogic, Inc.
IDW	Investigation-Derived Waste
IRP	Installation Restoration Program
ISWP	Installation-Specific Work Plan
LC-MS/MS	Liquid Chromatography and Tandem Mass Spectrometry
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
Navistar	Navistar International Corporation
ND	not detected
NEtFOSAA	n-ethyl perfluorooctanesulfonamidoacetic acid
NFRAP	No Further Remedial Action Planned
NL	not listed
NMeFOSAA	n-methyl perfluorooctanesulfonamidoacetic acid
OAC	Oklahoma Administrative Code
ODEQ	Oklahoma Department of Environmental Quality
OTIE	Oneida Total Integrated Enterprises
OWRB	Oklahoma Water Resources Board

ACRONYMS cont'd

PA	Preliminary Assessment
PFAS	per- and polyfluorinated alkyl substances
PFBS	perfluorobutanesulfonic acid
PFC	perfluorinated compound
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFTA	perfluorotetradecanoic acid
PFTrDA	perfluorotridecanoic acid
PFUnA	perfluoroundecanoic acid
pH	potential of hydrogen
PID	Photoionization Detector
PPE	personal protective equipment
PVC	polyvinyl chloride
QC	quality control
QPP	Quality Program Plan
RI	Remedial Investigation
RSL	Regional Screening Level
SI	Site Inspection
SIR	Site Inspection Report
SOP	Standard Operating Procedure
S.U.	Standard Unit
TCLP	toxicity characteristic leaching procedure
THQ	total hazard quotient
TOC	total organic carbon
U.S.	United States
USAF	United States Air Force
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

This Site Inspection (SI) Report (SIR) was prepared by Oneida Total Integrated Enterprises (OTIE) under Contract No. FA8903-16-D-0027, Task Order 0004, to document the results of SI activities conducted at four aqueous film forming foam (AFFF) release areas located at Air Force Plant #3 (AFP#3). The purpose of the SI was to determine, through environmental media sampling, if a release of per- and polyfluorinated alkyl substances (PFAS) has occurred at potential AFFF release areas identified by others during a Preliminary Assessment (PA) (HydroGeoLogic, Inc. [HGL], 2015) or during the installation scoping visit conducted by OTIE on 21 October 2016. The data presented in this SIR were collected and evaluated in accordance with the Final Installation-Specific Work Plan (ISWP) (OTIE, 2017) and the General Quality Program Plan (QPP) (Amec Foster Wheeler, 2017).

PFAS are a class of synthetic organofluorine compounds that possess a chemical structure that gives them unique properties, including thermal stability and the ability to repel both water and oil. These chemical properties make them useful components in a wide variety of consumer and industrial products, including non-stick cookware, food packaging, waterproof clothing, fabric stain protectors, lubricants, paints, and firefighting foams such as AFFF. AFFF concentrate contains fluorocarbon surfactants to meet required performance standards for fire extinguishing agents (Department of Defense [DoD] Military Specification MIL-F-24385F [SH], Amendment 1, 5 August 1984). The United States (U.S.) Air Force (USAF) began purchasing and using AFFF containing PFAS (specifically perfluorooctanesulfonic acid [PFOS] and/or perfluorooctanoic acid [PFOA]) for extinguishing petroleum fires and during firefighting training activities in 1970. AFFF was primarily used on USAF installations at fire training areas (FTAs), but may have also been used, stored or released from hangar fire suppression systems, at firefighting equipment testing and maintenance areas, and during emergency response actions for fuel spills and/or aircraft mishaps.

The U.S. Environmental Protection Agency (USEPA) Office of Water issued lifetime drinking water Health Advisory (HA) values for PFOS and PFOA in May 2016 that replaced the 2009 Provisional HA values. The HA values for PFOS and PFOA are 0.07 micrograms per liter (µg/L) for each constituent; however, when these two chemicals co-occur in a drinking water source, a conservative and health-protective approach is recommended that compares the sum of the concentrations (PFOS+PFOA) to the HA value (0.07 µg/L). HA values are not to be construed as legally enforceable federal standards and are subject to change as new information becomes available (USEPA, 2016a and 2016b). Although the USEPA has not established HA values for PFAS in soil, the USAF calculated a residential screening level of 1.26 milligrams per kilogram (mg/kg) for PFOS and PFOA in soil and sediment, based on a total hazard quotient (THQ) of 1.0, using the USEPA Regional Screening Level (RSL) calculator (https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search). This screening value was presented in the Final ISWP (OTIE, 2017). In April 2018, the USAF issued revised guidance, *PFAS Site Inspection Objectives and Follow-On Activities,* whereby a new residential screening level for soil and sediment for PFOS and PFOA of 0.126 mg/kg was calculated based on a THQ of 0.1 (USAF, 2018).

While PFOS and PFOA are the focus of the HA and provide specific targets for the USAF to address in the SI, USEPA has also derived RSL values for perfluorobutanesulfonic acid (PFBS) for which there is a Tier 2 toxicity value (Provisional Peer Review Toxicity Value) (USEPA, 2017). Based on the ISWP, concentrations of PFBS detected in groundwater and soil/sediment were compared to the USEPA RSLs of 400 µg/L and 1,300 mg/kg, based on a THQ of 1.0, respectively. In April 2018, the USAF issued revised guidance, *PFAS Site Inspection Objectives and Follow-On Activities,* whereby a new residential screening level for PFBS in groundwater of 40 µg/L and in soil and sediment of 130 mg/kg were calculated based on a THQ of 0.1 (USAF, 2018).

The USEPA and the Oklahoma Department of Environmental Quality (ODEQ) have not issued HA values or promulgated standards for any other PFAS constituents to date.

AFP#3 was a government-owned, contractor-operated plant located approximately nine miles northeast of downtown Tulsa, Oklahoma, adjacent to the Tulsa International Airport. The property was leased from the USAF as of 1995 for sublet to private companies and transferred by deed to the City of Tulsa in December 1999 (HGL, 2015). Current tenants include Federal Express, Spirit Aero Systems (an aerostructures manufacturing plant), and Navistar International Corporation (Navistar) (a bus manufacturing plant).

The PA provided findings from research conducted to determine whether and where AFFF, containing PFAS, was stored, handled, used or released at AFP#3. Based on the research conducted during the PA, as well as the information collected during an installation scoping visit conducted by OTIE on 21 October 2016, the following four AFFF release areas were recommended for SI:

1. AFFF Release Area 1: Former Site FT-07 (Installation Restoration Program [IRP] Site ID FT-07);
2. AFFF Release Area 2: DC-8 Fuel Spill Area;
3. AFFF Release Area 3: Unnumbered Outfall (Southeastern Property Boundary); and,
4. AFFF Release Area 4: Outfall 3.

The specific objectives of the SI were as follows:

- Determine if PFAS are present in soil, groundwater, or sediment at AFFF release areas selected for SI;
- Determine if PFOS and PFOA concentrations in soil or sediment exceed the calculated RSL of 0.126 mg/kg, based on a residential exposure scenario, and PFBS concentrations in soil or sediment exceed the USEPA residential RSL of 130 mg/kg;
- Determine if concentrations of PFOS, PFOA, or the sum of PFOS and PFOA, in groundwater exceed the USEPA HA value of 0.07 µg/L, and if PFBS concentrations in groundwater exceed the USEPA Tap Water RSL of 40 µg/L; and,
- Identify potential receptor pathways with immediate impacts to human health (immediate impact to human health is considered consumption of drinking water with PFOS/PFOA above the USEPA HA value or PFBS above the USEPA Tap Water RSL).

PFAS Analytical Results

PFOS was detected in surface and subsurface soil at AFFF Release Areas 1 and 2, and exceeded the calculated RSL of 0.126 mg/kg in surface soil (0.0-1.0 feet below ground surface [bgs]) at AFFF Release Area 1. PFOA and PFBS were detected in surface soil (0.0 to 1.0 feet bgs) at concentrations below the calculated and USEPA RSLs at AFFF Release Area 1.

PFOS, PFOA, and/or PFBS were detected in groundwater at AFFF Release Areas 1 and 2. PFOA and PFOS+PFOA exceeded the USEPA HA value of 0.07 µg/L at AFFF Release Areas 1 and 2. PFOS and PFBS were detected at AFFF Release Areas 1 and 2, but at concentrations below the HA and the USEPA Tap Water RSL.

PFOS was detected in sediments collected from AFFF Release Area 3 at concentrations below the calculated RSL of 0.126 mg/kg. No PFAS analytes were detected in the sediments collected from AFFF Release Area 4.

Surface and Subsurface Soil Receptors

Potential exposure receptors include workers, visitors, and/or trespassers involved in any activity that exposes them to the PFAS-impacted surface soil at AFFF Release Area 1. Based on the SI, potential complete pathways for human exposure to PFAS-impacted surface soil through inhalation, ingestion, and/or dermal contact were identified for AFFF Release Area 1.

Groundwater Receptors

Potential human exposure receptors from PFAS in groundwater include workers, site visitors, and/or trespassers at AFP#3 that may expose the shallow water table at AFFF Release Areas 1 and 2 where PFOA and PFOA+PFOA exceeded the USEPA HA value. Human groundwater receptors via the ingestion pathway are not present for the AFFF release areas at or downgradient of AFP#3 since the installation and surrounding area utilizes drinking water supplied by the City of Tulsa originating from surface water sources located more than 20 miles from the installation boundary, and no private drinking water wells were noted within a four-mile radius of the installation boundary downgradient of the AFFF release areas.

Sediment Receptors

Sediment in AFFF Release Area 3 and AFFF Release Area 4 is potentially accessible by workers, site visitors, and/or trespassers involved in any activity that exposes them through dermal contact to the impacted sediment, including recreational activities and drainage ditch/outfall maintenance activities. However, since PFOS was detected at concentrations below the calculated RSLs at AFFF Release Area 3 and below detection limits at AFFF Release Area 4, no potential complete pathways exist for human exposure to PFAS-impacted sediment through dermal contact.

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1.0 INTRODUCTION

This Site Inspection (SI) Report (SIR) was prepared by Oneida Total Integrated Enterprises (OTIE) under Contract No. FA8903-16-D-0027, Task Order 0004 between Amec Foster Wheeler Programs, Inc. (API) and the Air Force Civil Engineer Center (AFCEC), to document the results of SI activities conducted at four aqueous film forming foam (AFFF) release areas located at Air Force Plant #3 (AFP#3). The purpose of the SI was to determine, through environmental media sampling, if a release of per- and polyfluorinated alkyl substances (PFAS) has occurred at potential AFFF release areas identified by others during a Preliminary Assessment (PA) (HydroGeoLogic, Inc. [HGL], 2015), or from the installation scoping visit conducted by OTIE on 21 October 2016.

The data presented in this SIR were collected and evaluated in accordance with the Final Installation-Specific Work Plan (ISWP) (OTIE, 2017) and the General Quality Program Plan (QPP) (Amec Foster Wheeler, 2017).

1.1 PER- AND POLY-FLUORINATED ALKYL SUBSTANCES OVERVIEW

PFAS are a class of synthetic organofluorine compounds that possess a chemical structure that gives them unique properties, including thermal stability and the ability to repel both water and oil. These chemical properties make them useful components in a wide variety of consumer and industrial products, including non-stick cookware, food packaging, waterproof clothing, fabric stain protectors, lubricants, paints, and firefighting foams such as AFFF. AFFF concentrate contains fluorocarbon surfactants to meet required performance standards for fire extinguishing agents (Department of Defense [DoD] Military Specification MIL-F-24385F [SH], Amendment 1, 5 August 1984). The United States (U.S.) Air Force (USAF) began purchasing and using AFFF containing PFAS (perfluorooctanesulfonic acid [PFOS] and/or perfluorooctanoic acid [PFOA]) for extinguishing petroleum fires and during firefighting training activities in 1970, as confirmed by the following federal government documents:

- Military Specification for AFFF (MIL-F-24385), formally issued in 1969;
- General Accounting Office determination on sole source award protest to provide AFFF to the Navy in December 1969; and,
- *A History of USAF Fire Protection Training at Chanute Air Force Base*, 1964-1976 (Coates, 1977).

AFFF was primarily used on USAF installations at fire training areas (FTAs), but may have also been used, stored or released from hangar fire suppression systems, at firefighting equipment testing and maintenance areas, and during emergency response actions for fuel spills and/or aircraft mishaps.

The U.S. Environmental Protection Agency (USEPA) Office of Water issued lifetime drinking water Health Advisory (HA) values for PFOS and PFOA in May 2016 that replaced the 2009 Provisional HA values. The HA values for PFOS and PFOA are 0.07 micrograms per liter (µg/L) for each constituent; however, when these two chemicals co-occur in a drinking water source, a conservative and health-protective approach is recommended that compares the sum of the concentrations (PFOS+PFOA) to the HA value (0.07 µg/L). The HA values are non-regulatory concentrations of drinking water contaminants at or below which adverse health effects are not anticipated to occur over specific exposure durations (e.g., 1 day, 10 days, and a lifetime). They serve as informal technical guidance to assist federal, state, and local officials, and managers of public or community water systems in protecting public health when emergency spills or other contamination situations occur. A HA document provides information on the environmental properties, health effects, analytical methodology, and treatment technologies for removing drinking water contaminants. HA values are not to be construed as legally enforceable federal standards and are subject to change as new information becomes available (USEPA, 2016a and 2016b).

The USEPA has not published Regional Screening Levels (RSLs) for PFOS or PFOA for soil or sediment; however; a revised residential screening level of 0.126 milligrams per kilogram (mg/kg) for soil and sediment was calculated using the USEPA RSL calculator (https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search). This screening level was derived using a total hazard quotient (THQ) of 0.1, as directed in the USAF *PFAS Site Inspection Objectives and Follow-On Activities* (USAF, 2018).

While PFOS and PFOA are the focus of the HA and provide specific targets for the USAF to address in the SI, USEPA has also derived RSL values for perfluorobutanesulfonic acid (PFBS) for which there is a Tier 2 toxicity value (Provisional Peer Review Toxicity Value) (USEPA, 2017). Concentrations of PFBS detected in groundwater were compared to the USEPA RSL for Tap Water of 40 µg/L; whereas, PFBS in soil and sediment were compared to a revised USEPA RSL of 130 mg/kg, based on a THQ of 0.1, per the USAF issued revised guidance, *PFAS Site Inspection Objectives and Follow-On Activities* (USAF, 2018).

Table 1.1-1 below presents the screening values for comparing analytical results for PFOS, PFOA, and PFBS. Neither the USEPA nor Oklahoma Department of Environmental Quality (ODEQ) have issued HA values or promulgated standards for any other PFAS to date.

Table 1.1-1. Regulatory Screening Values.

Parameter	Chemical Abstract Number	USEPA Regional Screening Level Table (November 2017)[a]		Calculated RSL for Soils and Sediments [b] (mg/kg)	USEPA Health Advisory for Drinking Water for Groundwater[c,d] (µg/L)
		Residential Soils and Sediments (mg/kg)	Tap Water (µg/L)		
PFOS	1763-23-1	NL	NL	0.126	0.07
PFOA	335-67-1	NL	NL	0.126	
PFBS	375-73-5	130	40	NL	NL

Notes:

a USEPA Regional Screening Levels (2017a) [https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2017] using a THQ of 0.1. Soil screening values were used for screening PFBS in sediment.

b Screening levels, based on a residential exposure scenario, were calculated using the USEPA Regional Screening Level calculator (https://epa-prgs.ornl.gov/cgi-bin/ chemicals/csl_search) and a THQ of 0.1.

c USEPA, May 2016a. “Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)” and USEPA, 2016b. “Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA).”

d When both PFOA and PFOS are both present, the combined concentrations of PFOA and PFOS should be compared with the 0.07 µg/L health advisory level.

mg/kg – milligrams per kilogram
µg/L – micrograms per liter
NL – not listed
PFBS – perfluorobutanesulfonic acid
PFOA – perfluorooctanoic acid
PFOS – perfluorooctanesulfonic acid
RSL – Regional Screening Level
USEPA – Environmental Protection Agency

1.2 PROJECT OBJECTIVES

In accordance with DoD Instruction 4715.18, “Emerging Contaminants (ECs)” (DoD, 2009), the *Interim AF Guidance on Sampling and Response Actions for Perfluorinated Compounds at Active and Base Realignment and Closure (BRAC) Installations* (USAF, 2012), and the *SAF/IE Policy on Perfluorinated Compounds of Concern* (USAF, 2016) the USAF will:

1) Identify locations where there is a reasonable expectation that there may have been a release of PFAS (defined below) associated with USAF actions;

2) Determine if there is unacceptable risk to human health and the environment; and,

3) Address releases that pose an unacceptable risk, including offsite migration.

The primary objectives of this SI were to:

- Determine if PFAS are present in soil, groundwater, or sediment at AFFF release areas selected for SI;
- Determine if PFOS and PFOA concentrations in soil or sediment exceed the calculated RSL of 0.126 mg/kg, based on a residential exposure scenario, and PFBS concentrations in soil or sediment exceed the USEPA residential RSL of 130 mg/kg;

- Determine if concentrations of PFOS, PFOA, or the sum of PFOS and PFOA in groundwater exceed the USEPA HA value of 0.07 µg/L, and if PFBS concentrations in groundwater exceed the USEPA Tap Water RSL of 40 µg/L; and,
- Identify potential receptor pathways with immediate impacts to human health (immediate impact to human health is considered consumption of drinking water with PFOS/PFOA above the USEPA HA value or PFBS above the USEPA Tap Water RSL).

1.3 PROJECT SCOPE

AFFF release areas were selected for SI at AFP#3 based on research conducted by HGL (2015) during a PA, and from the installation scoping visit conducted by OTIE on 21 October 2016. The following four AFFF release areas recommended for SI are as follows:

- AFFF Release Area 1: Former Site FT-07 (Installation Restoration Program [IRP] Site ID FT-07);
- AFFF Release Area 2: DC-8 Fuel Spill Area;
- AFFF Release Area 3: Unnumbered Outfall (Southeastern Property Boundary); and
- AFFF Release Area 4: Outfall 3.

Media evaluated included surface and subsurface (vadose zone) soil, groundwater collected from temporary and existing monitoring wells, or sediment.

This SIR discusses and provides a comparison of the analytical results to screening values for PFOS, PFOA, and PFBS in soil, groundwater, and sediment. The remaining PFAS do not have screening values; therefore, only the results of PFOS, PFOA, and PFBS are discussed in detail and presented in figures. However, all data are presented in the soil, groundwater, and sediment analytical tables.

2.0 AFFF RELEASE AREA BACKGROUND

2.1 SITE LOCATION AND SETTING

AFP#3 is located approximately nine miles northeast of downtown Tulsa, Oklahoma, adjacent to the Tulsa International Airport (**Figure 2.1-1**). AFP#3 was a government-owned, contractor-operated plant that occupied approximately 750 acres.

2.2 SITE HISTORY

In 1940, the City of Tulsa purchased land adjacent to the municipal airport and transferred the property to the U.S. Government the following year for an aircraft plant. The Douglas Aircraft Company began aircraft manufacturing operations in March 1942. Operations at the plant were suspended from 1945 until 1950, and the land was used as a storage depot until it was reactivated for manufacturing in 1950. McDonnell Douglas began to use the plant to perform maintenance on the B-52, KC-135 and the F-4 in the early 1960s. Rockwell International leased a portion of the plant beginning in 1962 for aerospace product manufacturing. From the 1960s to mid-1990s, operations were drawing down and the plant closure process began. During this time, the plant was used primarily for military and commercial aircraft maintenance and manufacturing aerospace products and aircraft components. The City of Tulsa leased the entire plant from the Air Force by 1995 for sublease to private companies. The AFP#3 property was transferred by deed to the City of Tulsa in December 1999 (HGL, 2015). Current tenants include Federal Express, Spirit Aero Systems (an aerostructures manufacturing plant), and Navistar International Corporation (Navistar) (a bus manufacturing plant).

2.3 PREVIOUS INVESTIGATIONS

HGL was contracted by AFCEC to prepare a PA of FTA and non-FTA areas at AFP#3 to identify locations where PFAS may have been used and released into the environment, and to provide an initial assessment of possible migration pathways and receptors of potential contamination (HGL, 2015). Seven potential AFFF release areas were identified during the PA research. The following four AFFF release areas were recommended by HGL for SI (**Figure 2.3-1**):

1) Former Site FT-07 (IRP Site ID FT-07)**:** This former FTA was used semi-annually from approximately 1952 until at least 1983 for firefighting training. Approximately 50 gallons of AFFF may have been used during each fire training exercise from as early as 1970 to 1983.
2) DC-8 Fuel Spill Area: A fuel spill and fire occurred from a DC-8 aircraft while undergoing modifications in the mid-1980s. The amount of AFFF that was used for this emergency response was unknown; however, a former firefighter indicated that a couple of gallons of AFFF were used to suppress the fire. The AFFF used was released directly onto an unpaved area.
3) Unnumbered Outfall (Southeastern Property Boundary): This earthen-lined outfall drains stormwater from underground storm sewer lines on the southeastern portion of AFP#3,

which includes the area of the Former Site FT-07 where AFFF was used for firefighting training.

4) Outfall 3: This earthen-lined outfall is located approximately 55 feet south of the southern installation boundary and drains stormwater from underground storm sewer lines on the southeastern portion of AFP#3, which includes the area of the Former Site FT-07. AFFF released at Former Site FT-07 may have entered the stormwater lines and exited AFP#3 at Outfall 3.

3.0 FIELD ACTIVITIES AND ANALYTICAL PROTOCOL

SI activities were conducted at AFP#3 from 8 to 10 November 2017 at four AFFF release areas identified by others during the PA (HGL, 2015) and during the installation scoping visit conducted by OTIE on 21 October 2016 (**Figure 2.3-1**). Sample locations were determined following discussions between OTIE and AFP#3 and AFCEC personnel, and were documented in the Final ISWP (OTIE, 2017). Media sampled during the SI included surface soil, subsurface soil, and/or groundwater collected from temporary and existing permanent monitoring wells, and sediment.

Photographic documentation of the SI activities is provided in **Appendix A** and field documentation is provided in **Appendix B**. Inspection activities were recorded by field personnel on field activity daily logs (**Appendix B-1**), and daily PFAS protocol checklists were completed to ensure PFAS were not introduced by OTIE employees or subcontractors (**Appendix B-2**). A tailgate safety meeting was conducted each morning prior to beginning work, with the tailgate safety meeting reports provided in **Appendix B-3**.

Soil Boring Advancement and Soil Sample Collection

Five soil borings were advanced for the collection of soil samples and temporary monitoring well installation by an Oklahoma-licensed driller, Roddy Qualls Environmental Drilling of Weatherford, Texas, in accordance with Oklahoma Administrative Code (OAC) Title 785:35-7. Soil borings were initially cleared to a depth of five feet below ground surface (bgs) with a hand auger and completed using direct push technology (DPT) drilling methods. Soil samples were continuously collected from ground surface to first-encountered groundwater using a hand auger or decontaminated 5-foot Macro-Core® sampler with acetate liners in accordance with Standard Operating Procedure (SOP) AFW-02 (PFAS) – *Soil Sampling*, field-screened with a photoionization detector (PID) equipped with a 10.6 electron volt lamp for volatile organic vapors, and logged by a qualified geoscientist in accordance with the Unified Soil Classification System. The resulting soil boring information, PID readings, lithologic data, and soil sample depths are included on soil boring/monitoring well records provided in **Appendix B-4**. Samples for laboratory analysis were extracted from the hand auger or acetate liners and transferred directly into laboratory-provided, high-density polyethylene (HDPE) containers. Sample containers were sealed, labeled, packed into ice-filled coolers, and delivered under chain-of-custody (CoC) to Maxxam Laboratories in Ontario, Canada for PFAS analysis or Eurofins Lancaster Laboratories Environmental (ELLE) in Lancaster, Pennsylvania for physiochemical properties analysis. Soil Sample Collection Logs are provided in **Appendix B-5**.

Temporary Monitoring Well Installation

Temporary monitoring wells were installed in soil borings MW01001, MW01002, and MW01003 (AFFF Release Area 1), and MW02001 and MW02002 (AFFF Release Area 2), on 8 and 9 November 2017 to assess PFAS concentrations in groundwater at the former FTA and aircraft mishap area. Temporary monitoring wells were installed through 3.75-inch outside-diameter rods using DPT drilling techniques and screened from approximately 5 to 20 feet bgs (AFFF Release Area 1) and 5 to 25 feet bgs (AFFF

Release Area 2). Well construction was based on observed depth to water at the time of drilling and geologic conditions encountered. All new monitoring wells were constructed in accordance with OAC Title 785:35-7, the ISWP, and SOP AFW 04 (PFAS) – *Monitoring Well Installation*. The temporary monitoring wells were constructed of one-inch-diameter, Schedule 40 polyvinyl chloride (PVC) casing and a threaded 15 to 20-foot section of 0.010-inch, slotted one-inch-diameter Schedule 40 PVC well screen and end cap. A 12/20 silica sand filter pack was installed from the bottom of the boring to two feet above the screened portion of the well casing. A three-foot-thick bentonite seal was installed above the filter pack and hydrated in approximate six-inch-lifts. Well construction details are provided for the five temporary wells on well construction forms in **Appendix B-6. Table 3.0-1** summarizes the well construction details for the temporary and permanent monitoring wells.

The existing permanent monitoring well was developed in general accordance with SOP AFW 05 (PFAS) – *Well Development* using a peristaltic pump outfitted with disposable HDPE tubing. Well development continued until the field water quality parameters stabilized. Well Development Logs were completed and are included in **Appendix B-7**. The temporary wells were not developed prior to purging and sampling due to the low aquifer hydraulic conductivity and the possibility that the wells would not sufficiently recharge during the SI field event.

Groundwater Elevations

Depth-to-water measurements were recorded from each temporary and existing permanent monitoring well prior to groundwater purging and sampling, and groundwater elevations were calculated relative to top-of-casing elevations surveyed by an Oklahoma-licensed surveyor, Jividen and Company, PLLC. Groundwater depth at AFFF Release Area 1 was measured at 5.35 feet below top-of-casing (btoc) in temporary monitoring well MW01001, and the calculated groundwater elevation was 619.34 feet above mean sea level (amsl) (**Table 3.0-2**). Groundwater depths at AFFF Release Area 2 ranged from 13.10 feet btoc in monitoring well 5NMW13 to 17.41 feet btoc in temporary monitoring well MW02001, and the calculated groundwater elevations ranged from 613.90 (5MW13) to 616.40 (MW02001) feet amsl (**Table 3.0-2**). At the time of the SI, groundwater did not accumulate in temporary monitoring wells MW01002 and MW01003. During the utility clearing activities, a representative of the City of Tulsa indicated that a buried natural gas line had been installed in the vicinity of the former FTA extending in an east-west direction between MW01001 on the south side and MW01002 and MW01003 to the north. Because the wells on the north side of the site were dry and only one groundwater elevation was obtained, a groundwater flow direction could not be estimated and a gradient could not be calculated for AFFF Release Area 1. According to the PA, historical groundwater flow in the area of AFFF Release Area 1 was to the southeast (HGL, 2015) (**Figure 3.0-1**). Groundwater flow at AFFF Release Area 2, as measured from two temporary monitoring wells and permanent monitoring well 5MM13, was to the southeast at an approximate hydraulic gradient of 0.075 feet/feet (**Figure 3.0-2**).

Groundwater Sampling

The groundwater sampling program included the collection of groundwater samples for laboratory chemical analysis of PFAS from three of the five new temporary monitoring wells that contained groundwater and one existing permanent monitoring well. Samples were collected using low-flow groundwater sampling methods with a peristaltic pump. The HDPE tubing was connected to a flow-through cell whereby recovered groundwater was monitored for potential of hydrogen (pH), temperature, specific conductivity, dissolved oxygen, turbidity, and oxidation/reduction potential. Groundwater sampling equipment was calibrated on a daily basis prior to use, with the resulting data recorded on water quality sampling instrument calibration forms contained in **Appendix B-8**. Depth-to-water measurements and field parameters were monitored for one hour or until groundwater indicator parameters reached stabilization criteria in accordance with SOP AFW-03 (PFAS) – *Groundwater Sampling*. The flow-through cell was then removed and groundwater samples were collected directly into laboratory-provided HDPE containers from the discharge tubing.

The sample containers were sealed, labeled, packed on ice in an insulated cooler, and delivered to Maxxam Laboratories under CoC protocol. Groundwater sampling activities were documented on Groundwater Sampling Records provided in **Appendix B-9**.

Soil Boring/Temporary Monitoring Well Abandonment

The five temporary monitoring well casings and screens were removed, pressure washed, and disposed by the drillers subsequent to groundwater sampling and surveying. The five temporary monitoring well boreholes were abandoned with bentonite chips, grout, and clean sand on 9 November 2017 in accordance with SOP AFW-06 (PFAS) – *Borehole Abandonment*, OAC Title 785:35-11-2, and the Oklahoma Water Resources Board (OWRB) Plugging and Abandoned Wells Fact Sheet (OWRB, 2010).

Sediment Sampling

Sediment samples were collected to assess the presence or absence of PFAS at the drainage ditch and outfalls associated with AFFF Release Area 3 (Unnumbered Outfall) and AFFF Release Area 4 (Outfall 3) during the SI. Samples were collected with a stainless steel hand shovel, in accordance with SOP AFW-07 (PFAS) – *Sediment Sampling,* and placed in laboratory-provided HDPE containers. The sample containers were sealed, labeled, packed on ice in an insulated cooler, and delivered to Maxxam Laboratories under CoC protocol. Sample collection data was documented on the Sediment Sample Collection Logs provided in **Appendix B-10**.

Total Sample Counts

The following total sample counts for each media (including field duplicate samples) during SI activities at AFP#3 are listed below:

- 11 soil samples (including one field duplicate sample) were collected at five soil boring locations during the SI;

- Five groundwater samples (including one field duplicate sample) were collected from three temporary monitoring wells and one existing monitoring well during the SI; and,
- Four sediment samples (including one field duplicate sample) were collected at two AFFF release areas during the SI.

Samples collected during the SI were analyzed for the following 16 PFAS compounds:

- PFOS;
- PFOA;
- PFBS;
- Perfluoroheptanoic acid (PFHpA);
- Perfluorohexanesulfonic acid (PFHxS);
- Perfluorononanoic acid (PFNA);
- N-Ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA);
- N-Methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA);
- Perfluorodecanoic acid (PFDA);
- Perfluorotetradecanoic acid (PFTA);
- Perfluorododecanoic acid (PFDoA);
- Perfluorohexanoic acid (PFHxA);
- Perfluorotridecanoic acid (PFTrDA);
- Perfluoroundecanoic acid (PFUnA);
- 6:2 fluorotelomer sulfonate (FTS); and,
- 8:2 FTS.

Soil, groundwater, and sediment samples were analyzed by Maxxam Laboratories, a DoD Environmental Laboratory Accreditation Program accredited laboratory. Samples were analyzed by Modified USEPA Method 537 using Liquid Chromatography and Tandem Mass Spectrometry (LC-MS/MS). The LC-MS/MS method provides acceptable detection limits to confirm the presence of PFAS listed above. The laboratory analytical reports for the PFAS samples collected during the SI are included in **Appendix C**.

PFOS, PFOA, and PFBS analytical results are discussed in the following sections, while the analytical results for the remaining PFAS constituents are tabulated and provided at the conclusion of this SIR.

Co-occurrence of PFOS and PFOA (PFOS+PFOA) in aqueous samples was reported using the following guidelines:

1. If PFOS and PFOA are both detected in concentrations at or above the laboratory detection level (DL) in groundwater used for drinking water, then the reported concentration for PFOA was added to the reported concentration for PFOS.

2. If only PFOS or only PFOA is detected at or above the DL in groundwater, then the concentration of the detected analyte only is reported.

3. If neither PFOA nor PFOS are detected at concentrations at or above the DL, then co-occurrence was reported as Not Detected.

One composite surface soil sample and one composite subsurface soil sample were also collected at each AFFF release area where soil sampling was conducted and submitted to ELLE for laboratory analysis of physiochemical properties, including pH (USEPA Method 9045B), particle size analysis (ASTM International D422), and total organic carbon (TOC) content (USEPA 9060A or Lloyd Kahn Method). The laboratory analytical reports for the physiochemical properties samples collected during the SI are included in **Appendix C**.

Data Validation and Usability Assessment

Laboratory analytical data from soil, sediment and groundwater samples collected between 8 and 9 November 2017 and analyzed for PFAS compounds by Modified USEPA Method 537 were validated in December 2017 and February 2018. OTIE evaluated a total of 380 data records from field samples during the validation process and flagged less than 10% of the records J or UJ qualified as estimated values. Due to a laboratory error, analyses for NETFOSAA and NMeFOSAA were not performed during the initial sample submission. Despite being outside of the holding times for analysis of these compounds, all samples were re-run for the two missing PFAS constituents. Each of the soil, groundwater, and sediment samples, with the exception of the groundwater sample from 5MW13, were reanalyzed for the two analytes, and the results are presented on the appropriate tables. An insufficient volume of sample remained of the groundwater sample from 5MW13 after the original laboratory analysis; therefore, there are no NETFOSAA and NMEFOSAA results for this sample. The results for these two analytes from these later analytical runs are flagged "UJ^1." The "U" flag indicates that the analyte was not detected above the limit of detection, the "J" flag indicates that the result is approximated, and the "1" indicates that the analysis was performed beyond the method-defined holding time. The laboratory further stated, "Because of their chemical structure PFC's (PFAS) are chemically and biologically stable in the environment and resist typical environmental degradation processes. This would suggest a hold time would not have significant impact on the data."

A majority of the flagging was due to analyte concentrations between the DL and the Limit of Quantification, holding times and surrogate recoveries. Reanalysis and dilutions were within method specific criteria and did not require flagging. Analytical uncertainty due to sampling or analytical imprecision is not interpreted to adversely affect overall data usability.

OTIE validated data from soil, sediment, and groundwater samples that were collected between 8 and 9 November 2017 and analyzed for PFAS by Modified USEPA Method 537. In general, the results reviewed met acceptance criteria and are usable. For each of the areas sampled under this SI, the decision to advance each of the areas for further investigation was based on either non-qualified or qualified data that are not interpreted to impact overall data usability. Laboratory Quality Control (QC) performance was generally within criteria. Continuing calibration standards and Laboratory Review Checklists were within acceptance criteria. Analytical data are therefore, usable for the purpose of determining current project Chemicals of Concern concentrations in soil, groundwater and sediment at the affected property.

A description of the data validation scope, data validation procedures, and data validation observations and actions is presented in the data validation reports in **Appendix D.** Overall both qualified and non-qualified data did not affect data usability and met the project Data Quality Objectives and was used interpret SI investigation criteria.

Surveying

The soil borings and newly installed temporary monitoring wells were surveyed by an Oklahoma-licensed surveyor, Jividen and Company, for horizontal coordinates and/or top-of-casing elevations (**Table 3.0-1**). Horizontal coordinates were surveyed based on Oklahoma State Plane Coordinate System, North Zone, United States Survey Feet, North American Datum of 1983. Groundwater surface and top-of-casing elevations were collected based on North American Vertical Datum of 1988.

Investigation-Derived Waste

Investigation-Derived Waste (IDW) consisted of soil cuttings from soil boring advancement, well development water, groundwater sampling purge water, equipment decontamination water, disposable personal protective equipment (PPE), and other miscellaneous refuse. Used PPE and other miscellaneous refuse was placed in plastic bags and discarded into an on-site sanitary trash container for disposal at a sanitary landfill. Soil and liquid IDW was containerized in three Department of Transportation-approved 55-gallon steel drums. One drum containing soil IDW was collected from AFFF Release Area 1. The temporary wells at AFFF Release Area 1 did not yield surplus water; therefore, no liquid IDW was collected at this release area. One drum containing soil IDW and one containing liquid IDW were collected at AFFF Release Area 2. The drums were transported to a staging area on the southeast side of the Navistar plant as designated by Mr. Tom Scism of Navistar. A grab sample was collected from each drum of IDW during the SI (total of three IDW samples) on 9 November 2017. The samples were submitted to Maxxam Laboratories for PFAS analysis and ELLE for laboratory analysis by toxicity characteristic leaching procedure (TCLP) for volatile organic compounds, semi-volatile organic compounds, pesticides, herbicides, and RCRA 8 metals; and polychlorinated biphenyls, total petroleum hydrocarbons (gasoline range organics, oil range organics, and diesel range organics), flashpoint, pH, moisture, ignitability, and total cyanide, to determine the applicable disposal options (**Appendix C**). The three drums of IDW were transported from the installation by Oklahoma Environmental Services on 16 May 2018 and accepted at the Oklahoma City Landfill in Oklahoma City, Oklahoma on 17 May 2018. The non-hazardous waste manifests for the two drums of solid IDW and one drum of liquid IDW are provided in **Appendix E**.

A detailed description of sampling locations and results at each AFFF release area is provided in the following sections.

3.1 AFFF RELEASE AREA 1: FORMER SITE FT-07

This former FTA was used semi-annually from approximately 1952 until at least 1983 for firefighting training. Approximately 50 gallons of AFFF may have been used during each fire training exercise from as early as 1970 to 1983 (HGL, 2015).

3.1.1 Sample Location and Methodologies

3.1.1.1 Soil Samples

Soil borings MW01001, MW01002, and MW01003 were advanced on 8 November 2017 in the estimated source area where AFFF may have been released directly to soil (**Figure 3.1-1**) during historical firefighting training activities. Surface soil samples were collected between 0.0 to 1.0 feet bgs and subsurface soil samples were collected at depths ranging from 11.0 to 17.0 feet bgs for PFAS analysis. Composite soil samples were collected from each soil boring from 0.0 to 1.0 feet bgs and 11.0 to 17.0 feet bgs for TOC, pH, and particle size analysis. Groundwater was encountered at approximately 12 feet bgs in MW01001 during boring advancement at this AFFF release area.

3.1.1.2 Groundwater Samples

Temporary monitoring wells were installed in soil borings MW01001, MW01002, and MW01003 on 8 November 2017 to assess PFAS concentrations in the groundwater beneath the AFFF release source area (**Figure 3.1-1**). Temporary monitoring well MW01001 was sampled on 9 November 2017. The remaining two temporary wells, MW01002 and MW01003, were dry. The absence of groundwater may be attributed to the limited or low yielding shallow water-bearing zone which is typically encountered between 2 and 25 feet bgs.

3.1.2 Analytical Results

3.1.2.1 Soil Results

Three surface soil samples and three subsurface soil samples were collected from borings MW01001, MW01002, and MW01003 on 8 November 2017. PFAS results are provided in **Table 3.1-1**, illustrated on **Figure 3.1-2**, and summarized below.

MW01001:

- PFOS was detected below the calculated RSL from the surface sampling interval at a concentration of 0.098 mg/kg (0 to 1.0 feet bgs) and was not detected from the subsurface sampling interval (11.0 to 12.0 feet bgs).
- PFOA was not detected from either sampling interval.
- PFBS was not detected from either sampling interval.

MW01002:

- PFOS was detected above the calculated RSL from the surface sampling interval at a concentration of 0.40 mg/kg (0 to 1.0 feet bgs) and was not detected from the subsurface sampling interval (16.0 to 17.0 feet bgs).
- PFOA was detected below the calculated RSL from the surface sampling interval at an estimated concentration of 0.00076 mg/kg (0 to 1.0 feet bgs) and was not detected from the subsurface sampling interval (16.0 to 17.0 feet bgs).
- PFBS was detected below the calculated RSL from the surface sampling interval at an estimated concentration of 0.00069 mg/kg (0 to 1.0 feet bgs) and was not detected from the subsurface sampling interval (16.0 to 17.0 feet bgs).

MW01003:

- PFOS was detected below the calculated RSL from the surface sampling interval at a concentration of 0.0058 mg/kg (0 to 1.0 feet bgs) and was not detected from the subsurface sampling interval (15.0 to 16.0 feet bgs).
- PFOA was not detected from either sampling interval.
- PFBS was not detected from either sampling interval.

The composite TOC concentrations ranged from 1,090 mg/kg (11.0 to 17.0 feet bgs) to 4,020 mg/kg (0.0 to 1.0 feet bgs), while the composite pH concentrations ranged from 7.71 Standard Unit (S.U.) (11.0 to 17.0 feet bgs) to 8.30 S.U. (0.0 to 1.0 feet bgs). The particle size analytical results for the 0 to 1.0 feet bgs sample was 67.2% fines (silt and clay), 23.2% sand (fine to coarse), and 9.5% gravel (fine), while the 11 to 17 feet bgs sample was 48.2% fines (silt and clay), 28.1% sand (fine to coarse), and 23.8% gravel (fine). The material description for the 0 to 1.0 feet bgs sample was a dark brown to brown, clay with trace sand, while the 11 to 17 feet bgs sample was described as light brown to orange brown clay.

3.1.2.2 Groundwater Results

Two groundwater samples (one normal and one field duplicate) were collected from temporary monitoring well MW01001. MW01002 and MW01003 were dry at the time of the SI field work. PFAS results are provided in **Table 3.1-3**, illustrated in **Figure 3.1-3,** and summarized below.

MW01001:

- PFOS was detected below the USEPA HA value at a maximum concentration of 0.064 µg/L (field duplicate).
- PFOA was detected above the USEPA HA value at a concentration of 0.13 µg/L.
- PFOS+PFOA was detected above the USEPA HA value at a concentration of 0.194 µg/L.
- PFBS was detected below the USEPA Tap Water RSL at a maximum concentration of 0.58 µg/L.

3.1.3 Conclusions

PFOS, PFOA, and/or PFBS were detected in soil at AFFF Release Area 1. PFOS exceeded the calculated RSL in surface soil at temporary monitoring well MW01002. PFOA and PFOS+PFOA exceeded the USEPA HA value in temporary monitoring well MW01001, while PFBS was detected at concentrations below the USEPA Tap Water RSL. Groundwater samples were not obtained from MW01002 and MW01003 due to the lack of groundwater.

3.2 AFFF RELEASE AREA 2: DC-8 FUEL SPILL AREA

A fuel spill and subsequent fire occurred from a DC-8 aircraft while undergoing modifications in the mid-1980s. The amount of AFFF that was used for this emergency response was unknown; however, a former firefighter indicated a couple of gallons of AFFF were used to suppress the fire. The AFFF used at the DC-8 Fuel Spill Area was released directly onto an unpaved area (HGL, 2015).

3.2.1 Sample Location and Methodologies

3.2.1.1 Soil Samples

Soil borings MW02001 and MW02002 were advanced on 8 November 2017 in the vicinity of the DC-8 Fuel Spill Area where AFFF was likely released to the ground surface (**Figure 3.2-1**). Surface soil samples were collected from 0.0 to 1.0 feet bgs and subsurface soil samples were collected from 8.0 to 13.5 feet bgs for PFAS analysis. Composite soil samples were also collected from each soil boring from 0.0 to 0.5 feet bgs and 8.0 to 13.5 feet bgs for TOC, pH, and particle size analysis. Groundwater was encountered at approximately 18.0 to 20.0 feet bgs during boring advancement.

3.2.1.2 Groundwater Samples

Temporary monitoring wells were installed in soil borings MW02001 and MW02002 on 8 November 2017 to assess PFAS concentrations in the groundwater beneath the AFFF Release Area 2 source area (**Figure 3.2-1**). The temporary monitoring wells were sampled on 9 November 2017. Existing permanent monitoring well 5MW13, located approximately 350 feet southeast of the center of the source area, was developed and sampled on 8 November 2017 to assess PFAS concentrations in groundwater that may have migrated downgradient of the source area.

3.2.2 Analytical Results

3.2.2.1 Soil Results

Three surface soil samples (two normal and one duplicate) and two subsurface soil samples were collected from soil borings MW02001 and MW02002. PFAS results are provided in **Table 3.1-1**, illustrated in **Figure 3.2-2**, and summarized below.

MW02001:

- PFOS was detected below the calculated RSL from the surface sampling interval at a maximum concentration of 0.0015 mg/kg (0.0 to 1.0 feet bgs; field duplicate) and was not detected from the subsurface sampling interval (8.0 to 10.0 feet bgs).
- PFOA was not detected from either sampling interval.
- PFBS was not detected from either sampling interval.

MW02002:

- PFOS was detected below the calculated RSL from the surface sampling interval at a concentration of 0.0017 mg/kg (0.0 to 1.0 feet bgs) and was not detected from the subsurface sampling interval (12.5 to 13.5 feet bgs).
- PFOA was not detected from either sampling interval.
- PFBS was not detected from either sampling interval.

The composite TOC concentrations ranged from 1,050 mg/kg (8.0 to 13.5 feet bgs) to 8,090 mg/kg (0.0 to 1.0 feet bgs), while the composite pH concentrations ranged from 8.49 S.U. (0.0 to 1.0 feet bgs) to 8.68 S.U. (8.0 to 13.5 feet bgs). The particle size analytical results for the 0 to 1.0 feet bgs sample was 37.1% fines (silt and clay), 41.2% sand (fine to coarse), and 21.7% gravel (fine to coarse), while the 8.0 to 13.5 feet bgs sample was 42.6% fines (silt and clay), 27.7% sand (fine to coarse), and 29.7% gravel (fine). The material description for the 0 to 0.5 feet bgs sample was a dark brown to light brown, with trace gravel, while the 8.0 to 13.5 feet bgs sample was described as an orange brown clay with gravel.

3.2.2.2 Groundwater Results

Three groundwater samples were collected from temporary monitoring wells MW02001 and MW02002 and from existing permanent monitoring well 5NMW13. PFAS results are provided in **Table 3.1-3**, illustrated in **Figure 3.2-3,** and summarized below.

MW02001:

- PFOS was detected below the USEPA HA value at an estimated concentration of 0.013 µg/L.
- PFOA was detected above the USEPA HA value at an estimated concentration of 0.16 µg/L.
- PFOS+PFOA was detected above the USEPA HA value at an estimated concentration of 0.173 µg/L.
- PFBS was detected below the USEPA Tap Water RSL at an estimated concentration of 0.0080 µg/L.

MW02002:

- PFOS was detected below the USEPA HA value at a concentration of 0.026 µg/L.
- PFOA was detected above the USEPA HA value at a concentration of 0.41 µg/L.

- PFOS+PFOA was detected above the USEPA HA value at a concentration of 0.436 µg/L.
- PFBS was detected below the USEPA Tap Water RSL at a concentration of 0.035 µg/L.

5NMW13:

- PFOS was not detected.
- PFOA was detected below the USEPA HA value at an estimated concentration of 0.0087 µg/L.
- PFOS+PFOA was detected below the USEPA HA value at an estimated concentration of 0.0087 µg/L.
- PFBS was not detected.

3.2.3 Conclusions

PFOS was detected in surface soil samples at concentrations below the calculated RSLs. PFOA and PFOS+PFOA exceeded the USEPA HA value in groundwater samples collected from temporary wells MW02001 and MW02002.

3.3 AFFF RELEASE AREA 3: UNNUMBERED OUTFALL

This earthen-lined outfall drains stormwater from underground storm sewer lines on the southeastern portion of AFP#3, which includes the area of the Former Site FT-07 where AFFF was used for firefighting training (HGL, 2015).

3.3.1 Sample Location and Methodologies

3.3.1.1 Sediment Samples

Two sediment samples (SD03001 and SD03002) were collected on 8 November 2017 during the SI along the surface drainage ditch and at the Unnumbered Outfall near the southeastern property boundary to assess potential impacts from AFFF-containing surface and stormwater runoff from the AFFF Release Area 1 source area (**Figure 3.3-1**).

3.3.2 Analytical Results

3.3.2.1 Sediment Results

Two sediment samples were collected for PFAS analysis, with the results provided in **Table 3.1-4**, illustrated in **Figure 3.3-2**, and summarized below.

SD03001:

- PFOS was detected below the calculated RSL at a concentration of 0.0037 mg/kg.
- PFOA was not detected.
- PFBS was not detected.

SD03002:

- PFOS was detected below the calculated RSL at a concentration of 0.0019 mg/kg.

- PFOA was not detected.
- PFBS was not detected.

3.3.3 Conclusions

PFOS was detected in sediment samples at AFFF Release Area 3 at concentrations below the calculated RSL.

3.4 AFFF RELEASE AREA 4: OUTFALL 3

This earthen-lined outfall is located approximately 55 feet south of the southern installation boundary and drains stormwater from underground storm sewer lines on the southeastern portion of AFP#3, which includes the area of the Former Site FT-07 where AFFF was used for firefighting training (HGL, 2015).

3.4.1 Sample Location and Methodologies

One sediment sample (SD04001) and one field duplicate were collected on 8 November 2017 at Outfall 3 south of the southern AFP#3 property boundary to assess potential impacts from AFFF-containing surface and stormwater runoff from the AFFF Release Area 1 source area (**Figure 3.4-1**).

3.4.2 Analytical Results

3.4.2.1 Sediment Results

One sediment sample and one field duplicate were collected for PFAS analysis during the SI, with the results provided in **Table 3.1-4**, illustrated in **Figure 3.4-2**, and summarized below.

SD04001:

- PFOS was not detected.
- PFOA was not detected.
- PFBS was not detected.

3.4.3 Conclusions

PFOS, PFOA, and PFBS were not detected at AFFF Release Area 4.

4.0 MIGRATION/EXPOSURE PATHWAYS AND TARGETS

An updated base-wide conceptual site model table is provided as **Table 4.0-1**. The table provides an overview of the facility, physical, release, land use, exposure, and ecological profiles at AFP#3. The table has been updated to include information collected during this SI. A more detailed description of source area conditions and exposure pathways are described in the following sections.

4.1 SOIL (SURFACE AND SUBSURFACE) EXPOSURE PATHWAY

4.1.1 Local Geologic Setting

A majority of AFP#3 is positioned on an outcrop of Upper Terrace Sands of Quaternary age. This unconsolidated unit is typically less than 40 feet thick and is composed of sediments consisting of fine to medium–grained quartz sand, silt and clay, with a lag conglomerate locally at the base. These Quaternary deposits are underlain by the Nowata Formation of Pennsylvanian, Desmoinesian age, which can be segregated into two informal units, a lower shale interval, and an upper, interbedded limestone and shale interval termed the Nowata flagstone. The Nowata flagstone is typically less than 55 feet thick. The limestone varies from light olive gray to light brown in color and the shale is typically light olive gray in color (Oklahoma Geologic Society, 2013). The Nowata Formation outcrops along the east facing slope directly west of Mingo Road (HGL, 2015). Beneath these formations is the Oologah Formation of Pennsylvanian, Desmoinesian age, which is a thin to medium-bedded, carbonate mudstone to wackestone.

The soil type encountered at Former Site FT-07 (AFFF Release Area 1) and Outfall 3 (AFFF Release Area 4) is the Urban land-Dennis complex. This soil unit is described as a poorly drained silt loam to silty clay to clay extending to 78 inches deep, with slopes varying from 0 to 5 percent. The permeability is described as slow. The soil type found at the DC-8 Fuel Spill Area (AFFF Release Area 2) is the Okemah-Parsons-Pharaoh complex. This soil unit is described as poorly drained silt loam to clay extending to 80 inches deep, with slopes of 0 to 1 percent. The permeability is described as slow. The soil at the Unnumbered Outfall (AFFF Release Area 3) is the Wynona silty clay loam. This soil unit is described as a poorly drained silty clay loam extending to 60 inches deep, with slopes of 0 to 1 percent. The permeability is described as slow (United States Department of Agriculture, Natural Resources Conservation Service, 2006).

4.1.2 Soil Exposure Pathways and Targets

PFOS was detected in surface and subsurface soil at AFFF Release Areas 1 and 2. PFOS exceeded the calculated RSL of 0.126 mg/kg in surface soil (0.0-1.0 feet bgs) in AFFF Release Area 1 and is considered a release area for pathway analysis. PFOA and PFBS were detected in the surface soil (0.0 to 1.0 feet bgs) at concentrations below the calculated RSL in AFFF Release Area 1. Neither AFFF release area has a clean cover or impermeable cover above the impacted soils.

Surface and subsurface soil in the AFFF release areas are potentially accessible by workers, site visitors, and/or trespassers involved in any activity that exposes them to the impacted soil. Access to source area soil is not expected to change in the future.

Potential exposure routes for surface and subsurface soil include inhalation of impacted surface soil dust particles and ingestion and dermal contact with contaminants in the surface and subsurface soil.

4.1.3 Soil Exposure Conclusions

Based on the SI, potential complete pathways for human exposure to PFAS-impacted surface soil through inhalation, ingestion, and/or dermal contact were identified for AFFF Release Area 1.

4.2 GROUNDWATER MIGRATION PATHWAY

4.2.1 Local Hydrogeologic Setting

Two water-bearing transmissive zones have been identified beneath AFP#3. The shallow water-bearing zone is positioned between the Quaternary sediments and the Nowata Formation and is recharged through the infiltration of precipitation from areas upgradient of AFP#3. This water-bearing zone is typically encountered at depths between 2 and 25 feet bgs, with a gradient toward the east. This is considered a limited or low yield water-bearing zone and is not considered a practical potable water resource (HGL, 2015). The deeper water-bearing zone is present within the Nowata Formation at a depth of approximately 45 feet bgs with a gradient to the southeast. The deeper water-bearing zone is also considered to have low yield and not considered a practical potable water resource (HGL, 2015).

4.2.2 Groundwater Exposure Pathways and Targets

PFAS, once in groundwater, are highly mobile and will migrate near the same velocity as groundwater due to their high solubility and low partition coefficient value. PFAS are chemically and biologically stable in the environment and resist typical environmental degradation processes. As a result, these chemicals are extremely persistent in the environment, with a half-life greater than 41 years for PFOS and greater than 92 years for PFOA (USEPA, 2014). PFBS is generally less toxic and less bio-accumulative in wildlife and humans (USEPA, 2017).

PFOS, PFOA, and/or PFBS were detected in groundwater at AFFF Release Areas 1 and 2. PFOA and PFOS+PFOA exceeded the USEPA HA value of 0.07 µg/L at AFFF Release Areas 1 and 2, and are considered release areas for pathway analysis. PFOS and PFBS were detected at AFFF Release Areas 1 and 2, but at concentrations below the HA and USEPA Tap Water RSL, respectively. Based on current PFAS analytical results, AFFF Release Areas 1 and 2 are considered release areas for pathway analysis.

Potential human exposure receptors from PFAS in groundwater include workers, site visitors, and/or trespassers at AFP#3 involved in any activity that exposes them to the impacted groundwater at AFFF Release Areas 1 and 2. In addition, potential human exposure receptors include individuals located outside the installation boundary that may obtain drinking water from a private or public water supply well that draws groundwater from the impacted aquifer and is located downgradient of the AFFF source areas. A groundwater flow direction could not be determined at AFFF Release Area 1 during the SI field effort as groundwater was encountered in a single temporary monitoring well (MW01001). However, historical groundwater investigations of former Site FT-07 have indicated that the apparent groundwater flow is generally eastward and is a reflection of the local topography (HGL, 2015). Based on the groundwater elevations measured at the two temporary monitoring wells and a permanent monitoring well, the groundwater gradient at AFFF Release Area 2 is to the southeast.

A review of the OWRB Public Water Supply Systems in Oklahoma map indicated that potable water for AFP#3 is provided by the City of Tulsa. According to the City of Tulsa's website, the City obtains its drinking water supply from surface water sources: Lakes Spavinaw (approximately 44 miles east) and Eucha (approximately 58 miles east) on Spavinaw Creek and Lake Oologah (approximately 20 miles northeast) on the Verdigris River. Lakes Spavinaw and Eucha are owned and operated by the City of Tulsa. Lake Oologah is operated by the U.S. Army Corps of Engineers. The website noted a third emergency source of water is available from Lake Hudson on Grand River (City of Tulsa, Water & Sewer Department). A desktop water well review of the OWRB website did not indicate the presence of private drinking water wells in an apparent downgradient position of the AFFF release source areas within a four-mile radius of the property boundary.

4.2.3 Groundwater Migration Pathway Conclusions

Because AFP#3 obtains its potable water from municipal sources and the downgradient water wells do not appear to be used for potable water supply, human groundwater receptors via the ingestion pathway are not present at AFP#3.

Based on the SI, potential complete pathways for human exposure to PFAS-impacted groundwater were not identified for AFFF Release Areas 1 and 2.

4.3 SEDIMENT EXPOSURE PATHWAY

4.3.1 Sediment Exposure Pathways and Targets

PFOS and PFOA were detected in the sediments collected from AFFF Release Area 3 at concentrations below the calculated RSL of 0.126 µg/kg and was not detected in the sediments collected from AFFF Release Area 4.

Sediment in the release area is potentially accessible by workers, site visitors, and/or trespassers involved in any activity that exposes them to the impacted sediment including recreational activities and drainage ditch/outfall maintenance activities. Access to sediment is not expected to change in the future.

Potential exposure routes for sediment include dermal contact with submerged or exposed sediment during recreational activities, as well as drainage ditch and outfall maintenance activities. AFFF Release Area 3 and AFFF Release Area 4 are not used for recreational purposes.

4.3.2 Sediment Exposure Conclusions

Because PFOS was detected at concentrations below the calculated RSL in AFFF Release Area 3 and below detection limits at AFFF Release Area 4, no potential complete pathways for human exposure to PFAS-impacted sediment through dermal contact were identified for AFFF Release Area 3 and AFFF Release Area 4.

5.0 SUMMARY AND CONCLUSIONS

As stated in the introduction, the objectives of this study were to:

- Determine if PFAS are present in soil, groundwater, or sediment at AFFF release areas selected for SI;
- Determine if PFOS and PFOA concentrations in soil exceed the calculated RSL of 0.126 mg/kg, based on a residential exposure scenario, and PFBS concentrations in soil or sediment exceed the USEPA residential RSL of 130 mg/kg;
- Determine if concentrations of PFOS, PFOA, or the sum of PFOS and PFOA, in groundwater exceed the USEPA HA value of 0.07 µg/L, and if PFBS concentrations in groundwater exceed the USEPA Tap Water RSL of 40 µg/L; and,
- Determine if concentrations of PFOS or PFOA in sediment exceed the calculated residential RSL of 0.126 mg/kg, based on a residential exposure scenario; and,
- Identify potential receptor pathways with immediate impacts to human health (immediate impact to human health is considered consumption of drinking water with PFOS/PFOA above the USEPA HA value or PFBS above the USEPA Tap Water RSL).

Section 3.0 of this SI detailed the analytical results for PFAS at each AFFF release area. A summary table (**Table 5.0-1**) is also provided below which lists specific exceedances by area and media, fulfilling the objectives of the SI.

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Table 5.0-1. Summary of Analytical Results and Screening Level Exceedances.

AFFF Release Area	Parameter	Maximum Detected Concentration	Screening Value	Units	Number of Samples*/ Number of Exceedances	Exceeds Screening Level	Potentially Complete DW Exposure Pathway	Recommendation
AFFF Release Area 1 Former Site FT-07	Surface Soil (0 to 1.0 feet bgs)						No	Advance Area to RI
	PFOS	**0.40**	0.126	mg/kg	3/1	**Yes**		
	PFOA	0.00076 J	0.126	mg/kg	3/0	No		
	PFBS	0.00069 J	130	mg/kg	3/0	No		
	Subsurface Soil (11 to 17 feet bgs)							
	PFOS	ND	0.126	mg/kg	3/0	No		
	PFOA	ND	0.126	mg/kg	3/0	No		
	PFBS	ND	130	mg/kg	3/0	No		
	Groundwater							
	PFOS	0.064	0.07	µg/L	2/0	No		
	PFOA	**0.13**	0.07	µg/L	2/2	**Yes**		
	PFOS+PFOA	**0.194**	0.07	µg/L	2/2	**Yes**		
	PFBS	0.58	40	µg/L	2/0	No		
AFFF Release Area 2 DC-8 Fuel Spill Area	Surface Soil (0 to 1.0 feet bgs)						No	Advance Area to RI
	PFOS	0.0017	0.126	mg/kg	3/0	No		
	PFOA	ND	0.126	mg/kg	3/0	No		
	PFBS	ND	130	mg/kg	3/0	No		
	Subsurface Soil (8 to 14 feet bgs)							
	PFOS	ND	0.126	mg/kg	2/0	No		
	PFOA	ND	0.126	mg/kg	2/0	No		
	PFBS	ND	130	mg/kg	2/0	No		

AFFF Release Area	Parameter	Maximum Detected Concentration	Screening Value	Units	Number of Samples*/ Number of Exceedances	Exceeds Screening Level	Potentially Complete DW Exposure Pathway	Recommendation
AFFF Release Area 2 DC-8 Fuel Spill Area	Groundwater							
	PFOS	0.026	0.07	µg/L	3/0	No		
	PFOA	**0.41**	0.07	µg/L	3/2	**Yes**		
	PFOS+PFOA	**0.436**	0.07	µg/L	3/2	**Yes**		
	PFBS	0.035	40	µg/L	3/0	No		
AFFF Release Area 3 Unnumbered Outfall	Sediment							
	PFOS	0.0037	0.126	mg/kg	2/0	No	No	NFRAP
	PFOA	ND	0.126	mg/kg	2/0	No		
	PFBS	ND	130	mg/kg	2/0	No		
AFFF Release Area 4 Outfall 3	Sediment							
	PFOS	ND	0.126	mg/kg	2/0	No	No	NFRAP
	PFOA	ND	0.126	mg/kg	2/0	No		
	PFBS	ND	130	mg/kg	2/0	No		

Notes:

* includes normal and field duplicate samples (count does not include QC samples)
AFFF – aqueous film forming foam
bgs – below ground surface
DW – Drinking Water
J - The reported result is an estimated value.
µg/L – micrograms per liter
mg/kg – milligrams per kilogram
n/a – not applicable
ND – not detected
NFRAP – No Further Remedial Action Planned
NL – No Limit
PFBS – perfluorobutanesulfonic acid
PFOS – perfluorooctanesulfonic acid
PFOA – perfluorooctanoic acid
RI – Remedial Investigation

Potential human health pathways were identified and detailed in Section 4 of this SIR. The potential receptors and targets vary by AFFF release area. Media-specific pathways and receptors are discussed below.

Surface and Subsurface Soil Receptors

PFOS was detected in surface and subsurface soil at AFFF Release Areas 1 and 2, and exceeded the calculated RSL of 0.126 mg/kg in surface soil (0.0-1.0 feet bgs) at AFFF Release Area 1. Potential exposure receptors include workers, visitors, and/or trespassers involved in any activity that exposes them to the PFAS-impacted surface soil at AFFF Release Area 1

Based on the SI, potential complete pathways for human exposure to PFAS-impacted surface soil through inhalation, ingestion, and/or dermal contact were identified for AFFF Release Area 1.

Groundwater Receptors

PFOA and the sum of PFOS and PFOA in groundwater exceeded the USEPA HA value of 0.07 µg/L at AFFF Release Areas 1 and 2. Potential human exposure receptors from PFAS in groundwater include workers, site visitors, and/or trespassers at AFP#3 that may expose the shallow water table at AFFF Release Areas 1 and 2 where PFOA and PFOA+PFOA exceeded the USEPA HA value. Human groundwater receptors via the ingestion pathway are not present for the AFFF release areas at or downgradient of AFP#3 since the installation and surrounding area utilizes drinking water supplied by the City of Tulsa originating from surface water sources located more than 20 miles from the installation boundary, and no private drinking water wells were noted within a four-mile radius of the installation boundary downgradient of the AFFF release areas.

Sediment Receptors

PFOS was detected at concentrations below the calculated RSL in sediment samples collected from AFFF Release Area 3. Sediment in this release area is potentially accessible by workers, site visitors, and/or trespassers involved in any activity that exposes them through dermal contact to the impacted sediment including recreational activities and drainage ditch/outfall maintenance activities. However, since PFOS was only detected at concentrations below the calculated RSLs at AFFF Release Area 3 and below detection limits at AFFF Release Area 4, no potential complete pathways exist for human exposure to PFAS-impacted sediment through dermal contact.

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FIGURES

FIGURE ACRONYMS

AFFF	aqueous film forming foam	PCL	Protective Concentration Level
		PFAS	per- and polyfluorinated alkyl substances
FD	Field Duplicate Sample	PFBS	perfluorobutanesulfonic acid
ft bgs	feet below ground surface	PFOA	perfluorooctanoic acid
		PFOS	perfluorooctanesulfonic acid
GW	Groundwater		
		RSL	Regional Screening Level
HA	Health Advisory		
		SB	soil boring
µg/L	micrograms per liter	SD	sediment
mg/kg	milligrams per kilogram		
MW	monitoring well	THQ	Total Hazard Quotient
N	Normal Sample	USEPA	United States Environmental Protection Agency

FIGURE NOTES

Highlighted = Detected concentration of analyte exceeds United States Environmental Protection Agency (USEPA) Health Advisory (HA) value or USEPA Tap Water RSL for groundwater, **or** exceeds USEPA Regional Screening Level (RSL) for soil or sediment.
J = The reported result is an estimated value.
U = The analyte was not detected above the reported limit of detection.
Groundwater elevations in feet above mean sea level.
Approximate Groundwater Flow Directions are based on historical data (HGL, 2016).

Screening Values

Soil / Sediment	
Analyte	**USEPA RSL[a,b]**
Perfluorooctanoic acid (PFOA)	0.126 mg/kg
Perfluorooctanesulfonic acid (PFOS)	0.126 mg/kg
Perfluorobutanesulfonic acid (PFBS)	130 mg/kg
Groundwater	
Analyte	**USEPA HA[c,d]/RSL[a]**
Perfluorooctanoic acid (PFOA)	0.07 µg/L
Perfluorooctanesulfonic acid (PFOS)	0.07 µg/L
Perfluorobutanesulfonic acid (PFBS)	40 µg/L

Screening Value Table Notes:

[a] USEPA Regional Screening Levels (2017a) [https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2017] using a THQ of 0.1. Soil screening values were used for screening PFBS in sediment.

[b] Screening levels, based on a residential exposure scenario, were calculated using the USEPA Regional Screening Level calculator (https://epa-prgs.ornl.gov/cgi-bin/ chemicals/csl_search) and a THQ of 0.1.

[c] USEPA, May 2016a. "Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)" and USEPA, 2016b. "Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)."

[d] When both PFOA and PFOS are both present, the combined concentrations of PFOA and PFOS should be compared with the 0.07 µg/L health advisory level.

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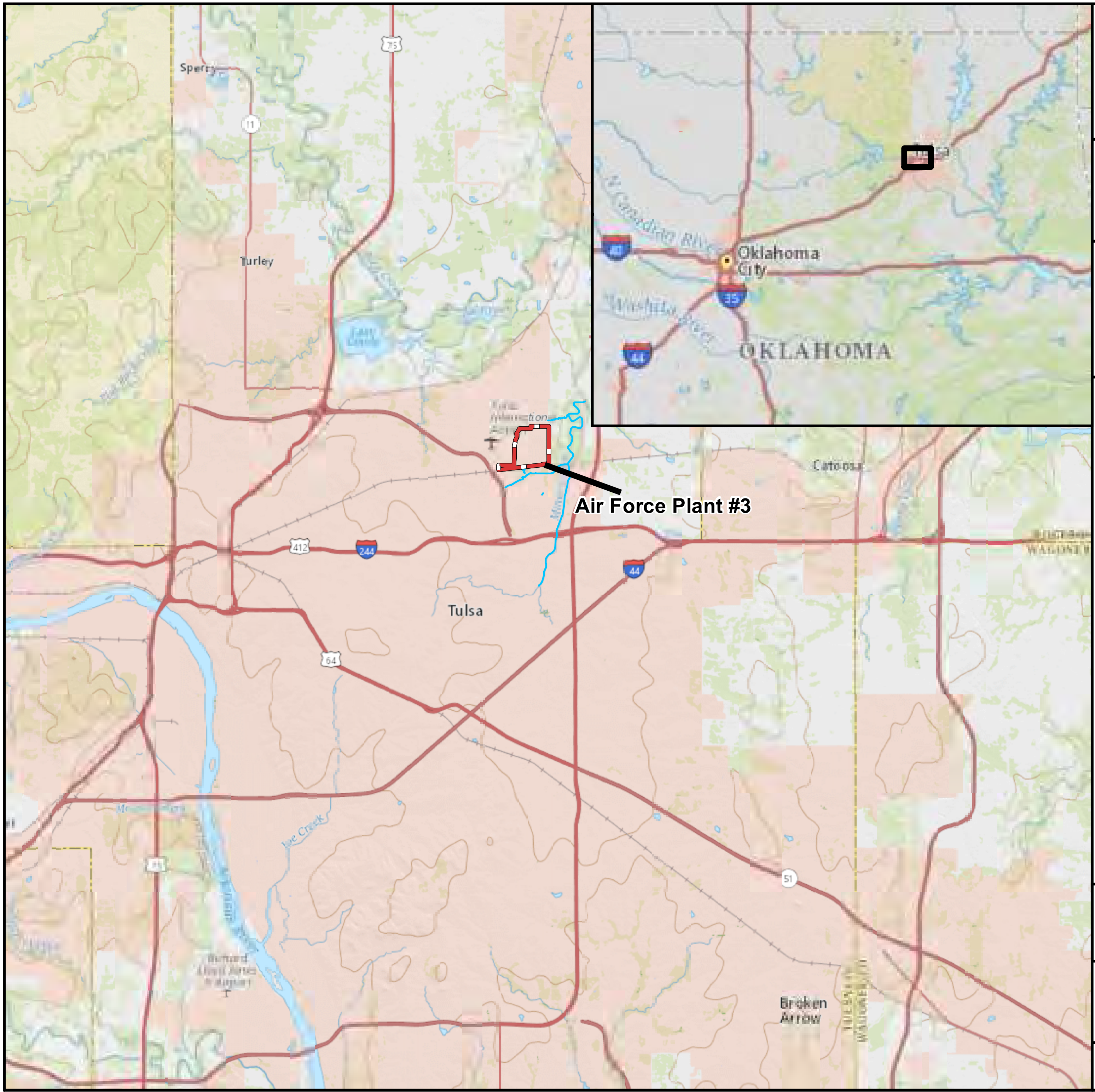

FIGURE 2.1-1
Installation Location Map
Air Force Plant #3
Tulsa, Oklahoma

Site Inspection of Aqueous
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Release Areas
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Site Inspection Report

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Symbol Key

🟥	Air Force Plant #3 Installation Boundary
~	Surface Water
☐	Approximate Zoomed Extent

Source: Esri 2016 USGS National Map

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Contract: FA8903-16-D-0027

By: RJK/BCW **8/8/2018**

0 2.5 5 Miles

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FIGURE 2.3-1
AFFF Release Areas
Air Force Plant #3
Tulsa, Oklahoma

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Symbol Key

▭	Air Force Plant #3 Installation Boundary
▭	AFFF Release Area
〰	Surface Water

Source: Esri 2016 USGS National Map

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By: BCW **8/8/2018**

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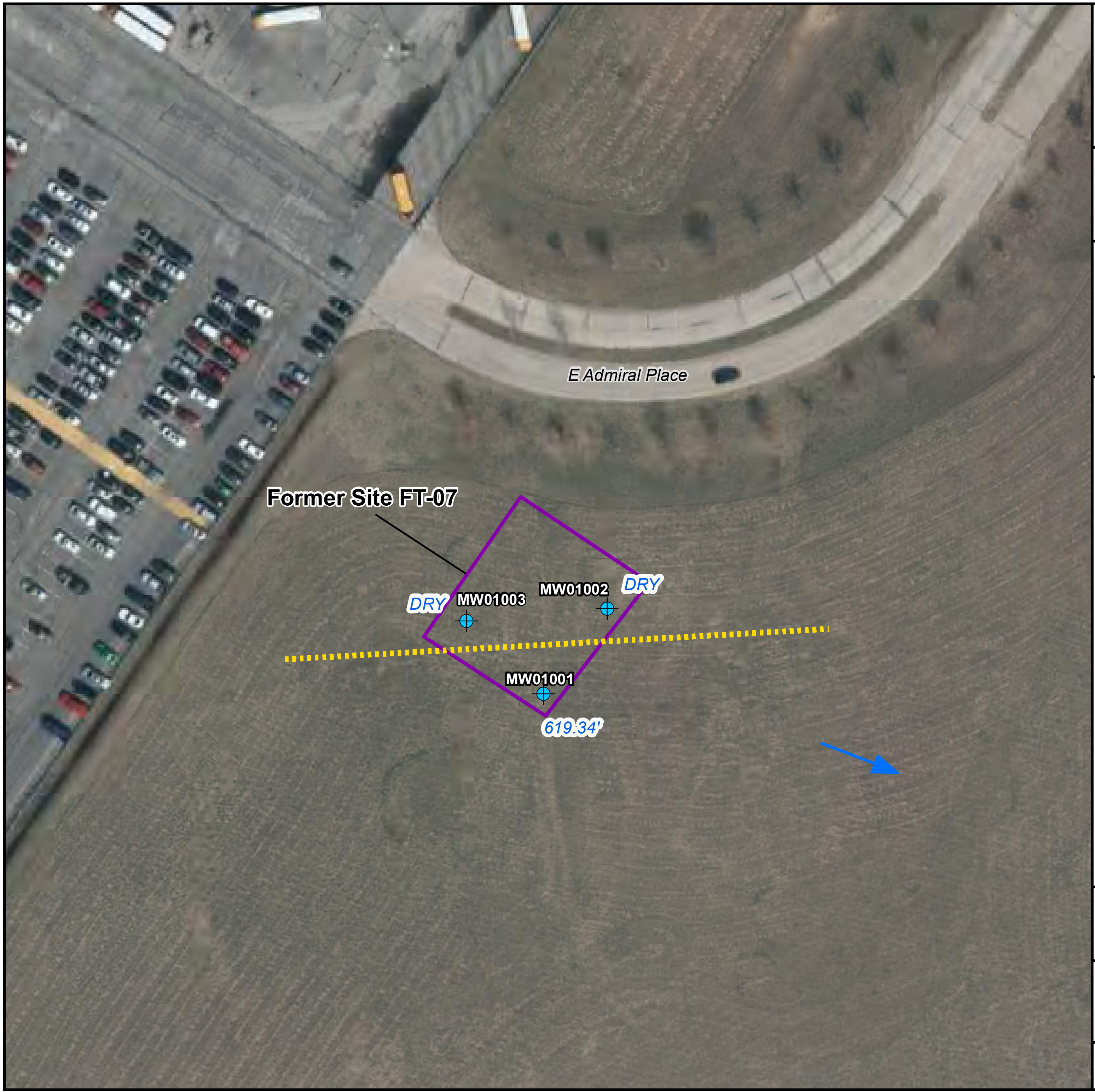

FIGURE 3.0-1
Groundwater Elevations (Nov 2017)
Former Site FT-07
AFFF Release Area 1
Air Force Plant #3
Tulsa, Oklahoma

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Symbol Key

⊕	Soil Boring/Temporary Monitoring Well
▭	AFFF Release Area
······	Natural Gas Line*
→	Historical Groundwater Flow Direction (HGL, 2015)

Notes

*Estimated area of Natural Gas Line; was previously unknown and was detected only during the utility locating in the field. Construction date unknown

**Groundwater Flow Direction could not be evaluated due to limited groundwater elevation data at the time of the SI

All groundwater elevations measured in feet above mean sea level.

Source: Esri 2016 Digital Globe

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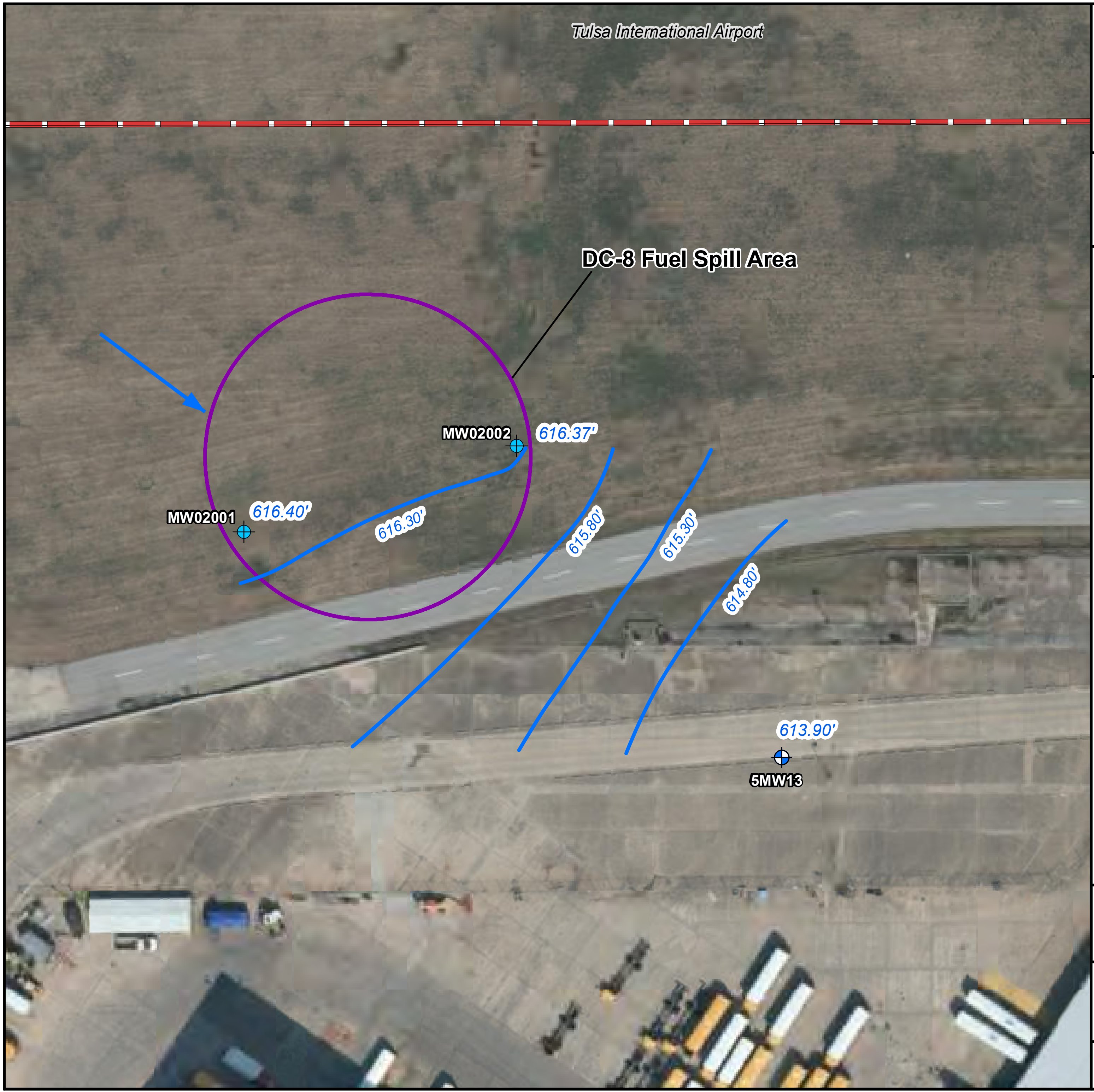

FIGURE 3.0-2
Groundwater Elevations (Nov 2017)
DC-8 Fuel Spill Area
AFFF Release Area 2
Air Force Plant #3
Tulsa, Oklahoma

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Film Forming Foam (AFFF)
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Symbol Key

⊕	Existing Monitoring Well
⊕	Soil Boring/Temporary Monitoring Well
🟥	Air Force Plant #3 Installation Boundary
🟪	AFFF Release Area
—	Groundwater Contours
→	Groundwater Flow Direction (Nov 2017)

Notes

All groundwater elevations measured in feet above mean sea level.

Source: Esri 2016 Digital Code

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FIGURE 3.1-1
Sampling Locations
Former Site FT-07
AFFF Release Area 1
Air Force Plant #3
Tulsa, Oklahoma

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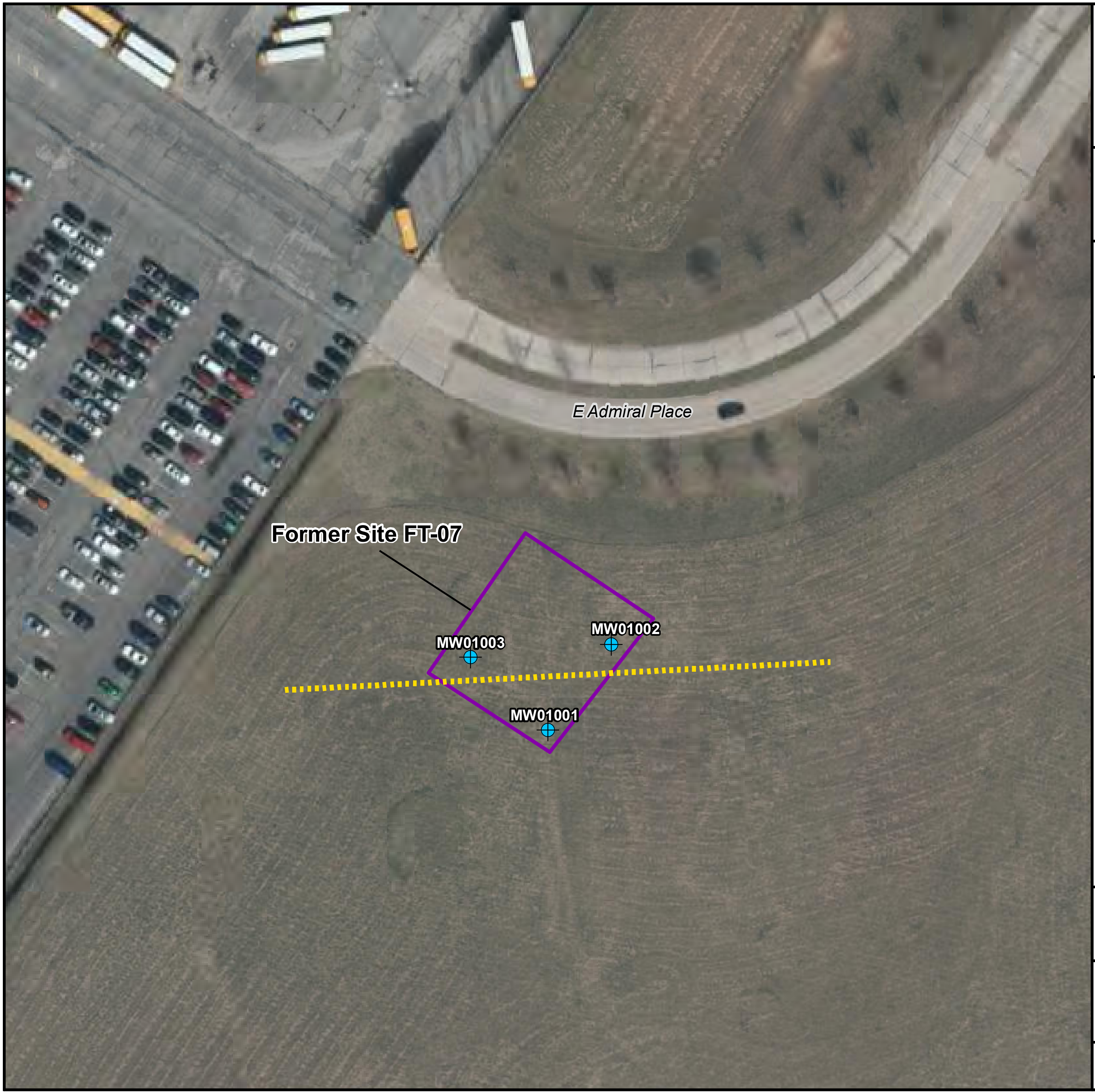

Symbol Key

⊕ Soil Boring/Temporary Monitoring Well

▭ AFFF Release Area

⋯ Natural Gas Line*

Notes

*Estimated location of Natural Gas Line; was previously unknown and was detected only during the utility locating in the field. Construction date unknown.

Source: Esri 2016 Digital Globe

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FIGURE 3.1-2
PFAS in Soil
Former Site FT-07
AFFF Release Area 1
Air Force Plant #3
Tulsa, Oklahoma

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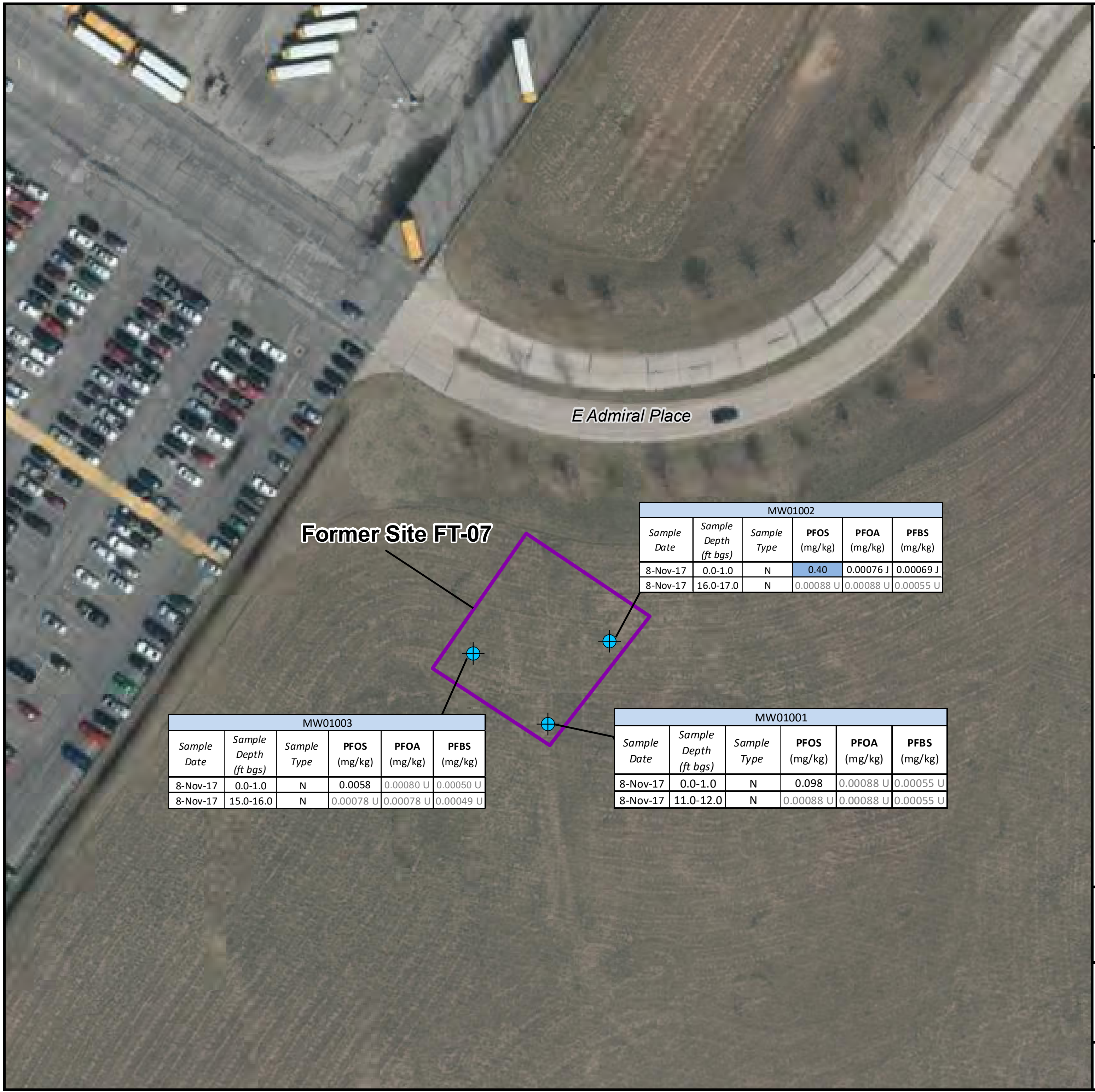

MW01002

Sample Date	Sample Depth (ft bgs)	Sample Type	PFOS (mg/kg)	PFOA (mg/kg)	PFBS (mg/kg)
8-Nov-17	0.0-1.0	N	0.40	0.00076 J	0.00069 J
8-Nov-17	16.0-17.0	N	0.00088 U	0.00088 U	0.00055 U

MW01003

Sample Date	Sample Depth (ft bgs)	Sample Type	PFOS (mg/kg)	PFOA (mg/kg)	PFBS (mg/kg)
8-Nov-17	0.0-1.0	N	0.0058	0.00080 U	0.00050 U
8-Nov-17	15.0-16.0	N	0.00078 U	0.00078 U	0.00049 U

MW01001

Sample Date	Sample Depth (ft bgs)	Sample Type	PFOS (mg/kg)	PFOA (mg/kg)	PFBS (mg/kg)
8-Nov-17	0.0-1.0	N	0.098	0.00088 U	0.00055 U
8-Nov-17	11.0-12.0	N	0.00088 U	0.00088 U	0.00055 U

Symbol Key

⊕ Soil Boring/Temporary Monitoring Well

▭ AFFF Release Area

Source: Esri 2016 Digital Globe

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Contract: FA8903-16-D-0027

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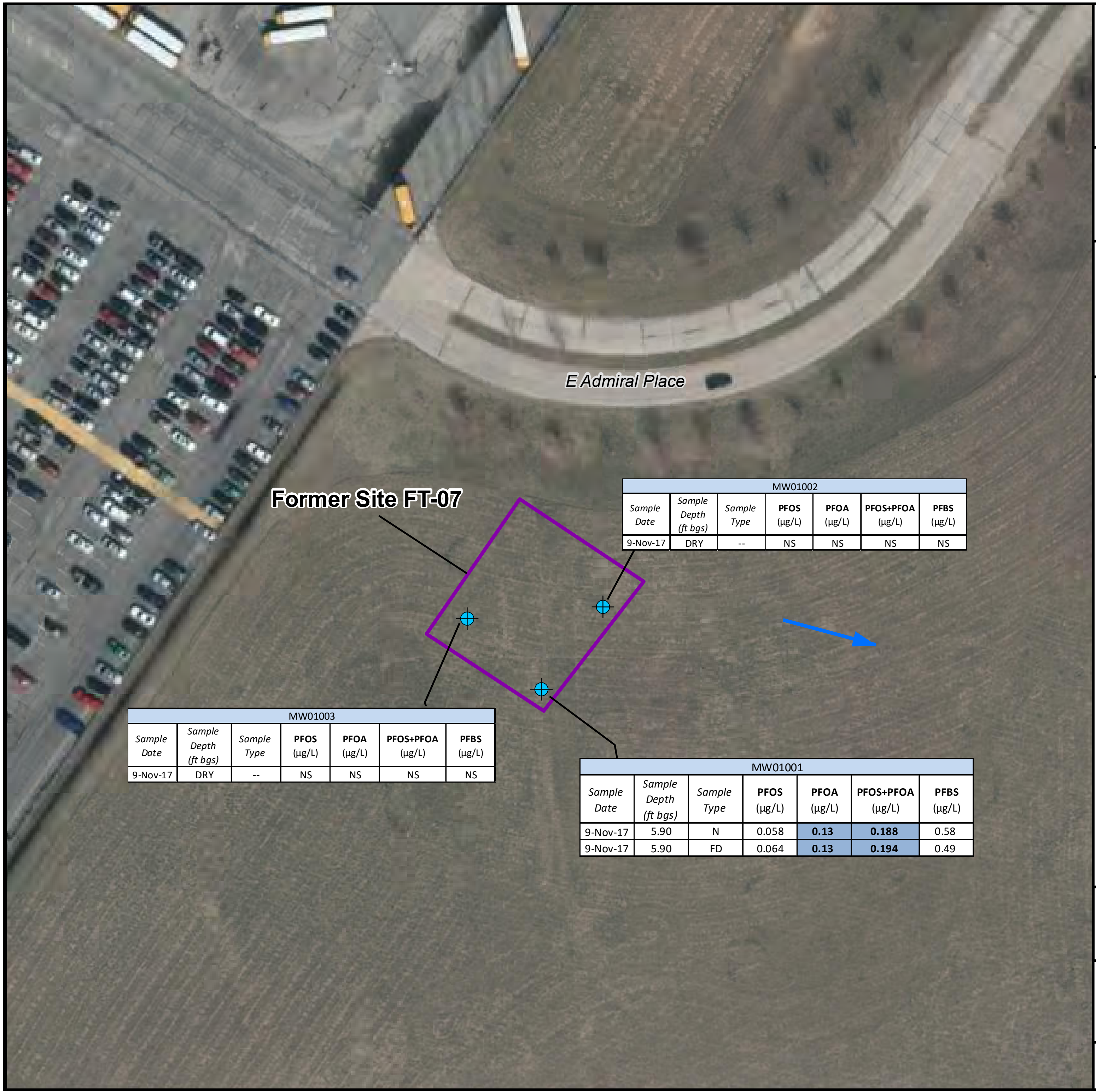

MW01002

Sample Date	Sample Depth (ft bgs)	Sample Type	PFOS (µg/L)	PFOA (µg/L)	PFOS+PFOA (µg/L)	PFBS (µg/L)
9-Nov-17	DRY	--	NS	NS	NS	NS

MW01003

Sample Date	Sample Depth (ft bgs)	Sample Type	PFOS (µg/L)	PFOA (µg/L)	PFOS+PFOA (µg/L)	PFBS (µg/L)
9-Nov-17	DRY	--	NS	NS	NS	NS

MW01001

Sample Date	Sample Depth (ft bgs)	Sample Type	PFOS (µg/L)	PFOA (µg/L)	PFOS+PFOA (µg/L)	PFBS (µg/L)
9-Nov-17	5.90	N	0.058	**0.13**	**0.188**	0.58
9-Nov-17	5.90	FD	0.064	**0.13**	**0.194**	0.49

FIGURE 3.1-3
PFAS in Groundwater
Former Site FT-07
AFFF Release Area 1
Air Force Plant #3
Tulsa, Oklahoma

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Release Areas
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Symbol Key

⊕	Soil Boring/Temporary Monitoring Well
▭	AFFF Release Area
→	Historical Groundwater Flow Direction (HGL, 2015)

Source: Esri 2016 Digital Globe

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Contract: FA8903-16-D-0027

By: BCW **8/8/2018**

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