National Aeronautics and Space Administration

FINAL

Preliminary Assessment and Site Investigation Work Plan for Per – and Polyfluoroalkyl Substances at

Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia

March 2019

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PRELIMINARY ASSESSMENT AND SITE INVESTIGATION WORK PLAN FOR PER- AND POLY FLUOROALKYL SUBSTANCES AT NASA WALLOPS FLIGHT FACILITY WALLOPS ISLAND, VIRGINIA

Submitted to:
National Aeronautics and Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia

Submitted by:
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CERTIFICATION

The enclosed document was prepared, and is being submitted, in accordance with the requirements of the Administrative Agreement On Consent between the United States Environmental Protection Agency and the National Aeronautics and Space Administration [U.S. EPA Docket Number RCRA-03-2004-0201TH].

I certify that the information contained in or accompanying this document is true, accurate, and complete.

I certify under penalty of law that this document and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

Signature: ________________

Name: Mr. David Liu

Title: NASA Project Coordinator

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APPENDICES

ACRONYMS

%	percent
AFFF	aqueous film forming foam
AFTF	Aviation Fuel Tank Farm
ARFF	aircraft rescue and fire fighting
bgs	below ground surface
CAP	corrective action plan
CDL	Construction Debris Landfill
CSM	conceptual site model
DoD	Department of Defense
DL	detection limit
DPT	direct push technology
ELAP	Environmental Laboratory Accreditation Program
FD	fire department
FRB	field reagent blank
ft	feet
FTA	fire training area
FFTA	Former Fire Training Area
FUDS	Formerly Used Defense Site
GSFC	Goddard Space Flight Center
HA	Health Advisory
HDPE	high density polyethylene
IDW	investigation derived waste
LOD	limit of detection
LOQ	limit of quantitation
mg/kg	milligram per kilogram
MS	matrix spike
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NEtFOSAA	n-ethyl perfluorooctanesulfonamidoacetic acid
NMeFOSAA	n-methyl perfluorooctanesulfonamidoacetic acid
ng/L	nanograms per liter
NTU	Nephelometric Turbidity Unit
OW	observation well
PA	Preliminary Assessment
PC	pollution control

ACRONYMS (CONTINUED)

PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutanesulfonic acid
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
PID	photoionization detector
PMW	perimeter monitoring well
PPE	personal protective equipment
PSL	project screening levels
QA/QC	quality assurance/quality control
RSL	Regional Screening Level
SI	Site Investigation
SOP	standard operating procedure
Tetra Tech	Tetra Tech, Inc.
TEUC	Trails End Utility Company
TOC	Town of Chincoteague
UCMR3	Third Unregulated Contaminant Monitoring Rule
µg/L	micrograms per liter
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VDH	Virginia Department of Health
WFF	Wallops Flight Facility
WOD	Waste Oil Dump
WWTP	waste water treatment plant

1.0 INTRODUCTION

The document has been prepared to present findings of a Preliminary Assessment (PA) for potential sources of per- and polyfluoroalkyl substances (PFAS) conducted at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's (GSFC) Wallops Flight Facility (WFF) (herein referred to as WFF) in Accomack County, Virginia (Figures 1-1). This document also serves as the work plan for conducting a Site Investigation (SI) at each of the areas identified as potential source areas in the PA. This document was prepared by Tetra Tech, Inc. (Tetra Tech) for WFF under Prime Contract Number NNG14WA44C, Task Order 08-13-2017.

1.1 PFAS PA SCOPE

The methods for conducting the PA included three primary activities to determine the potential PFAS source areas at NASA WFF:

- Literature Searches: NASA WFF search of facility documents for PFAS-associated key words, site-specific histories, and known use of Aqueous Film Forming Foam (AFFF)
- Web-based searches for general information on PFAS use, regulations, and health effects, and manufacturer information on AFFF formulations. United States Environmental Protection Agency (USEPA) Third Unregulated Contaminant Monitoring Rule (UCMR3) database.
- Site Interviews and Site Reconnaissance

1.2 SI WORK PLAN OBJECTIVES

This document details the planned sampling activities to be conducted at ten areas identified during the PA as potential PFAS source areas (Area). These Areas were selected based on known historical activities and suspected use of AFFF or other protein-based foams and PFAS data collected to date from NASA WFF. The primary objective is to investigate each identified area for the presence of PFAS, compare the results for select PFAS compounds to screening levels, and determine whether further investigation is warranted. The ten Areas identified for site investigations include (Figure 1-2):

- Area 1 – Fire Station
- Area 2 – D-1 West Fire Training Area
- Area 3 – Fire Training Pit
- Area 4 – Helicopter Crash Site
- Area 5 – Former Wastewater Treatment Plant (WWTP)
- Area 6 – Lear Jet Soil Bioremediation Landfarm
- Area 7 – Observation Well (OW) – 06 Area
- Area 8 – WWTP
- Area 9 – Former Fire Training Area (FFTA)

- Area 10 – Lear Jet Crash Site

Samples will also be collected from various outfalls throughout the facility, in addition to select wells at the Waste Oil Dump (WOD) and Construction Debris Landfill (CDL).

Based on area specific history and potential release scenarios, the specific objectives of this SI include the following:

- Evaluate presence of PFAS in surface soil, subsurface soil, groundwater, surface water (includes outfalls) and/or sediment from the SI Areas.

The environmental media listed above will all be analyzed for fourteen PFAS compounds, which include the six PFAS compounds under List 1 Contaminants in the USEPA's UCMR 3 program, which are: perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), perfluorobutanesulfonic acid (PFBS), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), and perfluoroheptanoic acid (PFHpA) (USEPA, 2016a).

The remaining eight PFAS compounds are: N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA), N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA), Perfluorodecanoic acid (PFDA), Perfluorododecanoic acid (PFDoA), Perfluorohexanoic acid (PFHxA), Perfluorotetradecanoic acid (PFTA), Perfluorotridecanoic acid (PFTrDA), and Perfluoroundecanoic acid (PFUnA).

1.3 DOCUMENT ORGANIZATION

This document presents the PA findings and provides the proposed SI sampling and the approach to be used in conducting field activities for the SI. This document is comprised of five numbered sections followed by a References section. Section 1.0 provides the introduction and the scope and general objectives of the PA/SI. Section 2.0 provides a summary of the facility background, PFAS investigation history at the facility, PA findings, and conceptual site model (CSM). Section 3.0 provides the project quality objectives to include information inputs, study area boundaries, and the analytical approach. Section 4.0 presents the field investigation rationale and methodology. Section 5.0 briefly describes the reporting and data validation requirements that includes field and laboratory data and validation. All figures and tables are presented after the References section.

2.0 FACILITY AND SITE BACKGROUND

2.1 FACILITY DESCRIPTION

WFF is located in Accomack County, Virginia, and consists of three land parcels—Main Base, Mainland, and Wallops Island (Figure 1-1). The Main Base is composed of approximately 2,000 acres and is located near the intersection of Virginia Routes 798 and 175. The Mainland parcel is approximately 1,200 acres and located 6 miles to the south of the Main Base on Virginia Route 679 and is connected to the Wallops Island parcel by a causeway constructed in 1960. The approximate 3,400-acre Wallops Island parcel is a 7-mile-long barrier island located immediately east of the Mainland. The Town of Chincoteague, Virginia, is located 5 miles east of the Main Base.

2.2 FACILITY HISTORY

NASA and its predecessor, National Advisory Committee for Aeronautics (NACA), have had a presence at WFF since 1945. NACA established a rocket launch site on the southern portion of Wallops Island (Wallops Station) in 1945 under the direction of the Langley Research Center and launched its first rocket in that year. NACA constructed launch and radar support and experimental facilities in 1946. Access to Wallops Island at that time was by water vessel only. Operations by NACA at WFF were limited to these test facilities until 1959 (Occu-Health, 1999). NASA absorbed Langley Research Center and other NACA field centers and facilities when it was created by the U.S. government in 1958. NASA expanded its presence at WFF with the acquisition of the Main Base and Mainland parcels in 1959. The Wallops Station was named Wallops Flight Center in 1974, and the name was changed to WFF in 1981, when it became part of GSFC, Greenbelt, Maryland (Wallace, 1997).

The Navy operated the Chincoteague Naval Auxiliary Air Station at the Main Base from 1942 until the transfer to NASA in 1959. During that time, the Navy constructed runways, buildings, and other support facilities for naval aviation and aviation ordnance testing and training (Occu-Health, 1999). NASA continues to maintain the runways and occupies many of the structures and buildings that were present at the time of the property transfer from the Navy. In addition, NASA has expanded and constructed additional buildings to support their mission and to provide support to other tenant organizations (NASA constructed the causeway that connects the Mainland to the island in 1960). The Navy used the north end of Wallops Island as a training area and maintained a series of ranges used to develop ordnance and ordnance delivery systems. Few permanent structures were built by the Navy and the north end of the island remains relatively undeveloped.

The mission of WFF has undergone several changes since it was established in 1959, but the main focus has been and continues to be rocket research, the management of suborbital projects, suborbital and orbital tracking, aeronautical research, and space technology research. NASA does not manufacture rockets or rocket fuels/propellants at WFF. Rocket motors are transported to the facility from other government facilities.

2.3 PFAS BACKGROUND

This section describes the historical and current uses of PFAS-containing materials, primary sources at NASA WFF, NASA WFF-specific uses, and regulatory status.

PFAS have been identified by the USEPA as “emerging contaminants” and are of environmental concern because of their persistence in the environment and in organisms, migration potential in aqueous systems (e.g., groundwater), historically ubiquitous use in commercial products, and their possible health effects at low levels of exposure. PFAS are man-made compounds with chemical properties similar to those reported for fluorocarbons. Due to the strength of multiple carbon-fluorine bonds, PFAS break down very slowly in industrial use and in the environment, and therefore are an emerging class of persistent environmental contaminants.

2.3.1 General PFAS Uses and Regulatory Status

PFAS are a class of man-made chemicals which are considered an “emerging contaminant” by the USEPA and are defined as a chemical or material that is characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards (USEPA, 2014). They are not found naturally in the environment. The chemical structure of PFAS allows treated products to be more stain-resistant, waterproof, and/or non-stick. PFAS have been used in the manufacture of a wide variety of products including fire-fighting foams (particularly AFFF), non-stick cookware, stain- and fire-resistant upholstery and clothing, waterproof fabric and food packaging. This wide use and chemical stability causes PFAS to be persistent in the environment. PFAS are soluble in water but resistant to typical environmental degradation processes and tend to bioaccumulate. Exposure and uptake of PFAS is primarily through ingestion but can also occur through hand-to-mouth transfer or inhalation of dusts. Dermal exposure and absorption is considered a minor exposure pathway. In 2006, the USEPA started a stewardship program in an attempt to phase out the most widely used PFAS compounds (specifically PFOA and PFOS), however many PFAS still remain in wide use. In 2016, the USEPA issued drinking water health advisory (HA) levels for PFOA and PFOS, or the sum of both chemicals, of 70 nanograms per liter (ng/L) (USEPA, 2016a, b). In addition, USEPA’s November 2017 tapwater Regional Screening Level (RSL) for PFBS is 40 micrograms per liter (µg/L). Currently, there are no regulatory or screening levels established for any other PFAS.

2.3.2 Potential PFAS Sources at NASA WFF

PFAS have been used in a variety of applications at government/military facilities, including as a component in AFFF, which was routinely used at fire-fighting training areas and equipment test areas, and is still used at crash sites and some fire suppression systems in hangars. In addition, current and historical AFFF storage and transfer areas are of potential concern for release to the environment. Historical reports of uncontrolled spills and the repeated use of AFFF during fire training and firefighting have been correlated with higher concentrations of PFAS in surface water and groundwater. As such, a key element for identifying significant PFAS sources at government/military facilities is the storage and use of AFFF.

PFAS from AFFF used in firefighting and fire suppression systems are considered to have the greatest potential for release of PFAS to the environment in terms of mass concentration at government/military installations. Other potential sources of PFAS to the environment include historical on-site land disposal areas/landfills containing operations wastes (e.g., from electroplating), waste water treatment sludges and effluents, or PFAS materials themselves. Landfill leachate could carry PFAS to groundwater.

AFFF in Fire-fighting Exercises and Fire Suppression

AFFFs are water-based (60-90 percent [%]) and frequently contain hydrocarbon-based surfactants such as sodium alkyl sulfate, and fluorosurfactants, such as fluorotelomers, PFOA, and/or PFOS. AFFF containing PFAS were developed in the early to mid-1960s for use on Class B fires and were put into routine use by the early 1970s and are still in use today. AFFF that was used at NASA WFF has been released to the environment and is impacting groundwater and potentially soil, surface water, and sediment.

AFFFs have the ability to spread over the surface of hydrocarbon-based liquids (i.e., create a film), thus limiting oxygen from contacting the surface of the ignited fuel while simultaneously cooling the surface temperature with the high-water content and preventing volatile fuels from escaping as ignitable vapor. These qualities make AFFF very effective for extinguishing burning aviation fuels.

Companies including 3M, DuPont, Ansul, and Chemguard were the primary fire-fighting foam producers that used fluoro-chemical surfactants in the production of AFFF. Typically, AFFF concentrate was proportionally mixed into water lines using in-line eductors or other proportioning devices to create the necessary foam solution ranging from 3% to 6% of the concentrate. As noted, AFFF was primarily used with Class B fuel fires because the chemical properties of PFAS in AFFF created a thick foam blanket. Class A fire-fighting foams were used to extinguish wood and grass fires, and do not contain PFAS. Therefore, Class A fire-fighting foams are not a concern for this PA.

Areas of interest for this PFAS PA include those where AFFF may have been applied or stored. These include current and former fire training areas, equipment test and cleanout areas, fire-fighting infrastructure (fire stations, AFFF storage/handling areas, etc.), aircraft crash sites, and equipment cleaning discharge locations. AFFF has not been used in fire suppression systems in hangars at NASA WFF. Therefore, hangars are not considered an area of interest.

Electroplating

Electroplating, specifically hard chromium plating, is an industrial activity where PFAS-containing mist suppressants may have been used. Electroplating consists of creating an electrolytic cell that enables a thin layer of metal to be deposited onto an electrically conductive metal surface. PFAS were sometimes used during the chromium electroplating process as a surfactant in chromic acid baths. As a surfactant, PFAS lowered the surface tension (adhesion of materials) by creating a thin, foamy layer on the surface of the chrome bath for mist-suppression. This mist-suppressant reduced the formation of airborne chromium aerosols during the plating process, which are known to be carcinogenic and allergenic. Areas where non-chromium electroplating operations were carried out would not be expected to have used PFAS-containing mist suppressants.

A plating shop was housed in former Building F-8 which is situated in the central portion of the Main Base. Building F-8 was demolished in 2007. The Final PA for WFF Formerly Used Defense Sites (FUDS) indicated the Building F-8 plating shop was used by the Department of Defense and NASA (United States Army Corps of Engineers [USACE], 2011). Between 1945 and the late 1950s, the Navy used Building F-8 as a machine shop and a sheet metal fabrication shop. From the early 1960s to 1989, a portion of Building F-8 was used by NASA as an electro-plating shop. Plating operations included copper, lead, and chromium. Effluent from the building was transported via sanitary sewer lines to the facility's WWTP (Area 5 – Former WWTP). In the mid-1980s NASA added a closed loop system from chemical etching to the operations in Building F-8. Effluent within regulatory limits was drained to the facility's WWTP (Area 5 – Former WWTP) via sanitary sewer lines. Effluent not meeting regulatory limits was disposed of properly at an off-site facility. Building F-8 was situated approximately 700 feet to the south of Area 3- Fire Training Pit. Further discussion on the proposed sampling near F-8 as part of the Area 3 investigation is provided in Section 4.0.

Landfill Operations, Waste Disposal Areas, and Wastewater Treatment Plants

Historically, landfills received wastes generated from government/military installations, including waste streams from operational areas (machine shops, electroplating operations, etc.), housing areas, and waste from WWTPs. These waste streams may contain industrial and/or consumer products that were either manufactured with PFAS or contain compounds that can degrade to PFAS which may leach out of the landfill. Additionally, waste material biosolids and sludge from WWTPs can contain PFAS. Areas of interest for this PFAS SI include the former and current WFF WWTPs. Groundwater at the WOD and CDL will also be evaluated for PFAS. Other than the WOD and CDL there are no other landfill operations or waste disposal areas associated with NASA activities, which would currently warrant further evaluation for PFAS during this SI.

Other Potential Sources

Due to the widespread use of PFAS, there may be activities other than the ones mentioned above where PFAS were used. PFAS have been used in some detergents and have been reported in groundwater near car washes at a New Hampshire site (NHDES, 2017). Certain types of aviation hydraulic fluids (for example, Skydrol®) have been determined to contain PFOS. An introduction of PFOS to the environment from PFOS-containing aviation hydraulic fluid would occur through a release of this fluid to the environment, which would include aircraft crash incidents. Two aircraft crash incidents have occurred at NASA WFF. Both incidents are being addressed in this SI and are discussed further in the PA under Section 2.5. No other significant releases of aviation hydraulic fluids have been reported at NASA WFF. PFAS-related substances are known to have been used in the manufacturing of photographic film, paper, and plates. Manufacturing of photographic related materials did not occur at NASA WFF, but photographic film development laboratories were located at the Main Base. Releases of PFAS are not currently associated with photographic film development. Currently, these facilities do not warrant further assessment for PFAS. PFAS have also been included in some stain-resistant paint formulations and other products. It is possible that in significant amounts, these could be sources of PFAS to the environment. No significant other PFAS sources have been identified at NASA WFF to date.

General Uncertainties Regarding PFAS

The objective of the PA was to identify potential PFAS sources based on historical site uses. However, PFAS have been used in a wide variety of products since their development and are considered emerging contaminants. Therefore, because of their prevalent historical uses and often lack of documentation of use, there is uncertainty regarding identification of all potential PFAS sources on the facility; if further discussions with facility personnel or review of previously-unknown documents identifies additional PFAS source areas, these will be investigated as warranted. The SI will investigate the suspected sources identified in the PA. Additionally, data (e.g., for groundwater, outfalls, etc.) collected during the SI will be considered to determine the presence of any additional PFAS sources beyond those identified in the PA. The SI will also consider that it may be difficult to distinguish between PFAS related to the site and background sources. Field standard operating procedures specific to PFAS sampling intend to minimize uncertainties associated with data collection.

Uncertainties also exist with regards to regulatory standards and future development of criteria and guidance related to PFAS compounds. As new regulatory standards and criteria for PFAS are developed, NASA and stakeholders will determine the appropriate path forward related to those changes.

2.4 PFAS BACKGROUND AT NASA WFF

During the 2014 Five Year Review for the FFTA site at WFF, PFAS compounds were identified as a possible issue because past firefighting training activities used AFFF containing PFAS compounds (NASA, 2014). After the USEPA issuance of the 70 ng/L HA for PFOA and PFOS in May 2016, a field investigation was conducted in late 2016 at the FFTA which consisted of collecting groundwater samples from 14 existing shallow monitoring wells and a drinking water sample from the NASA WFF finished drinking water. All monitoring well and drinking water samples collected during the 2016 investigation were analyzed for the six PFAS compounds under List 1 Contaminants in the USEPA's UCMR 3 program, which are: PFOA, PFOS, PFBS, PFNA, PFHxS, and PFHpA.

The analytical results from the 2016 FFTA investigation were presented in the February 2017 Data Summary Report (NASA, 2017a). PFAS analytical results for groundwater samples collected at the FFTA during this investigation are presented in Figure 2-1. PFOA and PFOS were detected at concentrations in groundwater with maximum concentrations of 3,600 ng/L and 24,000 ng/L, respectively. PFAS were not detected in the NASA WFF finished drinking water sample.

Due to elevated PFAS concentrations in FFTA groundwater, NASA began researching the use of AFFF at WFF and identified an additional five sites suspected of AFFF usage: The Main Base Fire House, the 1970s Fire Training Pit, the 1974 Helicopter Crash site, the 1998 Lear Jet Crash site, and recent D-1 West Training area. The PFAS investigation was expanded in April 2017 to investigate potential impacts to groundwater from these sites and drinking water and detailed in a Letter Work Plan (NASA, 2017b) and Letter Work Plan Addendum (NASA, 2017c). These activities included:

- Sampling NASA WFF drinking water system, including each of the five production wells and the finished drinking water,
- Sampling six additional shallow monitoring wells adjacent to some of the potential new sites,
- Sampling four temporary monitoring wells on the western and southern property boundaries,
- Sampling the Town of Chincoteague (TOC) drinking water system, including the three shallow and four deep production wells and the finished drinking water,

In May 2017, the PFAS investigation was further expanded to include:

- Sampling several offsite, adjacent residential wells, and
- Sampling the Trails End Utility Company (TEUC) drinking water system, including the one shallow well and two deep production wells and finished drinking water.

The first full round of PFAS sampling of the NASA WFF and TOC drinking water systems were completed between April 12-26, 2017 with analytical results presented in the *Final Letter Report, April 2017 PFAS Sampling, NASA Wallops Flight Facility, Wallops Island, Virginia* (NASA, 2017d). A spatial representation of PFAS analytical results from the April 2017 PFAS Investigation are presented in Figure 2-2. In addition to the samples shown in Figure 2-2, TOC finished drinking water was sampled on April 12 and 13, 2017. PFOA and PFOS were detected in the TOC finished drinking water, but at levels below the HA level.

TOC production well samples had detections of PFOA and PFOS in four of seven wells with concentrations ranging from 15 ng/L to 120 ng/L and 50 ng/L to 610 ng/L, respectively. Concentrations of PFOA and PFOS exceeded the HA levels in three of the TOC production wells (shallow wells TOC-3B and TOC-3C, and deep well TOC-05). Use of groundwater from these three wells and production well TOC-3A in the TOC drinking water system was discontinued.

NASA WFF production wells and finished drinking water samples from April 20, 2017 had no detections of PFOS or PFOA. Due to the shutdown of four TOC production wells, NASA WFF began supplementing the TOC drinking water supply with the water produced from the NASA WFF water supply system to meet TOC seasonally high-water demand.

Six existing monitoring wells and four temporary wells were also sampled in April 2017 at NASA WFF. PFOA was detected at concentrations ranging from 5.3 ng/L to 230 ng/L, exceeding the HA level in samples from three monitoring wells (AFTF-MW011D, AFTF-MW025D, and AFTF-MW026D). PFOS was detected at concentrations ranging from 3.4 ng/L to 1,700 ng/L, exceeding the HA level in samples from four monitoring wells (AFTF-MW011D, AFTF-MW025D, AFTF-MW026D, and MW-11-82-3). The former Aviation Fuel Tank Farm (AFTF) monitoring wells are located near the 1998 Lear Jet Crash and Fire House sites. The MW-11 wells are located near the 1970s Fire Training Pit site. PFOA and PFOS were not detected or were detected at low concentrations below the HA levels in samples collected from the four temporary well locations on the western and southern WFF property boundaries.

Three residential wells north of NASA WFF across Little Mosquito Creek, and the TEUC production wells and finished water were sampled in May 2017. PFAS were not detected in the residential wells, or TEUC production wells and finished drinking water. Results from the residential wells and TEUC sampling were provided to the stakeholders.

Subsequent sampling and monitoring of the NASA WFF and TOC production wells and drinking water systems have been ongoing since April 2017. Starting in November 2017 the sampling schedule of both water supply systems shifted from biweekly sampling to monthly sampling and is on-going. NASA WFF and TOC production wells extract water from the upper and middle Yorktown-Eastover aquifers which could influence vertical migration of potential contaminated groundwater from the Columbia aquifer. Some low PFAS concentrations below the HA have been detected in samples from production wells (WW01, WW02, WW04, WW05, TOC05, and TOC08) screened in the upper and middle Yorktown-Eastover aquifers. Results of the water supply sampling have been and continue to be provided to the stakeholders.

In September 2017, a network of nine perimeter monitoring well (PMW) clusters were installed at the facility to determine whether groundwater migrating from NASA WFF has been impacted by PFAS. The PMW clusters consist of a shallow well installed in the surficial Columbia aquifer and a deep well installed within the upper Yorktown-Eastover aquifer. In addition, six OWs were installed in the surficial aquifer adjacent to WFF production wells to conduct an opportunistic aquifer test to determine if production well pumping from the middle Yorktown-Eastover confining unit may be affecting the surficial aquifer. All work was conducted in accordance with Letter Work Plan – Perimeter Monitoring Well Installation and PFAS Sampling (NASA, 2017e) and Letter Work Plan - Production Well Aquifer Testing (NASA, 2017f).

In October 2017, the PMWs and OWs were sampled and analyzed for the six USEPA UCMR3 list PFAS compounds. The results of this investigation are presented in the *Data Summary Report, PFAS Perimeter Monitoring Well and Observation Well Installation and Sampling* (NASA, 2018). A second sampling event was conducted in February 2018. Figure 2-3 provides a spatial summary of the analytical results from both events. Based on these analytical results, concentrations of PFOS/PFOA combined were detected above the HA level of 70 ng/L in OW-06 during October 2017 and February 2018 at 86.8 ng/L and 75.5 ng/L, respectively. PFOA/PFOS combined was detected at an elevated concentration of 64.8 ng/L at PMW-01S in October 2017. During February 2018, PFOA/PFOS combined was detected at 87.4 ng/L, above the HA level of 70.

An opportunistic aquifer test using the six OWs was conducted from October 23, 2017 through December 7, 2017. Based on the responses observed in the OWs during normal pumping and non-pumping from the nearby WFF production wells, it was reasonable to conclude that minor hydraulic connection occurs between the surficial Columbia and middle Yorktown-Eastover aquifers, through the upper Yorktown-Eastover confining unit. Since water levels cannot be currently monitored in the WFF productions well or the upper Yorktown-Eastover aquifer, it is not known how this influence relates to potential migration rates between the two aquifers. The observed influence is minor and therefore likely has a negligible impact on contaminant migration between the two aquifers.

Lithologic and geophysical logs from installation of the PMWs and OWS were used to generate transects utilized to illustrate the interpreted geology and hydrogeology at NASA WFF. These cross-section figures were presented in the *Data Summary Report, PFAS Perimeter Monitoring Well and Observation Well Installation and Sampling* and are provided in Appendix A of this document (NASA, 2018).

Four quarterly rounds of groundwater sampling at the PMW and OW locations were conducted in 2018 to confirm the initial PFAS sampling results. Routine sampling of WFF and TOC production wells and drinking water supply continues to be conducted on a monthly basis until changes are decided by the stakeholders.

2.5 PRELIMINARY ASSESSMENT

A PA was conducted to evaluate potential sources of PFAS at NASA WFF and identify areas that need further evaluation or investigation. The PA was developed to identify potential 1) sources of PFAS used at NASA WFF, with estimates of periods of use; 2) release mechanisms and migration pathways, such as soil, groundwater, surface water, and sediment; and 3) receptors for exposure.

The approach for conducting the PA included the following activities to address:

- Literature Searches: NASA WFF search of facility documents for PFAS-associated key words, site-specific histories, and known use of AFFF. A list of records reviewed is provided in Appendix B.
- Web-based searches for general information on PFAS use, regulations, and health effects, and manufacturer information on AFFF formulations. USEPA UCMR3 database.
- Site Interviews and Site Reconnaissance. Interview information conducted during the PA is provided in Appendix C.

2.5.1 Site Location and Layout

As a result of records review and interviews conducted with NASA WFF personnel, ten areas were identified as locations that have been or may have been impacted by PFAS through the use of AFFF. These areas have been identified as areas requiring further evaluation for PFAS through a SI. These areas are all located on the Main Base portion of NASA WFF (Figure 1-2). The following sections provide a description of these areas and summarizes the documented or suspected releases of PFAS at these areas. A photo log presenting historical photographs of the areas recommended for further evaluation is provided in Appendix D.

Area 1 – Building B-129 Fire Station

The Building B-129 Fire Station is located in the central portion of the Main Base adjacent to the active WFF runway (Figure 2-4). This building serves as the office and quarters for fire department personnel and garage that houses fire fighting vehicles. Currently, these vehicles include three crash trucks, which are equipped to disperse AFFF. Each crash truck is equipped with a 420-gallon tank for AFFF concentrate and 3,000-gallon tank for water. Interview information indicates the AFFF concentrate tank for each crash truck is kept at capacity with 3% foam concentrate (NASA WFF Fire Department [FD] Interview, 11/15/17). Currently, filling of AFFF concentrate into the crash truck holding tanks is conducted by hand on the concrete surface at the fire station. There were no reported spills during filling. Empty containers of AFFF concentrate were disposed of as general waste.

NASA WFF FD personnel indicated it is common practice to periodically conduct nozzle tests for the crash truck to ensure the spray nozzles are not clogged. During these tests, only water is discharged through the nozzle. No AFFF concentrate is used. The tests consist of short bursts of water onto the concrete apron in front of the fire station garage bay doors. NASA WFF personnel are not aware of spray reaching the grass areas adjacent to the fire house. The concrete apron in front of the fire station is where the FD currently conducts its aircraft rescue and firefighting (ARFF) training, utilizing a portable ARFF training system fueled by propane. The FD uses water during training activities. WFF FD personnel indicated that AFFF has not been used during training activities at this location.

In the past, a 1,000-gallon capacity tank located at the back (west side) of the fire station was used to contain a pre-mixed AFFF and water for rapid refill of fire trucks. This tank was used from 1976-1977 and initially utilized protein-based foam and later 6% AFFF. Currently, the only AFFF concentrate stored at the fire station is the concentrate contained in the three crash trucks (1,260 gallons of 3% AFFF) parked at the building. The current reserve, AFFF concentrate inventory for the Main Base is stored at Building B-31, which is adjacent to the fire station (Figure 2-4). The total reserve inventory consists of 1,375 gallons of 3% AFFF stored in (2) 275-gallon totes and (15) 55-gallon drums. In addition to the NASA WFF FD AFFF inventory, the Mid-Atlantic Regional Spaceport uses a TriMax portable compressed air foam fire suppression system, which uses 5 gallons of 6% AFFF. NASA WFF Airfield Operations indicated they have installed and deployed approximately 15 TriMax portable fire suppression systems throughout the facility that they received in April 2018. This system is stored and maintained at the B-129 Fire Station. NASA WFF FD personnel indicated that there have been no reported spills or leaks from containers of the current AFFF inventory nor has there been spills or leaks from past inventories of AFFF.

Area 2 – D-1 West Fire Training Area

The D-1 West Fire Training Area was once used by the NASA WFF FD to conduct firefighting training activities (Figure 2-5). This area has also been used recently by the NASA WFF FD to test firefighting equipment. The D-1 Fire Training Area is situated in the central portion of the Main Base, adjacent to the Building D-001 aircraft hangar and consists of a paved concrete surface. An oil/water separator is located at this area and directs surface runoff through a system of sewer pipes to the WWTP located in the northern portion of the Main Base. The WWTP is identified as an SI area (Area 8) and is discussed further in a separate subsection below.

A review of historical photographs (Appendix D) confirmed the location where firefighting training activities occurred at the D-1 West Fire Training Area. The photographs also depicted firefighting training exercises conducted using water and a portable firefighting training system that is fueled by propane. Interviews with the NASA WFF FD validated the information obtained from the review of photographs (NASA WFF FD Interview, 11/15/17).

The D-1 West Fire Training Area is not currently used by the NASA WFF for firefighting training activities; however, the area is used to wash the crash trucks and since 2014, has been used to conduct annual refractometry tests. These tests are conducted to ensure the proper ratio of AFFF concentrate and water are dispersed from the crash truck nozzle. Information provided by the NASA WFF FD indicate approximately 15 to 20 gallons of 3% AFFF from each crash truck is used during the tests. NASA WFF FD personnel indicated refractometry tests were reportedly also conducted at NASA WFF in the late 70's; however, no records exist that can confirm the location of the testing and the volume of foam used during testing.

Area 3 – Fire Training Pit

The Fire Training Pit is an inactive fire training area located in the central portion of the Main Base. The Fire Training Pit was located in a grassy area adjacent to the intersection of Wormhoudt Road and Rehor Road (Figure 2-6). A review of an aerial photograph from 1974 depicts the location of the pit and shows evidence of burning around the pit (Appendix D). Interviews with the NASA WFF FD indicated firefighting activities were conducted in this area during the 1970's. A specific date was not provided as to when firefighting training activities ceased at the area. Interview information provided by the WFF FD indicated during firefighting training, JP-4 was placed in the pit and then ignited. Propane firefighting trainers were also used at this location for training activities. NASA WFF FD personnel indicated water was used to extinguish fires during training activities and do not recall AFFF being used at this location (NASA WFF FD Interview, 11/15/17).

Area 4 – Helicopter Crash Site

In 1974 a helicopter crash incident occurred in the northern portion of the Main Base in an area of grass adjacent to the north of runway 10-28 at the western portion of the runway (Figure 2-7). A review of historical photographs (Appendix D) and an interview conducted with NASA WFF FD personnel confirmed the location of the incident (NASA WFF FD Interview, 11/15/17). Based on the date of the incident and information provided through interviews with NASA WFF FD personnel, it was confirmed that protein-based foam was used during the FD response to the crash incident.

Area 5 – Former Wastewater Treatment Plant

The former NASA WFF WWTP is situated in the northeast portion of the Main Base (Figure 2-8). The area of the former plant is currently vacant and consists of maintained grass landscape. The plant operated from 1944 to 2000. Although the former plant ceased treatment operations in 2000, the drying beds were used to dry sludge material from the current WWTP until 2014. In 2014, the former WWTP was demolished. Information provided by NASA WFF facilities personnel indicated that during demolition, the concrete floor of the sludge drying beds was broken up and left in place to allow for drainage and the concrete walls of the beds were broken up and the rubble was used to backfill the area. Following demolition of the plant structures, the entire site was backfilled with soil (minimum of 2-feet of soil cover) and graded to drain towards the storm water outfall at the northeast corner of the former WWTP area. Although the former WWTP has been demolished, the permitted effluent outfall associated with the former plant remains in use as the effluent discharge point for the current WWTP. The effluent is discharged into an unlined stream that flows to the north into Little Mosquito Creek. The current plant is situated approximately 600 feet to the east of the former WWTP.

Interviews with NASA WFF FD personnel indicated that the sludge drying beds located in the western portion of the treatment plant were once used by the FD to conduct annual nozzle tests (NASA WFF FD Interview, 11/15/17). These tests were conducted by the NASA WFF FD from 2003 to 2014. Approximately 5 gallons of AFFF from each crash truck were used during each nozzle tests. Both 6% and 3% AFFF foam were used during training at this location.

Area 6 – Lear Jet Soil Bioremediation Landfarm

The Lear Jet Soil Bioremediation Landfarm is situated in the northwest portion of the Main Base (Figure 2-8). The landfarm was constructed in 1999 to bioremediate petroleum impacted soil from the following incidents that occurred on the Main Base:

- Lear Jet Crash Site (JP-5 and gasoline, approximately 400 cubic yards of soil), Virginia Department of Environmental Quality (VDEQ) Pollution Control (PC)# 99-2348.
- N-200 SATAN Radar Release site (hydraulic oil, approximately 10 cubic yards), VDEQ PC# 99-2282.
- Building X-76 Petroleum Spill Site (No. 2 fuel, approximately 12 cubic yards), VDEQ PC# 00-5119.

The landfarm was constructed and operated in accordance with a Corrective Action Plan (CAP) approved by the VDEQ. The bulk of the soil treated at the landfarm was from the Lear Jet Crash incident. Interview information provided by NASA WFF FD personnel indicated approximately 200 to 400 gallons of 6% AFFF was used during the response to the 1998 Lear Jet Crash incident (NASA WFF FD Interview, 11/15/17).

The Lear Jet Soil Bioremediation Landfarm includes liners, a leachate collection trench, and sediment traps. The perimeter of the cell is arranged in a “T” formation consisting of two rectangular units. The south unit measures 100 feet by 40 feet, perpendicular to the north unit (100 feet by 80 feet). The area of the landfarm is flat, with a slight grade (less than 5 %) on the south end. Based on interview information from NASA WFF environmental personnel, soil from the Lear Jet Crash Site was treated in the northern cell of the landfarm (LJT Interview, 1/25/18). In accordance with the CAP, soil in the treatment cell was periodically sampled to determine if remedial endpoints were met. As portions of soil contained in the treatment cell met these endpoints goals, they were removed from the cell and staged in a “clean fill” stockpile located adjacent to the south of the landfarm.

The 2004 Closure Assessment Report for the Lear Jet Soil Bioremediation Landfarm documents the achievement of remedial endpoints for petroleum impacted soil treated during remediation (NASA, 2004a). In October 2004, confirmation samples collected at the Lear Jet Crash and X-76 Fuel Oil Release portions of the landfarm confirmed the soil was remediated below the remedial endpoints. In accordance with the CAP, soils treated to levels below the remedial endpoints were suitable for use as “clean fill”. Sampling results for the N-200 SATAN Radar Release continually indicated petroleum concentrations in the soil exceeded the regulatory endpoints. As a result, in October 2004, NASA removed and transported the N-200 SATAN Radar Release soil from the landfarm to a permitted waste disposal and incineration facility for treatment. 35.19 tons of soil from the N-200 SATAN Radar Release were treated at this facility and subsequent confirmation sampling indicated remedial endpoints were met. In December 2004, the VDEQ Tidewater Regional Office issued a letter acknowledging the endpoints established in the CAP for the Lear Jet Bioremediation Landfarm were met and no further corrective action was necessary.

Based on a site visit and interviews with NASA environmental personnel on January 25, 2018, the majority of the “clean fill” has been removed from the stockpile (NASA WFF Environmental Interview, 1/25/18). There are no records of where the remediated petroleum impacted soil was transported to and used at the facility since the CAP indicated the soil was suitable for use as clean fill. It is believed that none of the clean fill was transported and used off base.

Area 7 – Observation Well 06 Area (New SI Area based on October 2017 sampling results)

Observation Well 06 (OW-06) was installed in the fall of 2017 as part of the well network established for the NASA WFF PMWs and OWs program for PFAS. During this effort, six OWs were installed in the shallow aquifer in the vicinity of the four active NASA WFF production wells (WW-01, -03, -04, and -05) (Figure 2-3). OW-06 is located near production well WW-01 which is situated in the central portion of the Main Base (Figure 2-9). The purpose of the OWs was to characterize the shallow groundwater around the production wells and to support the ongoing PFAS investigation at the facility. The OWs were also used for aquifer tests to determine whether NASA WFF water supply well pumping from the upper and middle Yorktown-

Eastover aquifers has an effect on the overlying Columbia aquifer, and whether any leakage across the upper Yorktown-Eastover confining unit may be occurring. Geological cross-section figures which present the interpretation of geology around the OWs are provided in Appendix A.

Groundwater samples collected from OW-06 in October 2017 contained PFOA at an estimated concentration of 4.37 ng/L and PFOS at 82.4 ng/L (combined concentration 86.77 ng/L). Routine sampling of NASA WFF production wells commenced in April 2017 and the program is ongoing. As of the January 2018 sampling event, PFAS has only been detected in production well WW-01 once. During the September 19, 2017 event, PFOA was detected in production well WW-01 at an estimated concentration of 14.6 ng/L. The results of the aquifer test suggested there is no significant influence between the overlying Columbia aquifer and the Yorktown-Eastover aquifers while production well WW-01 is in operation.

Interview information obtained from WFF FD did not reveal any incidents or training activities conducted by the FD that used AFFF in the general area of OW-06 (NASA WFF FD Interview, 11/15/17).

Area 8 – Wastewater Treatment Plant

The WFF WWTP is situated in the northwest portion of the Main Base (Figure 2-10). This plant was constructed to replace the former WWTP and commenced operations in 2000. There have been no known activities conducted at the WWTP which would have resulted in the release of products containing PFAS, such as AFFF; however, the plant receives storm water from various areas throughout the facility, including the oil water separator located at Area 2 - D-1 Fire Training Area. As discussed previously, the D-1 Fire Training Area is an area where AFFF has been used to test firefighting equipment. Effluent from the plant is discharged at the same permitted outfall utilized by the former WWTP. The effluent flows from the outfall into an unlined stream and flows northward into Little Mosquito Creek.

Area 9 – Former Fire Training Area

The FFTA is situated in the northern portion of the Main Base (Figure 2-11A and 2-11B). NASA began using the FFTA for firefighting training exercises in 1965 and continued using the area until 1987. It is reported that firefighting training, conducted twice a week during this time period, consisted of releasing combustible material onto the ground or into an open-top tank, shallow pit, or discarded airplane body, igniting the material, and extinguishing the flames. NASA removed about 120 cubic yards of contaminated soil from the Site in 1986 (NASA, 2004b). A series of follow-up environmental investigations and studies were completed and a final remedy for the FFTA Site was implemented in 2010. The final remedy documented in the Record of Decision (ROD) for the FFTA site included in-situ biological treatment (biostimulation), institutional controls, and monitoring (NASA, 2007). Site groundwater has been monitored under a post-ROD Long-Term Monitoring program since 2010 and is ongoing.

In 2014, a Five-Year Review was conducted for WFF, including an evaluation of the FFTA site (NASA, 2014). Due to the history of firefighting training conducted at the FFTA, the Five-Year Review identified PFAS as potentially present in site groundwater and recommended a groundwater investigation be conducted at the site prior to December 2018, before the next Five-Year Review. In December 2016, fourteen groundwater monitoring wells were sampled during the initial groundwater investigation for PFAS at the FFTA. PFOA and PFOS were detected in each of the fourteen wells sampled during this investigation (NASA, 2017a). PFOA was detected at concentrations ranging from 12 ng/L to 3,600 ng/L and PFOS was detected at concentrations from 35 ng/L to 24,000 ng/L.

A review of historical photographs and documents verified the location that firefighting training activities occurred at the FFTA. Information obtained during interviews with NASA WFF FD personnel substantiated information gathered during records review. The WFF FD indicated the FD trained at FFTA from around 1979/80 until 1991/92 (NASA WFF FD Interview, 11/15/17). Initially, protein based firefighting foam was used during training activities followed by the use of 6% AFFF. Upon completion of a firefighting training exercise, residual liquids were left on the ground or paved surface where the training was conducted. This was common practice/procedure at the time when training was conducted at the FFTA.

Area 10 – Lear Jet Crash Site

On October 27, 1998, a Lear 45 jet owned by the Lear Corporation left the runway at WFF and crashed while conducting flight-testing operations. The incident occurred at the left side of runway 22 at the intersection of runway 17-35 (Figure 2-12). The location of the crash incident was documented in incident reports. A pickup truck located in the path of the jet was struck and came to rest at the edge of the runway. The force of the impact separated the left-wing section of the aircraft from the fuselage and caused one of the wing tanks to rupture, spilling the contents on the ground. The jet and the truck both caught fire. The gas tank on the pickup truck also ruptured. The Wallops FD applied 6% AFFF foam and water to extinguish the flames. The quantity of water used, combined with the estimated 400 gallons (1,600 liters) of JP-5 fuel and approximately 15 to 20 gallons (60 to 80 liters) of gasoline, may have accelerated infiltration of the water/fuel mix into surrounding soils. Information obtained during interviews with NASA WFF personnel confirmed information gathered from record reviews of the incident (NASA WFF FD Interview, 11/15/17).

Due to the close proximity of the fuel spill to a storm water outfall and the sandy nature of the soil, it was decided that immediate removal of the petroleum contaminated soil was necessary to prevent migration of contaminants into this outfall which flows into Simoneaston Bay. Soils were removed and temporarily staged outside of building B-29 and covered with plastic. The Lear Jet Soil Bioremediation Landfarm site (Area 6) was constructed following VDEQ approval in May 1999 and commenced operations in September 1999.

Other PFAS Areas of Concern – Outfalls, CDL, and WOD

After further evaluation of the ten areas above, regulatory input, and the review of surficial drainage patterns in these areas, it was determined that storm water outfalls, CDL, and WOD should be investigated, see Figure 2-13. The outfalls, including the outfall from the waste water treatment plant, should be sampled directly at the discharge point, in conjunction with the surface water and sediment samples collected in these investigation areas. These outfalls may contain PFAS and could impact surface water and sediment in the surficial drainage features. Therefore, sampling of specific outfalls at the facility is included as a part of the SI.

The CDL and WOD were added to the SI since previous investigation at these sites did not evaluate PFAS and the activities conducted may have introduced materials containing PFAS (construction debris, hydraulic fluid, and various other wastes). Existing monitoring wells at these sites will be sampled to evaluate PFAS in groundwater.

2.5.2 No Further PFAS Assessment Needed

During the PA process, some areas were identified as facilities where AFFF may have been stored or used. Based on information obtained from interviews with NASA WFF FD personnel, these facilities were determined as areas which no additional evaluation for PFAS is needed. The following paragraphs provide a summary of these areas/facilities and information supporting the decision of no further assessment.

Buildings N-159 and D-001 – Main Base Aircraft Hangers

Buildings N-159 and D-001 are aircraft hangers situated in the central portion of the Main Base and are located adjacent to the facility's runways. Information obtained from interviews with NASA WFF FD personnel indicated both hangers are not equipped and have never been equipped with a fire suppression system (NASA WFF FD Interview, 11/15/17). NASA WFF FD personnel also indicated no incidents or training activities occurred at either building involving the use of AFFF.

Building X-15 - Island Fire Station

Building X-15 is the fire station situated on the Island Parcel which is located approximately 6 miles south of the Main Base parcel. Interview information obtained from the NASA WFF FD indicated that AFFF is stored at the fire station, but has never been used in response to an incident or for training purposes on the Island, including the October 28, 2014 Antares rocket explosion (NASA WFF FD Interview, 11/15/17). The NASA WFF FD maintains one firefighting vehicle on the Island which is equipped to disperse AFFF. The vehicle is a pickup truck equipped with a 10-gallon AFFF concentration reservoir, which contains 6% AFFF concentrate. The NASA WFF FD current inventory of AFFF on the island consists of 200 gallons of 6% AFFF stored in 5-gallon containers, which is stored at Building X-15. There have been no reported spills or releases of AFFF at the Island fire station or on the Island.

2.6 CONCEPTUAL SITE MODEL

The purpose of a CSM is to identify how contaminants may move in the environment and to establish possible pathways of exposure to human or ecological receptors form contaminated media (soil, water, air). The CSM establishes the following:

- Site sources of contamination
- Contaminant release mechanisms and transport/migration pathways

- Exposure routes
- Potential receptors

This information is necessary to determine possible exposure pathways. Components of the CSM for the subject sites are discussed below.

2.6.1 Site Sources of Contamination

The potential source of PFAS contamination at the following seven SI Areas is from known or suspected dispersion/use of AFFF:

- Area 1 – Fire Station
- Area 2 – D-1 West Fire Training Area
- Area 5 – Former WWTP
- Area 6 – Lear Jet Soil Bioremediation Landfarm
- Area 8 – WWTP
- Area 9 – FFTA
- Area 10 – Lear Jet Crash Site

The following areas were identified for further evaluation for PFAS through an SI. Information pertaining to the documented or suspected use of AFFF at or near these areas has not been substantiated.

Area 3 – Fire Training Pit: Information obtained through interviews with NASA WFF FD personnel indicated there was no documented used of PFAS at this training area. However, during the April 2017 PFAS sampling, PFAS was detected above the USEPA HA in a groundwater monitoring well located approximately 450 feet away.

Area 4 – Helicopter Crash Site: The incident occurred in 1974, which is prior to the 1977/78 timeframe where the NASA WFF FD switched from using protein-based foam to AFFF. Although this incident occurred before the transition period, a decision was made by NASA to retain this area for further evaluation of PFAS.

Area 7 – OW-06 Area: PFOA and PFOS have been detected in OW-06 at concentrations above the USEPA HA. However, information obtained through interviews with NASA WFF FD personnel indicated no incidents or training activities occurred in the area surrounding OW-06 involving the use of AFFF.

Other PFAS Areas of Concern – Outfalls, CDL, and WOD: PFAS sampling has not been conducted from the outfalls or at the CDL or WOD. The outfalls are being evaluated to determine if PFAS is present in surface water migrating from the facility. The CDL and WOD were selected for sampling due to previous activities conducted that could have introduced PFAS containing materials, although there is no specific information substantiating this postulation.

2.6.2 Transportation and Migration Pathways

Potential migration pathways at these Areas, include the following:

- Migration of PFAS from possible historical AFFF usage or release to surface soils.

Interviews with current facility personnel indicated incidents, training, and testing where AFFF was used and PFAS may have been released to the environment. If PFAS were released to surface soil, then the following migration pathways would potentially affect current conditions as follows:

- Downward migration of potential contaminants to subsurface soils via infiltration.
- Downward migration of contaminants to groundwater (if present in soil) via infiltration.
- Migration of contaminants in groundwater.
- Migration of contaminants to surface water and sediment from runoff, erosion, and effluent.

All of the suspected PFAS source Areas are located at the Main Base. These areas may receive drainage and runoff from the nearby runway, taxiways, and ramp areas during precipitation events. Storm water outfalls in some of these suspect Areas of the facility are being targeted for sampling during the SI. Surficial runoff and storm water can be potential pathways for spreading PFAS. The network of underground utilities will also be evaluated to determine whether they acted as conduits to convey PFAS.

2.6.3 Exposure Routes

The potential for contamination has not been evaluated at the following Areas:

- Area 1 – Fire Station
- Area 2 – D-1 West Fire Training Area
- Area 3 – Fire Training Pit
- Area 4 – Helicopter Crash Site
- Area 5 – Former WWTP
- Area 6 – Lear Jet Soil Bioremediation Landfarm
- Area 8 – WWTP
- Area 10 – Lear Jet Crash Site
- Other PFAS Areas of Concern – Outfalls, CDL, and WOD

Groundwater samples have been collected from an OW at Area 7 – OW06 Area and monitoring wells at Area 9 – FFTA. These wells are screened in the shallow aquifer (Columbia). Concentrations of PFOA and PFOS (individually or combined) have been detected in groundwater above USEPA HAs at these Areas. No other media has been evaluated for PFAS at these Areas.

If contaminants are present at any of the SI Areas, the primary media through which receptors could be exposed are surface soil. Future construction workers could potentially be exposed to subsurface soil if land disturbance activities were conducted. Exposure routes for soil would include dermal contact, ingestion, and inhalation. Exposure to shallow groundwater from these Areas is not expected. Drinking water at NASA WFF is obtained from a series of four production wells which are screened in the Yorktown-Eastover Aquifer, these production wells and the potable water source at the facility are sampled and analyzed for PFAS currently on a monthly basis. PFAS has been detected in two sampling events at low levels below 10 ng/L in samples collected from the potable drinking water at NASA WFF.

There is also potential for exposure to contaminants in surface water and sediments associated with Areas 8 - WWTP, Area 9 - FFTA, and Area 10 – Lear Jet Crash Site due to potential run-off from precipitation or shallow groundwater discharge into surface water and sediments linked to these areas. Little Mosquito Creek is potentially influenced from run-off or shallow groundwater discharge from Areas 8 and 9 as shown in Figures 2-10 and 2-11B, respectively. Simoneaston Bay may receive run-off from Area 10 as depicted in Figure 2-12

2.6.4 Potential Receptors

Human Receptors

Current human receptors to be evaluated for potential exposure to media at each site are limited to industrial workers (e.g., NASA employees), maintenance workers, construction workers, trespassers, and consumption of drinking water. Industrial workers may access the following areas on a daily basis:

- Area 1- Fire Station and Area 8 – WWTP.

Maintenance workers may access any of the SI areas periodically. Future construction workers would be a receptor at any of the SI areas if construction activities include land disturbance. If such activities would occur and the media is determined to be contaminated based on the findings of this SI, proper engineering controls such as dust suppression and personal protective equipment (PPE) would be used as necessary to limit exposure.

Trespassers are unlikely to access any of the SI areas because of the level of security (physical perimeter fence and patrol) on the Main Base. However, trespassers could access the bank of Little Mosquito Creek via boat, which include the surface water and sediment sample locations associated with Area 8 – WWTP and Area 9 – FFTA that are situated on the bank of the creek. Trespassers could also access via foot or boat, the surface water and sediment sample location associated with Area 10 – Lear Jet Crash Site that is situated at the confluence point of the surface water drainage ditch and the gut which flows into the northwest portion of Simoneaston Bay. Although these sample locations are situated on the Main Base property, they are not located within the facility perimeter security fence.

Ecological Receptors

Ecological receptors are limited due to the size, location and type of habitat associated with the sites. Each of the ten SI Areas identified for further evaluation for PFAS through an SI have been identified as having limited habitat for ecological receptors. The following SI areas are considered industrial areas or located adjacent to the active runway:

- Area 1 – Fire Station
- Area 2 – D-1 West Fire Training Area

- Area 3 – Fire Training Pit
- Area 4 – Helicopter Crash Site
- Area 7 – OW-06 Area
- Area 8 – WWTP
- Area 10 – Lear Jet Crash Site

Areas 5 – Former WWTP, 6 – Lear Jet Soil Bioremediation Landfarm, and 9 - FFTA border woodlands; however, the areas themselves provide limited ecological habitat. Effluent from Area 8 – WWTP and potentially shallow groundwater and surface run off from Area 9 – FFTA flow into Little Mosquito Creek. Area 10 – Lear Jet Crash Site is situated near a storm water drainage, surface run off from this area potentially flows to this storm water drainage which directs flow into Simoneaston Bay. Both Little Mosquito Creek and Simoneaston Bay and their surrounding wetlands serve as suitable habitat for aquatic flora and fauna.

3.0 PROJECT QUALITY OBJECTIVES

This SI is being conducted to evaluate whether PFAS has impacted soil, groundwater, surface water and sediment at select areas at NASA WFF. The section presents the data quality objectives for this investigation.

3.1 INFORMATIONAL INPUTS

Informational inputs for media to be sampled during this investigation are described in this section. All environmental media sampled during this investigation will be shipped to an independent laboratory for analysis. The following inputs are needed to meet the project objectives:

Previously Collected Data. Groundwater samples have been collected from Area 7 – OW06 Area and Area 9 - FFTA and were analyzed for PFAS during previous investigations. In addition, various investigations for PFAS have been conducted which include the collection of groundwater samples throughout the facility as described in Section 2.4. The SI requires evaluation of previously collected PFAS analytical data as well as newly collected data.

Field Screening Data (Area 9 - FFTA). Field screening data are needed to determine the depth at which definitive soil concentration data must be collected. Subsurface soil samples collected from Area 9 - FFTA will target a known area, impacted by petroleum contamination and utilized for firefighting training activities using AFFF. Visual observations and photoionization detector (PID) measurements will be used to help identify petroleum contamination and to assist in the selection of subsurface sampling depths at soil borings. PFAS may potentially be co-located or associated with areas impacted by petroleum due to the use of AFFF and petroleum products in the same locations during fire training activities. Visual and PID data inputs are considered qualitative because they do not provide a quantified value. This qualitative data is of sufficient quality to facilitate identification of actual sample depths selected for laboratory analysis.

Laboratory Analytical Data. All environmental media (i.e., surface and subsurface soil, groundwater, surface water, and sediment) sampled during this investigation will be analyzed for fourteen PFAS compounds as presented in Tables 3-1 through 3-3. All samples evaluated for PFAS will be analyzed via Method 537 by an independent laboratory. The following conventions will be used to report analytical laboratory data:

- Classify all results less than the Detection Limit (DL) as non-detects.
- Report non-detects at the Limit of Detection (LOD) with a "U" qualifier.
- J-flag positive results reported at concentrations between the DL and Limit of Quantitation (LOQ). These results will be used as reported, but with consideration for the additional uncertainty represented by the J flags.

Hazardous waste analyses will be conducted on investigation-derived waste (IDW) (e.g., decontamination water and groundwater). IDW will be containerized, stored, characterized, and disposed of in accordance with local, state, and federal law (refer to Section 4.3). These data are required to determine proper disposal procedures for IDW but are not needed for attaining project objectives.

Project Screening Levels. Project Screening Levels (PSLs) are numerical criteria that form the basis for determining whether PFAS are present at potentially unacceptable concentrations in environmental media sampled from the areas being investigated in the SI. Tables 3-1 through 3-3 present the PSLs for PFAS established for surface and subsurface soil, groundwater, and surface water and sediment samples, respectively.

The screening levels for PFOA and PFOS for direct contact to soil were calculated using USEPA's RSL calculator (https://www.epa.gov/risk/regional-screening-levels-rsls). The values are based on USEPA default exposure assumptions for residential exposure to soil by incidental ingestion and dermal contact and correspond to a hazard index of 0.1.

The protection of groundwater soil screening levels for PFOA and PFOS were calculated using USEPA's RSL calculator. The values assumed groundwater is used as a drinking water source and are based on a dilution attenuation factor of 1 and correspond to a hazard index of 0.1.

During this investigation groundwater results for PFAS will be compared against the USEPA drinking water HA levels for PFOA and PFOS, or the sum of both chemicals, of 70 ng/L (USEPA, 2016 b and c). This value is for ingestion of water by lactating women and assumes that only 20 % of a woman's daily exposure to PFOA and PFOS may come from ingestion of water. In addition, USEPA's November 2017 RSL table provides a screening level for PFBS in groundwater. The value is based on USEPA default exposure assumptions for residential exposure to water and corresponds to a hazard index of 0.1. Currently, there are no regulatory or screening levels established for NEtFOSAA, NMeFOSAA, PFDA, PFDoA, PFNA, PFHxA, PFHxS, PFHpA, PFTA, PFTrDA, or PFUnA.

No USEPA RSLs are available for surface water, therefore as recommended by USEPA Region III, 10-times the groundwater HA levels were used as the screening levels for (salty/brackish) surface water. The 10-times adjustment of the screening levels for (salty/brackish) surface water is recommended because salty/brackish surface water is not used for domestic purposes (e.g. bathing, cooking, and drinking).

No USEPA RSLs are available for sediment, therefore as recommended by USEPA Region III, 10-times the residential screening levels for soil were used as the screening levels for sediment. The adjustment of the screening levels by a factor of 10 is recommended for sediment because exposures to sediments (particularly those underwater) are anticipated to be less than exposures to soil.

As presented in Tables 3-1 through 3-3, eleven of the fourteen PFAS compounds analyzed during this SI do not have a PSL associated with the chemical. These compounds will be reported as detected with no comparison criteria.

3.2 STUDY AREA BOUNDARIES

The following paragraphs provide a description of the study area boundaries for this investigation. However, these boundaries may change based on conditions encountered in the field. Deviations from these boundaries will be documented as necessary with a field task modification request form.

The soil populations of primary interest are surface and subsurface soil at locations within the SI Areas that are a suspected PFAS source. For this investigation, surface soil will be defined as soil from 0 to 2 feet below ground surface (bgs). Subsurface soil will be defined as soil from 2-foot bgs and deeper, but above the water table (unsaturated soil).

The groundwater population of primary interest is groundwater potentially contaminated by PFAS. Groundwater at Area 7 – OW-06 Area and Area 9 – FFTA have been investigated for PFAS; however, groundwater from the other eight SI Areas have not been previously investigated for PFAS. Groundwater sampled during this investigation will be limited to the shallow Columbia Aquifer. The majority of the groundwater samples collected during this investigation will be grab samples collected via 5-foot screens spanning the water table from 1 foot above to 4 feet below. Some existing monitoring wells will be sampled and analyzed for PFAS during investigations at Areas 1 – Fire Station, 2 – D-1 West Fire Training Area, 9 – FFTA, CDL, and WOD. Based on migration pathways (infiltration), shallow groundwater (water table) would be most likely affected if soil at these areas have been impacted by PFAS.

The surface water and sediment population of primary interest are from water bodies within the facility that may have received surface run off, waste water effluent, or possible discharge from shallow groundwater which has potentially been impacted by PFAS. Surface water for this investigation will be defined by the water immediately below the surface. Sediment for this investigation will be defined as material 0 to 6 -inches below the sediment surface. Water collected from various outfalls will also be considered to be within the study boundaries.

3.3 ANALYTICAL APPROACH

The decision rules designed to determine whether project objectives have been attained are as follows:

- **Decision Rule 1:** If the analytical results of the SI indicate PFAS has been released to the environment at any of the identified PFAS Source Areas (concentrations are greater than the PSLs), then NASA will convene with the stakeholder team to determine the appropriate next step(s). These may include additional evaluations/investigations for the impacted environmental media to determine the nature and extent of PFAS.
- **Decision Rule 2:** If contaminant concentrations in environmental media (soil, groundwater, surface/outfall water, and sediment) are less than the PSLs or background, then NASA will put forth a recommendation for no further action will be taken at that PFAS Source Area.

- **Decision Rule 3:** If PFAS are detected, but are below PSLs, then spatial patterns of detections will be evaluated to determine if further investigation of the source of PFAS is necessary. NASA and stakeholders will discuss the results and determine the appropriate path forward regarding detections of PFAS below the PSLs.
- **Decision Rule 4:** If new regulatory standards or criteria for PFAS are developed, NASA and stakeholders will determine the appropriate path forward related to those new regulatory standards and criteria.

4.0 FIELD INVESTIGATION RATIONALE AND METHODOLOGY

To address the SI objectives, this investigation will include collection and analysis of surface and subsurface soil, groundwater, surface water and sediment. All media collected during this SI will be analyzed for the fourteen PFAS compounds listed in Tables 3-1 through 3-3 via EPA Method 537 (EPA, 2009). Due to the nature of PFAS and their prevalence in the environment and in many consumer products, special precautions will be taken to avoid introducing contaminants to the samples. All field sampling activities will be conducted per methods and protocols for collecting and handling environmental media analyzed for PFAS as outlined in Tetra Tech Standard Operating Procedure (SOP) SA-1.8 (Appendix E). This SOP is designed to supplement but not replace existing sampling specific SOPs. References to SOPs specific to each type of sampling are included in each of their respective sections. The location of each sample location will be recorded using a Global Position System device.

The following sections provide details and procedures for field sampling and analytical laboratory requirements for this investigation.

4.1 SITE PREPARATION

Site preparation activities include site observation and documentation and mark-out of sample locations. A dig permit will be obtained from NASA prior to any intrusive activities. Sample locations will be marked out with pin flags. The dig permit process does not involve a third-party utility clearance and utilities are marked and cleared by facility personnel.

4.2 LABORATORY ANALYTICAL SAMPLES

Soil samples and groundwater samples will be sent to a fixed-base laboratory that is a Department of Defense Environmental Laboratory Accreditation Program (ELAP)-approved and Virginia ELAP-approved laboratory. Samples will be analyzed on a 21-day turnaround time.

4.2.1 Soil Samples

Analytical results for PFAS from surface and subsurface soil samples will be compared to the respective PSLs provided in Table 3-1. Evaluation of these results will determine the appropriate path forward for PFAS in soil at each SI area.

Soil samples will be collected from each SI area with the exception of Area 8 – WWTP. Soil sampling is not proposed for Area 8 – WWTP since historical activities in the area did not include a potential release of PFAS substances to soil. Figures 2-4 through 2-9, 2-11, and 2-12 present the proposed soil sampling locations. Samples will be collected using direct push technology (DPT) methods. The proposed sample location rationale is presented in Table 4-1. Sample nomenclature and proposed analyses are detailed in

Table 4-2. Sampling activities will be conducted in accordance with Tetra Tech DPT specific SOP SA-2.5, soil sampling SOP SA-1.3, and PFAS sampling SOP SA-1.8 (Appendix E).

Continuous macrocore with disposable acetate sleeves will be advanced via a DPT rig at each sample location. Lithology data from the macrocores will be recorded on field log sheets. Samples will be collected directly from the acetate sleeves at the depth intervals designated in Table 4-1. After completion of each macrocore, soil cuttings will be placed back in their respective soil borings.

Down hole well drilling tools will be decontaminated between drilling locations. DPT tools will be decontaminated on a temporary decontamination pad and will consist of washing using a non-phosphate detergent followed by a potable water rinse. Fluids generated from decontamination will be containerized and managed as IDW.

4.2.2 Groundwater Samples

Concentrations of PFAS in groundwater samples will be compared to the respective PSLs provided in Table 3-2. The PSL comparison and evaluation of these results will help determine whether additional groundwater investigation is needed at each specific SI area.

Groundwater samples will be collected during the SI from temporary wells (i.e., groundwater grab samples) and existing monitoring wells. Figures 2-4 through 2-9, 2-11, 2-12, and 2-13 present the proposed groundwater sampling locations. The proposed sample location rationale is presented in Table 4-1. Sample nomenclature and proposed analyses are detailed in Table 4-2.

Temporary Well Sampling

Temporary wells will be installed via DPT. At each SI area, prior to the installation of the temporary wells, one or more soil borings may be collected to confirm lithology and depth of the water table. Soil borings will be collected through the advancement of continuous macrocores with disposable acetate sleeves via DPT. Lithology data from the macrocores will be recorded on field log sheets and be used to determine groundwater sample depth interval. After completion of the macrocore, soil cuttings will be placed back in their respective soil borings. Groundwater grab samples will be collected by advancing a stainless-steel screen point sampler (4- to 5-foot) via DPT to the target sampling depth. Sampling of temporary wells will be conducted in accordance with Tetra Tech DPT specific SOP SA-2.5 and PFAS sampling SOP (Appendix E).

The well screen will be purged with a peristaltic pump and using low flow purging techniques and a water quality meter to record typical parameters (i.e., temperature, conductivity, etc.). High density polyethylene (HDPE) and silicon tubing will be used for sample collection. If turbidity readings are not reduced below 10 Nephelometric Turbidity Units (NTUs) after purging for approximately 20 minutes, purging will be considered complete and a groundwater grab sample will be collected. Pertinent information regarding each sample will be recorded on sample log sheets and the project field notebook.

Down hole well drilling tools will be decontaminated between drilling locations. DPT tools will be decontaminated on a temporary decontamination pad and will consist of washing using a non-phosphate, fluorosurfactant-free detergent followed by a potable water rinse. Fluids generated from decontamination and groundwater sampling will be containerized and managed as IDW.

Existing Groundwater Monitoring Well Sampling

During this investigation, groundwater samples will be collected from existing monitoring wells at select areas. Groundwater sampling will be conducted using USEPA Region 3 Recommended Procedure for Low-Flow Purging and Sampling of Groundwater Monitoring Wells, Bulletin No. QAD023 and in general accordance with Tetra Tech groundwater sampling SOP SA-1.1 and PFAS sampling SOP SA-1.8 (Appendix E).

Prior to sampling, if present, tubing installed in the wells will be removed and replaced with new HDPE and silicone tubing. The wells will be purged and sampled with a peristaltic pump using low flow purging techniques. The following field parameters will be monitored using field meters and recorded on field log forms during sampling activities: pH, specific conductance, temperature, turbidity, dissolved oxygen, and oxidation-reduction potential, the water level in the well will be allowed to recover enough to collect field parameter readings prior to collecting a water sample. If the well does not purge dry using the low flow purging technique, groundwater parameters will be taken within no less than 2-minute intervals, depending on the flow rate. Sampling may be conducted once three consecutive readings, taken at 5 to 10-minute intervals, are within the following limits:

- pH ±0.2 standard units
- Specific conductance ±10%
- Temperature ±10%
- Turbidity less than 10 NTUs
- Dissolved Oxygen ±10%

If the above conditions have still not been met after the well has been purged for 4 hours, purging will be considered complete and sampling can begin. The final well stabilization parameters will be recorded on the field log forms and sample log sheets.

Purge water generated during sampling activities will be collected and managed as IDW.

4.2.3 Surface Water & Sediment Samples

Analytical results for PFAS from surface water (including outfall samples) and sediment samples will be compared to their respective PSLs provided in Table 3-3. Evaluation of these results will determine the appropriate path forward for PFAS at each respective area.

Surface water and sediment samples will be collected from SI Areas 8 - WWTP, 9 - FFTA, and 10 – Lear Jet Crash Site (Figures 2-10 through 2-12). Samples will also be collected from various outfalls (Figure 2-

13). The proposed sample location rationale is presented in Table 4-1. Sample nomenclature and proposed analyses are detailed in Table 4-2. Sampling activities will be conducted in accordance with Tetra Tech surface water and sediment sampling specific SOP SA-1.2 and PFAS sampling SOP SA-1.8 (Appendix E).

Surface water samples will be collected first followed by sediment samples and sampling will proceed in an upstream direction (farthest downgradient first and progressing upgradient). The surface water sample bottle will be filled by directly dipping it into the water. Sediment samples will be collected from the top foot of the stream bed using a stainless-steel tools or disposable plastic scoop. The presence and location of any groundwater seeps will be noted and mapped if they are observed at the sites. No IDW is anticipated to be generated from surface water or sediment sampling activities.

Surface water samples will be collected from selected outfalls or storm water culverts as a part of the SI. The sample bottles will be filled directly from each selected outfall. If the outfall does not contain flowing water, it will be noted, and no sample will be collected. Other field observations including photos will be collected at each outfall location.

4.2.4 QA/QC Samples

Environmental Media

Quality Assurance/Quality Control (QA/QC) samples will be collected during this investigation as summarized in Table 4-2. Field duplicate will be collected every 10 samples and matrix spike (MS) will be collected every 20 samples per media type. Each field duplicate collected will be assigned a blind sample identification number. A rinsate blank will be collected from decontaminated, non-dedicated equipment at a minimum rate of one sample per piece of equipment per week. Laboratory provided PFAS-free reagent water will be used to obtain the rinsate sample(s). A field reagent blank (FRB) sample will be collected at a rate of one per day during groundwater sampling activities. Water used to decontaminate non-dedicated equipment will be sampled and analyzed for PFAS. A sample(s) will be collected directly from the water source or if a bulk tank/container is used to store and transport the water to the decontamination area, a sample(s) will be collected of the water from the bulk tank/container.

4.2.5 Field Sample Custody Procedures

Sample containers will be provided from the lab and will be certified clean. Following sample collection, all samples will be labeled and immediately placed on ice in a cooler. A chain-of-custody form will be used to document the date and time of sample collection, the sampler’s name, and the specifications of analysis. The chain-of-custody form will accompany each shipment to the laboratory. The cooler will be secured using strapping tape along with a signed custody seal. Sample coolers will be delivered to a local courier location for priority overnight delivery to the lab for analysis.

4.2.6 Equipment Decontamination

Down hole well drilling tools will be decontaminated between drilling locations. As required, DPT tools may be decontaminated on a temporary decontamination pad at the drilling location. Sampling equipment decontamination will consist of washing using a non-phosphate detergent followed by a PFAS-free water rinse. If used, all other non-dedicated equipment will be decontaminated using this technique. All fluids generated during decontamination will be managed as IDW.

4.3 IDW MANAGEMENT

IDW should be limited to decontamination water, development groundwater, and sample purge groundwater. IDW will be captured, containerized in 55-gallon drums, labeled, and stored on the Main Base (Building B-29) and characterized for proper disposal. Unused soil from DPT macrocores will be placed back into the respective soil borings. IDW disposal will be coordinated by NASA. All used PPE will be bagged and disposed of as general garbage.

5.0 REPORTING AND DATA VALIDATION

An SI Report will be prepared to include a summary of work performed, any field modifications, field results and analytical data, a comparison of data to PSLs and reference values, and recommendations based on the evaluated data. PFAS compounds that do not have PSLs established for the chemical will be reported as detected with no comparison criteria.

5.1 FIELD DATA

Field data will include a summary of site conditions, sampling locations, and field observations.

5.2 LABORATORY DATA

Analytical data will be delivered to Tetra Tech as a laboratory report in portable document format and as electronic data deliverables. The laboratory report will include a narrative, copies of the chain-of-custody forms, method summary and references, summary of laboratory identification numbers, receipt logs, extraction and analysis logs, analytical results, QC results, and raw data.

5.3 VALIDATION

A validation of all laboratory data will be performed by Tetra Tech. The data will be reviewed and checked for compliance with method/procedure requirements, and data validation reports will be prepared to include the following elements:

- Samples included in the validation
- Validation guidelines used, including any project-specific modifications
- Review elements
- Discussion of validation results, including any qualifiers appended

Qualifiers used will be from USEPA Region 3 validation guidelines. The Data validation reports will be appended to the SI Report.

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TABLES

TABLE 3-1
SURFACE AND SUBSURFACE SOIL PROJECT ANALYTE LIST AND SCREENING CRITERIA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

ANALYTE	CAS	USEPA RSL Soil Screening Level for Groundwater Protection (mg/kg)(1)	USEPA RSL Residential Soil (mg/kg)(1)	Laboratory Limits (mg/kg) (2)		
				LOQ	LOD	DL
Matrix: Soil **Analytical Group: Per- and Polyfluoroalkyl Substances via Modified EPA Method 537**						
Perfluorooctanesulfonic acid (PFOS)	1763-23-1	3.8E-05 (3)	0.126 (3)	TBD	TBD	TBD
Perfluorooctanoic acid (PFOA)	335-67-1	1.7E-05 (3)	0.126 (3)	TBD	TBD	TBD
Total PFOA and PFOS	--	NC	NC	TBD	TBD	TBD
Perfluorobutanesulfonic acid (PFBS)	375-73-5	0.013	126	TBD	TBD	TBD
N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	--	NC	NC	TBD	TBD	TBD
N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	--	NC	NC	TBD	TBD	TBD
Perfluorodecanoic acid (PFDA)	335-76-2	NC	NC	TBD	TBD	TBD
Perfluorododecanoic acid (PFDoA)	307-55-1	NC	NC	TBD	TBD	TBD
Perfluoroheptanoic acid (PFHpA)	375-85-9	NC	NC	TBD	TBD	TBD
Perfluorohexanesulfonic acid (PFHxS)	355-46-4	NC	NC	TBD	TBD	TBD
Perfluorohexanoic acid (PFHxA)	307-24-4	NC	NC	TBD	TBD	TBD
Perfluorononanoic acid (PFNA)	375-95-1	NC	NC	TBD	TBD	TBD
Perfluorotetradecanoic acid (PFTA)	376-06-7	NC	NC	TBD	TBD	TBD
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	NC	NC	TBD	TBD	TBD
Perfluoroundecanoic (PFUnA)	2058-94-8	NC	NC	TBD	TBD	TBD

RSL - Regional Screening Level
mg/kg - milligram per kilogram
NC - no criteria
TBD - to be determined

LOQ - limit of quantitation
LOD - limit of detection
DL - detection limit
CAS - Chemical Abstract Service

1 - USEPA RSL Table (November, 2017). Value corresponds to a hazard quotient of 0.1.

2 - The selected laboratory must have limits less than the project screening levels.

3 - USEPA RSL Calculator (March 20, 2018). Value corresponds to a hazard quotient of 0.1.

TABLE 3-2
GROUNDWATER PROJECT ANALYTE LIST AND PROJECT SCREENING LEVELS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

ANALYTE	CAS	PSL for Groundwater (ng/l)	Laboratory Limits (ng/l) (1)		
			LOQ	LOD	DL
Matrix: Groundwater **Analytical Group: Per- and Polyfluoroalkyl Substances via Modified EPA Method 537**					
Perfluorooctanesulfonic acid (PFOS)	1763-23-1	70 (2)	TBD	TBD	TBD
Perfluorooctanoic acid (PFOA)	335-67-1	70 (2)	TBD	TBD	TBD
Total PFOA and PFOS	--	70 (2)	TBD	TBD	TBD
Perfluorobutanesulfonic acid (PFBS)	375-73-5	40,000 (3)	TBD	TBD	TBD
N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	--	NC	TBD	TBD	TBD
N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	--	NC	TBD	TBD	TBD
Perfluorodecanoic acid (PFDA)	335-76-2	NC	TBD	TBD	TBD
Perfluorododecanoic acid (PFDoA)	307-55-1	NC	TBD	TBD	TBD
Perfluoroheptanoic acid (PFHpA)	375-85-9	NC	TBD	TBD	TBD
Perfluorohexanesulfonic acid (PFHxS)	355-46-4	NC	TBD	TBD	TBD
Perfluorohexanoic acid (PFHxA)	307-24-4	NC	TBD	TBD	TBD
Perfluorononanoic acid (PFNA)	375-95-1	NC	TBD	TBD	TBD
Perfluorotetradecanoic acid (PFTA)	376-06-7	NC	TBD	TBD	TBD
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	NC	TBD	TBD	TBD
Perfluoroundecanoic (PFUnA)	2058-94-8	NC	TBD	TBD	TBD

PSL - Project Screening Level
RSL - Regional Screening Level
ng/l - nano grams per liter
NC - no criteria
TBD - to be determined

LOQ - limit of quantitation
LOD - limit of detection
DL - detection limit
CAS - Chemical Abstract Service

1 - The selected laboratory must have limits less than the project screening levels.

2 - USEPA (2016), Health Advisory applies to PFOS and PFOA, individualy or the sum of both compounds.

3 - USEPA Tapwater RSL (November 2017) and a hazard quotient of 0.1 due to noncancer additive effects.

TABLE 3-3
SURFACE WATER AND SEDIMENT PROJECT ANALYTE LIST AND PROJECT SCREENING LEVELS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
Page 1 of 1

ANALYTE	CAS	Surface Water PSL (ng/L)(1)	Laboratory Limits (ng/l) (2)			Sediment PSL based on EPA RSL Residential Soil (mg/kg)(2)	Laboratory Limits (mg/kg) (2)		
			LOQ	LOD	DL		LOQ	LOD	DL
Matrix: Surface Water and Sediment **Analytical Group: Per- and Polyfluoroalkyl Substances via Modified EPA Method 537**									
Perfluorooctanesulfonic acid (PFOS)	1763-23-1	700 [3]	TBD	TBD	TBD	1.26	TBD	TBD	TBD
Perfluorooctanoic acid (PFOA)	335-67-1	700 [3]	TBD	TBD	TBD	1.26	TBD	TBD	TBD
Total PFOA and PFOS	--	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorobutanesulfonic acid (PFBS)	375-73-5	400000 [3]	TBD	TBD	TBD	1,260	TBD	TBD	TBD
N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	--	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	--	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorodecanoic acid (PFDA)	335-76-2	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorododecanoic acid (PFDoA)	307-55-1	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluoroheptanoic acid (PFHpA)	375-85-9	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorohexanesulfonic acid (PFHxS)	355-46-4	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorohexanoic acid (PFHxA)	307-24-4	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorononanoic acid (PFNA)	375-95-1	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorotetradecanoic acid (PFTA)	376-06-7	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluorotridecanoic acid (PFTrDA)	72629-94-8	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD
Perfluoroundecanoic (PFUnA)	2058-94-8	NC	TBD	TBD	TBD	NC	TBD	TBD	TBD

RSL - Regional Screening Level
PSL - Project Screening Level
ng/l - nano grams per liter
mg/kg - milligram per kilogram
NC - no criteria

LOQ - limit of quantitation
LOD - limit of detection
DL - detection limit
TBD - to be determined
CAS - Chemical Abstract Service

1 - Sediment PSL is ten times the soil PSL from Table 3-1.
2 - The selected laboratory must have limits less than the project screening levels.
3 - Surface water value is ten times the groundwater PSL from Table 3-2.

TABLE 4-1
SAMPLE LOCATION RATIONALE
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
Page 1 of 3

Sample Location	Sample Location Rationale
Area 1 - B-129 Fire House (B-129)	
B129-SB01	Collect soil samples around the perimeter of Building B-129 and edge of concrete apron extending out from Building B-129 to determine if PFAS are present in soil above the PSL at the potential source area. Samples will be collected at edge of paved surfaces where run-off may have transported potential, residual AFFF to the soil. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
B129-SB02	
B129-SB03	
B129-SB04	
B129-SB05	
B129-SB06	Collect soil samples on east and west side of Building B-31 (stored AFFF concentrate) to determine if PFAS are present in soil above the PSL at the potential source area. Samples will be collected at edge of paved surfaces where run-off may have transported potential, residual AFFF to the soil. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
B129-SB07	
B129-TW01	Collect groundwater grab samples from the surficial aquifer, hydrologically downgradient of Building B-129 to assess if PFAS are present in groundwater above the PSL.
B129-TW02	
MW-11-13-2	Sample existing monitoring wells that are in close proximity to B-129 to determine if PFAS are present in groundwater above the PSL.
MW-11-26-3	
Area 2 - D-1 West Fire Training Area (D1W)	
D1W-SB01	Collect soil samples around perimeter of D1W to determine if PFAS are present in soil above the PSL at the potential source area. Samples will be collected at edge of paved surfaces where potential run-off from fire training activities may have flowed to soil or into the oil water separator. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
D1W-SB02	
D1W-SB03	
D1W-SB04	
D1W-TW01	Collect groundwater grab sample from the surficial aquifer within D1W to determine if PFAS are present in groundwater above the PSL.
D1W-TW02	Collect groundwater grab samples from the surficial aquifer, hydrologically downgradient of D1W to determine if PFAS are present in groundwater above the PSL.
D1W-TW03	
D1W-TW04	
MW-11-95-6D	Sample existing monitoring well in proximity of D1W to determine if PFAS are present in groundwater above the PSL.
Area 3 - Fire Training Pit (FTP)	
FTP-SB01	Collect soil samples in proximity to the former FTP to determine if PFAS are present in soil above the PSL at the potential source area. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
FTP-SB02	
FTP-SB03	
FTP-SB04	
FTP-SB05	Collect soil samples in the vicinity of former Building F-8 plating shop to determine if PFAS are present in soil above the PSL. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
FTP-SB06	Collect soil samples in the vicinity of former Building F-8 plating shop to determine if PFAS are present in soil above the PSL. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
FTP-TW01	Collect groundwater grab sample from the surficial aquifer to determine if PFAS are present in groundwater above the PSL. Location is within the footprint of former building F-8 (plating shop) and hydrologically downgradient of MW-11-41-3, where PFAS was previously detected.
FTP-TW02	Collect groundwater grab sample from the surficial aquifer to determine if PFAS are present in groundwater above the PSL. The location is between the FTP and MW-11-82-3, where PFAS was previously detected.
FTP-TW03	Collect groundwater grab sample from the surficial aquifer at the FTP to determine if PFAS are present in groundwater above the PSL.
FTP-TW04	Collect groundwater grab sample from the surficial aquifer at a location hydrologically downgradient of former FTP to determine if PFAS are present in groundwater above the PSL.
Area 4 - Helicopter Crash Site (HCS)	
HCS-SB01	Collect soil samples within area of HCS to determine if PFAS are present in soil above the PSL at the potential source area. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
HCS-SB02	
HCS-SB03	
HCS-TW01	Collect groundwater grab sample from the surficial aquifer within area of HCS to determine if PFAS are present in groundwater above the PSL.
HCS-TW02	Collect groundwater grab sample from the surficial aquifer, hydrologically downgradient of HCS to determine if PFAS are present in groundwater above the PSL.
HCS-TW03	
HCS-TW04	
Area 5 - Former Wastewater Treatment Plant (FWTP)	
FWTP-SB01	Collect soil samples in proximity of the FWTP drying beds to determine if PFAS are present above the PSL in the potential source area. Fire training activities using AFFF were conducted at former drying beds. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
FWTP-SB02	
FWTP-SB03	
FWTP-SB04	
FWTP-TW01	Collect groundwater grab sample from the surficial aquifer within area of FWTP drying beds to determine if PFAS are present in groundwater above the PSL.
FWTP-TW02	Collect groundwater grab samples from the surficial aquifer at or hydrologically upgradient/downgradient of FWTP drying beds to determine if PFAS are present in groundwater above the PSL.
FWTP-TW03	
FWTP-TW04	
FWTP-TW05	

TABLE 4-1
SAMPLE LOCATION RATIONALE
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
Page 2 of 3

Sample Location	Sample Location Rationale
Area 6 - Lear Soil Bioremediation Landfarm (LSBF)	
LSBF-SB01	Collect soil samples from the LSBF piles to determine if PFAS are present in soil above the PSL in the potential PFAS source area. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
LSBF-SB02	
LSBF-SB03	
LSBF-TW01	Collect groundwater grab samples from the surficial aquifer around the perimeter of the LSBF to determine if PFAS are present in groundwater above the PSL.
LSBF-TW02	
LSBF-TW03	
LSBF-TW04	
Area 7 - Observation Well 06 Area (OW-06)	
OW06-SB01	Collect soil samples at and surrounding OW-06 to determine if PFAS are present in soil above the PSL in the potential PFAS source area. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
OW06-SB02	
OW06-SB03	
OW06-SB04	
OW06-TW01	Collect groundwater grab samples from the surficial aquifer at OW-06 and surrounding areas to determine if PFAS are present in groundwater above the PSL. PFAS was previously detected in OW-06 yet there are no known PFAS source areas nearby.
OW06-TW02	
OW06-TW03	
OW06-TW04	
Area 8 - Wastewater Treatment Plant (WWTP)	
WWTP-SW01	Assess whether WWTP effluent is, or has been, impacted by PFAS at concentrations above the PSL.
WWTP-SW02	
WWTP-SD01	Assess whether sediment (0-6 inches) at the WWTP discharge point, and/or the confluence of the WWTP drainage culvert and Little Mosquito Creek, contains PFAS at concentrations above the PSL.
WWTP-SD02	
Outfall 001	Collect WWTP effluent sample to assess as a potential source of PFAS.
Area 9 - Former Fire Training Area (FFTA)	
FFTA-SB01	Collect soil samples at the FFTA to determine if PFAS is present in soil above the PSL in the area where fire fighting training activities were conducted using AFFF. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval. In addition, a subsurface soil sample (> 6 ft bgs) will be collected at each location biased towards evidence of petroleum impact (staining and/or elevated PID readings). In the absence of evidence from petroleum impact, a soil sample will be collected at 1-foot interval above the water table.
FFTA-SB02	
FFTA-SB03	
FFTA-SB04	
FFTA-SB05	
FFTA-SB06	
FFTA-SB07	
FFTA-TW01	Collect groundwater grab samples from the surficial aquifer, hydrologically upgradient of FFTA to determine if PFAS are present in groundwater above the PSL.
FFTA-TW02	
FFTA-TW03	
FFTA-TW04	Collect groundwater grab samples from the surficial aquifer, hydrologically downgradient of FFTA to determine if PFAS are present in groundwater above the PSL. A deeper groundwater grab will also be collected at FFTA-TW06 and FFTA-TW07 above the interstitial clay or at approximately 35-40 ft bgs if clay is not encountered.
FFTA-TW05	
FFTA-TW06	
FFTA-TW07	
FFTA-TW08	
FFTA-MW102D	Sample existing well in the northern portion of the FFTA, screened at the bottom portion of the surficial aquifer, to determine if PFAS are present in groundwater above the PSL.
FFTA-MW103D	Sample existing well in the eastern portion of the FFTA, screened at the bottom portion of the surficial aquifer, to determine if PFAS are present in groundwater above the PSL.
14-MW005	Sample existing water table well downgradient of the site, located adjacent to the un-named tributary that flows into Little Mosquito Creek (LMC) to determine if PFAS are present in groundwater above the PSL.
15-MW005	Sample existing monitoring wells located east of the un-named tributary that flows into LMC to determine if PFAS are present in groundwater above the PSL.
WFF9-MW2	
WFF1-MW7	
FFTA-SW01	Collect surface water samples downgradient of the FFTA to assess if PFAS are present in surface water above the PSL.
FFTA-SW02	
FFTA-SW03	
FFTA-SW04	
FFTA-SD01	Collect sediment samples (0-6 inches) downgradient of FFTA to determine if PFAS are present in sediment above the PSL .
FFTA-SD02	
FFTA-SD03	
FFTA-SD04	
Outfall 003	Collect surface water sample from outfalls to assess as a potential source of PFAS.
Outfall 5	
Outfall 6	
Outfall 13	

TABLE 4-1
SAMPLE LOCATION RATIONALE
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
Page 3 of 3

Sample Location	Sample Location Rationale
Area 10 - Lear Jet Crash Site (LJC)	
LJC-SB01	Collect soil at and surrounding the LJC to determine if PFAS are present in soil above the PSL. Soil samples will be collected at the 0-2 ft and the 4-6 ft bgs interval.
LJC-SB02	
LJC-SB03	
LJC-SB04	
LJC-SB05	
LJC-TW01	Collect groundwater grab samples from the surficial aquifer at the LJC to determine if PFAS are present in groundwater above the PSL .A deeper groundwater grab will also be collected at LJC-TW01 above the interstitial clay or at approximately 35-40 ft bgs if clay is not encountered.
LJC-TW03	Collect groundwater grab samples from the surficial aquifer, hydrologically downgradient of the LJC to determine if PFAS are present in groundwater above the PSL.
LJC-TW04	
LJC-TW02	Collect groundwater grab samples from the surficial aquifer, south of the LJC on the north and south side of an unnamed creek to determine if PFAS migrated into the creek and whether PFAS is present in groundwater above the PSL.
LJC-TW05	
LJC-SW01	Collect surface water samples from culvert hydrologically downgradient from the LJC to determine if PFAS are present in the surface water above the PSL.
LJC-SW02	
LJC-SD01	Collect sediment samples (0-6 inches) from culvert hydrologically downgradient from the LJC to determine if PFAS are present in sediment above the PSL
LJC-SD02	
Outfall 9	Collect surface water sample from outfalls to assess as a potential source of PFAS.
Outfall 10	
USACE Construction Debris Landfill (CDL)	
CDL-MW001	Collect groundwater samples from the CDL wells to evaluate the presence of PFAS in groundwater and whether the CDL is a potential source area.
CDL-MW002	
CDL-MW003	
CDL-MW004	
CDL-MW005	
CDL-MW006	
Waste Oil Dump (WOD)	
15-MW007	Collect groundwater samples from select WOD wells to evaluate the presence of PFAS in groundwater and whether the WOD is a potential source area.
WOD-MW002D	
WOD-MW008	
Other Facility Outfall Samples	
Outfall NOAA	Collect surface water sample from outfalls to assess as a potential source of PFAS.
Outfall 8	

PSL - Project Screening Level
AFFF- Aqueous Film Forming Foam
PFAS - Per- and Polyfluoroalkyl Substances
ft - feet
bgs - below ground surface
> - greater than
PID - photoionization detector

Notes:

[1] - Samples will be collected if surface water is being discharged during sampling event. If no surface water is found during sampling, no sample will be collected.

TABLE 4-2
SUMMARY OF SAMPLE NOMENCLATURE AND ANALYSIS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

Sample Nomenclature	Depth (feet)	Media	Analysis (Method)	Container	Preservation	Holding Time	Aqueous				Soil			
							Samples	QA/QC [1]			Samples	QA/QC [1]		
								Duplicate	MS	FRB		Duplicate	MS	FRB
Area 1 - B-129 Fire House														
B129-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once High Density Polyethylene (HDPE) jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					14	1	1	1
B129-SB01-0406	4 - 6													
B129-SB02-0002	0 - 2													
B129-SB02-0406	4 - 6													
B129-SB03-0002	0 - 2													
B129-SB03-0406	4 - 6													
B129-SB04-0002	0 - 2													
B129-SB04-0406	4 - 6													
B129-SB05-0002	0 - 2													
B129-SB05-0406	4 - 6													
B129-SB06-0002	0 - 2													
B129-SB06-0406	4 - 6													
B129-SB07-0002	0 - 2													
B129-SB07-0406	4 - 6													
B129-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	4	1	1	0				
B129-TW02-XXXX	TBD													
MW-11-13-2-2019XXXX	20 - 30													
MW-11-26-3-2019XXXX	21 - 31													
Area 2 - D-1 West Fire Training Area														
D1W-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					8	1	0	0
D1W-SB01-0406	4 - 6													
D1W-SB02-0002	0 - 2													
D1W-SB02-0406	4 - 6													
D1W-SB03-0002	0 - 2													
D1W-SB03-0406	4 - 6													
D1W-SB04-0002	0 - 2													
D1W-SB04-0406	4 - 6													
D1W-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	5	0	0	1				
D1W-TW02-XXXX	TBD													
D1W-TW03-XXXX	TBD													
D1W-TW04-XXXX	TBD													
MW-11-95-6D-2019XXXX	41 - 51													
Area 3 - Fire Training Pit														
FTP-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					12	2	1	1
FTP-SB01-0406	4 - 6													
FTP-SB02-0002	0 - 2													
FTP-SB02-0406	4 - 6													
FTP-SB03-0002	0 - 2													
FTP-SB03-0406	4 - 6													
FTP-SB04-0002	0 - 2													
FTP-SB04-0406	4 - 6													
FTP-SB05-0002	0 - 2													
FTP-SB05-0406	4 - 6													
FTP-SB06-0002	0 - 2													
FTP-SB06-0406	4 - 6													
FTP-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	4	1	0	0				
FTP-TW02-XXXX	TBD													
FTP-TW03-XXXX	TBD													
FTP-TW04-XXXX	TBD													

TABLE 4-2
SUMMARY OF SAMPLE NOMENCLATURE AND ANALYSIS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
Page 2 of 4

Sample Nomenclature	Depth (feet)	Media	Analysis (Method)	Container	Preservation	Holding Time	Aqueous				Soil			
							Samples	QA/QC [1]			Samples	QA/QC [1]		
								Duplicate	MS	FRB		Duplicate	MS	FRB
Area 4 - Helicopter Crash Site														
HCS-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					6	1	0	0
HCS-SB01-0204	4 - 6													
HCS-SB02-0002	0 - 2													
HCS-SB02-0204	4 - 6													
HCS-SB03-0002	0 - 2													
HCS-SB03-0204	4 - 6													
HCS-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	4	0	0	1				
HCS-TW02-XXXX	TBD													
HCS-TW03-XXXX	TBD													
HCS-TW04-XXXX	TBD													
Area 5 - Former Wastewater Treatment Plant														
FWTP-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					8	0	1	1
FWTP-SB01-0406	4 - 6													
FWTP-SB02-0002	0 - 2													
FWTP-SB02-0406	4 - 6													
FWTP-SB03-0002	0 - 2													
FWTP-SB03-0406	4 - 6													
FWTP-SB04-0002	0 - 2													
FWTP-SB04-0406	4 - 6													
FWTP-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	5	1	0	0				
FWTP-TW02-XXXX	TBD													
FWTP-TW03-XXXX	TBD													
FWTP-TW04-XXXX	TBD													
FWTP-TW05-XXXX	TBD													
Area 6 - Lear Soil Bioremediation Landfarm														
LSBF-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					6	1	0	0
LSBF-SB01-0406	4 - 6													
LSBF-SB02-0002	0 - 2													
LSBF-SB02-0406	4 - 6													
LSBF-SB03-0002	0 - 2													
LSBF-SB03-0406	4 - 6													
LSBF-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	4	1	1	1				
LSBF-TW02-XXXX	TBD													
LSBF-TW03-XXXX	TBD													
LSBF-TW04-XXXX	TBD													
Area 7 - Observation Well 06 Area														
OW06-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					8	0	0	1
OW06-SB01-0406	4 - 6													
OW06-SB02-0002	0 - 2													
OW06-SB02-0406	4 - 6													
OW06-SB03-0002	0 - 2													
OW06-SB03-0406	4 - 6													
OW06-SB04-0002	0 - 2													
OW06-SB04-0406	4 - 6													
OW06-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	4	0	0	0				
OW06-TW02-XXXX	TBD													
OW06-TW03-XXXX	TBD													
OW06-TW04-XXXX	TBD													

TABLE 4-2
SUMMARY OF SAMPLE NOMENCLATURE AND ANALYSIS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
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Sample Nomenclature	Depth (feet)	Media	Analysis (Method)	Container	Preservation	Holding Time	Aqueous				Soil			
							Samples	QA/QC [1]			Samples	QA/QC [1]		
								Duplicate	MS	FRB		Duplicate	MS	FRB
Area 8 - Wastewater Treatment Plant														
WWTP-SD01-0006	0 - 0.5	Sediment	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					2	1	1	0
WWTP-SD02-0006	0 - 0.5													
WWTP-SW01-2019XXXX	NA	Surface Water		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	2	1	1	1				
WWTP-SW02-2019XXXX	NA													
Outfall001-2019XXXX	NA	Surface Water		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	1	0	1	0				
Area 9 - Former Fire Training Area														
FFTA-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					21	2	1	1
FFTA-SB01-0406	4 - 6													
FFTA-SB01-XXXX	TBD													
FFTA-SB02-0002	0 - 2													
FFTA-SB02-0406	4 - 6													
FFTA-SB02-XXXX	TBD													
FFTA-SB03-0002	0 - 2													
FFTA-SB03-0406	4 - 6													
FFTA-SB03-XXXX	TBD													
FFTA-SB04-0002	0 - 2													
FFTA-SB04-0406	4 - 6													
FFTA-SB04-XXXX	TBD													
FFTA-SB05-0002	0 - 2													
FFTA-SB05-0406	4 - 6													
FFTA-SB05-XXXX	TBD													
FFTA-SB06-0002	0 - 2													
FFTA-SB06-0406	4 - 6													
FFTA-SB06-XXXX	TBD													
FFTA-SB07-0002	0 - 2													
FFTA-SB07-0406	4 - 6													
FFTA-SB07-XXXX	TBD													
FFTA-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	16	2	0	1				
FFTA-TW02-XXXX	TBD													
FFTA-TW03-XXXX	TBD													
FFTA-TW04-XXXX	TBD													
FFTA-TW05-XXXX	TBD													
FFTA-TW06-XXXX	TBD													
FFTA-TW06-XXXX[2]	TBD													
FFTA-TW07-XXXX	TBD													
FFTA-TW07-XXXX[2]	TBD													
FFTA-TW08-XXXX	TBD													
FFTA-MW102D-2019XXXX	37 - 47													
FFTA-MW103D-2019XXXX	38 - 48													
14-MW005-2019XXXX	1 - 6													
15-MW005-2019XXXX	7 - 12													
WFF9-MW2-2019XXXX	16 - 26													
WFF1-MW7-2019XXXX	2 - 12													
FFTA-SD01-0006	0 - 0.5	Sediment		One 6-once HDPE jar		28 days to extraction; 30 days to analysis					4	1	1	0
FFTA-SD02-0006	0 - 0.5													
FFTA-SD03-0006	0 - 0.5													
FFTA-SD04-0006	0 - 0.5													
FFTA-SW01-2019XXXX	NA	Surface Water		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	8	0	0	0				
FFTA-SW02-2019XXXX	NA													
FFTA-SW03-2019XXXX	NA													
FFTA-SW04-2019XXXX	NA													
Outfall003-2019XXXX	NA													
Outfall5-2019XXXX	NA													
Outfall6-2019XXXX	NA													
Outfall13-2019XXXX	NA													

TABLE 4-2
SUMMARY OF SAMPLE NOMENCLATURE AND ANALYSIS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA
Page 4 of 4

Sample Nomenclature	Depth (feet)	Media	Analysis (Method)	Container	Preservation	Holding Time	Aqueous				Soil			
							Samples	QA/QC[1]			Samples	QA/QC[1]		
								Duplicate	MS	FRB		Duplicate	MS	FRB
Area 10 - Lear Jet Crash Site														
LJC-SB01-0002	0 - 2	Soil	Method 537 Modified	One 6-once HDPE jar	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	28 days to extraction; 30 days to analysis					10	1	0	1
LJC-SB01-0406	4 - 6													
LJC-SB02-0002	0 - 2													
LJC-SB02-0406	4 - 6													
LJC-SB03-0002	0 - 2													
LJC-SB03-0406	4 - 6													
LJC-SB04-0002	0 - 2													
LJC-SB04-0406	4 - 6													
LJC-SB05-0002	0 - 2													
LJC-SB05-0406	4 - 6													
LJC-TW01-XXXX	TBD	Groundwater		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	6	1	0	1				
LJC-TW01-XXXX[2]	TBD													
LJC-TW02-XXXX	TBD													
LJC-TW03-XXXX	TBD													
LJC-TW04-XXXX	TBD													
LJC-TW05-XXXX	TBD													
LJC-SD01-0006	0 - 0.5	Sediment		One 6-once HDPE jar		28 days to extraction; 30 days to analysis					2	0	0	0
LJC-SD02-0006	0 - 0.5													
LJC-SW01-2019XXXX	NA	Surface Water		Two 125-mL HDPE bottles		14 days to extraction; 28 days for analysis	4	0	0	0				
LJC-SW02-2019XXXX	NA													
Outfall9-2019XXXX	NA													
Outfall10-2019XXXX	NA													
USACE Construction Debris Landfill														
CDL-MW001-2019XXXX	23 - 33	Groundwater	Method 537 Modified	Two 125-mL HDPE bottles	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	14 days to extraction; 28 days for analysis	6	0	0	1				
CDL-MW002-2019XXXX	14 - 24													
CDL-MW003-2019XXXX	3 - 13													
CDL-MW004-2019XXXX	4 - 14													
CDL-MW005-2019XXXX	4 - 14													
CDL-MW006-2019XXXX	11 - 21													
Waste Oil Dump														
15-MW007-2019XXXX	15 - 30	Groundwater	Method 537 Modified	Two 125-mL HDPE bottles	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	14 days to extraction; 28 days for analysis	3	0	0	0				
WOD-MW002D-2019XXXX	23 - 28													
WOD-MW008-2019XXXX	18 - 28													
Other Facility Outfall Samples														
NOAAOutfall-2019XXXX	NA	Surface Water	Method 537 Modified	Two 125-mL HDPE bottles	Cool to ≤10°C for up to 48 hours after sampling and prior to receipt at the laboratory, then ≤ 6°C during laboratory storage	14 days to extraction; 28 days for analysis	2	0	0	0				
Outfall8-2019XXXX	NA													
						TOTAL	**78**	**8**	**4**	**7**	**101**	**11**	**6**	**6**

QA/QC - Quality Assurance/ Quality Control
MS - Matrix Spike
FRB - Field Reagent Blank
TBD - To Be Determined

NA - Not Applicable
mL - Milliliter
°C - Degrees Centigrade

Notes:

[1] - One duplicate sample will be collected per ten parent samples for each matrix (i.e. soil, sediment, groundwater, and surface water); one MS will be collected per 20 samples for each matrix; one FRB will be collected per field sampling day.

[2] - Proposed deeper groundwater sample to be collected above the interstitial clay or at approximately 35-40 feet bgs if clay is not encountered. (Max DPT depth limitations at the site)

FIGURES

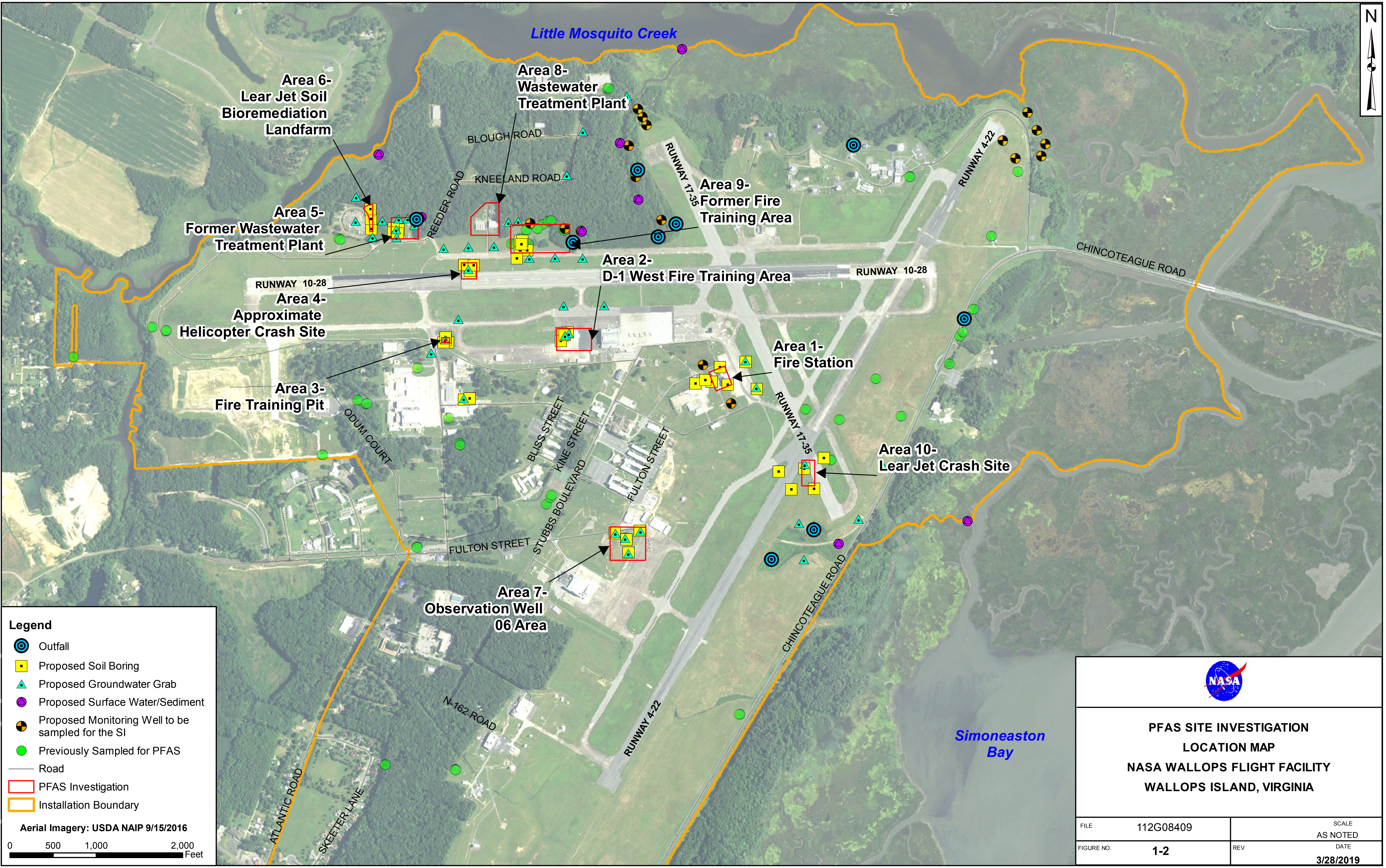
Aerial photograph from ESRI Bing Maps map service
(© 2011 Microsoft Corporation and its data suppliers).

TETRA TECH

FACILITY LOCATION MAP
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	SCALE AS NOTED
FIGURE NO. 1-1	REV DATE 7/9/14

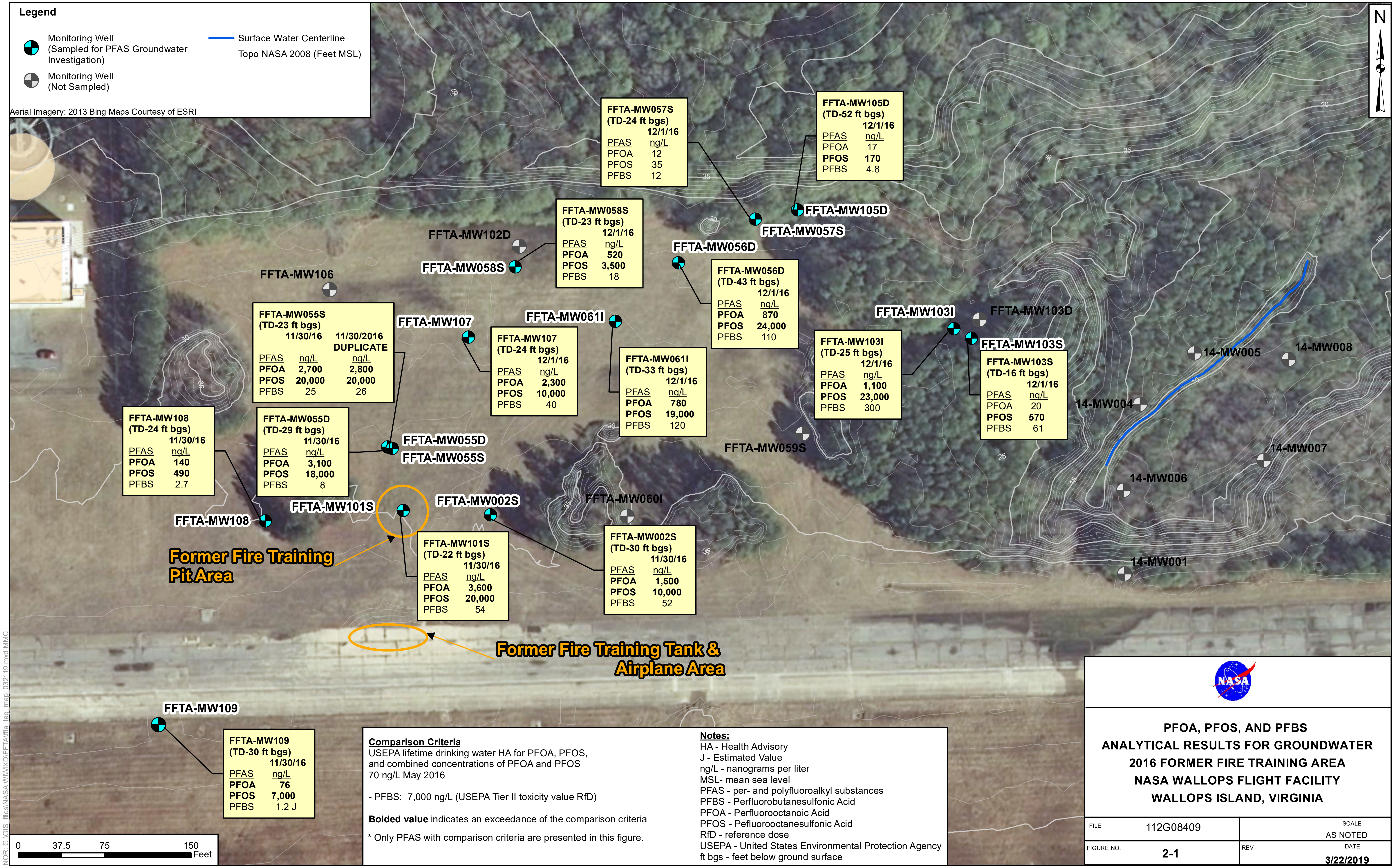
G:\GIS_files\NASA WI\MXD\AI20\AI20_sitelocmap_8x11.mxd MMC



NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_PROPOSED_1000.mxd MMC

PFAS SITE INVESTIGATION
LOCATION MAP
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	1-2	REV	DATE 3/28/2019



Comparison Criteria

USEPA lifetime drinking water HA for PFOA, PFOS, and combined concentrations of PFOA and PFOS 70 ng/L May 2016

- PFBS: 7,000 ng/L (USEPA Tier II toxicity value RfD)

Bolded value indicates an exceedance of the comparison criteria

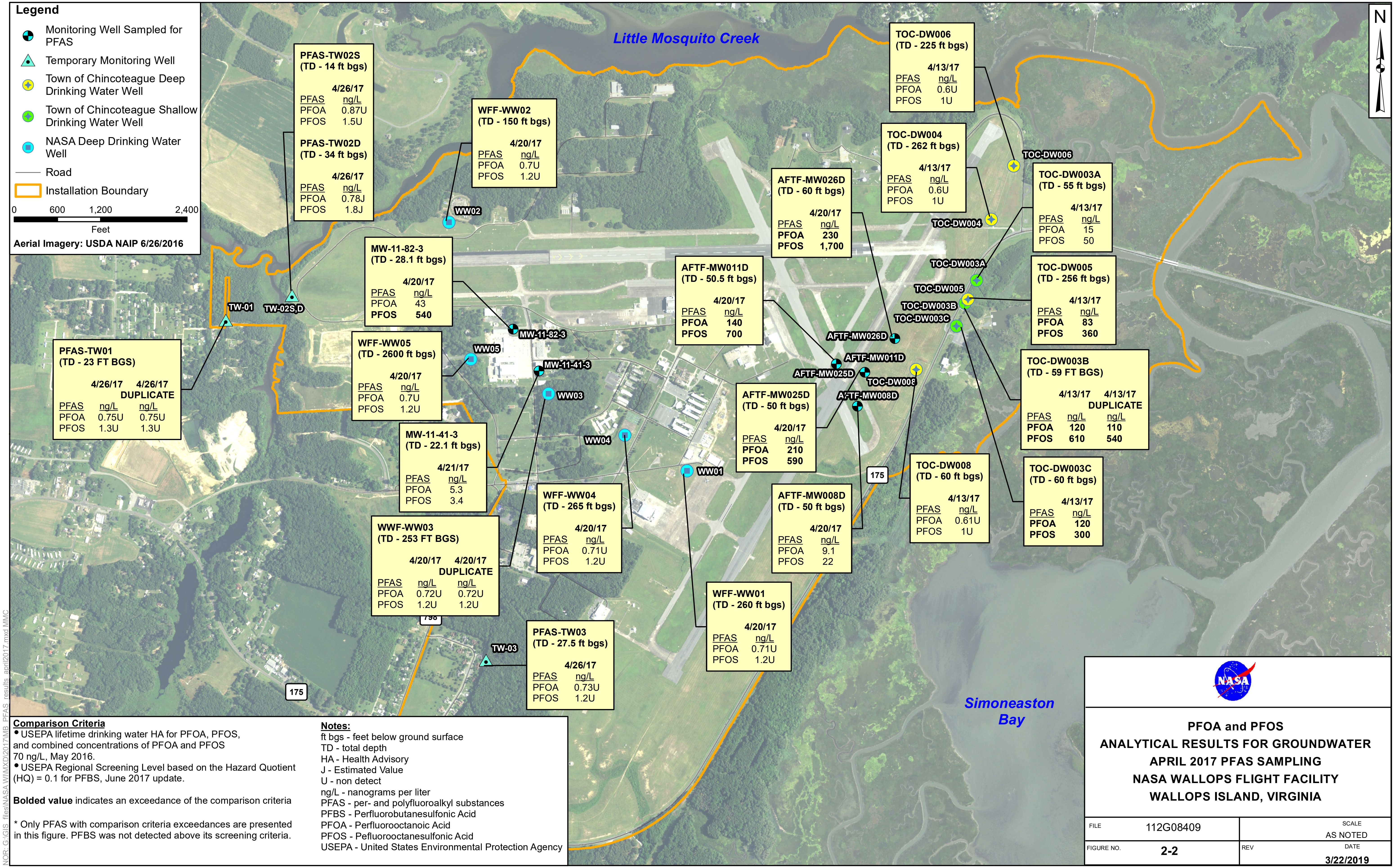
* Only PFAS with comparison criteria are presented in this figure.

Notes:

HA - Health Advisory
J - Estimated Value
ng/L - nanograms per liter
MSL- mean sea level
PFAS - per- and polyfluoroalkyl substances
PFBS - Perfluorobutanesulfonic Acid
PFOA - Perfluorooctanoic Acid
PFOS - Perfluorooctanesulfonic Acid
RfD - reference dose
USEPA - United States Environmental Protection Agency
ft bgs - feet below ground surface

PFOA, PFOS, AND PFBS ANALYTICAL RESULTS FOR GROUNDWATER 2016 FORMER FIRE TRAINING AREA NASA WALLOPS FLIGHT FACILITY WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-1	REV	DATE 3/22/2019



Legend

- ● Monitoring Well Sampled for PFAS
- ▲ Temporary Monitoring Well
- ● Town of Chincoteague Deep Drinking Water Well
- ● Town of Chincoteague Shallow Drinking Water Well
- ● NASA Deep Drinking Water Well
- — Road
- ▭ Installation Boundary

0 600 1,200 2,400
Feet

Aerial Imagery: USDA NAIP 6/26/2016

PFAS-TW02S
(TD - 14 ft bgs)

PFAS	4/26/17 ng/L
PFOA	0.87U
PFOS	1.5U

PFAS-TW02D
(TD - 34 ft bgs)

PFAS	4/26/17 ng/L
PFOA	0.78J
PFOS	1.8J

WFF-WW02
(TD - 150 ft bgs)

PFAS	4/20/17 ng/L
PFOA	0.7U
PFOS	1.2U

PFAS-TW01
(TD - 23 FT BGS)

PFAS	4/26/17 ng/L	4/26/17 DUPLICATE ng/L
PFOA	0.75U	0.75U
PFOS	1.3U	1.3U

MW-11-82-3
(TD - 28.1 ft bgs)

PFAS	4/20/17 ng/L
PFOA	43
PFOS	**540**

WFF-WW05
(TD - 2600 ft bgs)

PFAS	4/20/17 ng/L
PFOA	0.7U
PFOS	1.2U

MW-11-41-3
(TD - 22.1 ft bgs)

PFAS	4/21/17 ng/L
PFOA	5.3
PFOS	3.4

WWF-WW03
(TD - 253 FT BGS)

PFAS	4/20/17 ng/L	4/20/17 DUPLICATE ng/L
PFOA	0.72U	0.72U
PFOS	1.2U	1.2U

WFF-WW04
(TD - 265 ft bgs)

PFAS	4/20/17 ng/L
PFOA	0.71U
PFOS	1.2U

PFAS-TW03
(TD - 27.5 ft bgs)

PFAS	4/26/17 ng/L
PFOA	0.73U
PFOS	1.2U

AFTF-MW011D
(TD - 50.5 ft bgs)

PFAS	4/20/17 ng/L
PFOA	**140**
PFOS	**700**

AFTF-MW026D
(TD - 60 ft bgs)

PFAS	4/20/17 ng/L
PFOA	**230**
PFOS	**1,700**

AFTF-MW025D
(TD - 50 ft bgs)

PFAS	4/20/17 ng/L
PFOA	**210**
PFOS	**590**

AFTF-MW008D
(TD - 50 ft bgs)

PFAS	4/20/17 ng/L
PFOA	9.1
PFOS	22

WFF-WW01
(TD - 260 ft bgs)

PFAS	4/20/17 ng/L
PFOA	0.71U
PFOS	1.2U

TOC-DW006
(TD - 225 ft bgs)

PFAS	4/13/17 ng/L
PFOA	0.6U
PFOS	1U

TOC-DW004
(TD - 262 ft bgs)

PFAS	4/13/17 ng/L
PFOA	0.6U
PFOS	1U

TOC-DW003A
(TD - 55 ft bgs)

PFAS	4/13/17 ng/L
PFOA	15
PFOS	50

TOC-DW005
(TD - 256 ft bgs)

PFAS	4/13/17 ng/L
PFOA	**83**
PFOS	**360**

TOC-DW003B
(TD - 59 FT BGS)

PFAS	4/13/17 ng/L	4/13/17 DUPLICATE ng/L
PFOA	**120**	**110**
PFOS	**610**	**540**

TOC-DW008
(TD - 60 ft bgs)

PFAS	4/13/17 ng/L
PFOA	0.61U
PFOS	1U

TOC-DW003C
(TD - 60 ft bgs)

PFAS	4/13/17 ng/L
PFOA	**120**
PFOS	**300**

Comparison Criteria

- USEPA lifetime drinking water HA for PFOA, PFOS, and combined concentrations of PFOA and PFOS 70 ng/L, May 2016.
- USEPA Regional Screening Level based on the Hazard Quotient (HQ) = 0.1 for PFBS, June 2017 update.

Bolded value indicates an exceedance of the comparison criteria

* Only PFAS with comparison criteria exceedances are presented in this figure. PFBS was not detected above its screening criteria.

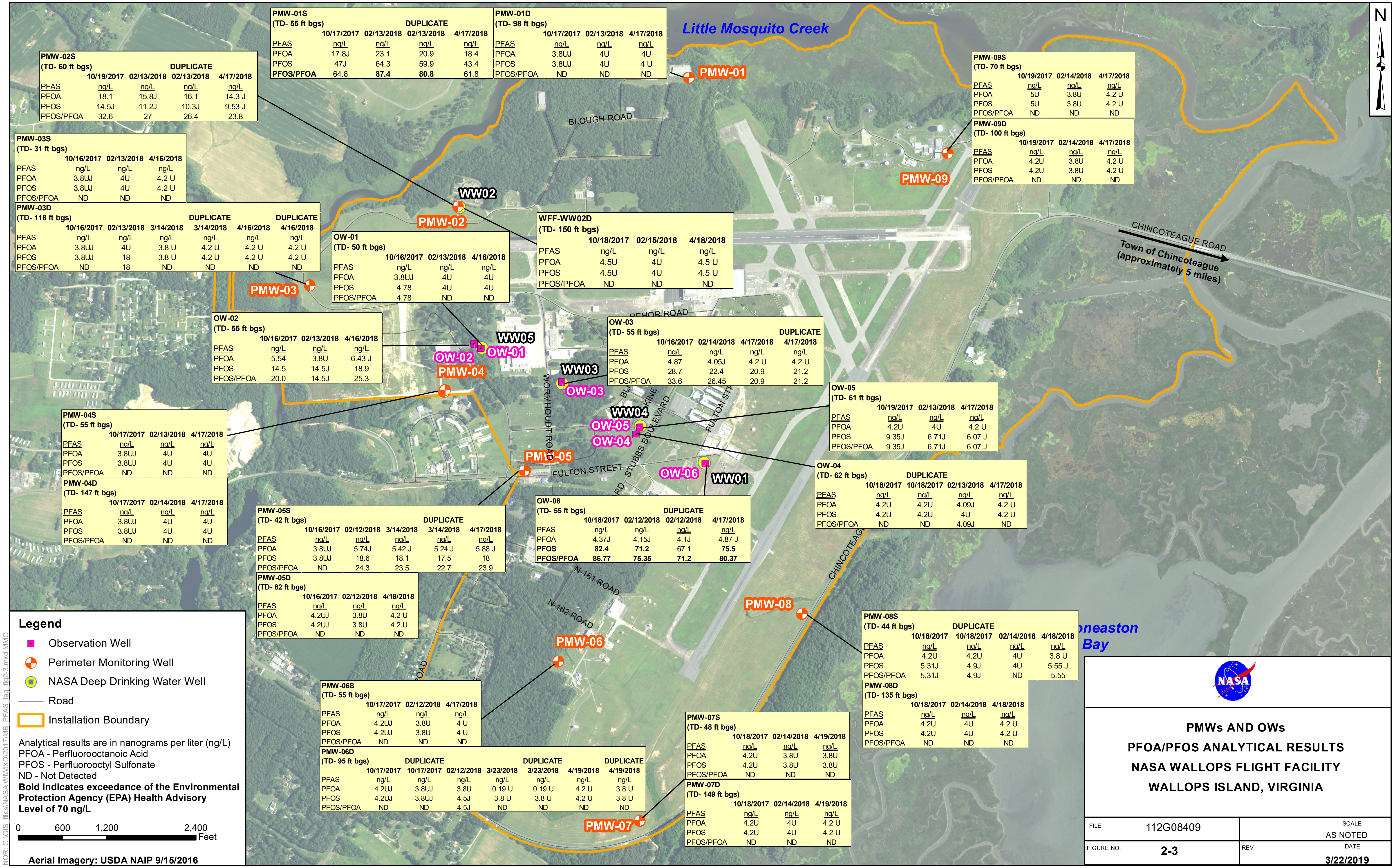
Notes:

ft bgs - feet below ground surface
TD - total depth
HA - Health Advisory
J - Estimated Value
U - non detect
ng/L - nanograms per liter
PFAS - per- and polyfluoroalkyl substances
PFBS - Perfluorobutanesulfonic Acid
PFOA - Perfluorooctanoic Acid
PFOS - Pefluorooctanesulfonic Acid
USEPA - United States Environmental Protection Agency

PFOA and PFOS
ANALYTICAL RESULTS FOR GROUNDWATER
APRIL 2017 PFAS SAMPLING
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-2	REV	DATE 3/22/2019

NOR: G:\GIS_files\NASA WI\MXD\2017MB_PFAS_results_april2017.mxd MMC



PMW-01S
(TD- 55 ft bgs)

	10/17/2017	02/13/2018	DUPLICATE 02/13/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L	ng/L
PFOA	17.8J	23.1	20.9	18.4
PFOS	47J	64.3	59.9	43.4
PFOS/PFOA	64.8	**87.4**	**80.8**	61.8

PMW-01D
(TD- 98 ft bgs)

	10/17/2017	02/13/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	3.8UJ	4U	4U
PFOS	3.8UJ	4U	4 U
PFOS/PFOA	ND	ND	ND

PMW-02S
(TD- 60 ft bgs)

	10/19/2017	02/13/2018	DUPLICATE 02/13/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L	ng/L
PFOA	18.1	15.8J	16.1	14.3 J
PFOS	14.5J	11.2J	10.3J	9.53 J
PFOS/PFOA	32.6	27	26.4	23.8

PMW-03S
(TD- 31 ft bgs)

	10/16/2017	02/13/2018	4/16/2018
PFAS	ng/L	ng/L	ng/L
PFOA	3.8UJ	4U	4.2 U
PFOS	3.8UJ	4U	4.2 U
PFOS/PFOA	ND	ND	ND

PMW-03D
(TD- 118 ft bgs)

	10/16/2017	02/13/2018	3/14/2018	DUPLICATE 3/14/2018	4/16/2018	DUPLICATE 4/16/2018
PFAS	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
PFOA	3.8UJ	4U	3.8 U	4.2 U	4.2 U	4.2 U
PFOS	3.8UJ	18	3.8 U	4.2 U	4.2 U	4.2 U
PFOS/PFOA	ND	18	ND	ND	ND	ND

OW-01
(TD- 50 ft bgs)

	10/16/2017	02/13/2018	4/16/2018
PFAS	ng/L	ng/L	ng/L
PFOA	3.8UJ	4U	4U
PFOS	4.78	4U	4U
PFOS/PFOA	4.78	ND	ND

WFF-WW02D
(TD- 150 ft bgs)

	10/18/2017	02/15/2018	4/18/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.5U	4U	4.5 U
PFOS	4.5U	4U	4.5 U
PFOS/PFOA	ND	ND	ND

PMW-09S
(TD- 70 ft bgs)

	10/19/2017	02/14/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	5U	3.8U	4.2 U
PFOS	5U	3.8U	4.2 U
PFOS/PFOA	ND	ND	ND

PMW-09D
(TD- 100 ft bgs)

	10/19/2017	02/14/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2U	3.8U	4.2 U
PFOS	4.2U	3.8U	4.2 U
PFOS/PFOA	ND	ND	ND

OW-02
(TD- 55 ft bgs)

	10/16/2017	02/13/2018	4/16/2018
PFAS	ng/L	ng/L	ng/L
PFOA	5.54	3.8U	6.43 J
PFOS	14.5	14.5J	18.9
PFOS/PFOA	20.0	14.5J	25.3

OW-03
(TD- 55 ft bgs)

	10/16/2017	02/14/2018	4/17/2018	DUPLICATE 4/17/2018
PFAS	ng/L	ng/L	ng/L	ng/L
PFOA	4.87	4.05J	4.2 U	4.2 U
PFOS	28.7	22.4	20.9	21.2
PFOS/PFOA	33.6	26.45	20.9	21.2

OW-05
(TD- 61 ft bgs)

	10/19/2017	02/13/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2U	4U	4.2 U
PFOS	9.35J	6.71J	6.07 J
PFOS/PFOA	9.35J	6.71J	6.07 J

PMW-04S
(TD- 55 ft bgs)

	10/17/2017	02/13/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	3.8UJ	4U	4U
PFOS	3.8UJ	4U	4U
PFOS/PFOA	ND	ND	ND

PMW-04D
(TD- 147 ft bgs)

	10/17/2017	02/14/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	3.8UJ	4U	4U
PFOS	3.8UJ	4U	4U
PFOS/PFOA	ND	ND	ND

OW-04
(TD- 62 ft bgs)

	10/18/2017	DUPLICATE 10/18/2017	02/13/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L	ng/L
PFOA	4.2U	4.2U	4.09J	4.2 U
PFOS	4.2U	4.2U	4U	4.2 U
PFOS/PFOA	ND	ND	4.09J	ND

PMW-05S
(TD- 42 ft bgs)

	10/16/2017	02/12/2018	3/14/2018	DUPLICATE 3/14/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L	ng/L	ng/L
PFOA	3.8UJ	5.74J	5.42 J	5.24 J	5.88 J
PFOS	3.8UJ	18.6	18.1	17.5	18
PFOS/PFOA	ND	24.3	23.5	22.7	23.9

OW-06
(TD- 55 ft bgs)

	10/18/2017	02/12/2018	DUPLICATE 02/12/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L	ng/L
PFOA	4.37J	4.15J	4.1J	4.87 J
PFOS	**82.4**	**71.2**	67.1	**75.5**
PFOS/PFOA	**86.77**	**75.35**	**71.2**	**80.37**

PMW-05D
(TD- 82 ft bgs)

	10/16/2017	02/12/2018	4/18/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2UJ	3.8U	4.2 U
PFOS	4.2UJ	3.8U	4.2 U
PFOS/PFOA	ND	ND	ND

PMW-08S
(TD- 44 ft bgs)

	10/18/2017	DUPLICATE 10/18/2017	02/14/2018	4/18/2018
PFAS	ng/L	ng/L	ng/L	ng/L
PFOA	4.2U	4.2U	4U	3.8 U
PFOS	5.31J	4.9J	4U	5.55 J
PFOS/PFOA	5.31J	4.9J	ND	5.55

PMW-08D
(TD- 135 ft bgs)

	10/18/2017	02/14/2018	4/18/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2U	4U	4.2 U
PFOS	4.2U	4U	4.2 U
PFOS/PFOA	ND	ND	ND

PMW-06S
(TD- 55 ft bgs)

	10/17/2017	02/12/2018	4/17/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2UJ	3.8U	4 U
PFOS	4.2UJ	3.8U	4 U
PFOS/PFOA	ND	ND	ND

PMW-06D
(TD- 95 ft bgs)

	10/17/2017	DUPLICATE 10/17/2017	02/12/2018	3/23/2018	DUPLICATE 3/23/2018	4/19/2018	DUPLICATE 4/19/2018
PFAS	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
PFOA	4.2UJ	3.8UJ	3.8U	0.19 U	0.19 U	4.2 U	3.8 U
PFOS	4.2UJ	3.8UJ	4.5J	3.8 U	3.8 U	4.2 U	3.8 U
PFOS/PFOA	ND	ND	4.5J	ND	ND	ND	ND

PMW-07S
(TD- 48 ft bgs)

	10/18/2017	02/14/2018	4/19/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2U	3.8U	3.8U
PFOS	4.2U	3.8U	3.8U
PFOS/PFOA	ND	ND	ND

PMW-07D
(TD- 149 ft bgs)

	10/18/2017	02/14/2018	4/19/2018
PFAS	ng/L	ng/L	ng/L
PFOA	4.2U	4U	4.2 U
PFOS	4.2U	4U	4.2 U
PFOS/PFOA	ND	ND	ND

Legend

- ■ Observation Well
- ⊕ Perimeter Monitoring Well
- ● NASA Deep Drinking Water Well
- — Road
- ▭ Installation Boundary

Analytical results are in nanograms per liter (ng/L)
PFOA - Perfluorooctanoic Acid
PFOS - Perfluorooctyl Sulfonate
ND - Not Detected
Bold indicates exceedance of the Environmental Protection Agency (EPA) Health Advisory Level of 70 ng/L

0 600 1,200 2,400 Feet

Aerial Imagery: USDA NAIP 9/15/2016

NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_tag_fig2-3.mxd MMC

PMWs AND OWs
PFOA/PFOS ANALYTICAL RESULTS
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE AS NOTED
FIGURE NO.	**2-3**	REV DATE **3/22/2019**

Legend

- ■ Proposed Soil Boring
- ▲ Proposed Groundwater Grab
- ● Proposed Monitoring Well to be sampled for the SI
- ● Monitoring Well
- — Road
- ▭ PFAS Investigation Area

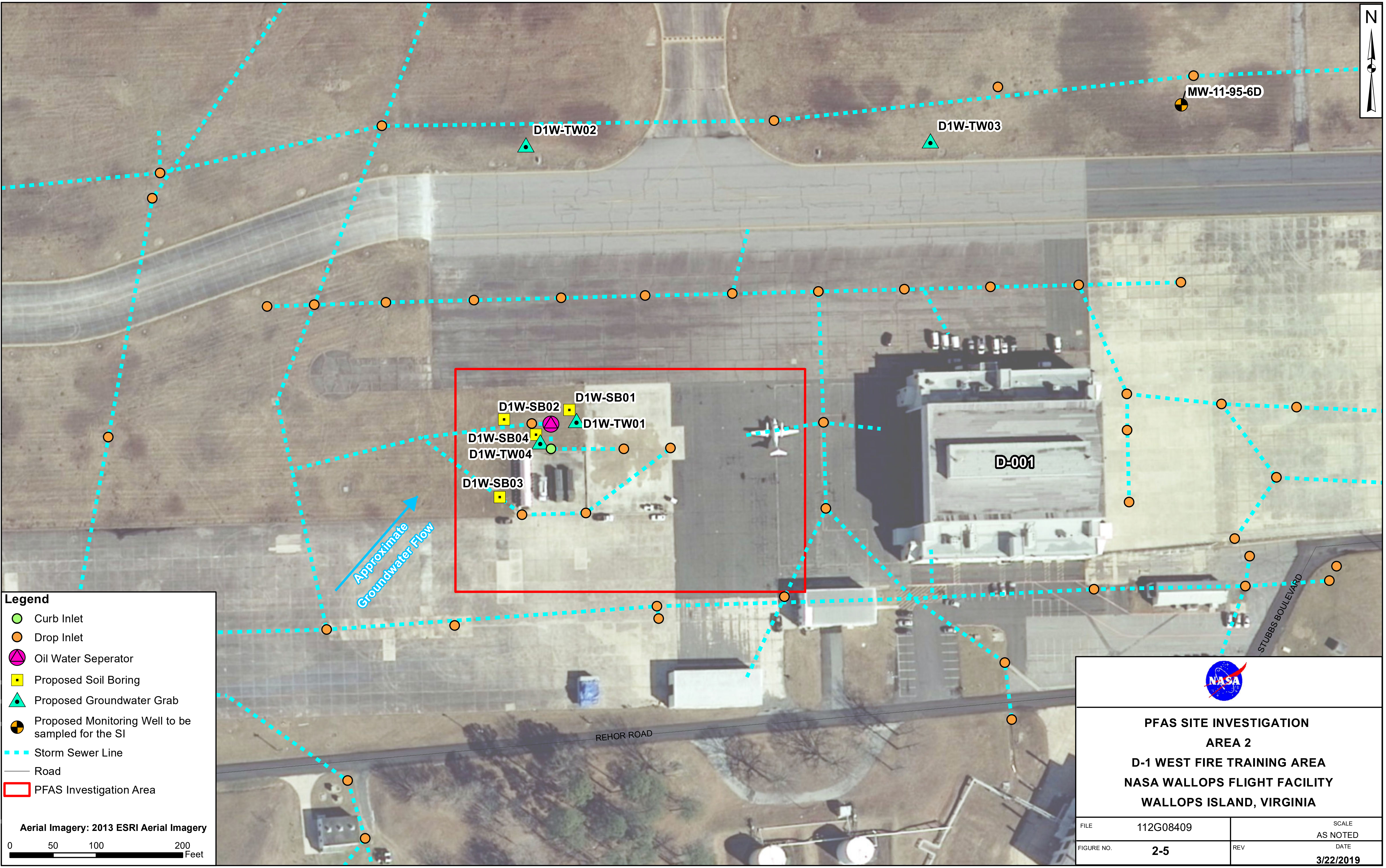
Aerial Imagery: 2013 ESRI Aerial Imagery

0 37.5 75 150
Feet

PFAS SITE INVESTIGATION
AREA 1
BUILDING B-129 FIRE STATION
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	**2-4**	REV	DATE **3/22/2019**

NOR: G:\GIS files\NASA WI\MXD\2017\MB PFAS Area 1.mxd MMC



PFAS SITE INVESTIGATION
AREA 2
D-1 WEST FIRE TRAINING AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-5	REV	DATE 3/22/2019

NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_Area_2.mxd MMC

Legend

- 🟨 Proposed Soil Boring
- ▲ Proposed Groundwater Grab
- ◐ Monitoring Well
- 🟢 Previously Sampled for PFAS
- — Road
- ▬ Former Fire Training Pit
- 🟥 PFAS Investigation Area

Aerial Imagery: 2013 ESRI Aerial Imagery

PFAS SITE INVESTIGATION
AREA 3
FIRE TRAINING PIT
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-6	REV	DATE 3/22/2019

NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_Area_3.mxd MMC

Legend

- 🟨 Proposed Soil Boring
- ▲ Proposed Groundwater Grab
- ● Previously Sampled for PFAS
- ◕ Monitoring Wells
- — Road
- ☐ PFAS Investigation Area

Aerial Imagery: 2013 ESRI Bing Maps

PFAS SITE INVESTIGATION
AREA 4
HELICOPTER CRASH SITE
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	**2-7**	REV	DATE **3/22/2019**

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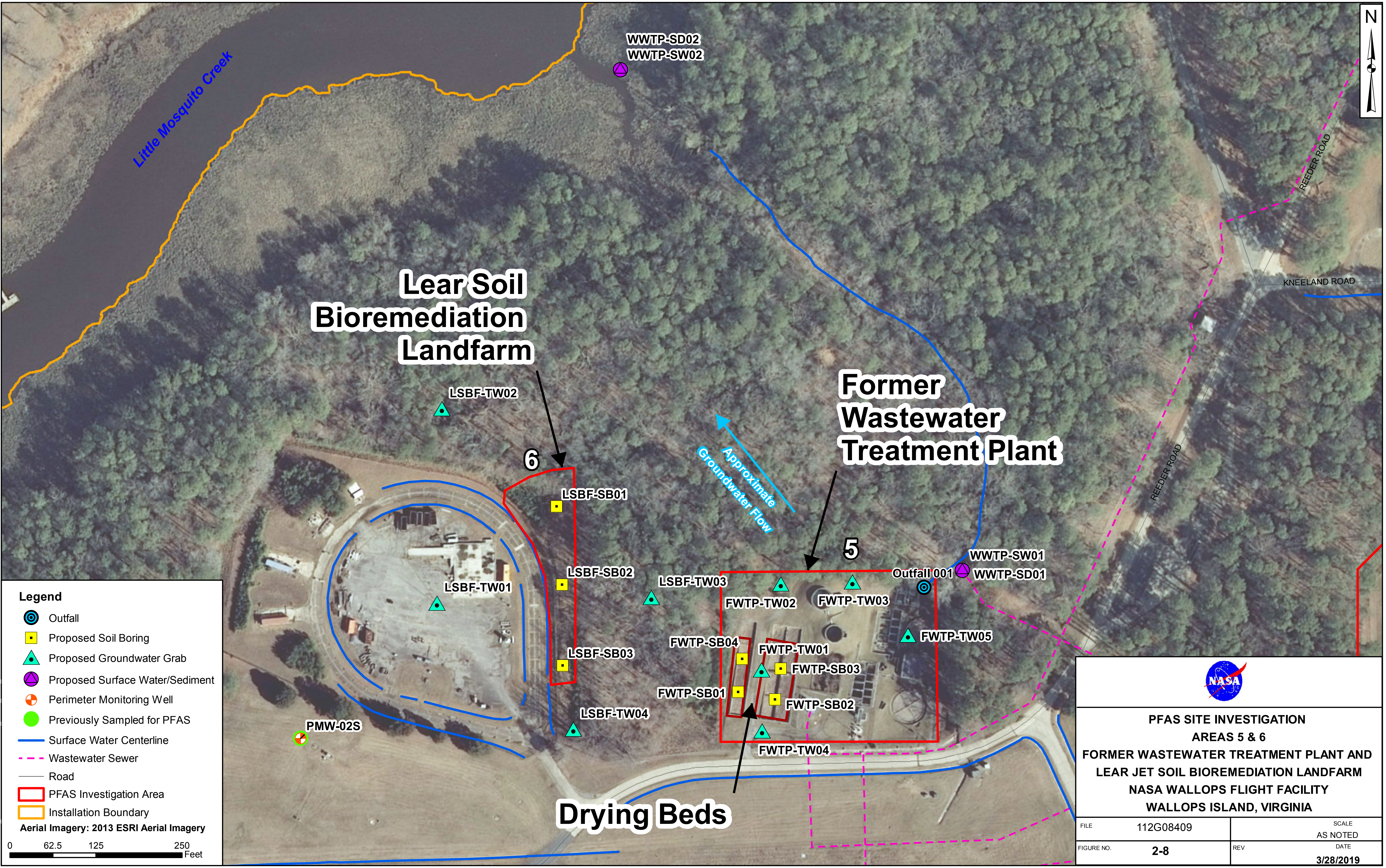

PFAS SITE INVESTIGATION
AREAS 5 & 6
FORMER WASTEWATER TREATMENT PLANT AND
LEAR JET SOIL BIOREMEDIATION LANDFARM
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-8	REV	DATE 3/28/2019

NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_Area_5.mxd MMC

Legend

- 🟨 Proposed Soil Boring
- ▲ Proposed Groundwater Grab
- 🟪 Observation Well
- ⊕ Town of Chincoteague Shallow Drinking Water Well
- ● Previously Sampled for PFAS
- — Road
- ▭ PFAS Investigation Area

Aerial Imagery: 2013 ESRI Bing Maps

PFAS SITE INVESTIGATION
AREA 7
OBSERVATION WELL 06 AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	**2-9**	REV	DATE 3/22/2019

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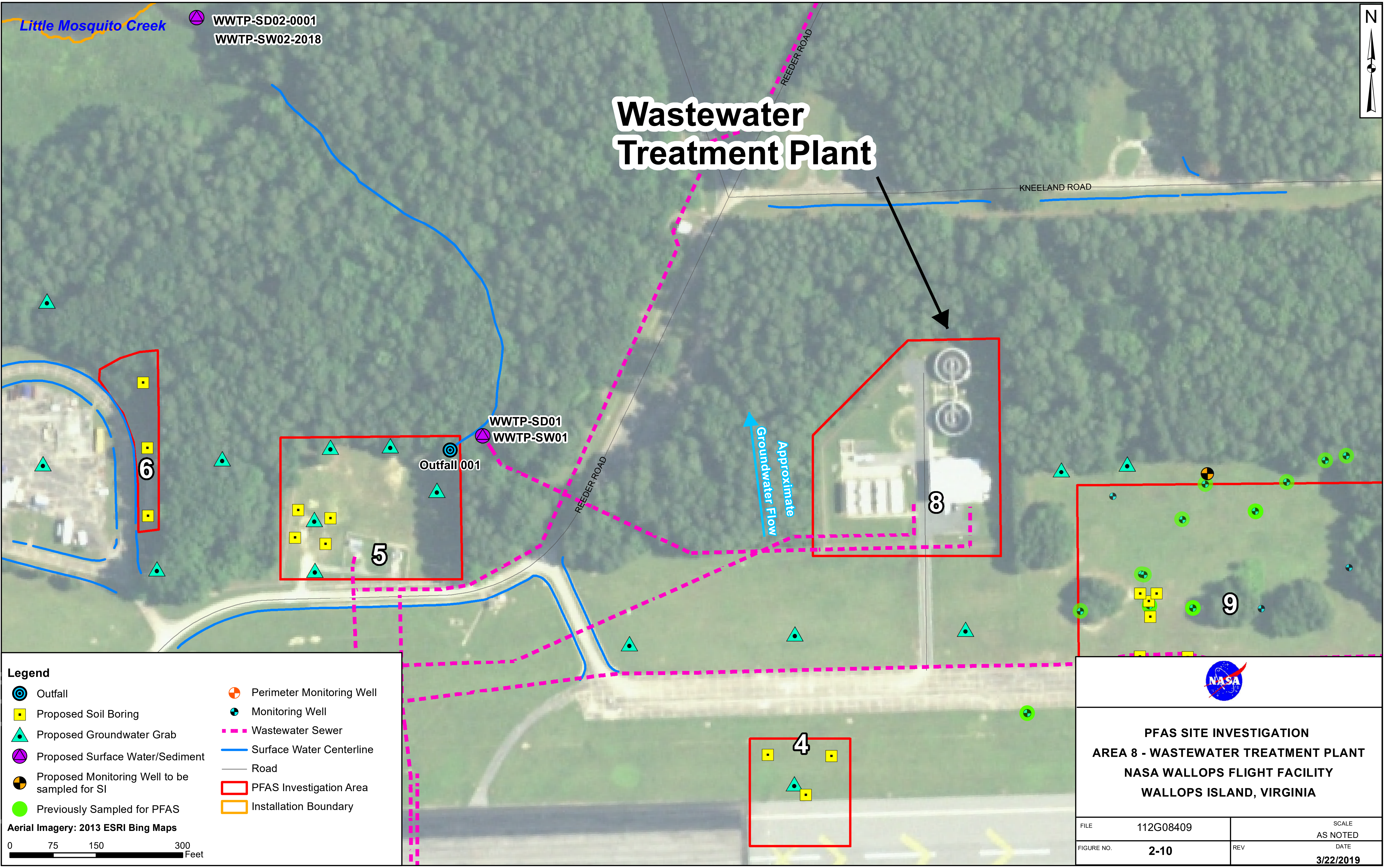

Legend

- ◎ Outfall
- 🟨 Proposed Soil Boring
- ▲ Proposed Groundwater Grab
- ● Proposed Surface Water/Sediment
- ● Proposed Monitoring Well to be sampled for SI
- 🟢 Previously Sampled for PFAS
- ● Perimeter Monitoring Well
- ● Monitoring Well
- Wastewater Sewer
- Surface Water Centerline
- Road
- 🟥 PFAS Investigation Area
- 🟧 Installation Boundary

Aerial Imagery: 2013 ESRI Bing Maps

PFAS SITE INVESTIGATION
AREA 8 - WASTEWATER TREATMENT PLANT
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-10	REV	DATE 3/22/2019

NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_Area_8_new.mxd MMC

Legend

- ◎ Outfall
- ▣ Proposed Soil Boring
- ▲ Proposed Groundwater Grab
- ◬ Proposed Surface Water/Sediment
- ◐ Monitoring Well
- ◐ Proposed Monitoring Well to be sampled for SI
- ● Previously Sampled for PFAS
- ━ Surface Water Centerline
- ─ Topo NASA 2008 (Feet MSL)

0 37.5 75 150 Feet

Aerial Imagery: 2013 Bing Maps Courtesy of ESRI

PFAS SITE INVESTIGATION
AREA 9
FORMER FIRE TRAINING AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-11A	REV	DATE 3/22/2019

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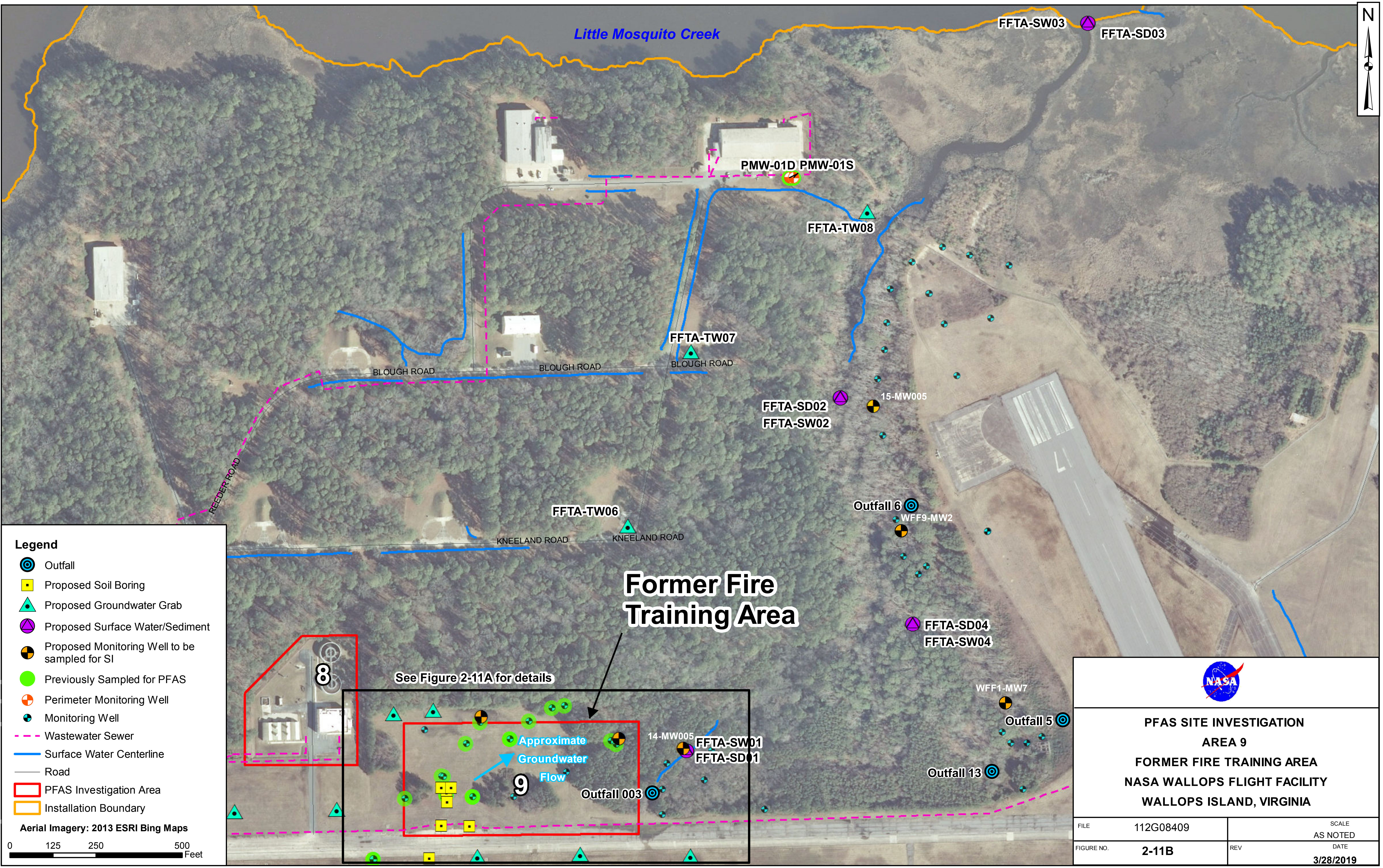
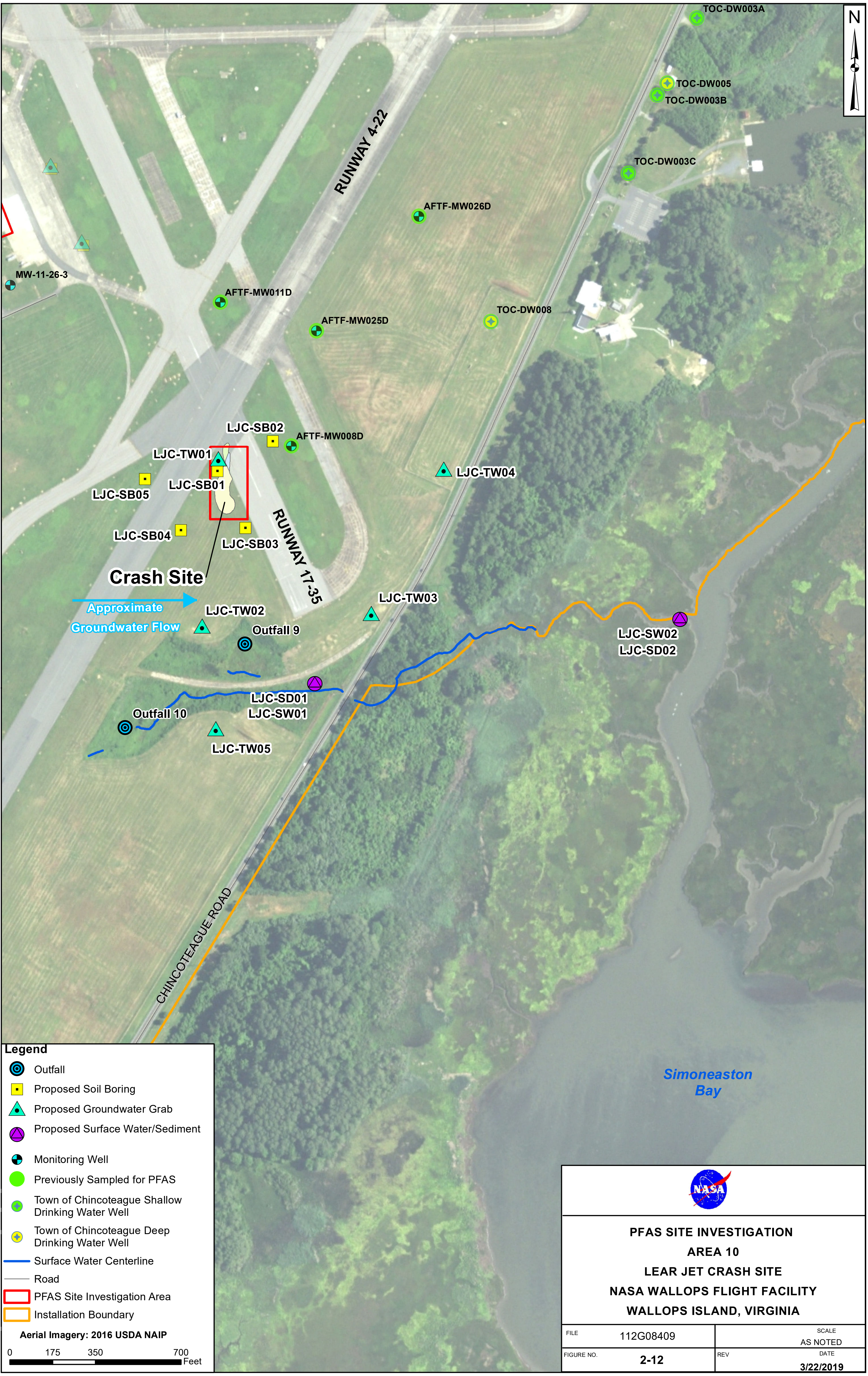


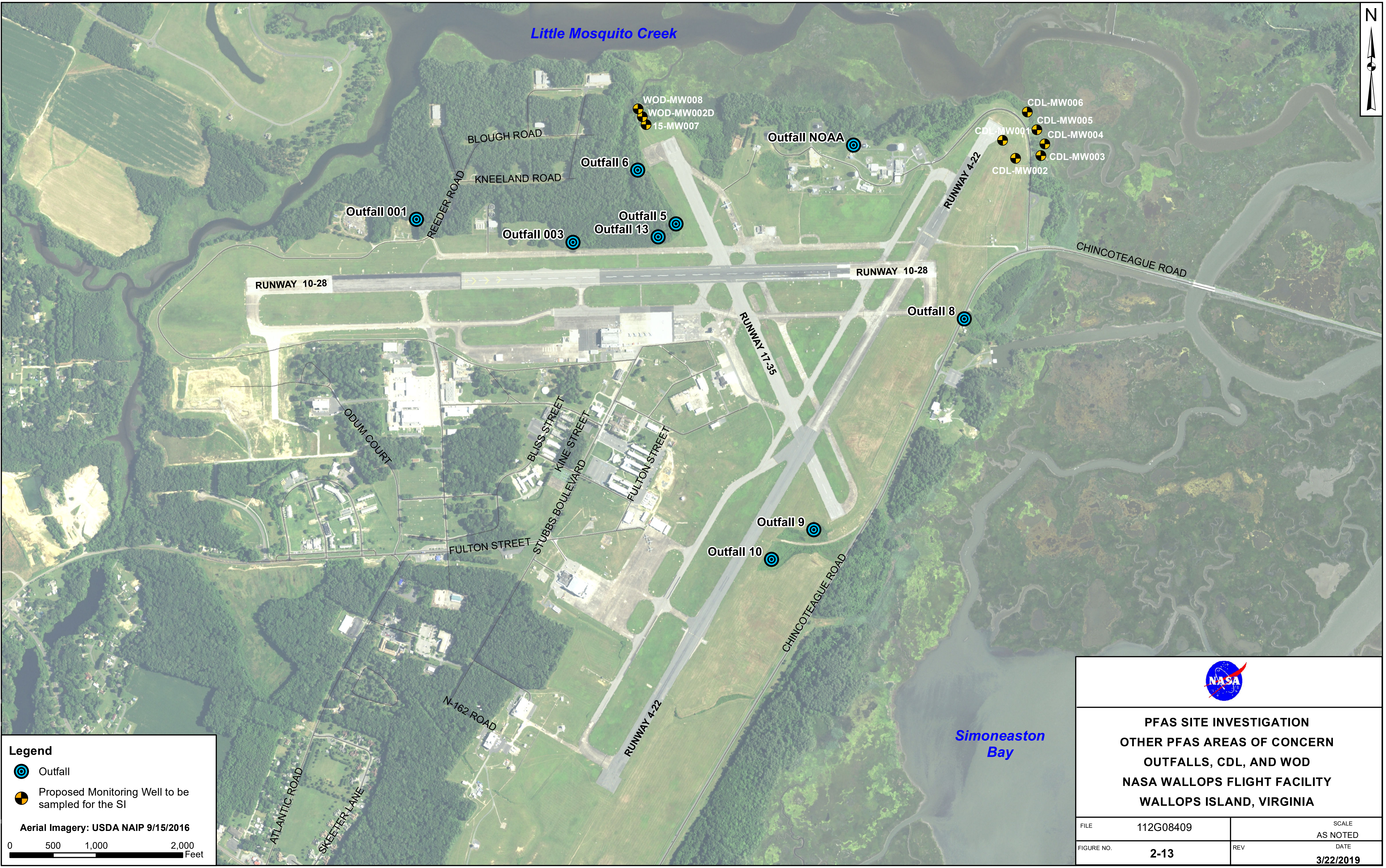
PFAS SITE INVESTIGATION
AREA 9
FORMER FIRE TRAINING AREA
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-11B	REV	DATE 3/28/2019



PFAS SITE INVESTIGATION
AREA 10
LEAR JET CRASH SITE
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE 112G08409	SCALE AS NOTED
FIGURE NO. **2-12**	REV	DATE **3/22/2019**



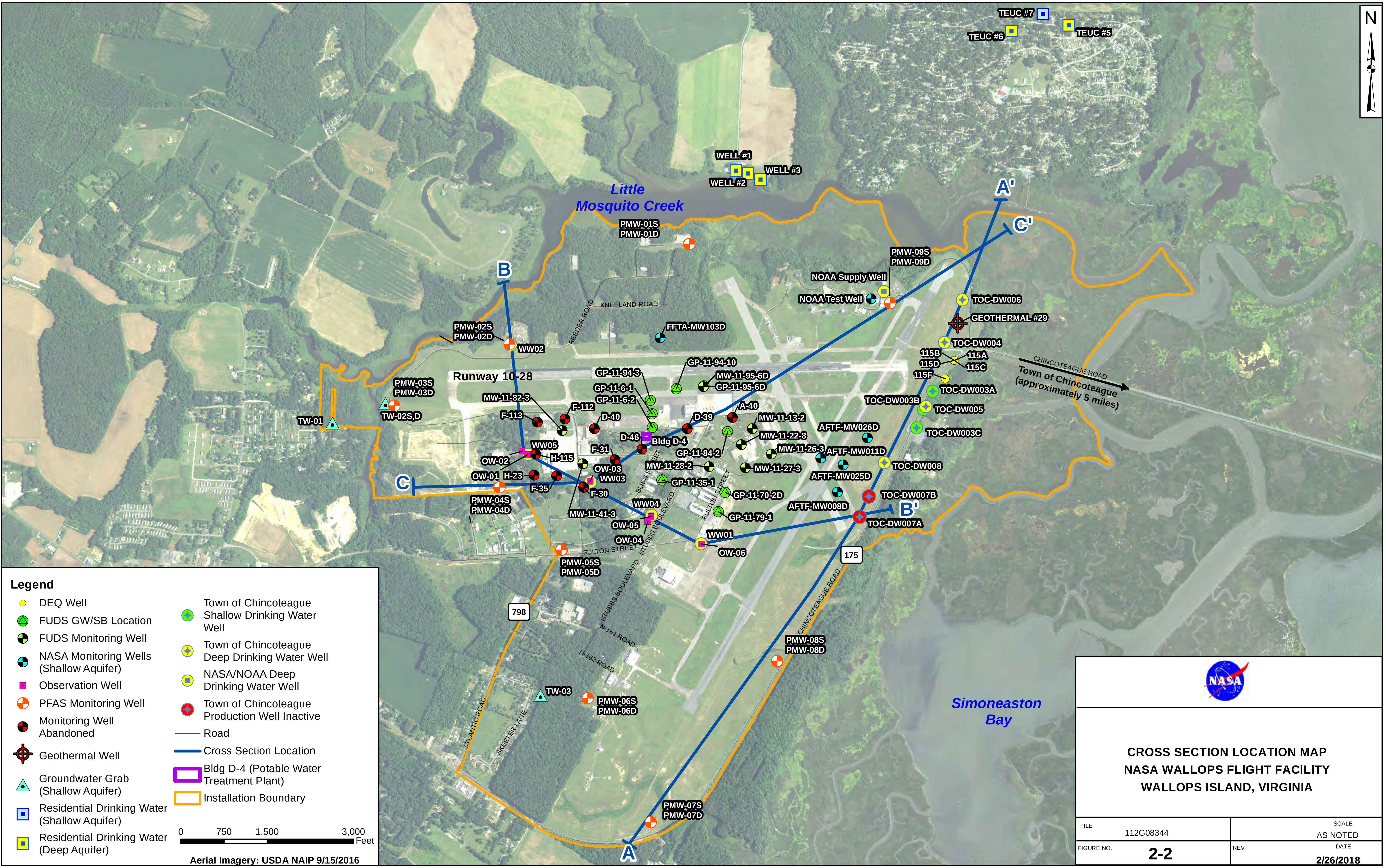
PFAS SITE INVESTIGATION
OTHER PFAS AREAS OF CONCERN
OUTFALLS, CDL, AND WOD
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE	112G08409	SCALE	AS NOTED
FIGURE NO.	2-13	REV	DATE 3/22/2019

NOR: G:\GIS_files\NASA WI\MXD\2017\MB_PFAS_Outfalls.mxd MMC

APPENDICES

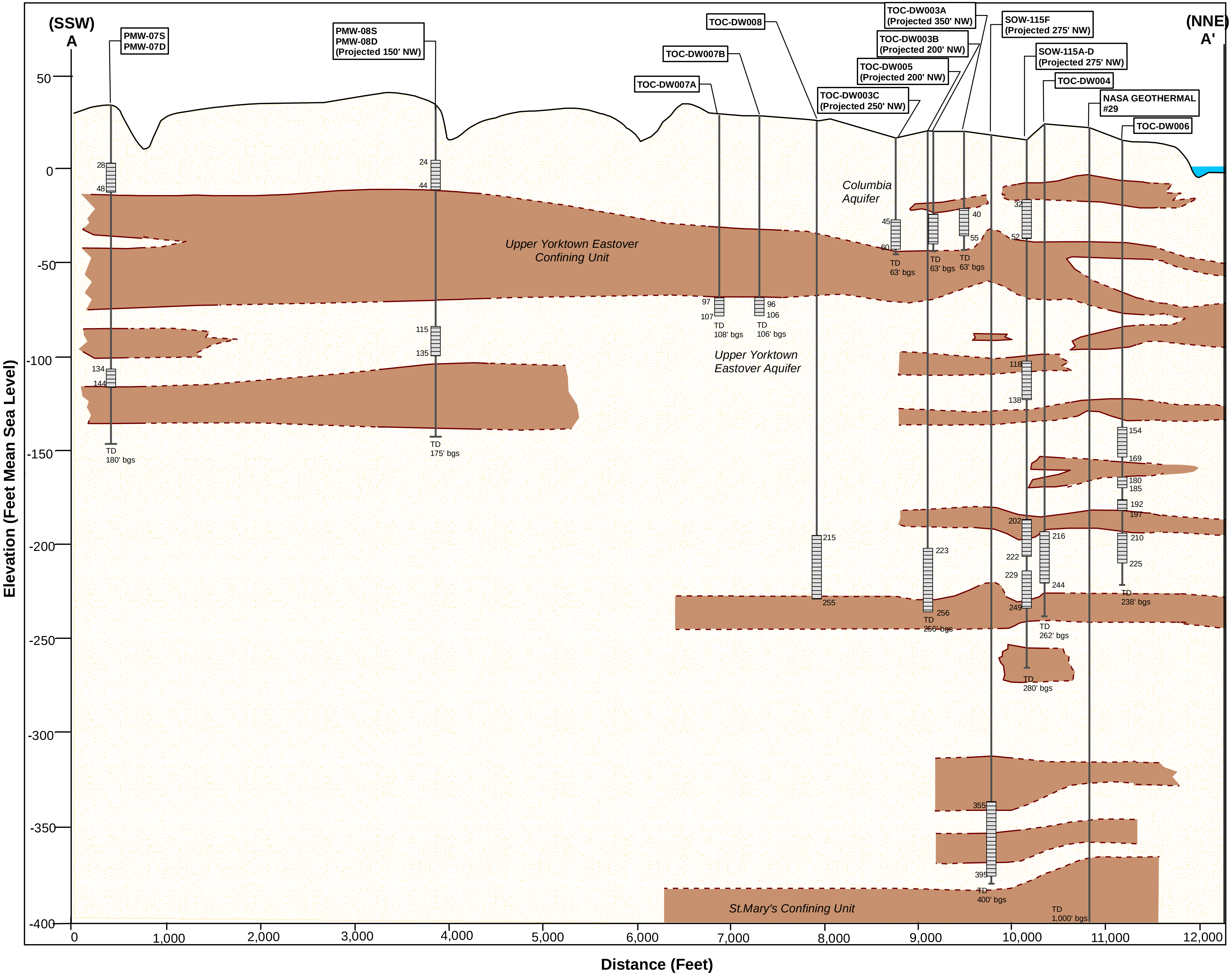
APPENDIX A
NASA WFF GEOLOGICAL CROSS-SECTION FIGURES



NOR: G:\GIS_files\NASA WI\MXD\xsections\MB_xsec_loc_ABC.mxd MMC

CROSS SECTION LOCATION MAP
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

FILE 112G08344	SCALE AS NOTED
FIGURE NO. 2-2	REV	DATE 2/26/2018



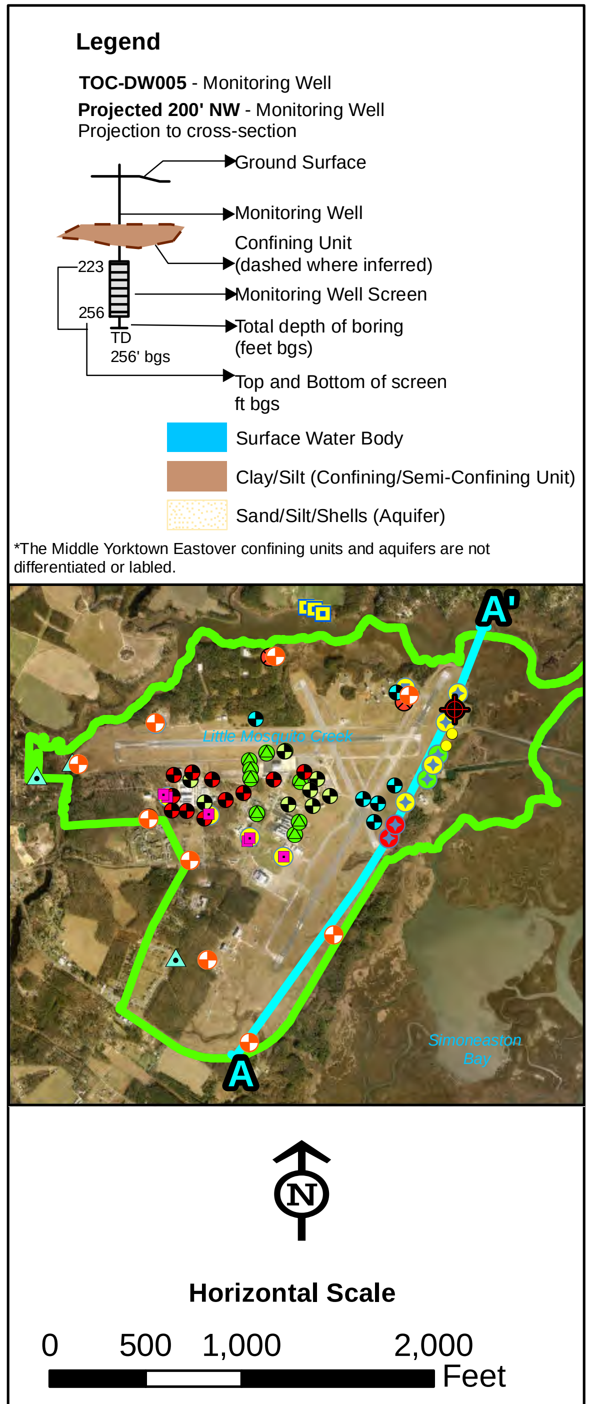


FIGURE 2-3
GEOLOGIC CROSS SECTION A-A'
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

11/28/2017

Bing Maps aerial:
Aerial photograph from ESRI Bing Maps map service
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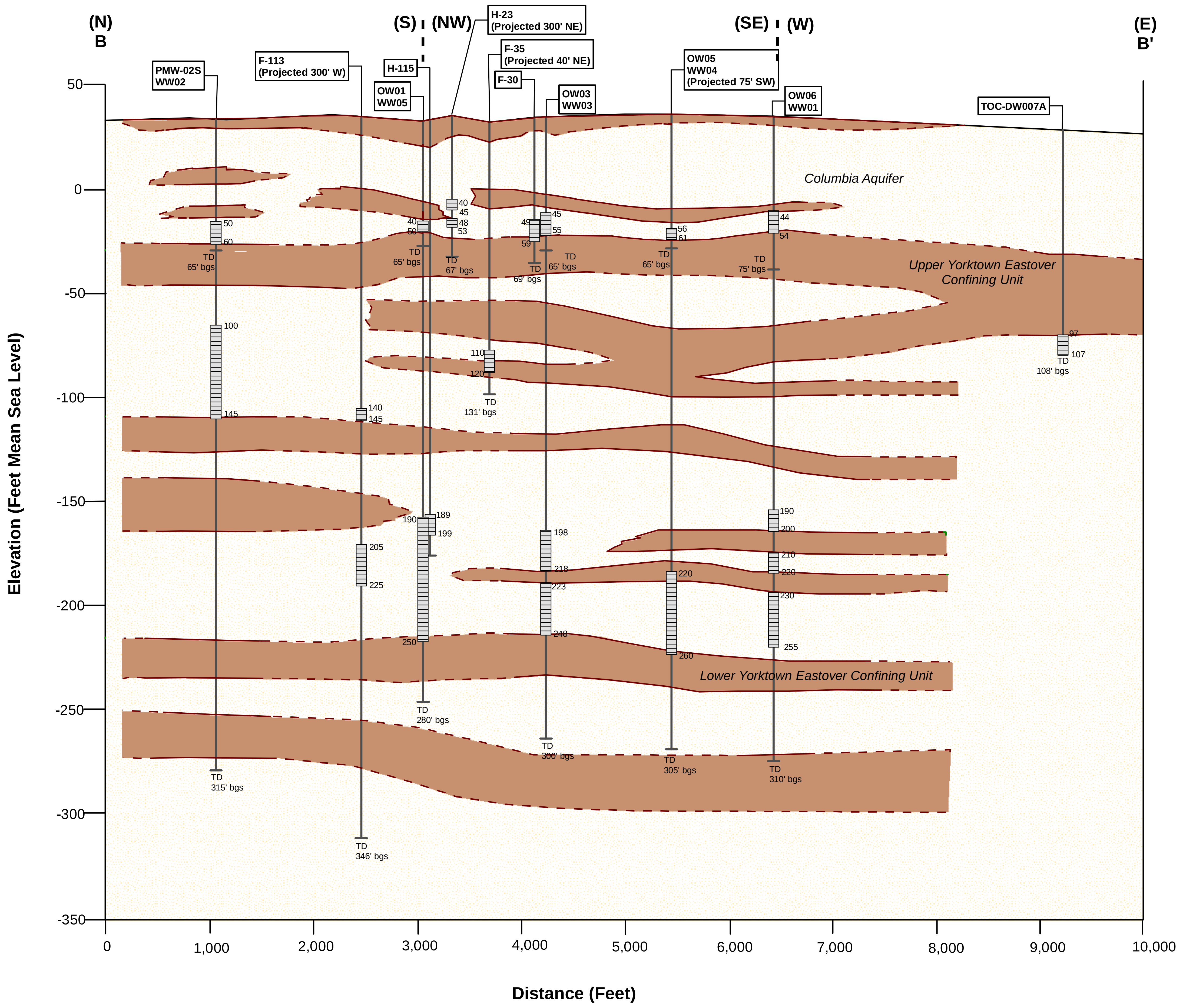
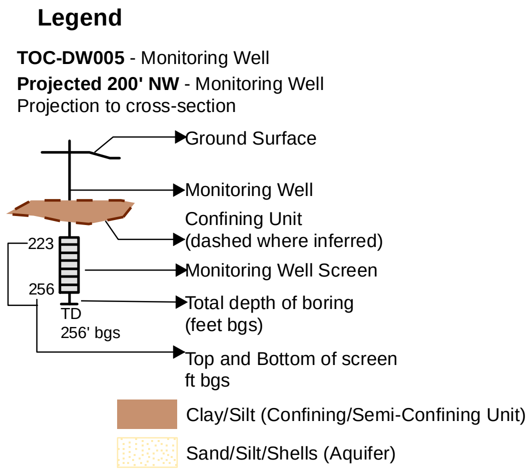
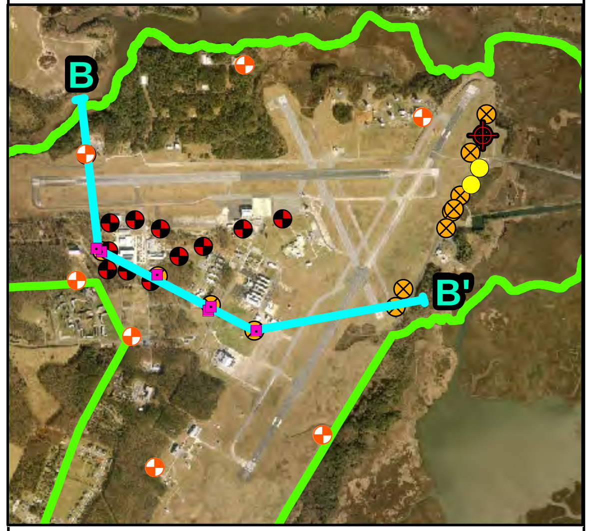
Coordinate System: North American Datum, 1983
Universal Transverse Mercator, Zone 18, North, Meters

Path: G:\GIS_files\NASA WI\MXD\xsections\MB_cross_section_A-A_VERSION2.mxd





*The Middle Yorktown Eastover confining units and aquifers are not differentiated or labled.



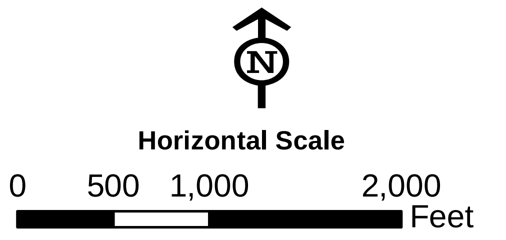


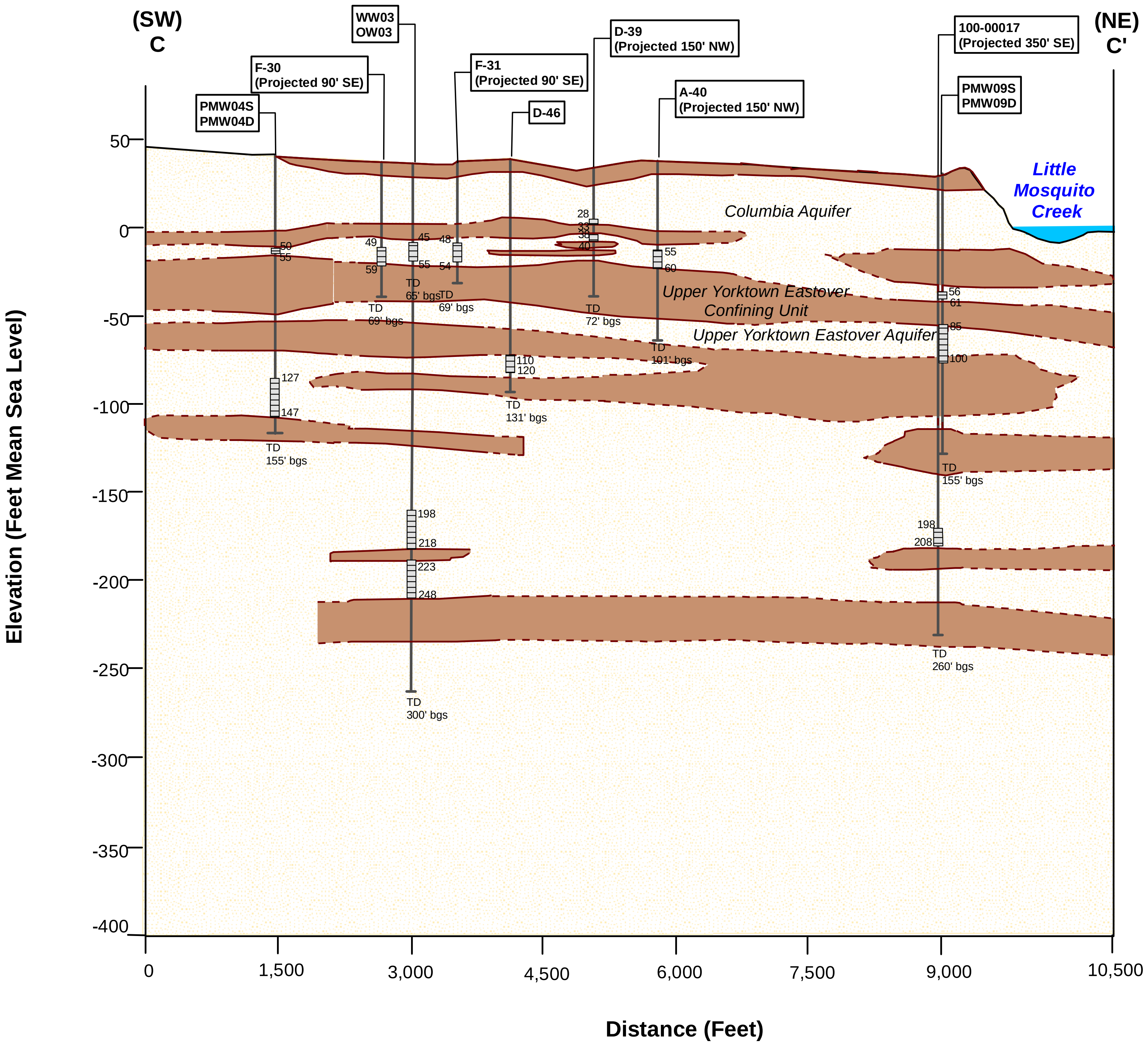
FIGURE 2-4
GEOLOGIC CROSS SECTION B-B'
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

11/28/2017

Bing Maps aerial:
Aerial photograph from ESRI Bing Maps map service
(© 2010 Microsoft Corporation and its data suppliers).

Coordinate System: North American Datum, 1983
Universal Transverse Mercator, Zone 18, North, Meters

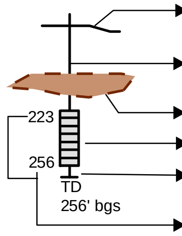
Path: G:\GIS_files\NASA WI\MXD\sections\MB_cross_section_B-Bver2.mxd



Legend

TOC-DW005 - Monitoring Well

Projected 200' NW - Monitoring Well Projection to cross-section



Ground Surface

Monitoring Well

Confining Unit (dashed where inferred)

Monitoring Well Screen

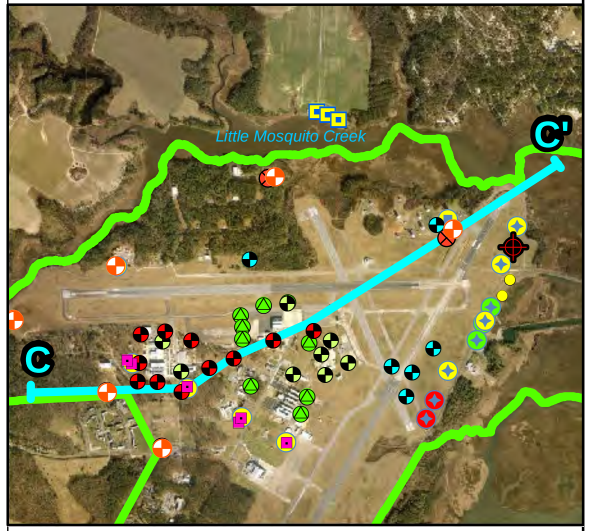
Total depth of boring (feet bgs)

Top and Bottom of screen (ft bgs)

🟦 Surface Water Body

🟫 Silt/Clay (Confining/SemiConfining Unit)

▨ Sand/Silt/Shells (Aquifer)



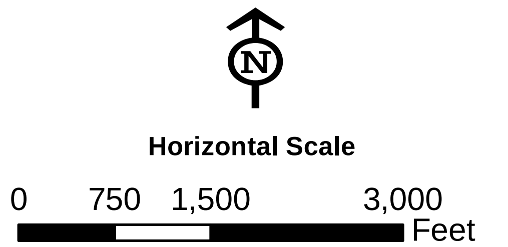


FIGURE 2-5
GEOLOGIC CROSS SECTION C-C'
NASA WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

11/28/2017

Bing Maps aerial:
Aerial photograph from ESRI Bing Maps map service
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Coordinate System: North American Datum, 1983
Universal Transverse Mercator, Zone 18, North, Meters

Path: G:\GIS_files\NASA WI\MXD\sections\MB_cross_section_C-C_version2.mxd

APPENDIX B
RECORDS REVIEWED

APPENDIX B
LIST OF REVIEWED DOCUMENTS
NASA WALLOPS FLIGHT FACILITY PFAS PRELIMINARY ASSESSEMENT
WALLOPS ISLAND, VIRGINIA
PAGE 1 OF 1

Date	Title	Area	Doc Type	Author Affiliation
Dec-04	Closure Assessment Report, NASA Wallops Flight Facility, Wallops Island, Virginia	Area 6	REPORT	NASA
Dec-04	Supplemental Remedial Investigation Report Former Fire Training Area. NASA Wallops Flight Facility, Wallops Island, Virginia	Area 9	REPORT	NASA
Jan-14	Final Five-Year Review, National Aeronautics and Space Administration, Goddard Space Flight Facility, Wallops Island, Virginia	Area 9	REPORT	NASA
May-17	Substances at Former Fire Training Area, Goddard Space Flight Facility, Wallops Flight Center Wallops Island, Virginia	Area 9	REPORT	NASA
Mar-18	Draft Data Summary Report, PFAS Perimeter Monitoring Well and Observation Well Installation and Sampling, NASA Wallops Flight Facility, Wallops Island, Virginia	Facility-Wide	REPORT	NASA
Dec-07	Record of Decision, Former Fire Training Area. NASA Wallops Flight Facility	Area 9	REPORT	NASA
Apr-01	National Transportation Safety Board Aviation Accident Final Report - Accident Number IAD99FA008	Area 10	REPORT	NTSB
Oct-17	Final Letter Report, April 2017 PFAS Sampling, NASA Wallops Flight Facility, Wallops Island, Virginia	Facility-Wide	REPORT	NASA
Apr-99	Corrective Action Plan, Lear 45 Aircraft Crash Site, Runway 10-28, Main Base, NASA-GSFC-WFF, Accomack County, Virginia	Area 6 and Area 10	LETTER	NASA
Jun-00	Corrective Action Monitoring Report Bioremediation Cell	Area 6	REPORT	NASA
Sep-00	Corrective Action Monitoring Report #2 - Soil Bioremediation Land Farm	Area 6	REPORT	NASA
Dec-16	Data Summary Report, September 2016 Groundwater Monitoring, Former Fire Training Area	Area 9	REPORT	NASA
Sep-11	Final Formerly Used Defense Sites Preliminary Assessment, Wallops Flight Facility	Facility-Wide	REPORT	USACE
Jun-13	Draft Formerly Used Defense Sites Preliminary Assessment II, Wallops Flight Facility	Facility-Wide	REPORT	USACE
1954 - 2013	Historical Photographs, NASA WFF	Facility-Wide	PHOTO	NASA

Date - Date document was published.
Area - Areas evaluated in the document.
Doc Type - Type of document.
Author Affiliation - Group which prepared the report.
NASA - National Aeronautics and Space Administration
NTSB - National Transportation Safety Board
USACE - United States Army Corps of Engineers

APPENDIX C
INTERVIEW INFORMATION

PFAS PRELIMINARY ASSESSMENT INTERVIEW FORM

NASA Wallops Flight Facility, Wallops Island, Virginia

Personnel from the NASA WFF Fire Department and Environmental Office were interviewed for this Preliminary Assessment. Personnel from the NASA WFF Fire Department were interviewed on November 15, 2017. Follow up questions and responses exchanged with fire department personnel were conducted via e-mail facilitated by NASA environmental personnel.

The following provides a summary of NASA WFF Fire Department Personnel and Environmental Personnel interviewed during this Preliminary Assessment.

NASA WFF Fire Department:

Chief Jim Adkins serves as the fire chief for NASA WFF. Chief Adkins has been with the NASA WFF Fire Department since 2014.

Captain Tim McCready serves as a captain with the NASA WFF Fire Department. Captain McCready has been with the NASA WFF Fire Department since 1976.

NASA WFF Environmental Office

Ms. Susan Dunn is an environmental scientist with the NASA WFF Environmental Office. She has worked in the environmental office at the facility since 2003.

Mr. Shane Whealton is an environmental scientist with the NASA WFF Environmental Office. He has worked in the environmental office at the facility since 2001.

The following provides documentation of the interviews conducted with NASA WFF Fire Department and Environmental Office Personnel. The information provided below was primarily provided by personnel from the fire department. Responses from NASA WFF Environmental Office personnel are distinguished as necessary in the summary below.

AFFF

1. What type of AFFF was used on this installation (i.e. 3%, 6%, High Expansion Foam)? Where are the AFFF purchase records maintained?

AFFF purchased/storage records are maintained with WFF FD. 1977/78 was the transition time for switch from protein based foam to AFFF (initial batch of AFFF was Ansul).

Current Inventory: WFF FD – is info on current AFFF inventory correct?

- 205 gallons Ansulite 6% (manufactured 2013), stored at Building X-15 (Island Fire Station) on the Island.
- (2) 275 gallons Buckeye platinum 3% (manufactured 2013), Stored at Main Base Building B-31
- (15) 55 gallon drums Buckeye platinum 3% (manufactured 2013-14), stored at Main Base Building B-31.

Prior to 1977/78 protein based foam was used at NASA WFF. 1977/78 was the timeframe for transitioning to AFFF (3M/Ansul).

We have no knowledge of inventories prior to 1977.

2. What manufacturer's AFFF products are used on this installation (i.e. 3M, Ansul, Chemguard)? Dates of use for each manufacturer?

See above under question #1.

Our records are not specific and we can only account for what has been in the inventory since WICC II took over the contract in 2014. Anything before that is anecdotal only and comes from memory. We can't pin down dates however, all three main manufacturers have been used in the past.

3. Where has the AFFF solution been handled (mixed, contained, transferred, etc.)?

- WFF Main Base: D-1 West Fire Training Area and Building B-129 WFF Main Base Fire Station. A 1,000-gallon tank was once used at B-129 to store premixed foam/water for rapid refill of fire trucks. This tank was located at the back (west side) of the current B-129 Main Base Fire Station. The tank was used from 1976-77. The tank initially contained protein foam then was changed to 6% foam. All filling of fire trucks with foam concentrate at the MB is done at B-129 on the concrete surface at the fire station. The foam concentrate is poured into the trucks by hand. We are not aware of any incidents where foam was "dumped" from crash trucks.
- WFF FD is not aware of "dumping" of foam/water from crash rescue trucks at the fire station.
- WFF Island: Bldg. X-15 Island Fire Station. Storage only, never used/discharged from equipment.

Hangars and Buildings

4. *Are your automated fire suppression systems currently charged with AFFF or have they been retrofitted for use of high expansion foam?*

Hangers at WFF are not and have never been equipped with a fire suppression system. Buildings at NASA WFF equipped with fire suppression systems are not or have never been charged with AFFF.

5. *Do you have an inventory of the amount of AFFF stored on the installation or present in automated fire suppression systems?*

See question #1 for inventory/storage. No AFFF used in fire suppression systems. Hangers are not equipped with fire suppression system.

6. Can you describe the procedure on how the suppression systems are supplied with AFFF?

Not applicable.

7. Have there been inadvertent releases of AFFF from hangar fire suppression systems? When? What quantity? How was it cleaned up?

Not applicable.

8. How are AFFF releases handled (i.e. when the suppression system goes off)? Who maintains the system? Where are the maintenance records?

Not applicable.

Trucks and Trailers

9. Provide a list of trucks and trailers currently carrying AFFF and where they are parked/stored?

See the attached NASA WFF Fire Department Apparatus list for details.

10. How much AFFF (gallons) is carried/stored in the specified trucks and trailers?

- Fire Fighting Vehicles equipped with AFFF are parked in the **Building B-129 Fire Station Garage**. Each truck holds 420 gallons of foam concentrate. That is a total of 1,260 gallons of AFFF Concentrate currently stored in the three active crash rescue trucks.
- **Island Fire Station X-15**: 2011 Chevy Silverado (Truck ID No. Brush 26), 5 gallons is on the Brush Truck

<u>11. Do you test the trucks for spray patterns to make sure equipment is working properly?</u>

- **Building B-129 Fire Station**: Nozzle tests are conducted in front of the Fire Station garage bays. The test are conducted to ensure truck nozzles are not blocked and properly operating. The nozzle sprays are short bursts that spray on to the concrete surface in front of the garage bays. These tests are not conducted for spray patterns. We are not aware of the foam spray reaching the grass areas adjacent to the fire house.
- **D-1 West Fire Training Area (Wash Rack)**: We have performed annual refractometry testing, at the wash rack annually since 2014. We use the current stocks of foam on the trucks to perform the test and usually the amount of foam used is approximately 10-20 gallons of foam mixture per truck. This testing has only been done recently as the equipment to perform such testing was purchased under my (Chief Atkins) watch. Previously it was performed in the late 70's but no records exist and we cannot confirm locations of the testing or amounts of foam. We are unsure if other foam tests have been done here; however, it is likely that some foam has been sprayed on the runways and taxiways at some point in the history of the airfield. We don't have knowledge of specific incidents.
- **Former Wastewater Treatment Plant:** The drying beds were once used to conduct Annual Nozzle Testing (2003 -2014). Approximately 5 gallons of foam/water mix was used during each test. Both drying beds were used to conduct the tests. In general, the spray patterns were contained within the former drying beds.

<u>12. How often are these spray tests performed and can you provide the locations of these tests?</u>

- Currently a <u>Refractometry Test</u> is done annually for the fire trucks at the <u>D-1 Wash Racks.</u> This practice began in 2014 though present time. Foam is used in the refractometry testing (that is what is being measured in the refractometer, it measures the foam quality in the solution as it comes out of the nozzles). See above answer for the description of the process.
- Prior to 2014, the drying beds at the <u>former NASA WWTP</u> was used to conduct Annual Truck Nozzle tests. 6% and 3% foam was used at this location to conduct these tests. 2003-2014 was the transition period for AFFF foam. Pre-2005 "old foam" was used at this location.

<u>13. Can you describe the procedure on how trucks and trailers are supplied with AFFF? Where does this resupply occur? Is there secondary containment in this area? What do you do with the empty concentrate containers?</u>

- The AFFF concentrate is poured in to the truck holding tanks by hand. This is done on the concrete pad (by the garage doors) at the B-129 Fire House. The empty containers for the AFFF is thrown out as general trash. AFFF is not a listed hazardous material so it has been disposed of by the normal means of discarding general trash/refuse.
- It has been confirmed that a similar practice is done for the Chevy Silverado kept at the Island Fire Station Building X-15.

<u>14. Can you provide the procedures on how these vehicles are cleaned/decontaminated and where vehicle cleaning is performed currently as well as in the past?</u>

- All fire vehicles are cleaned/washed at the D-1 Wash Rack Area.
- Fire vehicles at the Island are washed in front of Building X-15, the Island Fire Station.
- There are no specific procedure on how trucks are washed/cleaned.

<u>15. When AFFF was used during a fire training exercise, how was the AFFF cleaned up and disposed of?</u>

- AFFF was not cleaned up.
- WFF FD indicated AFFF was left to evaporate, was contained in the fire training area, and/or washed away.

Records, Spill logs, Historical Information

16. Do you have recollection or records of AFFF being used in response to:

a. Fuel releases to prevent fires?

No incidents/records are known where AFFF was used in response to a fuel release.

b. Historical emergency response sites (i.e. crash sites and fires)?

- 1974 Helicopter Crash: Protein foam was used for this incident. No AFFF was used. No official reports of the incident are known to exist.
- 1998 Lear Jet Crash: The incident occurred on October 27, 1998. A Lear Jet collided with a Ford Ranger pickup truck during flight-testing. The pickup truck was located in the path of the jet at the edge of the runway. WFF FD estimates that 200-400 gallons of 6% Ansul foam was used during this incident.

c. Emergency runway landings where foam might have been used as a precaution?

None. No records or memory exists of spraying runways as a precautionary measure and it is not common practice to do so now.

d. How were these releases cleaned up? Were soils removed? Sent where?

NASA WFF Environmental Department*:*

- Lear Jet Crash: approximately 400 cubic yards of petroleum impacted soil were excavated from the crash site and remediated at the Lear Soil Bioremediation Landfarm. The landfarm was located in the NW portion of the MB, adjacent to and to the west of the former WWTP. The landfarm was constructed in 1999.
- On 1/25/18, LJT confirmed location of the Lear Soil Bioremediation Landfarm. The landfarm was located in the northern portion of the site. As the upper portions of the soil met cleanup goals, the "clean soil" was then scraped off, moved in an area directly south of the landfarm and staged in a pile. Soils meeting cleanup goals were approved for use as clean fill material throughout the MB facility (in accordance with the VDEQ approved Corrective Action Plan [CAP]). There are no known records documenting where "clean fill" from the landfarm was transported for re-use at the MB.

17. If not written records or incomplete written records, do you have anecdotal/verbal information and locations of spills or other emergency response incidents where AFFF was used?

None currently. No other incidents other than what has been provided in this interview are known of. The WFF FD was shown the location of Area 7 – Observation Well-06 (OW-06), where PFAS has been detected. WFF FD was asked if they were aware of any incidents or training activities involving the use of AFFF occurred near OW-06. WFF FD was not aware of any incidents or training activities conducted near OW-06.

18. What are the non-FTA locations where:

a. AFFF release systems are installed (i.e. Hangars, Wastewater Treatment Plants, and Fire Stations)

No facilities at NASA WFF are equipped a fire suppression systems that are or have been charged with AFFF.

b. Where are these locations that currently contain or have contained AFFF (Building numbers)

See question #1 for AFFF storage info (quantities and building ID).

c. If converted from AFFF, when did they convert the system to high expansion foam?

Not Applicable

19. Can you provide any other locations where AFFF has been stored, released, or used (i.e. hangars, buildings, bulk fuel tank farms, fire stations, firefighting equipment testing and maintenance areas, emergency response sites, storm water/surface water, waste water treatment plants, and AFFF ponds/lagoons)?

a. Was discharge from a WWTP ever used to irrigate a golf course or lawns?

NASA Environmental Department: No. Effluent from both the current and former WFF WWTP is discharged to the same point. The effluent is directed through an unlined, un-named tributary that empties into Little Mosquito Creek. An oil/water separator is located at the D-1 West Fire Training Area. Run-off from this area that enters the oil/water separator is transported through a sanitary sewer system to the active WWTP.

b. Was sludge from a WWTP ever used in land applications or disposed of at the on-site (or off-site) landfill?

NASA Environmental Department: NASA WFF WWTPs have disposed of sludge material from WWTP operation at the Accomack County Landfill. The sludge material has been routinely sent to this facility for disposal after analytical confirmation the material was non-hazardous.

Fire Training Areas (FTA)

20. Confirm all FTAs identified during research are correct, and list FTAs identified during site visit. Please show their locations on a base map.

- Area 1 - Building B-129 Fire Station: A portable propane fueled fire training system is used in front of the fire station. Water is used to extinguish the simulated fire during training. Portable propane systems are currently the only approved method or fuel authorized for ARFF training (FAA regulations).
- Area 2 – D-1 West Fire Training Area. Area is not currently being used for fire training activities. The area was only used in the early to mid 1970's and only used water.
- Area 3 – Fire Training Area. The Fire Training Pit was used from approximately 1978 until 2001. Training occurred periodically approximately 12 times a year (monthly). Currently inactive. Hole/pit contained JP-4, then was ignited. Propane was also used at this location. During training at this location, water was used to extinguish the fires. AFFF was not used at this location.
- Area 9 – Former Fire Training Area. NASA WFF FD indicated they trained at the facility from around 1979/80 till 1991/92. Currently inactive. Initially the FD used protein based foam for training at the FFTA, then transitioned to AFFF. WFF FD indicated after an exercise was conducted, there were no procedures to clean up/dispose of the AFFF. Flammable liquids were dispersed onto the ground, into a shallow pit, an old airplane fuselage, and/or into a tank and ignited for firefighting training exercises.

21. What are the years of operation for each FTA?

See question #20 above.

22. How many FTAs are active versus inactive?

See question #20 above.

23. What types of fuels/flammables were used at the FTAs?

See question #20 above.

24. For inactive FTAs, when was the last time that fire training using AFFF was conducted at each one?

- Area 3 – Former Fire Training Area (FFTA). Last used during the 1970's. Currently inactive.
- Area 9 – WFF FD indicated they trained at the facility from around 1979/80 till 1991/92. Currently inactive.

25. Can we have a base wide map of monitoring well locations?

Refer to NASA WFF GIS map.

26. Is there anyone else or other base organization personnel that you would recommend we interview? Name, organization, position, phone number, e-mail. Not applicable.

27. NASA Environmental Department - *Do you have a chrome plating shop on base? Years of operation? Was foam used to suppress vapors in the process?*

NASA Environmental Department: Building F-8 located on the MB contained a plating shop. It was used by DoD and NASA. Currently, details on the type of plating conducted at the facility are unknown. The building was demolished in January 2007.

28. Where does your water supply come from?

NASA Environmental Department:

The potable water source for NASA WFF is currently obtained from 4 production wells located on the MB parcel that are screened in the Yorktown-Eastover Aquifer. Prior to July 2017, there were 5 production wells in-service. Production Well WW-02 was removed from service in May 2017, due to detections of PFOA/PFOS. Maximum concentrations detected from samples collected on 5/23/17: PFOA at 1.9 ng/L; PFOS at 11 ng/L. Combined concentration total at 12.9 ng/L, below the EPA drinking water Health Advisory of 70 ng/L.

29. Are there any tenants that use AFFF?

NASA WFF Fire Department Response:

Mid-Atlantic Regional Spaceport (MARS) currently has 5 gallons of new foam stored at Building B-129 (WFF MB Fire Station). FD indicated MARS has not used the foam. MARS uses a TriMax portable Compressed air Foam System. It is serviced here at B-129 and they use Ansul 6% AFFF.

The NASA WFF Airport (Aircraft Operations) also uses a similar system but it is using NOVAcool which does not contain PFAS. We hope to transition MARS to this product.

NASA Environmental Department:

Airfield Operations provided information to NASA Environmental Office via e-mail on 4/7/18. Airfield Operations is expecting to take delivery of TriMAX portable fire suppression systems at the end of April 2018. These units are to be deployed on various ramps and storage facilities and used on the airfield ramps.

NASA WFF Fire Department Interview Information:

Interviewee:	Chief Jim Adkins
Position:	Chief - NASA WFF Fire Department
Date/time of Interview:	November 15, 2017, 0930
Interviewer:	Ernie Wu (Tetra Tech) and Susan Dunn (LJT & Associates)

Interviewee:	Captain Tim McCready
Position:	Captain - NASA WFF Fire Department
Date/time of Interview:	November 15, 2017, 0930
Interviewer:	Ernie Wu (Tetra Tech) and Susan Dunn (LJT & Associates)

NASA WFF Environmental Office Interview Information:

Interviewee:	Susan Dunn
Position:	Environmental Scientist – NASA Environmental Department
Date/time of Interview:	January 24, 2017 and e-mail correspondences November 2017 through March 2018.
Interviewer:	Ernie Wu (Tetra Tech)

Interviewee:	Shane Whealton
Position:	Environmental Scientist – NASA Environmental Department
Date/time of Interview:	January 24, 2017
Interviewer:	Ernie Wu (Tetra Tech)

APPENDIX D
PHOTOGRAPHIC LOG

Photo: 1	Area 1: Building B-129 Fire Station

View of the western side of Building B-129 Main Base Fire Station, looking to the east/northeast.

Photo: 2	Area 2: D-1 West Fire Training Area

Aircraft Rescue and Fire Fighting exercise using a portable, propane fueled system.

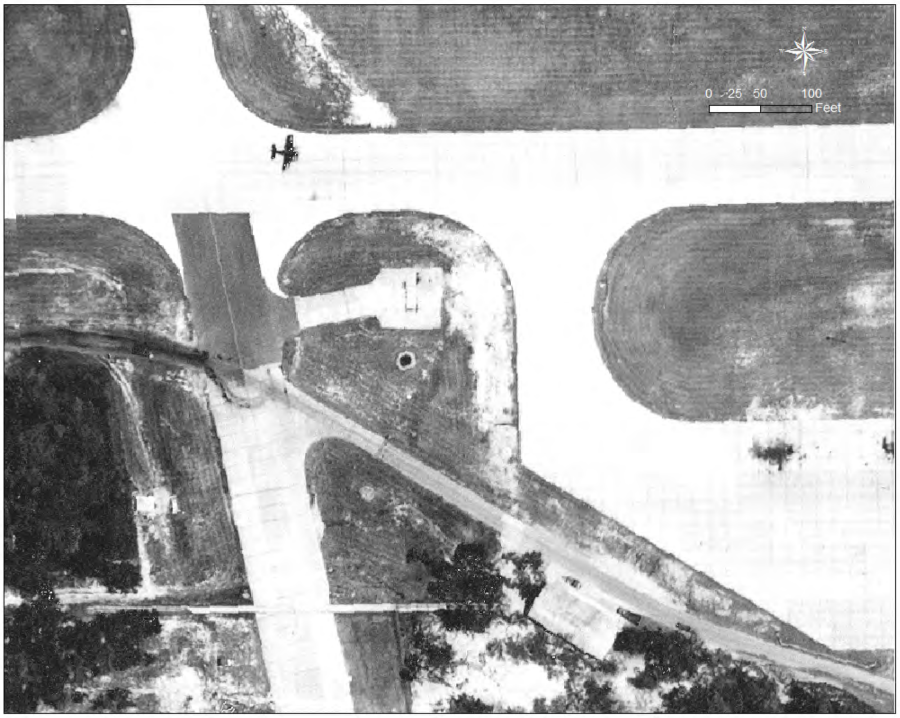	
Photo: 3	Area 3: Fire Training Pit
1954 aerial photograph of the Fire Training Pit.	
	
Photo: 4	Area 4: Helicopter Crash Site
1974 Helicopter Crash Site view facing the west/southwest.	

Photo: 5 Area 5: Former Wastewater Treatment Plant

2013 aerial photograph of the Former Wastewater Treatment Plant.

Photo: 6 Area 5: Former Wastewater Treatment Plant

View of the former drying bed area at the Former Wastewater Treatment Plant (January 2018).

Photo: 7 Area 7: Observation Well 06 Area

View from Observation Well -06 looking to the south/southwest.

Photo: 8 Area 8 – Wastewater Treatment Plant

View of the permitted wastewater effluent discharge point.

Photo: 9 | Area 8 – Wastewater Treatment Plant

View of the permitted wastewater effluent discharge point.

Photo: 10 | Area 9 – Former Fire Training Area

View of the fire training tank at the Former Fire Training Area.

Photo: 11 Area 9 – Former Fire Training Area

View of the fire training tank at the Former Fire Training Area.

Photo: 12 Area 9 – Former Fire Training Area

View of the training pit area at the Former Fire Training Area.

Photo: 13	Area 10 – Lear Jet Crash Site

View of the Lear Jet Crash Site during soil excavation activities.

APPENDIX E
STANDARD OPERATING PROCEDURES

TETRA TECH

STANDARD OPERATING PROCEDURE

Number SA-1.1	Page 1 of 36
Effective Date 7/15/2016	Revision 9
Applicability Tetra Tech, Inc., NUS Operating Unit	
Prepared Earth Sciences Department	

Subject
GROUNDWATER SAMPLE ACQUISITION AND ONSITE WATER QUALITY TESTING

Approved
T. Johnston

tom. johnston @tetratec h.com

Digitally signed by: tom. johnston@tetratech.com
DN: CN = tom. johnston@tetratech.com
Date: 2016.07.14 10:17:45 -05'00'

TABLE OF CONTENTS

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the process to be used for purging groundwater monitoring wells prior to sampling, for collecting groundwater samples, and for measuring groundwater quality parameters.

2.0 SCOPE AND APPLICABILITY

This document provides information on proper sampling equipment, onsite water quality testing, safety measures to ensure the safety of the field technician(s), and techniques for groundwater sampling. All personnel are encouraged to review the information contained herein to facilitate planning of the field sampling effort. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require modifications to methodology.

WARNING:

- Sample containers can be contaminated during storage if nearby volatile substances infiltrate the surrounding air and migrate into the containers. This can occur even when containers are capped. Therefore, containers that have been stored onsite for longer than 6 months should not be used.

Note: Whereas most air-borne contamination is likely to be associated with organic substances, inorganic substances such as hydrochloric acid (muriatic acid) can emit inorganic vapors that infiltrate sample containers.

3.0 GLOSSARY

Conductivity – Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions and their total concentration, mobility, valence, and relative concentrations and on temperature. Conductivity is highly dependent on temperature and should be reported at a particular temperature, e.g., 20.2 milliSiemens per centimeter (mS/cm) at 14 degrees Celsius (°C).

Dissolved Oxygen (DO) – DO concentrations in natural water (including groundwater and surface water) and wastewater depend on the physical, chemical, and biochemical activities in the water sample.

Groundwater Sample – A quantity of water removed from the ground, usually via a monitoring well that may or may not be lined with a well casing, and typically in a manner that is designed to represent the in-situ quality of one or more parameters of interest regarding the water in the ground.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode immersed in water, as referenced against a reference electrode. Also commonly referred to as redox potential or Eh. A reference electrode commonly used in the field is the silver/silver chloride electrode, which has a voltage offset of about 210 millivolts (mV) from the standard hydrogen electrode (SHE). To convert field ORP measurements to equivalent SHE values, approximately 210 mV must be added to the ORP values obtained using the silver/silver chloride electrode. The actual offset depends on the concentration of the potassium chloride (KCl) solution in the field reference electrode and the temperature. Offsets typically range from 199 (saturated KCl) to 205 (3.5 Molar KCl) to 222 mV (1 Molar KCl) at 25°C and are greater at lower temperatures.

pH – A unitless number equal to the negative logarithm (base 10) of the hydrogen ion activity, expressed in moles per liter. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is related to the hydrogen ion concentration. This is an inverse relationship, meaning that the pH decrease with increasing hydrogen ion concentration.

pH Paper - Indicator paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution's pH.

Representativeness – A qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been collected.

Salinity – The measurement of dissolved salts in a given mass of solution. Note: most field meters determine salinity automatically from conductivity and temperature. The value will be displayed in either parts per thousand (ppt) or percent (e.g., 35 ppt equals 3.5 percent). The parts per thousand symbol ($^{0}/_{00}$) is not the same as the percent symbol (%).

Specific Conductance – Specific conductance is the electrical conductivity across an electrical cell of specified geometry in an electrolyte solution. The electrical current is carried by charged atoms or molecules in the solution (i.e., ions). Standard measurements are commonly made at, or normalized to, a standard temperature of 25°C. Temperature normalizations commonly are automated by the specific conductance meters used to make these measurements. Temperature compensation, however, adjusts only for changes in instrument response caused by temperature changes. The temperature compensation does not correct for changes in conductance that result from changes in ion mobility. Hence the reason most measurements are made at the standard temperature of 25°C.

Turbidity – Turbidity in water is caused by suspended matter such as clay, silt, and fine organic and inorganic matter. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - The Project Manager is responsible for determining the sampling objectives, initial sampling locations, and field procedures used in the collection of groundwater samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager identifies sampling locations.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan (HASP) or equivalent. This includes but is not be limited to performing air quality monitoring during sampling, boring and excavation activities, and ensuring that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO or SSO designee may also be required to advise the Field Operations Leader (FOL) on other safety-related matters regarding sampling, such as mitigative measures to address potential hazards from hazardous objects or conditions.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of samples in accordance with this SOP or other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, boring logs, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

Project Hydrogeologist – This individual is responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), equipment to be used, and providing detailed input in this regard to the project planning documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of site sampling personnel.

Field Operations Leader (FOL) – This individual is primarily responsible for the execution of the planning document containing the Sampling and Analysis Plan (SAP). This is accomplished through management of a field sampling team for the proper acquisition of samples. He or she is responsible for the supervision of onsite analyses; ensuring proper instrument calibration, care, and maintenance; sample collection and handling; the completion and accuracy of all field documentation; and making sure that custody of all samples obtained is maintained according to proper procedures. When appropriate and as directed by the FOL, such responsibilities may be performed by other qualified personnel (e.g., field technicians) where credentials and time permit. The FOL is ultimately responsible for adherence to Occupational Safety and Health Administration (OSHA) regulations during these operations through self-acquisition or through the management of a field team of samplers.

General personnel qualifications for groundwater sample collection and onsite water quality testing include the following:

- OSHA 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate procedures for sample documentation, handling, packaging, and shipping.

5.0 HEALTH AND SAFETY

Specific safety and health precautions are identified throughout this SOP. In addition to those precautions, the following general hazards may be incurred during sampling activities:

- Knee injuries from kneeling on hard surfaces.
- Slips, trips, and falls.
- Cuts and lacerations.
- Traffic hazards associated with sampling in parking areas and roadways and along highways and railways.

Methods of avoiding these hazards are provided below.

Knee injuries – Many monitoring wells are installed as flush mounts. Personnel are required to kneel to open these wells and to take groundwater level measurements, etc. This could result in knee injuries from kneeling on stones/foreign objects and general damage due to stress on the joints. To combat this hazard:

- Clear any foreign objects from the work area.
- Wear hard-sided knee pads.

Slips, Trips, and Falls – These hazards exist while traversing varying terrains carrying equipment to sample wells. To minimize these hazards:

- Pre-survey well locations. Eliminate, barricade, or otherwise mark physical hazards leading to the locations.
- Carry small loads that do not restrict the field of vision.
- Travel the safest and clearest route (not necessarily the shortest).

Cuts and Lacerations – To prevent cuts and lacerations associated with groundwater sampling, the following provisions are required:

- Always cut away from yourself and others when cutting tubing or rope. This will prevent injury to yourself and others if the knife slips.
- Do not place items to be cut in your hand or on your knee.
- Change blades as necessary to maintain a sharp cutting edge. Many accidents result from struggling with dull cutting attachments.
- Whenever practical, wear cut-resistant gloves (e.g., leather or heavy cotton work gloves) at least on the hand not using the knife.
- Keep cutting surfaces clean and smooth.
- Secure items to be cut -- do not hold them against the opposing hand, a leg, or other body part.
- When transporting glassware, keep it in a hard-sided container such as a cooler so that if there is a fall, you will be less likely to get cut by broken glass.
- DO NOT throw broken glass or glass ampoules into garbage bags. Place broken glass and glass ampoules in hard-sided containers such as a cardboard box or directly into a dumpster. DO NOT reach into garbage bags to retrieve any item accidentally thrown away. Empty the contents onto a flat surface to avoid punctures and lacerations from reaching where you cannot see.

Vehicular and Foot Traffic Hazards – When sampling along the roadway or near traffic patterns, follow the following precautions:

- Motorists may be distracted by onsite activities – ASSUME THEY DO NOT SEE YOU OR MEMBERS OF YOUR FIELD CREW.
- DO NOT place obstructions (such as vehicles) along the sides of the road that may cause site personnel to move into the flow of traffic to avoid your activities or equipment or that will create a blind spot.
- **Provide a required free space of travel.** Maintain at least 6 feet of space between you and moving traffic. Where this is not possible, use flaggers and/or signs to warn oncoming traffic of activities near or within the travel lanes.
- Face Traffic. Whenever feasible, if you must move within the 6 feet of the required free space or into traffic, attempt to face moving traffic at all times. Always leave yourself an escape route.
- Wear high-visibility vests to increase visual recognition by motorists.

- Do not rely on the vehicle operator's visibility, judgment, or ability. Make eye contact with the driver. Carefully and deliberately use hand signals so they will not startle or confuse motorists or be mistaken for a flagger's direction before moving into traffic.

- Your movements may startle a motorist and cause an accident, so move deliberately. Do not make sudden movements that might confuse a motorist.

6.0 PROCEDURES

6.1 General

For information derived from a groundwater sample to be useful and accurate, the sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of analysis to keep any changes in water quality parameters to a minimum.

CAUTION

A closed well may generate and accumulate gases due to biological degradation, evolution of volatile chemicals from groundwater into the air, or other chemical actions. These gases may also be artificially generated, such as in the case of air sparging or extraction wells, which may take several days to depressurize. See Section 6.6.2 for safety measures to be employed to protect sampling personnel.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air or nitrogen, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water sample due to external influences of the sampling technique(s). In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. Concentration gradients resulting from mixing and dispersion processes, layers of variable geologic permeability, and the presence of separate-phase product (e.g., floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase contaminant concentrations in the collected sample compared to what is representative of the integrated water column as it naturally occurs at that point, resulting in the collection of a non-representative sample.

To safeguard against collecting non-representative samples, the following approach shall be followed prior to sample acquisition:

CAUTION

Mechanical agitation of well water may cause off-gas generation of volatile contaminants, creating an inhalation exposure to the sampler(s). Where avoiding an inhalation exposure is not possible and mechanical agitation is possible, pump into closed-top containers to control potential air emissions.

1. If possible, position yourself (and the sampling equipment) upwind of the well head.

2. Purge the monitoring well to be sampled prior to obtaining any samples from it. Evacuation of three to five well volumes is recommended prior to sampling, unless low-flow purging and sampling methods are utilized as described in Section 6.7 (Consult the site-specific SAP for exact purging parameters). In a high-yielding groundwater formation and where there is no stagnant water in the well above the

screened section, extensive evacuation prior to sample withdrawal is not as critical as it is in a low-yielding well or in wells containing stagnant water.

3. For wells with low yields that are purged dry during sampling, evacuate the well and allow it to recover to 75 percent of full capacity prior to sample acquisition. If the recovery rate is fairly rapid [generally 300 milliliters (mL) per minute or greater], attempt to continue evacuation until the number of well volumes specified in the SAP is achieved. If this cannot be accomplished, allow recovery to 75 percent of capacity and begin sampling.

CAUTION

For moderate to high-yielding monitoring wells, an evacuation rate that does not cause excessive turbulence in the well should be selected. There is no absolute safeguard against contaminating the sample with stagnant water; hence, special techniques are required for purging to minimize the potential for sample contamination (see below).

4. For moderate to high-yielding monitoring wells, use one of the following purge techniques:

   - Place a submersible pump or the intake line of a surface pump or bailer just below the water surface when removing the stagnant water.
   - While purging and as the water level decreases, lower the pump or intake line as the water level drops in the well. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. After this is accomplished, a bailer or other approved device may be used to collect the sample for analysis.
   - Unless otherwise directed, place the intake line of the sampling pump (or the submersible pump itself) near the center of the screened section, and pump approximately one casing volume of water from the well at a low purge rate equal to the well's recovery rate (low-flow sampling).

6.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform to the guidelines in SOP SA-6.1.

The following equipment shall be on hand when sampling groundwater wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment – Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler materials, ice, labels, and chain-of-custody documents.
- Field tools and instrumentation
  - Multi-parameter water quality meter with an in-line sample chamber capable of measuring ORP, pH, temperature, DO, specific conductance, turbidity, and salinity, or individual meters (as applicable).
  - pH Paper.
  - Camera and film (if appropriate). Approval prior to use may be required (see SOP SA-6.3).
  - Appropriate keys (for locked wells).

  - Water level indicator and/or oil-water interface probe if separate-phase product is expected.

- Pumps
  - Shallow-well pumps: Centrifugal, bladder, suction, or peristaltic pumps with drop lines and air-lift apparatus (compressor and tubing) where applicable.
  - Deep-well pumps: Submersible pump and electrical power-generating unit, or bladder pumps where applicable.
- Other sampling equipment – Bailers, graduated cylinder, stopwatch, and inert line with tripod-pulley assembly (if necessary).
- Pails – Plastic, graduated.
- Clean paper or cotton towels for cleaning equipment.
- Buckets with lids for collecting purge water.
- Decontamination solutions – Deionized water, potable water, phosphate-free laboratory-grade detergent, and analytical-grade solvent (e.g., pesticide-grade isopropanol), as required.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, cleaned prior to use, reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging and sample collection.

6.3 Calculations of Well Volume

To ensure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to know the volume of standing water in the well pipe (including well screen where applicable). This volume can be easily calculated by the following method. Calculations shall be entered in the site logbook or field notebook or on a sample log sheet form or equivalent electronic form(s) (see SOP SA-6.3):

1. Obtain all available information on well construction (location, casing, screen, etc.).
2. Determine well or inner casing diameter.
3. Measure and record static water level (depth below ground level or top of casing reference point).
4. Determine depth of well by sounding using a clean, decontaminated, weighted tape measure or water level indicator.
5. Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).
6. Calculate one static well volume in gallons $V = (0.163)(T)(r^2)$

where: V = Static volume of well in gallons.
T = Linear feet of water in the well.
r = Inside radius of well casing in inches.
0.163 = Conversion factor (compensates for conversion of casing radius from inches to feet; cubic feet to gallons; and pi (π)).

7. Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

Measuring devices may become contaminated when gathering the above information if they are submerged in contaminated water. Decontamination of the tape or water level indicator must be conducted between measurements in different wells as follows:

1. Saturate a paper towel or clean cotton towel with deionized water.

2. As the measuring device is extracted, wipe the tape, changing the cleaning surface frequently.

3. After it is extracted, rinse the probe or tape using a spray bottle of deionized water over a bucket or similar collection container.

Based on the contaminant (oily, etc.), it may be necessary to use a soap and water wash and rinse to remove contaminants. Isopropanol can be used on the probe/tape. However, it is recommended that the use of solvents on the tape be minimized because they could degrade the protective covering or possibly remove the scale designations. If isopropanol (or some other solvent) is used, assure that the manufacturer/supplier Safety Data Sheet (SDS) is obtained, kept onsite at a readily available location with other SDSs, and reviewed by personnel prior to the first usage of the solvent. Also, add the substance to the site-specific Hazardous Chemical Inventory list (see Section 5 of the Tetra Tech Health and Safety Manual (available on the Health and Safety link of the My Tetra Tech intranet site, Tetra Tech Hazard Communication Program, and OSHA Standard 29 Code of Federal Regulations [CFR] 1910.1200).

6.4 Evacuation of Static Water – Purging

6.4.1 General

The amount to be purged from each well will be determined prior to sample collection. This amount will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of the aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately, the well can be pumped until parameters such as temperature, specific conductance, pH, and turbidity (as applicable) have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook or field notebook or on standardized data sheets or an equivalent electronic form(s).

6.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A provides guidance on the proper evacuation device to use for given sampling situations. All of these techniques involve equipment that is portable and readily available.

Bailers

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of tubing equipped with a base plate and ball check-valve at the bottom. Bailers are typically comprised of stainless steel and plastic. They come in a variety of sizes, but the two most often used are 2 inches and 4 inches in diameter. An inert non-absorbent line such as polyethylene rope is used to lower and then raise the bailer to retrieve the sample. As the bailer is lowered into the water column, the ball is pushed up allowing the tube to be filled. When the bailer is pulled upward, the ball seats in the base plate preventing water from escaping.

Advantages of bailers include the following:

- There are few limitations on size and materials used.
- No external power source is needed.
- Bailers are inexpensive and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Splashing the bailer into the water or transfer of sample may cause aeration.
- The use of a bailer does not permit constant in-line monitoring of groundwater parameters.
- Use of bailers is physically demanding, especially in warm temperatures at personal protection equipment (PPE) levels above Level D.

Safety concerns using a bailer include the following:

- Muscle stress and strain, especially when using 4-inch bailers and when pulling from excessively deep wells.
- Entanglement, possible hand/finger injuries, and rope burns during a sudden release of the bailer back down the well.
- Direct contact with contaminants of concern and sample preservatives when discharging the bailer contents because there is not a high level of control during a direct pour, and splashing and indirect contact with contaminants/preservatives could occur.

Control measures for these hazards are provided in Section 6.6.2.

Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, and peristaltic pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low-volume pump that uses rollers to squeeze flexible tubing to create suction. This tubing can be dedicated to a well to prevent cross-contamination from well to well. Suction pumps are all portable, inexpensive, and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause loss of dissolved gases and volatile organics. Another limitation of these pumps is that they require a secondary energy source to drive them. Electrically driven pumps may require portable generators as energy sources. Air diaphragm pumps require air compressors and/or compressed gas cylinders to drive them. The advantage of the peristaltic pump is that it can operate from either a built in power source or a portable battery source. Safety measures associated with these pumps are provided below.

Air-Lift and Gas-Lift Samplers

This group of pump samplers uses gas pressure either in the annulus of the well or in a Venturi to force groundwater up a sampling tube. These pumps are also relatively inexpensive. Air- or gas-lift samplers are more suitable for well development than for sampling because the samples may be aerated as a result of pump action. Aeration can cause pH changes and subsequent trace metal precipitation or loss of volatile organics.

Submersible Pumps

Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed gas or electricity. Operation principles vary, and displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for 2-inch-diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include the following:

- They may have low delivery rates.
- Many models are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding of the impellers with some of these pumps.
- Decontamination of internal components can be difficult and time consuming.

Compressed Gases

Safety concerns using compressed gases as an energy source in these pumps are numerous. The nitrogen gas or compressed air is provided in a compressed gas cylinder at a pressure of approximately 2,000 pounds per square inch (psi). If damaged, these cylinders can become dangerous projectiles. Additionally, a sudden release of a cylinder's contents can involve considerable force that could cause significant damage to the eyes and/or skin. Protective measures include the following:

- Always wear safety impact glasses when handling compressed gases.
- Always administer compressed gases through an appropriate pressure-reducing regulator.
- When clearing the cylinder connection port, open the cylinder valve only enough to clear foreign debris. During this process, always position the cylinder valve so that it faces away from you and others.
- If the cylinder is designed to accept a valve protection cap, always keep that protection cap in place, except when the cylinder is connected for use.

- When using the cylinder, lay the cylinder on its side to avoid the potential of it falling and knocking the valve off (and becoming a missile).

- DO NOT use the compressed nitrogen or air to clean clothing or to spray off the skin. Small cuts in the protective layer of the skin may permit the gas to enter into the bloodstream, presenting the potential danger of an embolism.

See the project-specific HASP (or equivalent) for additional direction concerning cylinder safe handling procedures pertaining to the safe handling, transportation, and storage of compressed gas cylinders.

Electrical Shock

Even in situations where portable batteries are used, the potential for electrical shock exists. This potential risk is increased in groundwater sampling activities because of the presence of groundwater near the batteries. This potential is also increased in (prohibited) situations where jury-rigging of electrical connections is performed. Other potential hazards occur when field samplers open the hood of a running car to access the battery as a power source. To control these hazards:

- If you are unfamiliar with electrical devices, do not experiment, get help, and get the proper equipment necessary to power your device.

- Use the proper portable power inverters for cigarette lighter connections to minimize the need to access the battery under the hood of your vehicle.

- Use of electrical generators may pose a number of hazards including noise, those associated with fueling, and indirect sample influence.

To minimize or eliminate electrical generator hazards:

- Inspect the generator before use. Ensure that the generator and any extension cords are rated for the intended operation and have a Ground Fault Circuit Interrupter (GFCI) in line to control potential electrical shock.

- Fuel the generator before purging and sampling to avoid loss of power during sampling.

- Fuel engines only when they are turned OFF and have cooled sufficiently to prevent a fire hazard.

- Place the generator and any fuel source at least 50 feet from the well to be sampled to avoid indirect influence to the sample from fuel vapors or emission gases.

Lifting Hazards

This hazard may be experienced when moving containers of purge water, equipment, cylinders, etc. To control these potential hazards:

- Do not fill purge buckets to more than 80 percent of their capacity.

- Obtain a gas cylinder of sufficient size to complete the designated task but not too large to handle. K-size cylinders weigh approximately 135 pounds and are difficult to handle. M-size cylinders weigh approximately 50 pounds and are easier to handle and move.

- When necessary, get help lifting and moving gas cylinders and other heavy objects. Minimize twisting and turning while lifting. If it is necessary to move these cylinders or generators over significant distance, use mechanical means (carts, etc.).

- Use proper lifting techniques as described in Section 4.4 of the Tetra Tech Health and Safety Manual.

6.5 Onsite Water Quality Testing

This section describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific conductance
- Temperature
- DO
- ORP
- Turbidity
- Salinity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous waste site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, or colloidal material or other suspended matter.

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Because instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use. Most meters used to measure field parameters require calibration on a daily basis. Refer to SOP SA-6.3 for an example equipment calibration log.

6.5.1 Measurement of pH

6.5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken and recorded on the groundwater sample log sheet (Attachment B) or equivalent electronic form.

Two methods are given for pH measurement: the pH meter and pH indicator paper. Indicator paper is used when only an approximation of the pH is required or when pH meter readings need to be verified, and the pH meter is used when a more accurate measurement is needed. The response of a pH meter can be affected by high levels of colloidal or suspended solids, but the effect is generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, or colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

6.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or alkalinity determination) and specific, or narrower range, pH range paper.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to (in this instance, hydrogen) ion activity (which is usually similar to concentration) across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to the ion concentration is generated and measured.

6.5.1.3 Equipment

The following equipment is to be used for obtaining pH measurements:

- A stand-alone portable pH meter or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).

- Combination electrode with polymer body to fit the above meter. Alternately, a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs.

- Buffer solutions, as specified by the manufacturer. If the buffer solutions are considered hazardous per 29 CFR 1910.1200 (Hazard Communication) or the volumes used are greater than consumer commodity levels, the SSO shall obtain SDSs from the manufacturer for the specific buffer solutions (see Section 4 of the Tetra Tech Health and Safety Manual regarding the Hazard Communication Program).

- pH indicator paper to cover the pH range 2 through 12.

- Manufacturer's operation manual. All personnel must be familiar with the equipment operation to ensure that the integrity of samples is preserved and that the equipment is operated safely.

6.5.1.4 Measurement Techniques for Field Determination of pH

pH Meter

The following procedure shall be used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

1. Inspect the instrument and batteries prior to initiation of the field effort.

2. Check that the buffer solutions are used for field calibration prior to their expiration dates. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.

3. If applicable, make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).

4. Calibrate the meter and electrode(s) on a daily use basis (or as recommended by manufacturer) following manufacturer's instructions. Record calibration data on a water quality meter calibration log sheet (Attachment C) or equivalent electronic form.

5. Immerse the electrode(s) in the sample. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. The failure of the measurements to stabilize must be clearly noted in the logbook or equivalent electronic form.

6. Read and record the pH of the sample. pH shall be recorded to the nearest 0.01 pH standard unit. Also record the sample temperature (unless otherwise specified in the SAP, record temperatures to the nearest whole degree Fahrenheit or 0.5 degree Celsius).

7. Rinse the electrode(s) with deionized water.

8. Store the electrode(s) in an accordance with manufacturer’s instructions when not in use.

Any visual observation of conditions that may interfere with pH measurement, such as oily materials or turbidity, shall be noted and avoided as much as possible.

pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, or 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown, then the investigation shall start with wide-range paper and proceed with successively narrower range paper until the sample pH is determined. To measure the pH with pH paper:

1. Collect a small portion of sample into a clean container.

2. Dip the pH paper into this small portion of sample.

3. Compare the color of the paper to the color chart that is provided with the pH paper and read the corresponding pH from the chart.

4. Record the pH value from the chart on the sample log sheet.

5. Discard the used pH paper as trash.

6. Discard the small volume of sample that was used for the pH measurement with the other investigative-derived waste.

6.5.2 Measurement of Specific Conductance

6.5.2.1 General

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

Specific conductance at 25°C is used as a standard of comparison for different water sources as conductivity changes with temperature. It is important to obtain a specific conductance measurement soon after taking a sample because temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect specific conductance. Most conductivity meters in use today display specific conductance in units of mS/cm, which is the conductivity normalized to a temperature of 25°C. These are the required units to be recorded on the groundwater sample log field form or equivalent electronic form. If a sample cannot be cooled or warmed (as appropriate) to 25°C, this should be noted in the field documentation

6.5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, and the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases, and salts such as hydrochloric acid, sodium carbonate, and sodium chloride, respectively, are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not dissociate in aqueous solution, conduct a current very poorly if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on the ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell, which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

6.5.2.3 Equipment

The following equipment is needed for taking specific conductance measurements:

- Stand-alone portable conductivity meter or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available that may also be used to monitor salinity and temperature. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirements of the sampling program.

6.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are as follows (calibration shall be conducted according to manufacturer's instructions):

1. Check batteries and calibrate instrument before going into the field.

2. Calibrate on a daily use basis (or as recommended by manufacturer), according to the manufacturer's instructions and record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used for calibration.

3. Rinse the cell with one or more portions of the sample to be tested or with deionized water and shake excess water from the cell.

4. Immerse the electrode in the sample and measure the conductivity.

5. Read and record the results in a field logbook or on a sample log sheet or equivalent electronic form.

6. Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for troubleshooting assistance.

6.5.3 Measurement of Temperature

6.5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field because collected water samples may rapidly equilibrate with the temperature of their surroundings.

6.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury-filled, dial-type thermometers or combination meters equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22). In addition, various meters such as specific conductance or DO meters that have temperature measurement capabilities may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

6.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample, use the following procedure:

1. Immerse the thermometer in the sample until temperature equilibrium is obtained (1 to 3 minutes). To avoid the possibility of cross-contamination, the thermometer shall not be inserted into samples that will undergo subsequent chemical analysis.

2. Record values in a field logbook or on a sample log sheet or equivalent electronic form.

If a temperature meter or probe is used:

1. Calibrate the instrument according to manufacturer's recommendations prior to use.

2. Immerse the meter/probe in the sample until temperature equilibrium is obtained (1 to 3 minutes). To avoid the possibility of cross-contamination, the meter/probe shall not be inserted into samples that will undergo subsequent chemical analysis.

3. Record values in a field logbook or on a sample log sheet or equivalent electronic form.

6.5.4 Measurement of Dissolved Oxygen

6.5.4.1 General

DO levels in natural water and wastewater depend on the physical, chemical, and biochemical activities in the water body. In addition, the growth of many aquatic organisms and the rate of corrosivity are dependent on DO concentrations. Thus, analysis for DO is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ because concentrations may show a large change in a short time if the sample is not adequately preserved.

The monitoring method discussed herein is limited to the use of DO meters. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters using a membrane electrode are suitable for highly polluted waters because the probe is completely submersible and is not susceptible to interference caused by color, turbidity, or colloidal material or suspended matter.

6.5.4.2 Principles of Equipment Operation

DO probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH^-) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode. This rate is proportional to the oxygen concentration in the water being measured.

Because the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, leaving the surface of the solution undisturbed.

DO probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases such as chlorine or with gases such as hydrogen sulfide that are not easily depolarized from the indicating electrode. If a gaseous interference is suspected, it shall be noted in the field logbook and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer. This compensation can counteract some of the temperature effects, but not all of them.

6.5.4.3 Equipment

The following equipment is needed to measure DO concentrations:

- A stand-alone portable DO meter or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Sufficient cable to allow the probe to contact the sample.

- Manufacturer's operation manual.

6.5.4.4 Measurement Techniques for Dissolved Oxygen Determination

DO probes differ as to instructions for use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure DO concentrations:

1. Check the DO meter batteries before going to the field.
2. Condition the probe in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
3. Calibrate the instrument in the field according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature.
4. Record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form.
5. Rinse the probe with deionized water.
6. Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells may be moved up and down to achieve the required mixing.
7. Record the DO content and temperature of the sample in a field logbook or on a sample log sheet or equivalent electronic form.
8. Rinse the probe with deionized water.
9. Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable because sample handling is not involved. This however may not always be practical.

Special care shall be taken during sample collection to avoid turbulence that can lead to increased oxygen solubilization and positive test interferences.

6.5.5 Measurement of Oxidation-Reduction Potential

6.5.5.1 General

ORP provides a measure of the tendency of organic or inorganic chemicals to exist in an oxidized state. The ORP parameter therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of reduced to oxidized species in the sample.

6.5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and is dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as DO, may be correlated with ORP to provide knowledge of the quality of the solution, water, or wastewater.

6.5.5.3 Equipment

The following equipment is needed for measuring the ORP of a solution:

- A combination meter with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

6.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring ORP:

1. Check the equipment using the manufacturer's recommended reference solution and check its batteries before going to the field.
2. Thoroughly rinse the electrode with deionized water.
3. If the probe does not respond properly to the recommended reference solution, verify the sensitivity of the electrodes by noting the change in millivolts when the pH of a test solution is altered. The ORP will increase when the pH of a test solution decreases, and the ORP will decrease when the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note that the ORP drops sharply when the caustic is added (i.e., pH increases) thus indicating that the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions or the probe should be replaced.
4. Record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form.

6.5.6 Measurement of Salinity

6.5.6.1 General

Salinity is a unitless property of industrial and natural waters. It is the measurement of dissolved salts in a given mass of solution. Most field meters determine salinity automatically from conductivity and temperature. The displayed value will be displayed in either parts per thousand (ppt) or percent (e.g., 35 ppt equals 3.5 percent).

6.5.6.2 Principles of Equipment Operation

Salinity is determined automatically from the meter's conductivity and temperature readings according to algorithms (such as are found in Standard Methods for the Examination of Water and Wastewater).

Depending on the meter, the results are displayed in either ppt or percent. The salinity measurements are carried out in reference to the conductivity of standard seawater (corrected to salinity = 35 ppt).

6.5.6.3 Equipment

The following equipment is needed for salinity measurements:

- A multi-parameter water quality meter capable of measuring conductivity and temperature and converting them to salinity (e.g., Horiba U-22 or YSI 600 series).
- Calibration solution as specified by the manufacturer.
- Manufacturer's operation manual.

6.5.6.4 Measurement Techniques for Salinity

The steps involved in taking salinity measurements are as follows (standardization shall be conducted according to manufacturer's instructions):

1. Check the expiration date of the solutions used for field calibration and replace them if they are expired.
2. Check batteries and calibrate the meter before going into the field.
3. Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on a water quality meter calibration log sheet or equivalent electronic form.
4. Rinse the cell with the sample to be tested. This is typically accomplished as the probe is placed in line during the collection of the purge water up to the time of sample acquisition.
5. Immerse the multi-probe in the sample and measure the salinity. Read and record the results in a field logbook or on a sample log sheet or equivalent electronic form.
6. Rinse the probes with deionized water.

6.5.7 Measurement of Turbidity

6.5.7.1 General

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Turbidity in water is caused by suspended matter such as clay, silt, or other finely divided organic and inorganic matter and microscopic organisms including plankton.

It is important to obtain a turbidity reading immediately after taking a sample because irreversible changes in turbidity may occur if the sample is stored too long.

6.5.7.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method, which is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidimeter. Therefore, nephelometric turbidity units (NTUs) based on the formazin preparation will approximate units derived from the candle turbidimeter, but will not be identical to them.

6.5.7.3 Equipment

The following equipment is needed for turbidity measurements:

- A turbidity meter (preferably a stand-alone meter such as a LaMotte 2020) that calibrates easily using test cells with standards such as 0.0, 1.0, and 10 NTUs, or a combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22). The range of calibration standards should bracket the measured sample turbidities.

- Calibration solution and sample tubes, as specified by the manufacturer.

- Manufacturer's operation manual.

6.5.7.4 Measurement Techniques for Turbidity

The steps involved in taking turbidity measurements utilizing an electrode (e) or light meter (l) are listed below (standardization shall be done according to manufacturer's instructions):

1. Check the expiration date of the solutions used for field calibration and replace them if they are expired.

2. Check batteries and calibrate the instrument before going into the field.

3. Calibrate on a daily basis according to the manufacturer's instructions, and record all pertinent information on a turbidity meter calibration log sheet (Attachment C) or equivalent electronic form.

4. When using the YSI 600 and/or Horiba U-22, rinse the electrode with one or more portions of the sample to be tested or with deionized water.

5. When using the Lamotte 2020, fill the light meter’s glass test cell with approximately 5 mL of sample, screw on the cap, wipe off glass to remove all residue that could intercept the instrument’s light beam, place the test cell in the light meter, aligning the arrow on the cap of the test cell to the arrow on the meter, and close the lid.

6. Immerse the electrode in the sample and measure the turbidity.

7. The reading must be taken immediately because suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.

8. Read and record the results in a field logbook or on a sample log sheet or equivalent electronic form. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.

9. Rinse the electrode or test cell with deionized water.

6.6 Sampling

6.6.1 Sampling Plan

The sampling approach consisting of the following shall be developed as part of the project planning documents approved prior to beginning work in the field:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
- Intended number, sequence, volumes, and types of samples. If the relative degree of contamination between wells is insignificant, a sampling sequence that facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells. In situations where the well is not well-characterized and the nature or extent of airborne contamination is unknown, it is recommended that head space analysis using a photoionization detector (PID) or flame ionization detector (FID) is performed to rate the wells, sampling from least contaminated to most contaminated. Refer to the project-specific HASP (or equivalent) for appropriate information and direction on air monitoring requirements.
- Sample preservation requirements.
- Work schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirements for split samples, access problems, location of keys, etc.
- The FOL shall ensure that the sampling method(s) to be employed is accurately represented in the HASP (or equivalent), indicating the types of sampling to be employed and the hazards. If the methods are not accurately represented, the FOL should rectify this with the HASP (or equivalent) author.
- The FOL shall ensure that sampling teams understand the sampling approach that they are to follow. Where sampling teams are made up of personnel from multiple locations, personal sampling experiences may vary. Therefore, the FOL shall review project-specific requirements, SOPs, and protocol to be followed. The FOL will conduct periodic surveys to ensure that these methods are being completed per his/her direction.

6.6.2 Sampling Methods as Related to Low-Flow Sampling

The collection of a groundwater sample consists of the following steps:

1. Ensure the safety of the sample location. Take a few minutes to evaluate the area for physical hazards (trip hazards, uneven ground, overhanging branches, etc.) and natural hazards (snakes, bees, spiders, etc.) that may exist in the area or that may have constructed nests in the well head. Snakes often like

to sun themselves on concrete well pads. Follow provisions in the project-specific HASP (or equivalent) and/or Tetra Tech Health and Safety Manual for addressing natural hazards.

2. As indicated earlier, some monitoring wells have the potential to contain pressurized headspace (e.g., through the generation of gases form contaminated groundwater, due to biological processes, degradation of contaminants, or simply based on location such as near a landfill or in areas that intersect lithological abnormalities) or through intentional artificial means such as those associated with air sparging systems. Injection or extraction wells may be artificially pressurized and may remain so for several days after the system has been turned off. This presents a hazard to people opening these wells. The Field Sampling Technician shall employ the following practices to minimize these hazards:

   - Wear safety glasses to protect the eyes. If site-specific observations and conditions indicate that the wells may be pressurized, wear a full-face shield over the safety impact eye protection.

   - DO NOT place your face or any other part of your body over the well when opening because this may place you in a strike zone.

   - Open the well cover at arms' length, then step away and allow the well to off gas and stabilize.

   Follow directions provided in the project-specific HASP (or equivalent), Work Plan, and/or SAP pertaining to the use of volatile chemical detection equipment (PID or FID) within the breathing zone of the sampler during sampling to determine the need to retreat from the work area and/or for the use of respiratory protection (as specified in the HASP or equivalent).

3. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data on a groundwater sampling log sheet or equivalent electronic form; then calculate the fluid volume in the well pipe (as previously described in this SOP). It is imperative that downhole equipment be adequately decontaminated between wells to prevent cross-contamination. Just as sampling occurs from the least contaminated to the most contaminated, it is also recommended that groundwater level measurements be taken in this manner.

4. Calculate volume of well water to be removed as described in Section 6.3.

5. Select the appropriate purging equipment (see Attachment A) or as designated within the governing Work Plan/SAP. If an electric submersible pump with packer is chosen, go to Step 10.

6. Lower the purging equipment or intake into the well to a short distance below the water level or mid-screen as indicated in project-specific documentation and begin water removal. Remember that some contaminants are "bottom dwellers," and in these cases, project-specific direction may specify placing the intake just above (1 to 2 feet) the well bottom. Secure the pump intake at the well and secure the effluent at the collection container and begin pumping. The pumping rate will be determined based on the decrease in the water level (see Section 6.7) or as directed in your project-specific documents or this SOP. Purge water is generally collected in a 5-gallon bucket or similar open- or closed-top container. To minimize the potential for spills and back injuries, do not fill 5-gallon buckets beyond approximately 80 percent of their capacity. Dispose of purge water as indicated in the planning document(s). Where necessary, slow the pumping rate or lower the pump intake as required to maintain submergence.

7. Estimate the approximate rate of discharge frequently and record it on the Low Flow Purge Data Sheet (see Attachment D). Estimate flow rate by noting the amount of discharge in a bucket or graduated cylinder per unit time using a watch with a second hand or a stopwatch.

8. Observe the peristaltic pump tubing intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics.

9. Purge a minimum of three to five well casing volumes before sampling (or as directed by the site-specific SAP). In low-permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recover to 75 percent of initial water level before sampling. Do not overfill purge containers because this increases the potential for spills and lifting injuries.

10. If sampling using a submersible pump, lower the pump intake to mid-screen (or the middle of the open section in uncased wells) and collect the sample. If sampling with a bailer, lower the bailer to just below the water surface.

11. For pump and packer assemblies only: Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. Purge a volume equal to at least twice the screened interval (or unscreened open section volume below the packer) before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.

12. If the recovery time of the well is very slow (e.g., 24 hours or greater), sample collection can be delayed until the following day. If the well has been purged early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record this occurrence in the site logbook or equivalent electronic form. When this occurs, contact the analytical laboratory to alert them that a reduced sample volume(s) will be submitted for analysis.

13. Fill sample containers and preserve and label them as described in SOP SA-6.1. Many sample bottles will contain preservative when they are shipped to the field. In those cases, do not add preservative.

14. Replace the well cap and lock it as appropriate. Make sure the well is readily identifiable as the source of the sample.

15. Process sample containers as described in SOP SA-6.1.

16. Decontaminate equipment as described in SOP SA-7.1.

6.7 Low-Flow Purging and Sampling

6.7.1 Scope and Application

Low-flow purging and sampling techniques may be required for groundwater sampling activities. The purpose of low-flow purging and sampling is to collect groundwater samples that contain "representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at or near natural flow conditions. This minimum-stress procedure emphasizes negligible water level drawdown and low pumping rates to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 1 inch or more and a saturated screen length, or open interval, of 10 feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semivolatile organic compounds [VOCs and SVOCs], pesticides, polychlorinated biphenyls [PCBs], metals, and other inorganic ions [cyanide, chloride, sulfate, etc.]). This low-flow procedure is not designed for collection of non-aqueous phase liquid samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs).

This procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 10 NTUs and to achieve a water level drawdown of less than 0.3 foot during purging and sampling. If these goals cannot be achieved, sample collection can take place provided that the remaining criteria in this procedure are met.

6.7.2 Equipment

The following equipment is required (as applicable) for low-flow purging and sampling:

- Adjustable rate submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon).
- Disposable clear plastic bottom-filling bailers to be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing – Teflon, Teflon-lined polyethylene, polyethylene, polyvinyl chloride (PVC), Tygon, or stainless steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device with 0.01-foot accuracy (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Interface probe.
- Flow measurement supplies.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments – pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional indicators - ORP, salinity, and DO. A flow-through cell (also referred to as an in-line sample chamber) is required.
- Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s) and other forms (see Attachments B through D) or equivalent electronic form(s).
- Sample bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags and/or labels.
- Well construction data, location map, field data from last sampling event (if available).
- Field Sampling Plan.
- PID or FID instrument for measuring volatile organic vapors per the HASP (or equivalent).

6.7.3 Purging and Sampling Procedure

1. Open the monitoring well as stated earlier and step away. Prepare sampling equipment while allowing 3 to 5 minutes to allow the water level to reach equilibrium. In situations where VOCs are the primary contaminants of concern, air monitoring of the samplers' breathing zone areas may be required by the HASP or equivalent (typically with a PID or FID).

2 Measure the water level immediately prior to placing the pump in the well and record the water level on the Low-Flow Purge Data Form or equivalent electronic form immediately prior to placing the pump or tubing into the well.

3. Lower the measuring device further into the well to collect the total depth measurement. Again wait 3 to 5 minutes to allow the well to equilibrate to the initial water level prior to placing the pump or pump intake in the well.

4. Record the total well depth on the Low-Flow Purge Data Form or equivalent electronic form immediately prior to placing the pump or tubing into the well.

5. Lower the pump or tubing slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible, keep the pump intake at least 2 feet above the bottom of the well to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbidity-free water samples may be difficult if there is 3 feet or less of standing water in the well.

6. Start with the initial pump rate set at approximately 0.1 liter per minute. Use a graduated cylinder and stopwatch to measure the pumping rate. Adjust the pumping rate as necessary to prevent drawdown from exceeding 0.3 foot during purging. If no drawdown is noted, the pump rate may be increased (to a maximum of 0.4 liter per minute) to expedite the purging and sampling event. The pump rate will be reduced if turbidity is greater than 10 NTUs after all other field parameters have stabilized. If groundwater is drawn down below the top of the well screen, purging shall cease or the well shall be pumped to dryness and then allowed to recover before purging continues. Well recovery to 75 percent is necessary prior to sampling. Slow-recovering wells should be identified and purged at the beginning of the workday to maximize field work efficiency. If possible, samples should be collected from these wells within the same workday and no later than 24 hours after the end of purging.

7. Measure the water level in the well every 5 to 10 minutes using the water level meter. Record the well water level on the Low Flow Purge Data Form (Attachment D) or equivalent electronic form.

8. Record on the Low Flow Purge Data Form every 5 to 10 minutes the water quality parameters (pH, specific conductance, temperature, turbidity, ORP, DO, and salinity or as specified by the approved site-specific planning document) measured by the water quality meter and turbidity meter. If the cell needs to be cleaned during purging operations, continue pumping (allow the pump to discharge into a container) and disconnect the cell. Rinse the cell with distilled/deionized water. After cleaning is completed, reconnect the flow-through cell and continue purging. Document the cell cleaning on the Low-Flow Purge Data Form or equivalent electronic form.

9. Estimate the flow rate by noting the amount of discharge in a graduated cylinder per unit time using a watch with a second hand. Remeasure the flow rate any time the pump rate is adjusted and periodically during purging. This will determine if a reduction in rate has occurred due to possible battery depletion.

10. During purging, check for the presence of bubbles in the flow-through cell. The presence of bubbles is an indication that connections are not tight. If bubbles are observed, check for loose connections and tighten, repair, or replace them as necessary to achieve a tight connection.

11. Wait until stabilization is achieved, or a minimum of two saturated screen volumes have been removed and three consecutive readings, taken at 5 to 10 minute intervals, are within the following limits, then begin sampling:

    - pH ±0.2 standard units
    - Specific conductance ±10%
    - Temperature ±10%
    - Turbidity less than 10 NTUs
    - DO ±10%

12. If the above conditions have not been met after the well has been purged for 4 hours, purging will be considered complete and sampling can begin. Record the final well stabilization parameters from the Low-Flow Purge Data Form onto the Groundwater Sample Log Form or equivalent electronic form.

NOTE: VOC samples are preferably collected first, directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

13. If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples:

    - Collect samples for non-VOC analyses first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample for VOCs, and record the new flow rate.

    - Reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel) or clamp, which should reduce the flow rate by constricting the end of the tubing. Proceed with sample collection.

    - Insert a narrow-diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, then collect the sample from the narrow diameter tubing.

    - Prepare samples for shipping as per SOP SA-6.1.

7.0 REFERENCES

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ATTACHMENT A

PURGING EQUIPMENT SELECTION

Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level <25 feet	X	X	X	X	X			
	Water Level >25 feet	X			X				
2-Inch	Water level <25 feet	X	X	X	X	X	X		
	Water Level >25 feet	X			X		X		
4-Inch	Water level <25 feet	X	X	X	X	X	X	X	X
	Water Level >25 feet	X			X		X	X	X
6-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X
8-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X

ATTACHMENT A
Purging and Sampling Equipment Selection (Updated July 2016)

Manufacturer	Model Name/ Number	Principle of Operation	I/E[1]	Maximum Outer Diameter (OD)/ Length (L)[2]	Construction Materials[3] (with Lines and Tubing)	Lift Range (Feet)	Delivery Rates or Volumes[4]	Main Source(s) of Information[5]	Comments
Commonly Used Purging/Sampling Equipment									
GeoTech Environmental Equipment, Inc.	Geopump (Series I or II)	Portable; peristaltic vacuum (suction) or pressure - reversible pump	E	3.5" x 8" x 8"	Not applicable (NA)	0 - 27	0 - 1,000 mL/min	Mfg./Pine	Variable speed; operate with 12 volt (V) direct current (DC) or 120V alternating current (AC) power source.
Grundfos Pumps Corporation	Redi-Flo2	Portable; submersible pump	I	1.8" OD x 11" L	SS; PTFE (i.e., Teflon®)	0 - 250	100 mL/min to 9 gpm	Pine/PNNL	Variable speed (adjustable flow rate); ideal for purging or sampling.
QED Environmental Systems	Sample Pro	Portable; bladder pump (positive displacement)	I	1.75" OD x 12" L	SS: PTFE or PE disposable bladder	0 - 250	0 - 800 mL/min	Mfg.	First pump developed specifically to bring the advantages of low-flow sampling to sites with non-dedicated pumps.
QED Environmental Systems	Well Wizard	Dedicated; bladder pump (positive displacement)	I	1.66" OD x 41" L	SS; PTFE bladder, HDPE, PP	0 - 1,000	0 - 2,000 mL/min	Pine/PNNL	Ideal for deep well applications and long-term monitoring. Available in a variety of sizes and materials.
Less Commonly Used Purging/Sampling Equipment									
Bennett Sample Pumps, Inc.	Bennett 1800-8	Portable; piston pump (positive displacement)	I	1.8" OD x 23.625" L	SS: PTFE, PP, Nylon	0 - 1,000	100 mL/min to 2.6 gpm	Mfg./PNNL	Variable speed (adjustable flow rate); ideal for purging or sampling. Discharge rates are difficult to control.
Cole-Parmer Inst. Co.	Masterflex 7571-00	Portable; peristaltic vacuum (suction) or pressure - reversible pump	E	16" x 10.25" x 11"	NA	0 - 27	0.06 - 680 mL/min	Mfg./Pine	Peristaltic pumps are not recommended for sampling volatile organic compounds (VOCs).
Fultz Pumps, Inc.	Fultz SP300	Portable; gear driven pump (positive displacement)	I	1.75" OD x 9.16" L	SS; PTFE gears, Viton®	0 - 200	100 mL/min to 2.4 gpm	Mfg./PNNL	Variable speed (adjustable flow rate); ideal for purging or sampling. Low extraction rates are difficult to control.
GeoTech Environmental Equipment, Inc.	Keck SP12	Portable; progressive cavity pump (positive displacement)	I	1.75" OD x 25" L	SS; EPDM stator, PE	0 - 150	100 mL/min to 1.2 gpm	Mfg./PNNL	Variable speed (adjustable flow rate); ideal for purging or sampling. Low extraction rates are difficult to control.
GeoTech Environmental Equipment, Inc.	SS Geosub	Portable; single speed submersible purge pump	I	1.75" OD x 13.2" L	SS; PTFE, Viton®	0 - 200	low flow to 10 mL/min	Mfg./Pine	Only 12V SS pump with Teflon® cable according to GeoTech brochure.
GeoTech Environmental Equipment, Inc.	NA	Portable; centrifugal purge pump		NA	NA	0 - 55	2.5 gpm max.	Mfg.	Not recommended for sampling.
GeoTech Environmental Equipment, Inc.	Various	Portable; bladder pump (positive displacement)	I	0.675-1.66" OD	SS or PVC; PTFE or PE bladder; FEP or PE tubing	0 - 200 SS; 0 - 250 PVC	NA	Mfg.	Various sizes are available. Pump is also available in PVC instead of SS.
GeoTech Environmental Equipment, Inc.	Bailer	Portable; grab (positive displacement)	I	Various sizes	Various materials - HDPE, PVC, SS, or fluoropolymer	No limit	NA	Mfg.	Low cost, easy operation; potential churning could increase turbidity. Typically a last-resort option.
Grundfos Pumps Corporation	Redi-Flo3	Portable; submersible pump	I	2.9" OD	SS; PVDF, Viton®, Tefzel®	0 - 360	8 gpm max.	Pine/PNNL	Not designed for low flow use.
Grundfos Pumps Corporation	Redi-Flo4	Portable; submersible pump	I	3.8" OD	SS; PTFE	0 - 600	100 mL/min to 10 gpm	Pine/PNNL	Variable speed (adjustable flow rate); ideal for purging or sampling.
KYB	HydroStar™	Portable; single-action piston pump (positive displacement)	I	1.66" OD	SS; PTFE	0 - 400	100 mL/min to 5 gpm	Mfg./PNNL	Variable speed (adjustable flow rate); ideal for purging or sampling. Discharge rates are difficult to control.

ATTACHMENT A
Purging and Sampling Equipment Selection (Updated July 2016)

Manufacturer	Model Name/ Number	Principle of Operation	I/E[1]	Maximum Outer Diameter (OD)/ Length (L)[2]	Construction Materials[3] (with Lines and Tubing)	Lift Range (Feet)	Delivery Rates or Volumes[4]	Main Source(s) of Information[5]	Comments
Landtec North America	Nu-Matic 4	Dedicated; pneumatic displacement pump	I	3.5" OD x 43.25" L	SS	0 - 275	10 gpm max.	Pine	Float activated, fully automatic; ideal for the harsh environment of landfill conditions.
ProActive Environmental Products	SS Monsoon (and others)	Portable; Low Flow pumps available in a variety of sizes	I	1.82" OD x 7.5" L	SS; PE	0 - 120	10 mL/min to 3.5 gpm	Pine/GeoTech	12V DC - designed for continuous purging and low flow sampling.
QED Environmental Systems	Eliminator	Portable; bladder pump (positive displacement)	I	3" OD x 40" L	SS; PTFE or elastomer bladder, Q-Tal®, Viton®	0 - 230	6 gpm max.	Pine	High capacity; designed for light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL) removal in 4" wells.
QED Environmental Systems	Pulse Pump	Portable; pneumatic displacement pump	I	1.66" OD x 20" L	SS; PTFE	0 - 230	2 gpm max.	Pine	Especially suited for DNAPL recovery. Requires compressed air, external timer.
Solinst Canada Ltd.	404 WaTerra	Portable; inertial reciprocating pump (positive displacement)	I	Various sizes	SS or Delrin® footvalve; HDPE tubing	0 - 200	2 gpm max.	Pine	Low cost, easy operation; potential churning could increase turbidity. Simple alternative to a bailer.
Solinst Canada Ltd.	407 Integra	Portable; bladder pump	I	1" or 1.66" OD	SS or PVC; FEP bladder (disposable PE available)	SS - 0 - 500 PVC - 0-100	3.3 L/min at 150'	Pine	Regular or low flow applications.
Solinst Canada Ltd.	408 DVP	Portable; pneumatic drive pump	I	1.66" OD x 24" L	SS or PVC; FEP bladder	SS - 0 - 500 PVC - 0-100	3.3 L/min at 150'	Pine	Regular or low flow applications - can deliver high flow rates.
Solinst Canada Ltd.	408M DVP	Portable; micro pneumatic drive pump	I	0.375" OD	FEP tubing	0 - 240	20 - 150 mL/min	Pine	Uses coaxial FEP tubing, easy to transport and install; ideal for low flow and narrow down-hole applications.
Solinst Canada Ltd.	410	Portable; peristaltic (negative pressure) pump	E	13" x 5" x 6"	NA	0 - 27	120 - 3,500 mL/min	Pine	Ideal for vapor sampling, water from shallow wells, or surface water.
TIMCO Mfg. Co., Inc.	Bailer	Portable; grab (positive displacement)	I	Various sizes	PVC, PP, others	No limit	250 mL/foot of bailer	Old SOP	Other sizes, materials, models available; optional bottom-emptying device available, no solvents used.
No-Purge Sampling Equipment (Available Options on Some Projects)									
Amplified Geochemical Imaging (AGI), LLC	AGI Universal Sampler (formerly Gore-Sorber™ Module)	Passive container; diffusion-type sampler	I	0.25" OD x 8" L	Waterproof, vapor-permeable GORE-TEX™ polymer membrane of expanded PTFE	0 - 32	NA	ITRC PSC-5	Demonstrated to be applicable to a variety of (but not all) VOCs, semivolatile organic compounds (SVOCs), and polycyclic aromatic hydrocarbons (PAHs); not designed for inorganics.
GeoInsight, Inc.	HydraSleeve™	Passive container; grab-type sampler	I	1.5-2.6" OD x 30" L	PE tubing with PE reed-valve	No limit	650 - 1,250 mL	ITRC PSC-5	Demonstrated to be applicable to a variety of VOCs and inorganics.
Mutiple Manufacturers	RPPS	Rigid Porous Polyethylene Sampler (RPPS); diffusion-type sampler	I	1.5" OD x 5" L	Rigid PE tube - thin sheets of foamlike porous PE with a Delrin® plug	No limit	80 - 100 mL	ITRC PSC-5	Developed by Don Vroblesky (USGS). Demonstrated to be applicable to a variety of water-soluble organics and inorganics.
Mutiple Manufacturers	PDB	Passive Diffusion Bag (PDB) Sampler; diffusion-type sampler	I	1.2-2" OD, 18-24" L	LDPE with HDPE cap; some vendors use other materials and sizes	No limit	75 - 350 mL	ITRC PSC-3	Developed by Don Vroblesky (USGS) and Thomas Hyde (GE). Demonstrated to be applicable to a variety of (but not all) VOCs; not for inorganics.

ATTACHMENT A
Purging and Sampling Equipment Selection (Updated July 2016)

Manufacturer	Model Name/ Number	Principle of Operation	I/E[1]	Maximum Outer Diameter (OD)/ Length (L)[2]	Construction Materials[3] (with Lines and Tubing)	Lift Range (Feet)	Delivery Rates or Volumes[4]	Main Source(s) of Information[5]	Comments
ProHydro, Inc.	Snap Sampler™	Pneumatic actuator; grab-type sampler	I	1.7-3.4" OD x 19-22+" L	Acetal with PFA-coated SS spring; optional SS weight; 40 mL glass vials or 125-350 mL PP bottles	0 - 2,500	40 - 1,400 mL	ITRC PSC-5	Demonstrated to be applicable to a variety of VOCs and inorganics. Up to 4 bottles may be employed together.
Multi-Level Groundwater Monitoring System (MLS) (Used on Some Projects based on Stakeholder Agreement)									
FLUT, Ltd. Co.	Water FLUTe™	Dedicated; gas drive sampling, liner seals entire borehole wall.	I	Various sizes	NA	NA	NA	Mfg.	Practical to collect large volumes; can use low flow method; minimizes investigation-derived waste (IDW); proven technology.
Solinst Canada Ltd.	Continuous Multichannel Tubing (CMT)	Dedicated; 3 or 7-channel tubing designed to isolate and monitor depth discrete zones.	I	Up to 7 ports	NA	NA	NA	Mfg.	Low cost and easy to install; ideal for shallow applications; single tube for effective sealing.
Solinst Canada Ltd.	Waterloo	Dedicated; double valve or bladder pump sampling; packers separate ports at multiple depths.	I	Various sizes	NA	NA	NA	Mfg.	Practical to collect large volumes; can use low flow method; minimizes IDW; proven technology.
Schlumberger	Westbay	Dedicated; packers separate ports at multiple depths.	I	Various sizes	NA	NA	NA	Mfg.	Transducer and sampler are on a wire line; minimizes IDW; proven technology. Low long-time maintenance costs.

Footnotes:

1 - I/E - Internal (I) or external (E) to the well.

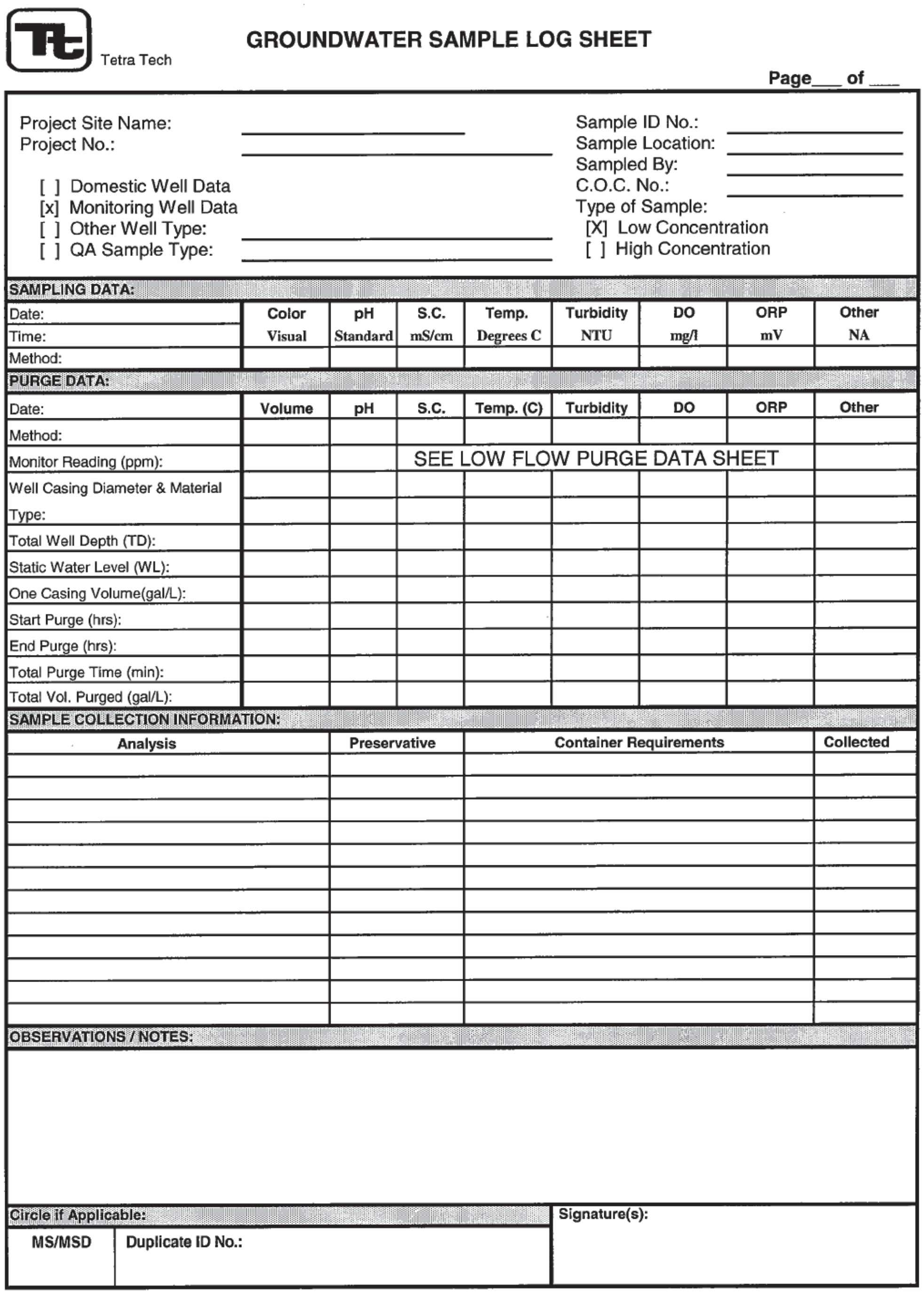
2 - For external pumps, the size is given in three dimensions (i.e. length, width, height); for internal pumps, the size is given in outside diameter (OD) and length (L) (in inches).

3 - Construction materials for pumps and associated equipment include: SS = stainless steel; PTFE = polytetrafluoroethylene; HDPE = high density polyethylene; PP = polypropylene; PE = polyethylene; PVC = polyvinyl chloride; FEP = fluorinated ethylene propylene; PVDF = polyvinylidene difluoride; EPDM = ethylene-propylene-diene elastomr; LDPE = low density polyethylene; PFA = perfluoroalkoxy.

4 - Rate or volume abbreviations: mL/min = milliliters per minute; gpm = gallons per minute; L/min = liters per minute; max. = maximum; mL = milliliters.

5 - Sources of information include specification sheets from the manufacturer (i.e., "Mfg."); equipment rental company websites - Pine Environmental (www.pine-environmental.com); GeoTech (www.geoenvtech.com); and guidance documents from Pacific Northwest National Laboratory (PNNL) (i.e., PNNL-13690) and Interstate Technology & Regulatory Council (ITRC) (i.e., PSC-3 and PSC-5 available at www.itrcweb.org).

ATTACHMENT B
GROUNDWATER SAMPLE LOG SHEET (EXAMPLE)



Tetra Tech

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: ____________________
Project No.: ____________________

[ ] Domestic Well Data
[x] Monitoring Well Data
[ ] Other Well Type: ____________________
[ ] QA Sample Type: ____________________

Sample ID No.: ____________________
Sample Location: ____________________
Sampled By: ____________________
C.O.C. No.: ____________________
Type of Sample:
[X] Low Concentration
[ ] High Concentration

SAMPLING DATA:

Date:	**Color**	**pH**	**S.C.**	**Temp.**	**Turbidity**	**DO**	**ORP**	**Other**
Time:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	mV	NA
Method:								

PURGE DATA:

Date:	**Volume**	**pH**	**S.C.**	**Temp. (C)**	**Turbidity**	**DO**	**ORP**	**Other**
Method:								
Monitor Reading (ppm):			SEE LOW FLOW PURGE DATA SHEET					
Well Casing Diameter & Material								
Type:								
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD **Duplicate ID No.:**

Signature(s):

ATTACHMENT C
EQUIPMENT CALIBRATION LOG (EXAMPLE)

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EQUIPMENT CALIBRATION LOG

PROJECT NAME : ______________________

INSTRUMENT NAME/MODEL: ______________________

SITE NAME: ______________________

MANUFACTURER: ______________________

PROJECT No.: ______________________

SERIAL NUMBER: ______________________

Date of Calibration	Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot No.)	Remarks and Comments
			Pre-calibration	Post-calibration	Pre-calibration	Post-calibration		

ATTACHMENT D (EXAMPLE)
LOW FLOW PURGE DATA SHEET

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: ____________________ **WELL ID.:** ____________________
PROJECT NUMBER: ____________________ **DATE:** ____________________

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments

SIGNATURE(S): ____________________ **PAGE___OF___**

APPENDIX D

STANDARD OPERATING PROCEEDURES

SA-1.2 - Surface Water and Sediment Sampling

TETRA TECH

STANDARD OPERATING PROCEDURE

Number SA-1.2	Page 1 of 23
Effective Date 9/12/2016	Revision 8
Applicability Tetra Tech, Inc., NUS Operating Unit	
Prepared Earth Sciences Department	
Approved T. Johnston	tom. johnston @tetratech.com Digitally signed by: tom. johnston@tetratech.com DN: CN = tom. johnston@tetratech.com Date: 2016.09.12 13:25:51 -05'00'

Subject
SURFACE WATER AND SEDIMENT SAMPLING

TABLE OF CONTENTS

SECTION **PAGE**

ATTACHMENTS

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes procedures and equipment commonly used for collecting environmental samples of surface water and aquatic sediment either for onsite examination and chemical testing or for offsite laboratory analysis.

2.0 SCOPE AND APLICABILITY

The information presented in this document is applicable to all environmental sampling of surface waters (Section 5.3) and aquatic sediments (Section 5.5), except where the analyte(s) may interact with the sampling equipment or may leach from the sampling equipment into the collected samples. The collection of concentrated sludges or hazardous waste samples from disposal or process lagoons often requires methods, precautions, and equipment different from those described herein and should be described in site-specific planning documents.

WARNING:

Sample containers can be contaminated during storage if nearby volatile substances infiltrate the surrounding air and migrate into the containers. This can occur even when containers are capped. Therefore, containers that have been stored on site for longer than 6 months should not be used.

Note: Whereas most air-borne contamination is likely to be associated with organic substances, inorganic substances such as hydrochloric acid (muriatic acid) can emit inorganic vapors that infiltrate sample containers.

3.0 GLOSSARY

Analyte – Chemical or radiochemical material whose concentration, activity, or mass is measured.

Composite Sample – A sample representing a physical average of grab samples.

Environmental Sample – A quantity of material collected in support of an environmental investigation that does not require special handling or transport considerations as detailed in SOP SA-6.1.

Grab Sample – A portion of material collected to represent material or conditions present at a single unit of space and time.

Hazardous Waste Sample – A sample containing (or suspected to contain) concentrations of contaminants that are high enough to require special handling and/or transport considerations per SOP SA-6.1.

Representativeness – A qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been collected.

4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - The Project Manager is responsible for determining the sampling objectives, initial sampling locations, and field procedures used in the collection of soil samples. The Project Manager also has the overall responsibility for seeing that all surface water and sediment sampling activities are properly conducted by appropriately trained personnel in accordance with applicable planning documents.

Field Operations Leader (FOL) - This individual is primarily responsible for the execution of the planning document containing the Sampling and Analysis Plan (SAP). This is accomplished through management of a field sampling team for the proper acquisition of samples. He or she is responsible for the supervision of onsite analyses; ensuring proper instrument calibration, care, and maintenance; sample collection and handling; the completion and accuracy of all field documentation; and making sure that custody of all samples obtained is maintained according to proper procedures. When appropriate and as directed by the FOL, such responsibilities may be performed by other qualified personnel (e.g., field technicians) where credentials and time permit. The FOL is responsible for finalizing the locations for collection of surface water and sediment samples. The FOL is ultimately responsible for adherence to Occupational Safety and Health Administration (OSHA) regulations during these operations through self-acquisition or through the management of a field team of samplers.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan (HASP). This includes ensuring that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO or SSO designee may also be required to advise the FOL on other safety-related matters such as mitigative measures to address potential hazards from hazardous objects or conditions.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of samples in accordance with this SOP and other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

General personnel qualifications for groundwater sample collection and onsite water quality testing include the following:

- OSHA 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate procedures for sample documentation, handling, packaging, and shipping.

5.0 HEALTH AND SAFETY

Precautions to preserve the health and safety of field personnel implementing this SOP are distributed throughout. The following general hazards may also exist during field activities, and the means of avoiding them must be used to preserve the health and safety of field personnel:

Bridge/Boat Sampling – Potential hazards associated with this activity include:

- Traffic – one of the primary concerns as samplers move across a bridge because free space of travel is not often provided. Control measures should include:
    - When sampling from a bridge, if the samplers do not have at least 6 feet of free travel space or physical barriers separating them and the traffic patterns, the HASP will include a Traffic Control Plan.
    - The use of warning signs and high-visibility vests are required to warn oncoming traffic and to increase the visibility of sample personnel.

- Slips, trips, and falls from elevated surfaces are a primary concern. Fall protection shall be worn when or if samplers must lean over a rail to obtain sample material. A Fall Protection Competent Person (in accordance with OSHA fall protection standards) must be assigned to ensure that fall protection is appropriately and effectively employed.

- Water hazards/drowning – if someone enters the water from an elevated surface (such as a bridge or dock) and when sampling from a boat. To minimize this potential, personnel shall wear United states Coast Guard (USCG)-approved floatation devices, and the sampling crew must also have on hand a Type IV Throwable Personal Floatation Device with at least 90 feet of 3/8-inch rope. See Section 5.5.2 of this SOP.

- Within the HASP, provisions will also be provided concerning the requirement of a Safe Vessel Certification or the necessity to conduct a boat inspection prior to use. In addition, the HASP shall also specify requirements as to whether the operator must be certified as a commercial boat operator and whether members of the sampling team must have a state-specific safe boating certification.

Entering Water to Collect Samples – Several hazards are associated with this activity and can be mitigated as follows:

- Personnel must wear a USCG-approved Floatation Device (selected and identified in the HASP). The SSO shall ensure that the device selected is in acceptable condition and suitable for the individual using it. This includes consideration of the weight of the individual.

- Lifelines shall be employed from a point on the shore. This activity will always be conducted with a Buddy. See Section 6.5.2.

- Personnel shall carry a probe to monitor the bottom ahead of them for drop offs or other associated hazards.

- The person in the water shall exercise caution concerning the path traveled so that the lifeline does not become entangled in underwater obstructions such as logs, branches, stumps, etc., thereby restricting its effectiveness in extracting the person from the water.

- Personnel shall not enter waters on foot in situations where natural hazards including alligators, snakes, as well as sharks, gars, and other predators within inland waterways may exist.

- In all cases, working along and/or entering the water during high currents or flood conditions shall be prohibited.

- Personnel shall not enter bodies of water where known debris exists that could result in injuries from cuts and lacerations.

Sampling in marshes or tidal areas in some instances can be accomplished using an all-terrain vehicle (ATV). This is not the primary recommended approach because the vehicle may become disabled, or weather conditions or tidal changes could result in environmental damage as well as loss of the vehicle. The primary approach is recommended to be on foot where minimal disturbance would occur. The same precautions specified above with regard to sediment disturbance apply as well as the previously described safety concerns associated with natural hazards. The natural hazards include alligators, bees (nests in dead falls and tree trunks), snakes, etc. In addition, moving through and over this terrain is difficult and could result in muscle strain and slips, trips, and falls. Common sense dictates that the sampler selects the most open accessible route over moderate terrain. Move slowly and deliberately through challenging terrain to minimize falls. Mud boots or other supportive personal protective equipment (PPE) should be considered and specified in the HASP to permit samplers to move over soft terrain with the least amount of effort. In these situations, it is also recommended, as the terrain allows, that supplies be loaded and transported in a sled over the soft ground.

Working in these areas, also recognize the following hazards and means of protection against them:

Insects are also a primary concern. These include mosquitoes, ticks, spiders, bees, ants, etc. The HASP will identify those particular to your area. Typical preventative measures include:

- Use insect repellant. Approval of various repellants should be approved by the Project Chemist or Project Manager.

- Wearing light-colored clothing to control heat load due to excessive temperatures. In addition, it makes it easier to detect crawling insects on your clothing.

- Taping pants to boots to deny access. Again, this is recommended to control access to the skin by crawling insects. Consultation with the Project Health and Safety Officer SSO/Health and Safety Manager is recommended under extreme heat loads because this will create conditions of heat stress.

- Performing a body check to remove insects. The quicker you remove ticks, the less likely they will become attached and transfer bacteria to your bloodstream. Have your Buddy check areas inaccessible to yourself. This includes areas such as the upper back and between shoulder blades where it is difficult for you to examine and even more difficult for you to remove.

Safety Reminder

If you are allergic to bee or ant stings, it is especially critical that you carry your doctor-recommended antidote with you in these remote sampling locations due to the extended time required to extract incapacitated individuals as well as the effort required to extract them. In these scenarios, instruct your Buddy in the proper administration of the antidote. In all cases, if you have received a sting, administer the antidote regardless of the immediate reaction, evacuate, and seek medical attention as necessary. The FOL and/or SSO will determine when and if you may return to the field based on the extent of the immune response and hazards or potential hazards identified in these locations. To the FOL and SSO, this is a serious decision you have to make as to whether to take someone vulnerable to these hazards into a remote location where you may not be able to carry them out. Consider it wisely.

Poisonous Plants – To minimize the potential of encountering poisonous plants in the field, at least one member of the field team needs to have basic knowledge of what these plants look like so that they can be recognized, pointed out to other field personnel, and avoided if at all possible. If the field team cannot avoid contact and must move through an area where these plants exist, the level of PPE shall include Tyvek coveralls and enhanced decontamination procedures for the removal of oils from the tooling and/or equipment.

Temperature-Related Stress – Excessively cold temperatures may result in cold stress, especially when entering the water either intentionally or by accident. Provisions for combating this hazard should be maintained at the sample location during this activity. Excessively hot temperatures may result in heat stress especially in scenarios where equipment is packed through the marsh.

Because all of these activities are conducted outside, electrical storms are a significant concern. The following measures will be incorporated to minimize this hazard:

- Where possible, utilize commercial warning systems and weather alerts to detect storms moving into the area.

- If on or in the water, get out of the water. Move to vehicles or preferably into enclosed buildings with plumbing and wiring.

- Where warning systems are not available, follow the 30/30 Rule (i*f there are less than 30 seconds between thunder and lightning, go inside for at least 30 minutes after the last thunder).*

See the Tetra Tech Health and Safety Manual (available at the Health and Safety link of the "My Tetra Tech" intranet page) for additional protective measures.

6.0 PROCEDURES

NOTE: If documentation such as a Certificate of Analysis is provided with sample containers to demonstrate their cleanliness, submit the documentation to the project manager for inclusion in the project file.

NOTE: If sample containers that have been stored on site for more than 6 months are used for sampling, a note should be entered into the field log to explain why the containers were used. In such cases, collection of additional field blanks may be useful. These blanks may be used to identify the contamination source.

6.1 Introduction

Collecting a representative sample of surface water or sediment may be difficult because of water movement, stratification, or heterogeneous distribution of the targeted analytes. To collect representative samples, one must standardize sampling methods related to site selection, sampling frequency, sample collection, sampling devices, and sample handling, preservation, and identification. Regardless of quality control applied during laboratory analyses and subsequent scrutiny of analytical data packages, reported data are no better than the confidence that can be placed in the representativeness of the samples. Consult Appendix C for guidance on sampling that should be considered during project planning and that may be helpful to field personnel.

6.1.1 Surface Water Sampling Technique

Samples collected during site investigations may be grab samples or composite samples. The following general procedures apply to various types of surface water and sediment collection techniques:

- If a pre-preserved sample container is not used and the container is not pre-cleaned (See Section 6.1.2), rinse the sample container at least once with the surface water to be sampled before the sample is collected. This is not applicable when sample containers are provided pre-preserved with chemicals because doing so will wash some or all of the preservative out of the bottle. For sample containers that are certified to be clean, pre-rinsing is not recommended.

- For sampling moving water, collect the farthest downstream sample first, and continue sample collection in an upstream direction. In general, work from zones suspected of low contamination to zones of high contamination.

- Take care to avoid excessive agitation of water samples because loss of volatile constituents could result.

- When obtaining water samples in 40 mL vials with septum-lined lids for volatile organics analysis, fill the container completely (with a meniscus) to exclude any air space in the top of the vial and to be sure that the Teflon liner of the septum faces in after the vial is filled and capped. Turn the vial upside down and tap gently on your wrist to check for air bubbles. If air bubbles rise in the bottle, add additional sample volume to the container or recollect the sample to obtain a representative sample that has not lost VOCs through volatilization.

- Do not sample at a water surface, unless sampling specifically for a known constituent that is immiscible with, and on top of, the water.

- Do not sample at the bottom of the water column, unless sampling specifically for a known constituent that is immiscible with, and is expected to be found at the bottom of, the water column.

6.1.2 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type to be acquired. In general, the most representative surface water samples are obtained from mid-channel at a stream depth of 0.5 foot below water surface in a well-mixed stream; however, project-specific planning documents will address site-specific sampling requirements including sample collection points and sampling equipment. The most frequently used samplers include the following:

- Peristaltic pump
- Bailer
- Dip sampler
- Weighted bottle
- Hand pump
- Kemmerer
- Depth-integrating sampler

The dip sampler and weighted bottle sampler are used most often, and detailed discussions for these devices and the Kemmerer sampler are addressed subsequently in this section.

The criteria for selecting a sampler include:

1. Disposability and/or easy decontamination.

2. Inexpensive cost (if the item is to be disposed).

3. Ease of operation.

4. Non-reactive/non-contaminating properties. Samples may be contaminated by contaminated sample containers, and analytes may be lost through precipitation, decomposition, adsorption or other mechanisms that result from interaction with the sample container. Decomposition also may occur when analytes volatilize out of a sample or react with light. Correct sample container selection and use of preservation such as chemical preservatives, cooling, and protection from light are necessary to retard the degradation of samples.

Measurements collected for each sample (grab or each aliquot collected for compositing) shall include but not be limited to:

- Specific conductance
- Temperature
- pH

- Dissolved oxygen

Sample measurements shall be conducted as soon as the sample is acquired. Measurement techniques described in SOP SA-1.1 shall be followed. All pertinent data and results shall be recorded in a field notebook or on sample log sheets (see Attachment A) or an equivalent electronic form(s). These analyses may be selected to provide information on water mixing/stratification and potential contamination. Various types of water bodies have differing potentials for mixing and stratification.

In general, the following equipment is necessary for obtaining surface water samples. Additional equipment may be necessary depending on circumstances and field conditions.

- Required sampling equipment and associated documentation, which may include:
    - Remote sampling pole.
    - Sample containers Sample containers shall conform to the guidelines in SOP SA-6.1.
    - Weighted bottle sampler.
    - Kemmerer sampler, or other device.
    - Decontamination equipment.
    - Required paperwork (see SOP SA-6.3 and Attachments A and B to this SOP).
    - Required decontamination equipment.
    - Sealable polyethylene bags (e.g., Ziploc® baggies).
    - Heavy-duty cooler.
    - Ice.
    - Paper towels and garbage bags.
    - Chain-of-custody records and custody seals.
- Real-time air monitoring instrument (e.g., PID, FID) as directed in the project-specific planning document.
- Required PPE as directed in the project-specific planning document, which may include:
    - Nitrile surgeon’s or latex gloves (layered as necessary).
    - Safety glasses.
    - Other items identified on the Safe Work Permit that may be required based on location-specific requirements (e.g., hearing protection, steel-toed work boots, hard hat). These provisions will be listed in the HASP or addressed by the FOL and/or SSO.

Safety Reminder

The use of latex products may elicit an allergic reaction in some people. Should this occur, remove the latex gloves, treat for an allergic reaction, and seek medical attention as necessary.

Dip Sampling

Specific procedures for collecting a dip or grab sample of surface water can vary based on site-specific conditions (e.g., conditions near the shore and how closely a sampler can safely get to the shore). In some cases, e.g., when a sample container does not fit onto an available remote sampling pole, or pre-preserved sample containers are required, a transfer bottle must be used to collect sample material that is then transferred to the actual sample container. The general procedure for collecting a sample using a pole or directly from the water body is as follows:

1. Select the appropriate sample container based on the governing project-specific planning document.

NOTE: Samples designated for volatile chemical analyses should be collected first.

2. Remove the sample container cap. Do not place the cap where it might become contaminated (e.g., on the ground).

2. If sample material will be collected directly into an unpreserved container that can be dipped below the water surface, follow the steps immediately below; otherwise, proceed to Step 4.

    a. Securely attach the sample container to a remote sampling pole of sufficient length to reach below the surface of the water to be sampled.

    b. While facing upstream, invert the sample container connected to the pole so the opening faces downward, and carefully dip it to a stream depth of 0.5 foot below the water surface (or as directed by project-specific planning documents). If possible, avoid contacting the bottom of the water body because this could disturb sediment that may compromise the integrity of the surface water sample.

    c. Slowly turn the bottle right-side up allowing the bottle to fill.

    d. Replace the cap quickly and securely on the sample container. In the case of samples designated for VOC analysis, ensure that the cumulative size of air bubbles in the 40 mL vial is no greater than the size of a pea. It is best to exclude all air, if possible.

4. When using a transfer bottle (e.g., because the final sample container contains preservative or does not fit securely onto a dip pole), follow the steps below:

    a. Attach a transfer bottle to a remote sampling dip pole or plan to fill the transfer bottle directly. This bottle may be a large- or wide-mouth bottle, but small openings may be better for shallow surface water bodies to prevent inclusion of surface debris.

    b. While facing upstream, invert the transfer bottle so the opening faces downward and carefully dip it to a stream depth of 0.5 foot below the water surface (or as directed by project-specific planning documents). If possible, avoid contacting the bottom of the water body because this could disturb sediment that may compromise the integrity of the surface water sample.

    c. While avoiding contact between the transfer bottle and sample container, transfer the surface water sample from this intermediate container to the appropriate sample container with minimal agitation.

For samples to be analyzed for VOCs, minimal agitation is especially important to prevent loss of the volatiles.

d. Replace the cap quickly and securely on the sample container. In the case of samples designated for VOC analysis, ensure that the cumulative size of air bubbles in the 40 mL vial is no greater than the size of a pea. It is best to exclude all air, if possible.

5. Use a paper towel to clean and dry the outside of the sample container.

6. Affix a sample label to each sample container, ensuring that each label is completed legibly and completely, addressing all of the categories described in SOP SA-6.3.

7. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

Constituents measured in grab samples collected near the water surface may not be a true representation of the total concentration distributed throughout the water column and in the horizontal cross section. Therefore, as possible based on site conditions, the sampler may be required to augment dip samples with samples that represent both dissolved and suspended constituents and both vertical and horizontal distributions.

CAUTION

In areas prone to natural hazards such as alligators and snakes, etc., always use a buddy as a watch. Always have and use a lifeline or throwable device to extract persons who could potentially fall into the water. Be attentive to the signs, possible mounds indicating nests, and possible slides into the water. Remember that although snakes are typically encountered on the ground, they can appear on low-hanging branches. Be attentive to your surroundings because these may indicate that hazards are nearby.

Weighted Bottle Sampling

A grab sample can also be collected using a weighted holder that allows a bottle to be lowered to any desired depth, opened for filling, closed, and returned to the surface. This allows discrete sampling with depth. Several of these samples can be combined to provide a vertical composite. Alternatively, an open bottle can be lowered to the bottom and raised to the surface at a uniform rate so that the bottle collects a sample throughout the total water column depth and is just filled on reaching the surface. The resulting sample using either method will roughly approach what is known as a depth-integrated sample.

A closed weighted bottle sampler consists of glass or plastic bottle with a stopper, a weight and/or holding device, and lines to open the stopper and lower or raise the bottle. The general procedure for sampling with this device is as follows:

1. Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).

2. When the desired depth is reached, pull out the stopper with a sharp jerk of the stopper line.

3. Allow the bottle to fill completely, as evidenced by the absence of air bubbles.

4. Raise the sampler and cap the bottle quickly and securely. In the case of samples designated for VOC analysis, ensure that the cumulative size of air bubbles in the 40 mL vial is no greater than the size of a pea. It is best to exclude all air, if possible.

5. Use a paper towel to clean and dry the outside of the container. This bottle may be used as the sample container as long as the bottle is an approved container type. If this bottle is not the sample bottle, transfer the sample from this intermediate container to the appropriate sample container with minimal agitation while avoiding contact between the two sample containers. For samples to be analyzed for VOCs, minimal agitation is especially important to prevent loss of the volatiles.

6. Affix a sample label to each sample container, ensuring that each label is completed legibly and completely, addressing all of the categories described in SOP SA-6.3.

7. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

Kemmerer Sampler

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon-coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless steel or acrylic cylinder with rubber stoppers that leave the ends open while it is lowered in a vertical position (thus allowing free passage of water through the cylinder). A "messenger" is sent down the line when the sampler is at the designated depth to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill sample bottles. The general procedure for sampling with this device is as follows:

1. Gently lower the sampler to the desired depth.

2. When the desired depth is reached, send down the messenger to close the cylinder and then raise the sampler.

3. Open the sampler valve to fill each sample bottle (filling bottles for volatile analysis first, with minimal agitation). For samples to be analyzed for VOCs, minimal agitation is required to prevent loss of the VOCs.

4. Cap the bottle quickly and securely. Ensure that the cumulative size of air bubbles in 40 mL VOC vials is no greater than the size of a pea. It is best to exclude all air, if possible.

5. Use a paper towel to clean and dry the outside of the sample container.

6. Affix a sample label to each sample container, ensuring that each label is completed legibly, and completely, addressing all of the categories described in SOP SA-6.3.

7. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

6.2 Onsite Water Quality Testing

Onsite water quality testing shall be conducted as described in SOP SA-1.1.

6.3 Sediment Sampling

6.3.1 General

If composite surface water samples are collected, sediment samples are usually collected at the same locations as the associated surface water samples. If only one sediment sample is to be collected, the sampling location shall be approximately at the center of the water body, in a depositional area if possible based on sample location restraints (see below), unless the SAP states otherwise.

Generally, coarser-grained sediments are deposited near the headwaters of reservoirs. Bed sediments near the center of a water body will be composed of fine-grained materials that may, because of their lower porosity and greater surface area available for adsorption, contain greater concentrations of contaminants. The shape, flow pattern, bathymetry (i.e., depth distribution), and water circulation patterns must all be considered when selecting sediment sampling sites. In streams, areas likely to have sediment accumulation (e.g., bends, behind islands or boulders, quiet shallow areas or very deep, low-velocity areas) shall be sampled, in general, and areas likely to show net erosion (i.e., high-velocity, turbulent areas) and suspension of fine solid materials shall be generally avoided. Follow instructions in the SAP, as applicable.

Chemical constituents associated with bottom material may reflect an integration of chemical and biological processes. Bottom samples reflect the historical input to streams, lakes, and estuaries with respect to time, application of chemicals, and land use. Bottom sediments (especially fine-grained material) may act as a sink or reservoir for adsorbed heavy metals and organic contaminants (even if water column concentrations are less than detection limits). Therefore, it is important to minimize the loss of low-density "fines" during any sampling process.

Samples collected for volatile organic compound (VOC) analysis must be collected prior to any sample homogenization. Regardless of the method used for collection, the aliquot for VOC analysis must be collected directly from the sampling device (hand auger bucket, scoop, trowel), to the extent practical. If a device such as a dredge is used, the aliquot should be collected after the sample is placed in the mixing container prior to mixing.

In some cases, the sediment may be soft and not lend itself to collection by plunging Encore^{TM} or syringe samplers into the sample matrix. In these cases, it is appropriate to open the sampling device, (Encore^{TM} barrel or syringe) prior to sample collection, and carefully place the sediment in the device, filling it fully with the required volume of sample.

On active or former military sites, ordnance items may be encountered in some work areas. Care should be exercised when handling site media (such as if unloading a dredge as these materials may be scooped up). If suspected ordnance items are encountered, stop work immediately, move to shore and notify the Project Manager and Health and Safety Manager.

All relevant information pertaining to sediment sampling shall be documented as applicably described in SOP SA-6.3 and Attachment B or an equivalent electronic form.

6.3.2 Sampling Equipment and Techniques for Sampling Bottom Materials

A bottom-material sample may consist of a single scoop or core, or may be a composite of several individual samples in the cross section. Sediment samples may be obtained using onshore or offshore techniques.

SAFETY REMINDER

The following health and safety provisions apply when working on/over/near water:

- At least two people are required to be present at the sampling location in situations where the water depth and/or movement deem it necessary, each wearing a USCG-approved Personal Flotation Device.

- A minimum of three people are required if *any* of the following conditions are anticipated or observed:

  - Work in a waterway that is turbulent *or* swift that could sweep a sampler downstream should he or she fall in accidentally.

- The underwater walking surface (e.g., stream/river bed) is suspected or observed to involve conditions that increase the potential for a worker to fall into the water. Examples include large/uneven rocks or boulders, dense mud or sediment that could entrap worker's feet, etc.

- Waterway is tidal, and conditions such as those listed above could rapidly change.

The third person in the above condition must be equipped and prepared to render emergency support [e.g., lifeline, tethered Personal Flotation Device (Throwable Type IV, life saver), skiff, means to contact external emergency response support, etc.]

The following sampling devices may be used to collect sediment samples:

- Scoop sampler
- Dredge sampler
- Coring sampler
- Stainless steel or disposable trowel

Each type of sampler is discussed below.

In general, the following equipment if necessary for obtaining sediment samples:

- Required sampling equipment, which may include a scoop sampler, dredge sampler, coring sampler, or stainless steel or pre-cleaned disposable trowel.

- Stainless steel bowl or pre-cleaned disposable bowl to homogenize sample.

- Real-time air monitoring instrument (e.g., PID, FID) as directed in the project-specific planning document.

- Required PPE as directed in the project-specific planning document, which may include:

  - Nitrile surgeon’s or latex gloves (layered as necessary).

  - Safety glasses.

  - Other items identified on the Safe Work Permit that may be required based on location-specific requirements (e.g., hearing protection, steel-toed work boots, hard hat). These provisions will be listed in the HASP or addressed by the FOL and/or SSO.

  - Required paperwork (see SOP SA-6.3 and Attachments A and B to this SOP).

  - Required decontamination equipment.

  - Required sample containers.

  - Sealable polyethylene bags (e.g., Ziploc® baggies).

  - Heavy-duty cooler.

  - Ice.

- Paper towels and garbage bags.
- Chain-of-custody records and custody seals.

Scoop Sampler

A scoop sampler consists of a pole to which a jar or scoop is attached. The pole may be made of bamboo, wood, PVC, or aluminum and be either telescoping or of fixed length. The scoop or jar at the end of the pole is usually attached using a clamp.

If the water body can be sampled from the shore or if the sampler can safely wade to the required location, the easiest and best way to collect a sediment sample is to use a scoop sampler. Scoop sampling also reduces the potential for cross-contamination. The general scoop sampling procedure is as follows:

1. Reach over or wade into the water body.

2. While facing upstream (into the current), scoop the sampler along the bottom in an upstream direction. Although it is very difficult not to disturb fine-grained materials at the sediment-water interface when using this method, try to keep disturbances to a minimum.

3. If collecting sediment for VOC analysis, fill the sample container(s) for VOC analysis at this time and quickly and securely replace the cap(s) on the container(s).

4. Transfer the remaining sediment sample material to the bowl and homogenize the sediment.

5. Fill the containers for all remaining analyses and quickly and securely replace the caps on the containers as they are filled.

6. Use a paper towel to clean and dry the outside of each container.

7. Affix a sample label to each container, ensuring that each label is completed legibly and completely, addressing all of the categories described in SOP SA-6.3.

8. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

Dredge Samplers

Dredges are generally used to sample sediments that cannot easily be obtained using coring devices (e.g., coarse-grained or partially cemented materials) or when large quantities of sample are required. Dredges generally consist of a clam shell arrangement of two buckets. The buckets may either close upon impact or be activated by use of a "messenger." Some dredges are heavy and may require use of a winch and crane assembly for sample retrieval. The three major types of dredges are Peterson, Eckman, and Ponar.

The Peterson dredge is used when the bottom is rocky, in very deep water, or when the flow velocity is high. The Peterson dredge shall be lowered very slowly as it approaches bottom, because it can force out and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high flow velocities.

The Ponar dredge is a Peterson dredge modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends, thus reducing the "shock wave." The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates.

The general procedure for using a dredge sampler is as follows:

1. Gently lower the dredge to the desired depth.
2. When the desired depth is reached, send the messenger down the cable to close the cylinder and then carefully raise the sampler.
3. Open the sampler to retrieve the sediment.
4. If collecting sediment for VOC analysis, fill the sample container(s) for VOC analysis at this time and quickly and securely replace the cap(s) on the container(s).
5. Transfer the remaining sediment sample material to the bowl and homogenize the sediment.
6. Fill the containers for all remaining analyses and quickly and securely replace the caps on the containers as they are filled.
7. Use a paper towel to clean and dry the outside of each container.
8. Affix a sample label to each container, ensuring that each label is completed legibly and completely, addressing all of the categories described in SOP SA-6.3.
9. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

<u>SAFETY REMINDER</u>

Safety concerns using these dredges include lifting hazards, pinches, and compressions (several pinch points exist within the jaws and levers). In all cases, handle the dredge by the rope to avoid capturing fingers/hands.

<u>Coring Samplers</u>

Coring samplers are used to sample vertical columns of sediment. Many types of coring devices have been developed depending on the depth of water from which the sample is to be obtained, the nature of the bottom material, and the length of core to be collected. They vary from hand-push tubes to electronic vibrational core tube drivers.

Coring devices are particularly useful in pollutant monitoring because turbulence created by descent through the water is minimal, thus the fines at the sediment-water interface are only minimally disturbed. The sample is withdrawn intact, permitting the removal of only those layers of interest.

In shallow, wadeable waters, the use of a core liner or tube manufactured of Teflon or plastic is recommended for the collection of sediment samples. Caution should be exercised not to disturb the bottom sediments when the sample is obtained by wading in shallow water. The general procedure to collecting a sediment sample with a core tube is as follows:

1. Push the coring tube into the substrate until 4 inches or less of the tube is above the sediment-water interface. When sampling hard or coarse substrates, a gentle rotation of the tube while it is being pushed will facilitate greater penetration and decrease core compaction.

2. Cap the top of the tube to provide suction and reduce the chance of losing the sample.

3. Slowly extract the tube so as not to lose sediment from the bottom of the tube during extraction, and cap the bottom of the tube before removing it from the water. This will also help to minimize loss of sample.

4. If collecting sediment for VOC analysis, fill the sample container(s) for VOC analysis at this time and quickly and securely replace the cap(s) on the container(s).

5. Transfer the remaining sediment sample material to the bowl in which it will be homogenized and homogenize the remainder of the sediment.

6. Fill the containers for all analyses other than VOCs, and quickly and securely replace their caps as they are filled.

7. Use a paper towel to clean and dry the outside of each container.

8. Affix a sample label to each container, ensuring that each label is completed legibly and completely, addressing all of the categories described in SOP SA-6.3.

9. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

In deeper, non-wadeable water bodies, sediment cores may be collected from a bridge or boat using different coring devices such as Ogeechee Sand Pounders, gravity cores, and vibrating coring devices. All three devices utilize a core barrel with a core liner tube system. The core liners can be removed from the core barrel and replaced with a clean core liner after each sample. Before extracting the sediment from the coring tubes, the clear supernatant above the sediment-water interface in the core should be decanted from the tube. This is accomplished by turning the core tube to its side and gently pouring the liquid out until fine sediment particles appear in the waste liquid. Post-retrieval processing of samples is the same as above.

7.0 REFERENCES

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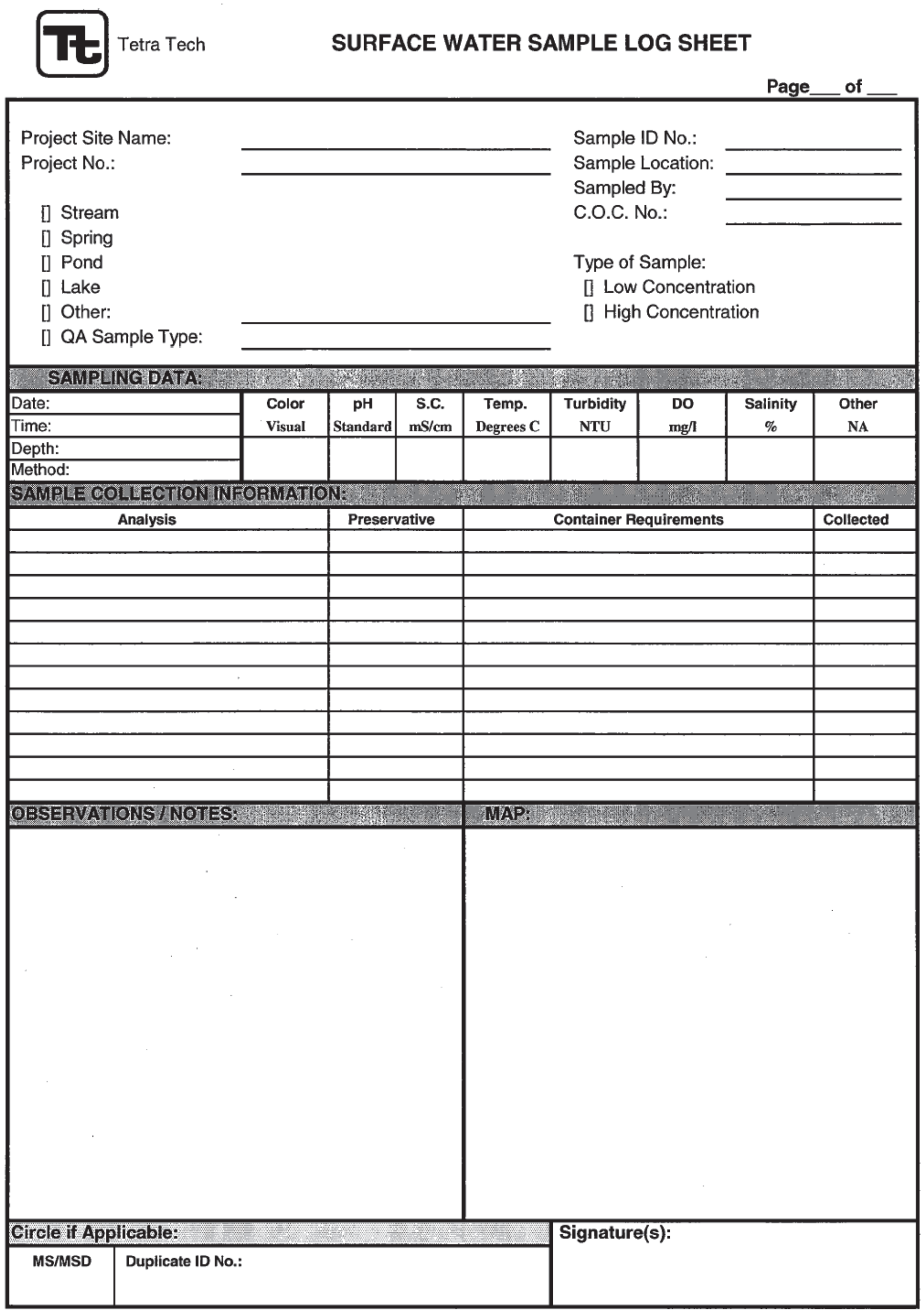
U.S. Geological Survey, 1977. National Handbook of Recommended Methods for Water-Data Acquisition. Office of Water Data Coordination, USGS, Reston, Virginia.

ATTACHMENT A
SURFACE WATER SAMPLE LOG SHEET (EXAMPLE)



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SURFACE WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: ____________________
Project No.: ____________________

[] Stream
[] Spring
[] Pond
[] Lake
[] Other: ____________________
[] QA Sample Type: ____________________

Sample ID No.: ____________
Sample Location: ____________
Sampled By: ____________
C.O.C. No.: ____________

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

MAP:

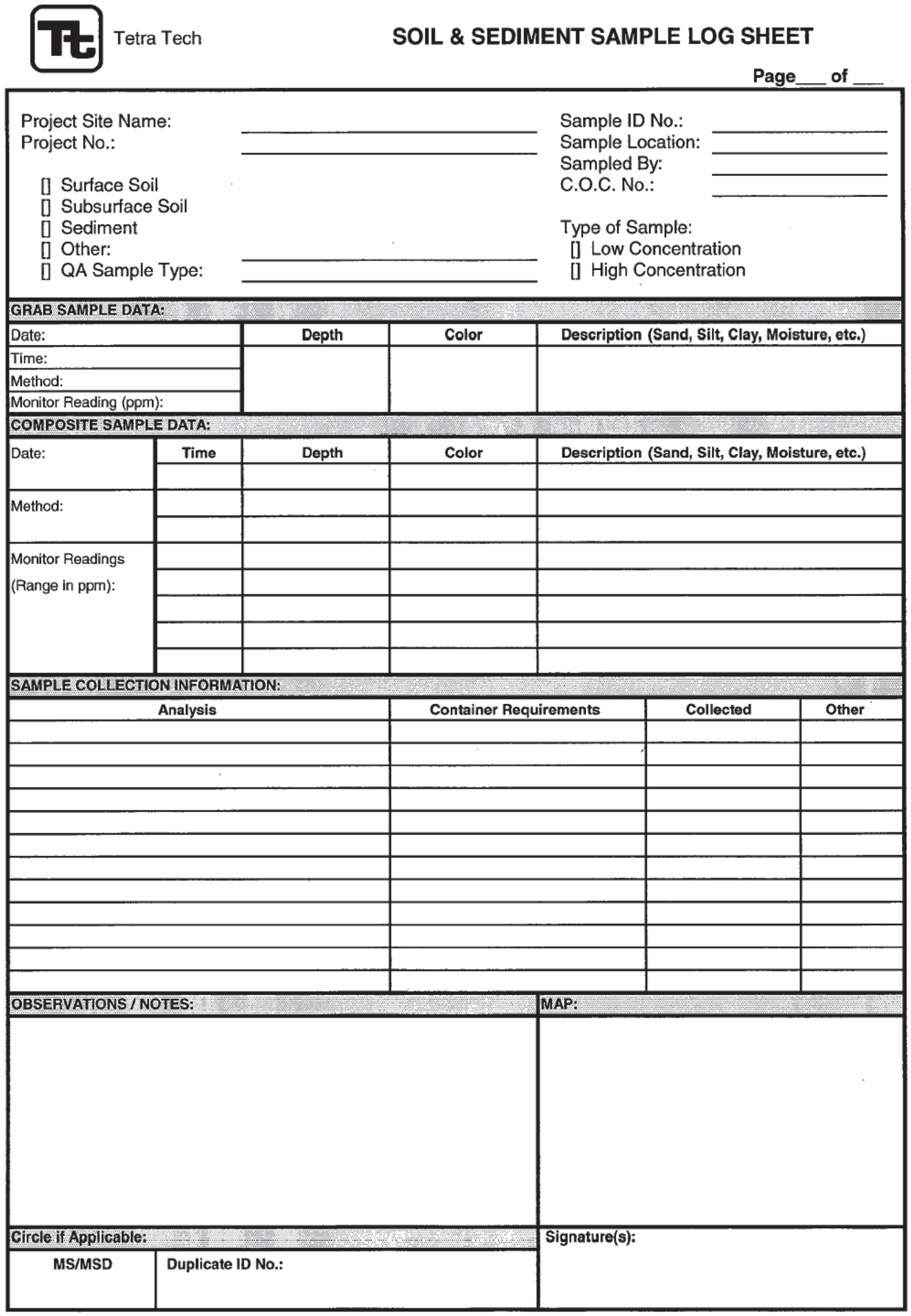
Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

ATTACHMENT B
SOIL & SEDIMENT SAMPLE LOG SHEET (EXAMPLE)



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SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: ____________________
Project No.: ____________________

☐ Surface Soil
☐ Subsurface Soil
☐ Sediment
☐ Other: ____________________
☐ QA Sample Type: ____________________

Sample ID No.: ______________
Sample Location: ______________
Sampled By: ______________
C.O.C. No.: ______________

Type of Sample:
☐ Low Concentration
☐ High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

APPENDIX C
GUIDANCE ON SAMPLING DESIGN AND SAMPLE COLLECTION

C.1 Defining the Sampling Program

Many factors are considered in developing a sampling program for surface water and/or sediment, including study objectives, accessibility, site topography, physical characteristics of the water body (e.g., flow and mixing), point and diffuse sources of contamination, and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on vertical and lateral mixing within the body of water. For sediment, dispersion depends on bottom current or flow characteristics, sediment characteristics (e.g., density, size), and geochemical properties (that affect adsorption/desorption). The hydrogeologist developing the sampling plan must therefore know not only the mixing characteristics of streams and lakes but must also understand the role of fluvial-sediment transport, deposition, and chemical sorption.

C.1.1 Sampling Program Objectives

The scope of the sampling program must consider the contaminant sources and potential pathways for transport of contamination to or within a surface water body. Contaminant sources may include point sources (leaky tanks, outfalls, etc.) or nonpoint sources (e.g., contaminated runoff). The major pathways for surface water contamination (not including airborne deposition) are overland runoff, leachate influx to the water body, direct waste disposal (solid or liquid) into the water body, and groundwater flow influx from upgradient contaminant sources. The relative importance of these pathways, and therefore the design of the sampling program, is controlled by the physiographic and hydrologic features of the site, the drainage basin(s) that encompasses the site, and the history of site activities.

Physiographic and hydrologic features to be considered include slopes and runoff direction, areas of temporary flooding or pooling, tidal effects, artificial surface runoff controls such as berms or drainage ditches (and when they were constructed relative to site operation), and locations of springs, seeps, marshes, etc. In addition, the obvious considerations such as the locations of man-made discharge points to the nearest stream (intermittent or flowing), pond, lake, estuary, etc. shall be considered.

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly non-detectable concentrations. Such dispersion does not, however, always readily occur. For example, obtaining a representative sample of contamination from a main stream immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation include: (1) moving the sampling location far enough downstream to allow for adequate mixing, or (2) collecting integrated samples in a cross section. Also, non-homogeneous distribution is a particular problem with regard to sediment-associated contaminants, which may accumulate in low-energy environments (coves, river bends, deep spots, or even behind boulders) near or distant from the source while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

The distribution of particulates within a sample itself is an important consideration. Many organic compounds are only slightly water soluble and tend to adsorb onto particulate matter. Nitrogen, phosphorus, and heavy metals may also be transported by particulates. Samples must be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

C.1.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and consideration of site conditions must be balanced against the costs of collection as controlled by accessibility. Bridges or piers are the first choice for locating a sampling station on a stream because bridges provide ready access and also permit the sampling technician to sample any point across the stream. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes, reservoirs, or larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment. Wading for samples is not recommended unless it is known that contaminant levels are low so that skin contact will not produce adverse health effects. This provides a built in margin of safety in the event that wading boots or other protective equipment should fail to function properly. If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample.

Under ideal and uniform contaminant dispersion conditions in a flowing stream, the same concentrations of each contaminant would occur at all points along the cross section. This situation is most likely downstream of areas of high turbulence. Careful site selection is needed to ensure, as nearly as possible, that samples are taken where uniform flow or deposition and good mixing conditions exist.

The availability of stream flow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Stream flow data in association with contaminant concentration data are essential for estimating the total contaminant loads carried by the stream. If a gaging station is not conveniently located on a selected stream, the project hydrogeologist shall explore the possibility of obtaining stream flow data by direct or indirect methods. Remember these locations are also where you may encounter natural hazards as these are areas where they hunt. Always exercise extreme caution.

C.1.3 Frequency of Sampling

The sampling frequency and objectives of the sampling event will be defined by the project planning documents. For single-event site or area characterization sampling, both bottom material and overlying water samples shall be collected at the specified sampling stations. If valid data are available on the distribution of a contaminant between the solid and aqueous phases, it may be appropriate to sample only one phase, although this is not often recommended. If samples are collected primarily for monitoring purposes (i.e., consisting of repetitive, continuing measurements to define variations and trends at a given location), water samples should be collected at a pre-established and constant interval as specified in the project plans (often monthly or quarterly and during droughts and floods). Samples of bottom material should generally be collected from fresh deposits at least yearly, and preferably seasonally, during both spring and fall.

The variability in available water quality data shall be evaluated before determining the number and collection frequency of samples required to maintain an effective monitoring program.

C.2 Surface Water Sample Collection

C.2.1 Streams, Rivers, Outfalls, and Drainage Features

Methods for sampling streams, rivers, outfalls, and drainage features (ditches, culverts) at a single point vary from the simplest of hand-sampling procedures to the more sophisticated multi-point sampling techniques known as the equal-width-increment (EWI) method or the equal-discharge-increment (EDI) methods (see below).

Samples from different depths or cross-sectional locations in the watercourse taken during the same sampling episode shall be composited. However, samples collected along the length of the watercourse or at different times may reflect differing inputs or dilutions and therefore shall not be composited. Generally, the number and type of samples to be taken depend on the river's width, depth, and discharge and on the suspended sediment the stream or river transports. The greater the number of individual points that are sampled, the more likely that the composite sample will truly represent the overall characteristics of the water.

In small streams less than about 20 feet wide, a sampling site can generally be found where the water is well mixed. In such cases, a single grab sample taken at mid-depth in the center of the channel is adequate to represent the entire cross section.

For larger streams, at least one vertical composite shall be taken with one sample each from just below the surface, at mid-depth, and just above the bottom. The measurement of dissolved oxygen (DO), pH, temperature, conductivity, etc., shall be made on each aliquot of the vertical composite and on the composite itself. For rivers, several vertical composites shall be collected, as directed in the project planning documents.

C.2.2 Lakes, Ponds, and Reservoirs

Lakes, ponds, and reservoirs have a much greater tendency to stratify than rivers and streams. The relative lack of mixing requires that more samples be obtained. The number of water sampling sites on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, measurement of DO, pH, temperature, etc. is to be conducted on each aliquot of the vertical composite and on the composite itself. In naturally formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical composites shall be composited to form a single sample if a sample representative of the water column is required. These vertical composites are often collected along a transect or grid. In some cases, it may be of interest to form separate composites of epilimnetic and hypolimnetic zones. In a stratified lake, the epilimnion is the thermocline that is exposed to the atmosphere. The hypolimnion is the lower, "confined" layer that is only mixed with the epilimnion and vented to the atmosphere during seasonal "overturn" (when density stratification disappears). These two zones may thus have very different concentrations of contaminants if input is only to one zone, if the contaminants are volatile (and therefore vented from the epilimnion but not the hypolimnion), or if the epilimnion only is involved in short-term flushing (i.e., inflow from or outflow to shallow streams). Normally, however, a composite consists of several vertical composites with samples collected at various depths.

In lakes with irregular shape and with bays and coves that are protected from the wind, separate composite samples may be needed to adequately represent water quality because it is likely that only poor mixing will occur. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements are now made in situ using sensors and automatic readout or recording devices. Single and multi-parameter instruments are available for measuring temperature, depth, pH, oxidation-reduction potential (ORP), specific conductance, DO, some cations and anions, and light penetration.

C.2.3 Estuaries

Estuarine areas are, by definition, zones where inland freshwaters (both surface and ground) mix with oceanic saline waters. Knowledge of the estuary type may be necessary to determine sampling locations.

Estuaries are generally categorized into one of the following three types dependent on freshwater inflow and mixing properties:

- Mixed Estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically, this type of estuary is shallow and is found in major freshwater sheet flow areas. Because this type of estuary is well mixed, sampling locations are not critical.

- Salt Wedge Estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries, the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally back and forth with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.

- Oceanic Estuary - characterized by salinities approaching full-strength oceanic waters. Seasonally, freshwater inflow is small, with the preponderance of the fresh-saline water mixing occurring near or at the shore line.

Sampling in estuarine areas is normally based on the tidal phase, with samples collected on successive slack tides (i.e., when the tide turns). Estuarine sampling programs shall include vertical salinity measurements at 1- to 5-foot increments, coupled with vertical DO and temperature profiles.

APPENDIX D

STANDARD OPERATING PROCEEDURES

SA-1.3 - Soil Sampling

TETRA TECH

STANDARD OPERATING PROCEDURE

Number SA-1.3	Page 1 of 31	
Effective Date 9/12/2016	Revision 11	
Applicability Tetra Tech, Inc., NUS Operating Unit		
Prepared Earth Sciences Department		
Subject SOIL SAMPLING	Approved T. Johnston	tom. johnston @tetratec h.com Digitally signed by: tom. johnston@tetratech.com DN: CN = tom. johnston@tetratech.com Date: 2016.09.12 13:23:24 -05'00'

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ATTACHMENTS

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures to be used to collect surface, near-surface, and subsurface soil samples. Additionally, it describes the methods for sampling of test pits and trenches to determine subsurface soil and rock conditions and for recovery of small-volume or bulk samples from pits.

2.0 SCOPE AND APPLICABILITTY

This document applies to the collection of surface, near-surface, and subsurface soil samples obtained through hand digging, hand augering, drilling, or machine excavating at sites for which laboratory testing, onsite visual examination, and onsite testing is required.

WARNING:

Sample containers can be contaminated during storage if nearby volatile substances infiltrate the surrounding air and migrate into the containers. This can occur even when containers are capped. Therefore, containers that have been stored on site for longer than 6 months should not be used.

NOTE: Whereas most air-borne contamination is likely to be associated with organic substances, inorganic substances such as hydrochloric acid (muriatic acid) can emit inorganic vapors that infiltrate sample containers.

3.0 GLOSSARY

Composite Sample - A composite sample is a combination of more than one grab sample from various locations and/or depths and times that is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples shall not be collected for volatile organics analysis.

Confined Space - As stipulated in 29 Code of Federal Regulations (CFR) 1910.146, a confined space means a space that: (1) is large enough and so configured that an employee can bodily enter and perform assigned work; (2) has limited or restricted means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, pits, and excavations); and (3) is not designed for continuous employee occupancy. Tetra Tech considers all confined space as permit-required confined spaces.

Grab Sample - One sample collected at one location and at one specific time.

Hand Auger - A sampling device used to extract soil from the ground.

Representativeness – A qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been collected.

Sample for Non-Volatile Analyses - Includes all chemical parameters other than volatile organics (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-barrel sampler is typically available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-barrel samplers commonly range in size from 2 to 3.5 inches outside diameter (OD). The larger sizes are commonly used when a larger volume of sample material is required (see Attachment B).

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher, excavator, or bulldozer).
Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches OD and from 18 to 54 inches in length.

4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - The Project Manager, who is qualified by having completed project management training and by being appointed as the program or office manager, is responsible for determining the sampling objectives, selecting planned sampling locations, and selecting field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan (HASP) or equivalent. This will include (but not be limited to) performing air quality monitoring during sampling, boring, and excavation activities and to ensure that workers and off-site (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the Field Operations Leader (FOL) on other safety-related matters regarding boring, excavation, and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - This individual is primarily responsible for the execution of the planning document containing the Sampling and Analysis Plan (SAP). This is accomplished through management of a field sampling team for the proper acquisition of samples. He or she is responsible for and qualified to execute the supervision of onsite analyses; ensuring proper instrument calibration, care, and maintenance; sample collection and handling; the completion and accuracy of all field documentation; and making sure that custody of all samples obtained is maintained according to proper procedures. When appropriate and as directed by the FOL, such responsibilities may be performed by other qualified personnel (e.g., field technicians) where credentials and time permit. The FOL is responsible for finalizing the locations for collection of surface, near-surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits, and trenches and for adherence to Occupational Safety and Health Administration (OSHA) regulations during these operations through self-acquisition or through the management of a field team of samplers.

Project Geologist/Sampler - The Project Geologist/sampler is responsible for the proper acquisition of samples in accordance with this SOP and/or other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

General personnel qualifications for groundwater sample collection and onsite water quality testing include the following:

- OSHA 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.
- Familiarity with appropriate procedures for sample documentation, handling, packaging, and shipping.

5.0 HEALTH AND SAFETY

Health and safety precautions are identified for individual sample collection procedures throughout this SOP. In addition to those precautions, the following general hazards may be incurred during sampling activities:

- Knee injuries from kneeling on hard or uneven surfaces
- Slips, trips, and falls
- Cuts and lacerations
- Traffic hazards associated with sampling in parking areas, along railroads, roadways and highways.

Methods of avoiding these hazards are provided below.

Knee injuries – If kneeling is required during soil sampling, this could result in knee injuries from stones/foreign objects and general damage due to stress on the joints. To minimize this hazard:

- Clear any foreign objects from the work area.
- Wear hard-sided knee pads.
- Stretch ligaments, tendons and muscles before, during and after. Take breaks as frequently as necessary.
- Report pre-existing conditions to the SSO if you feel this activity will aggravate an existing condition.

Slips, Trips, and Falls – These hazards exist while traversing varying terrains carrying equipment to sample locations. To minimize these hazards:

- Pre-survey sampling locations. Eliminate, barricade, or otherwise mark physical hazards leading to the locations.
- Carry small loads that do not restrict the field of vision.
- Travel the safest and clearest route (not necessarily the shortest).

Cuts and Lacerations - To prevent cuts and lacerations associated with soil sampling, the following provisions are required:

- Always cut away from yourself and others when cutting tubing or rope. This will prevent injury to yourself and others if the knife slips.
- Do not place items to be cut in your hand or on your knee.
- Change blades as necessary to maintain a sharp cutting edge. Many accidents result from struggling with dull cutting attachments.
- Whenever practical, wear cut-resistant gloves (e.g., leather or heavy cotton work gloves) at least on the hand not using the knife.
- Keep cutting surfaces clean and smooth.
- Secure items to be cut – do not hold them against the opposing hand, a leg, or other body part.
- When transporting glassware, keep it in a hard-sided container such as a cooler so that if there is a fall, you will be less likely to get cut by broken glass.
- DO NOT throw broken sample jars or glass ampoules into garbage bags. Place broken glass and glass ampoules in hard-sided containers such as a cardboard box or directly into a dumpster. DO NOT reach into garbage bags to retrieve any item accidentally thrown away. Empty the contents onto a flat surface to avoid punctures and lacerations from reaching where you cannot see.

Vehicular and Foot Traffic Hazards – When sampling along the roadway or near traffic patterns, follow the following precautions:

- Motorists may be distracted by onsite activities – ASSUME THEY DO NOT SEE YOU OR MEMBERS OF YOUR FIELD CREW.
- DO NOT place obstructions (such as vehicles) along the sides of the road that may cause site personnel to move into the flow of traffic to avoid your activities or equipment or that will create a blind spot.
- **Provide a required free space of travel**. Maintain at least 6 feet of space between you and moving traffic. Where this is not possible, use flaggers and/or signs to warn oncoming traffic of activities near or within the travel lanes.
- Face Traffic. Whenever feasible, if you must move within the 6 feet of the required free space or into traffic, attempt to face moving traffic at all times. Always leave yourself an escape route.
- Wear high-visibility vests to increase visual recognition by motorists.
- Do not rely on the vehicle operator’s visibility, judgment, or ability. Make eye contact with the driver. Carefully and deliberately use hand signals so they will not startle or confuse motorists or be mistaken for a flagger’s direction before moving into traffic.
- Your movements may startle a motorist and cause an accident, so move deliberately. Do not make sudden movements that might confuse a motorist.
- When working along active rail lines, notify the proper organization to ensure they are aware that you are in the area and that working schedules can be determined.

Sample Containers - Sample containers shall conform to the guidelines in SOP SA-6.1.

6.0 PROCEDURES

The following procedures address surface and subsurface sampling. Equipment lists specific to each type of sampling are provided in the applicable sections below.

If documentation such as a Certificate of Analysis is provided with sample containers to demonstrate their cleanliness, submit the documentation to the Project Manager for inclusion in the project file.

Section 6.1 provides an overview of the sampling processes. The procedures described In Section 6.2 begin with transferring sample material from a sampling device or directly from the ground surface into a sample container. Beginning with Section 6.3, various sample collection techniques and processes that are used for collecting surface or subsurface soil samples prior to transferring to sample containers are described.

CAUTION

Each situation must be evaluated individually to determine the applicability and necessity for obtaining a utility clearance ticket/dig permit. Common sense dictates, prior to digging or boring with power equipment, no matter what the depth, or digging by hand in a manner that could damage unprotected underground utilities, that a dig permit is required. See SOP HS-1.0, Utility Locating and Excavation Clearance, for additional clarification. If you do not know or are unsure as to whether a ticket is necessary – **Get the Ticket**.

6.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they migrate to the water table, and can establish the amount of contamination absorbed or adsorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a site. These variations, along with vegetation, can affect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during sampling operations, particularly noting sampling locations, depths, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. Certain vegetation species can create degradation products that can alter contaminant concentrations in soil. This is why vegetation types and extent of degradation of this foliage must be recorded. To prevent degradation, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers, and be analyzed as soon as possible after collection. In addition, to the extent possible, vegetation should be removed from the sample.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. It is the intent of this document to present the most commonly employed soil sampling methods used at environmental investigation sites.

6.2 Soil Sample Collection

6.2.1 Procedure for Preserving and Collecting Soil Samples for Volatile Organic Compound Analysis

Samples collected using traditional methods such as collection in a jar with no preservation have been known to yield non-representative samples due to loss of volatile organic compounds (VOCs). To prevent such losses, preservation of samples with methanol or sodium bisulfate may be used to minimize volatilization and biodegradation. This preservation may be performed either in the field or laboratory, depending on the sampling methodology employed. Because of the large number of sampling methods and associated equipment required, careful coordination between field and laboratory personnel is needed.

Soil samples to be preserved by the laboratory and analyzed for VOCs may be collected using Method SW-846, 5035. Encore™ or equivalent samplers are used for this. For samples preserved in the field, laboratories are currently performing low-level analyses (sodium bisulfate preservation) and high- to medium-level analyses (methanol preservation) depending on the needs of the end user.

The following procedures outline the necessary steps for collecting soil samples to be preserved at the laboratory, and for collecting soil samples to be preserved in the field with methanol or sodium bisulfate.

6.2.1.1 Soil Samples to be Preserved at the Laboratory

Soil samples collected for volatile organic analysis that are to be preserved at the laboratory shall be obtained using a hermetically sealed sample vial such as an EnCore™ sampler. Each sample shall be obtained using a reusable sampling handle (T-handle) that can be provided with the EnCore™ sampler when requested and purchased. Collect the sample in the following manner for each EnCore™ sampler:

1. Scene Safety - Evaluate the area where sampling will occur. Ensure that the area is safe from physical, chemical, and natural hazards. Clear or barricade those hazards that have been identified.

2. Wear the appropriate personal protective equipment (PPE). This will include, at a minimum, safety glasses and nitrile surgeon's gloves. If you must kneel on the ground or place equipment on the surface being sampled, cover the ground surface with plastic to minimize surface contamination of your equipment and clothing. Wear knee pads to protect your knees from kneeling on hard or uneven surfaces.

3. Load the Encore™ sampler into the T-handle with the plunger fully depressed.

4. Expose the area to be sampled using a hand trowel or similar device to remove surface debris.

5. Press the T-handle against the freshly exposed soil surface, forcing soil into the sampler. The plunger will be forced upward as the cavity fills with soil.

6. When the sampler is full, rotate the plunger and lock it into place. If the plunger does not lock, the sampler is not full. This method ensures there is no headspace. Soft soil may require several plunges or forcing soil against a hard surface such as a sample trowel to ensure that headspace is eliminated.

7. Use a paper towel to remove soil from the side of the sampler so a tight seal can be made between the sample cap and the rubber O-ring.

8. With soil slightly piled above the rim of the sampler, force the cap on until the catches hook the side of the sampler.

9. Remove any surface soil from the outside of the sampler and place in the foil bag provided with the sampler. Good work hygiene practices and diligent decontamination procedures prevents the spread of contamination even on the outside of the containers.

10. Label the bag with appropriate information in accordance with SOP SA-6.3.

11. Place the full sampler inside a lined cooler with ice and cool to <6˚C. Make sure any required trip blanks and temperature blanks are also in the cooler. Secure custody of the cooler in accordance with SOP SA-6.3.

12. Typically, collect three Encore™ samplers at each location. Consult the SAP or laboratory to determine the required number of Encore™ samplers to be collected.

13. The T-handle shall be decontaminated before moving to the next interval or location using a soap and water wash and rinse, and where applicable, the selected solvent as defined in the project planning documents.

Using this type of sampling device eliminates the need for field preservation and the shipping restrictions associated with preservatives. A complete set of instructions is included with each Encore™ sampler.

After the Encore™ samples are collected, they should be placed on ice immediately and delivered to the laboratory within 48 hours (following the chain-of-custody and documentation procedures outlined in SOP SA-6.1). Samples must be preserved by the laboratory within 48 hours of sample collection.

6.2.1.2 Soil Samples to be Preserved in the Field

Soil samples preserved in the field may be prepared for analyses using both the low-level (sodium bisulfate preservation) and high- to medium-level (methanol preservation) methods.

Safety Reminder

When using chemicals in the field to preserve samples, the FOL and/or SSO must ensure that Safety Data Sheets (SDSs) have been provided with the chemicals to be used. They also must ensure that these chemicals have been added to the Chemical Inventory List contained within the Hazard Communication section of the HASP or equivalent. Lastly, but most importantly, the FOL and/or SSO must review the hazards with personnel using these chemicals and ensure that provisions are available for recommended PPE and emergency measures (e.g., eyewash, etc.).

Methanol Preservation (High to Medium Level):

Bottles may be pre-spiked with methanol in the laboratory or prepared in the field. Soil samples to be preserved in the field with methanol shall utilize 40 to 60 mL glass vials with septum-lined lids. Each sample bottle shall be filled with 25 mL of demonstrated analyte-free purge-and-trap grade methanol. The preferred method for adding methanol to the sample bottle is by removing the lid and using a pipette or scaled syringe to add the methanol directly to the bottle.

CAUTION

NEVER attempt to pipette by mouth

In situations where personnel are required to spike the septum using a hypodermic needle, the following provisions for handling sharps must be in place:

- Training of personnel regarding methods for handling of sharps
- Hard-sided containers for the disposal of sharps
- Provisions for treatment in cases where persons have received a puncture wound

Soil shall be collected with the use of a decontaminated (or disposable), small-diameter coring device such as a disposable tube/plunger-type syringe with the tip cut off. The outside diameter of the coring device must be smaller than the inside diameter (ID) of the sample bottle neck.

A small electronic balance or manual scale will be necessary for measuring the volume of soil to be added to the methanol-preserved sample bottle. Calibration of the scale shall be performed prior to use and intermittently throughout the day according to the manufacturer’s requirements.

The sample should be collected as follows:

1. Weigh the unused syringe and plunger to the nearest 0.01 gram.

2. Pull the plunger back and insert the syringe into the soil to be sampled.

3. Collect 8 to 12 grams of soil by pushing the syringe barrel into the soil.

4. Weigh the sample and adjust until obtaining the required amount of sample.

5. Record the sample weight to the nearest 0.01 gram in the field logbook and/or on the sample log sheet.

6. Extrude the weighed soil sample into the methanol-preserved sample bottle taking care not to contact the sample container with the syringe.

7. If dirty, wipe soil particles from the threads of the bottle and cap. Cap the bottle tightly.

8. After capping the bottle, swirl the sample (do not shake) in the methanol and break up the soil such that all of the soil is covered with methanol.

9. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

Sodium Bisulfate Preservation (Low Level):

CAUTION

Care should be taken when adding the soil to sodium bisulfate solution. A chemical reaction of soil containing carbonates (limestone) may cause the sample to effervesce or the vial to possibly explode. To avoid this hazard or hazards of this type, a small sample aliquot should be subjected to the sample preservative. If it effervesces in an open air environment, utilize an alternative method such as Encore™ or 2-ounce jar.

Bottles may be prepared in the laboratory or in the field with sodium bisulfate solution. When collecting samples in vials that are pre-preserved with sodium bisulfate, collect the samples as described above for methanol-preserved samples.

1. Samples to be preserved in the field using the sodium bisulfate method are to be prepared and collected as follows:
   a) Add 1 gram of sodium bisulfate to 5 mL of laboratory-grade deionized water in a 40 to 60 mL glass vial with septum-lined lid.

   b) Collect the soil sample and record the sample weight to the nearest 0.01 gram in the field logbook or on the sample log sheet as described for methanol preservation.

   c) Add the weighed sample to the sample vial.

   d) Collect duplicate samples using the methanol preservation method on a one-for-one sample basis because it is necessary for the laboratory to perform both low-level and medium-level analyses.

   e) Place the samples on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

NOTE

If lower detection limits are necessary, an option to field preserving with sodium bisulfate may be to collect EnCore™ samplers at a given sample location. Consult the planning documents to determine whether this is required. If it is, collect samples in accordance with the Encore™ sampling procedure above and then send all samplers to the laboratory to perform the required preservation and analyses.

6.2.2 Procedure for Collecting Soil Samples for Non-Volatile Analyses

Samples collected for non-volatile analyses may be collected as either grab or composite samples as follows:

1. To ensure collection of a representative sample, use a stainless steel trowel or other approved tool, to transfer the entire depth interval of the soil to be sampled to a stainless steel bowl, re-sealable plastic bag, or disposable inert plastic tray.

NOTE: Contact with plastic materials, especially if the contact is prolonged, may cause contamination of samples with phthalates and other contaminants contained in the plastic. Loss of analytes due to adsorption or reaction with plastics also is possible. When in doubt about contamination potential, or potential loss of analyte due to adsorption/reaction, consult the Project Manager or use non-plastic bowls or other equipment to the extent possible when mixing samples.

2. Remove roots, vegetation, sticks, and stones larger than the size of a green pea.

3. Thoroughly mix the soil to obtain as uniform a texture and color as practicable. The soil type, moisture content, amount of vegetation, and other factors may affect the amount of time required to obtain a properly mixed sample. In some cases, it may be impossible to obtain a uniform sample appearance. Use the field logbook to describe any significant difficulties encountered in obtaining a uniform mixture.

4. Transfer a portion of the mixed soil to the appropriate sample containers and close the containers.

5. Label the sample containers in accordance with SOP SA-6.3.

6. Place the containers in a cooler of ice as soon after collection as possible.

7. Prepare the sample shipment and ship the samples in accordance with SOP SA-6.1.

NOTE

Cooling may not be required for some samples depending on the scheduled analyses. Consult the planning documents if in doubt regarding correct sample preservation conditions. When in doubt – Cool to <6˚C.

NOTE

Head space is permitted in soil sample containers for non-volatile analyses to allow for sample expansion.

6.2.3 Procedure for Collecting Undisturbed Soil Samples

NOTE

Use of thin-walled undisturbed tube samplers is restricted by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soil with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dennison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soil. Using these devices normally increases sampling costs, and therefore their use should be weighed against the need for acquiring an undisturbed sample. These devices are not discussed in this SOP because they are not commonly used.

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) shall be employed using the following collection procedure:

1. In preparation for sampling utilizing a drill rig, field personnel must complete the following activities:

   - Ensure that all subsurface drilling activities are preceded by a utility clearance for the area to be investigated. This includes activities described in SOP HS-1.0, Utility Location and Excavation Clearance, as well as any location-specific procedures that may apply.

   REMEMBER

   If you are digging near a marked utility (within the diameter of an underground utility that has been marked plus 18 inches), you must first locate the utility through vacuum extraction or hand digging to ensure that your activities will not damage the utility.

   - Complete an Equipment Inspection Checklist for the drill rig or direct-push technology (DPT) rig. This checklist will be provided in the HASP.

   - Review the Safe Work Permit prior to conducting the activity.

   - Review the activity to be conducted.

2. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and/or clean out the borehole to the desired sampling depth. Be careful to minimize potential disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

CAUTION

The use of bottom-discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Only the use of side-discharge bits is permitted.

3. Determine whether a stationary piston-type sampler is required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used.

4. Prior to inserting the tube sampler into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal. In addition, the check valve maintains a positive suction within the tube to help retain the sample.

5. A stainless steel tube sampler is typically used to minimize chemical reaction between the sample and the sampling tube.

6. Remove the plastic end caps from the sampling tube and, with the sampling tube resting on the bottom of the hole and the water level in the boring at groundwater level or above, push the tube into the soil with a continuous and rapid motion, without impacting or twisting. If the soil is too hard to penetrate by pushing alone, careful hammering may be used by minimizing drop distance (tapping) of the hammer. Before pulling the tube, turn it at least one revolution to shear the sample off at the bottom. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.

7. Upon removal of the sampling tube from the hole, measure the length of sample in the tube and also the length penetrated.

8. Remove disturbed material in the upper end of the tube and measure the length of sample again.

9. After removing at least 1 inch of soil from the lower end, place enough packing material (clean inert material such as paper or cloth) tightly in each end of the Shelby tube and then pour melted wax into each end to make at least a ½-inch wax plug and then add more packing material to fill the voids at both ends.

10. Place plastic caps on the ends, tape the caps in place, and dip the ends in wax to prevent loss of soil.

11. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label.

12. Mark the "up" direction on the side and upper end of the tube with indelible ink.

13. Complete a chain-of-custody form (see SOP SA-6.3) and other required forms (including Attachment A of this SOP).

14. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

CAUTION

To preserve sample integrity do not allow tubes to freeze, and store the samples vertically with the same orientation they had in the ground, (i.e., top of sample is up) in a cool place out of the sun at all times.

CAUTION

A primary concern in the preparation of the wax plugs is the potential for the heat source and melted wax to cause a fire and/or burns. Follow the directions below to prevent injury or fire.

Electrical Heating

Using hot plates to melt the wax is acceptable. In an outdoor setting, make sure a Ground Fault Circuit Interrupter (GFCI) is employed within the electrical circuit. If a portable generator is used, ensure that the generator is an adequate distance from the sampling operation (at least 50 feet). Ensure that the extension cord is rated for the intended load and for outdoor use and is free from recognizable damage. Ensure flammable preservatives are not employed or stored near the hot plate. Although a Hot Work Permit is not required, scene safety evaluation by site personnel of the above elements is. As always, if a fire potential exists, the provisions for extinguishing must be immediately accessible as well as any provisions for first aid measures.

Open Flame

If an open flame is used, the following provisions are necessary:

- Complete a Hot Work Permit and any local permit required for elevated temperature applications. The Hot Work Permit, provided in your HASP, will aid the FOL and/or the SSO in ensuring that fire protection provisions (extinguishers, fire watches, etc.) are in place as well as ensuring that local requirements have been addressed.

- Ensure that water is available to address any wax splashes or contact. If possible, immerse the contacted area. Where this is not possible, run water over the area and apply cold compresses. The need for medical attention or first aid shall be determined on site under the direction of the SSO.

6.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples for subsequent analysis is by use of a stainless steel shovel, hand auger, soil corer, or stainless steel or disposable plastic trowel.

NOTE

Multiple depth intervals are used to describe surface soil. Sometimes surface soil is defined as soil from 0 to 2 inches below ground surface (bgs), and sometimes it is defined as soil from other depths such as 0 to 2 feet bgs. Ensure that the definition of surface soil depth is clear before collecting surface soil samples.

For the purposes of instruction, the terms “surface soil” and “near-surface soil” are used in this SOP as follows:

- Surface soil - 0 to 6 inches bgs
- Near-surface soil - 6 to 18 inches bgs

If these intervals are defined differently in the planning documents, substitute the appropriate depth ranges.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel or pre-cleaned disposable trowel.
- Stainless steel hand auger, soil corer, or shovel.
- Real-time air monitoring instrument (e.g., photoionization or flame ionization detector [PID], [FID]) as directed in project planning document.
- Required PPE.
  - Nitrile surgeon's or latex gloves may be used, layered as necessary.
  - Safety glasses.
  - Other – Items identified on the Safe Work Permit may be required based on location-specific requirements such as hearing protection, steel-toed work boots, and a hard hat when working near a drill rig. These provisions will be listed in the HASP or directed by the FOL and/or SSO.

Safety Reminder

The use of latex products may elicit an allergic reaction in some people. Should this occur, remove the latex gloves, treat for an allergic reaction, and seek medical attention as necessary.

- Required paperwork (see SOP SA-6.3 and Attachment A of this SOP).
- Required decontamination equipment.
- Required sample container(s).
- Wooden stakes or pin flags.
- Re-sealable plastic bags.
- Heavy duty cooler.
- Ice.
- Chain-of-custody records and custody seals.

When acquiring surface soil samples, use the following procedure:

1. Place padding or use knee pads when kneeling near the sample location. If necessary, place plastic sheeting to provide a clean surface for sample equipment to avoid possible cross- contamination.
2. Carefully remove vegetation, roots, twigs, litter, etc. to expose an adequate soil surface area to accommodate sample volume requirements.
3. Using a pre-cleaned syringe or EnCore^{TM} samplers, follow the procedure in Section 6.2.1 for collecting surface soil samples for volatile analysis. Surface soil samples for volatile organic analysis should be collected deeper than 6 inches bgs because shallower material has usually lost most of the volatiles

through evaporation. Ensure that the appropriate surface soil depth is being analyzed in accordance with the planning document.

4. Using decontaminated sampling tools, thoroughly mix in place a sufficient amount of soil to fill the remaining sample containers. See Section 6.5 of this procedure for hand auger instruction, as needed.

5. Transfer the sample into those containers utilizing a stainless steel trowel.

6. Cap and securely tighten all sample containers.

7. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.

8. Proceed with the handling and processing of each sample container as described in SOP SA-6.1.

9. Site restoration – Whenever removing sample materials, always restore the surface. It is our intent to leave the area better than we found it. Do NOT create trip hazards in areas where pedestrian traffic may exist.

6.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6 to 18 inches) can be accomplished with tools such as shovels, hand auger, soil corers, and stainless steel or pre-cleaned disposable trowels and the equipment listed under Section 6.5 of this procedure.

To obtain near-surface soil samples, the following protocol shall be used:

1. With a clean shovel, make a series of vertical cuts in the soil to the depth required to form a square approximately 1 foot by 1 foot.

2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel or pre-cleaned disposable trowel to remove any loose soil.

3. Follow steps 1 through 9 of Section 6.3.

6.5 Subsurface Soil Sampling With Hand Augers and Soil Corers

Hand augering and Use of Soil Corers are similar. Hand augering requires turning the auger while it advances whereas soil corers are not necessarily turned during advancement.

6.5.1 Hand Augering

A hand augering system generally consists of a variety of stainless steel bucket bits (approximately 6.5 inches long and 2, 2.75, 3.25, and 4 inches in diameter), series of extension rods (available in 2-, 3-, 4- and 5-foot lengths), and a T-handle connected to extension rods and to the auger bucket. A larger diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then it is withdrawn. The larger-diameter bit is then replaced with a smaller-diameter bit, lowered down the hole, and slowly turned into the soil to the completion depth (approximately 6 inches). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil either from the surface, or to depths in excess of 12 feet. However, the presence of subsurface rocks and landfill material and collapse of the borehole normally limit sampling depth.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes).
- Stainless steel mixing bowls or re-sealable plastic bags.
- The equipment listed in Section 6.3.
- Miscellaneous hand tools as required to assemble and disassemble the hand auger units.

CAUTION

Potential hazards associated with hand augering include:

- Muscle strain and sprain due to over twisting and/or over compromising yourself.
- Equipment failure due to excessive stress on the T-handle or rods through twisting. Failure of any of these components will result in a sudden release and potential injury due to that failure.

As in all situations, any intrusive activities that could damage underground utilities shall be proceeded by a Dig/Excavation permit/ticket. Call the Utility Locating service in the area or your Site Safety Officer for more information. When in doubt – **Get the Ticket!**

To obtain soil samples using a hand auger, use the following procedure:

1. Wearing designated PPE, attach a properly decontaminated bucket bit to a clean extension rod and attach the T-handle to the extension rod.
2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).
3. Twist the bucket into the ground while pushing vertically downward on the auger. The cutting shoes fill the bucket as it is advanced into the ground.
4. As the auger bucket fills with soil, periodically remove any unneeded soil.
5. Add rod extensions as necessary to extend the reach of the auger. Also, note (in a field notebook, boring log, and/or on a standardized data sheet) any changes in the color, texture or odor of the soil as a function of depth. The project-specific planning document (SAP, HASP, etc.) describe requirements for scanning the soil with a real-time air monitoring instrument (e.g., PID, FID, etc.) and recording the measurements.
6. After reaching the desired depth (e.g., the top of the interval to be sampled), slowly and carefully withdraw the apparatus from the borehole to prevent or minimize movement of soil from shallower intervals to the bottom of the hole.
7. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is to be smaller in diameter than the bucket bit employed to initiate the borehole.
8. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.

9. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.

10. Discard the top of the core (approximately 1 inch), which represents any loose material collected by the bucket bit before penetrating the sample material.

11. Using a pre-cleaned syringe or EnCore^{TM} sampler, follow the procedure in Section 6.2.1 for collecting a soil sample for volatile compound analysis directly from the bucket bit.

12. Utilizing a properly decontaminated stainless steel trowel or dedicated disposable trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl or re-sealable plastic bag.

13. Homogenize the sample material as thoroughly as practicable then fill the remaining sample containers. Refer to Section 6.2.2.

14. Follow steps 4 through 7 listed in Section 6.3.

6.5.2 Sampling Using Stainless Steel Soil Corers

A soil corer is a stainless steel tube equipped with a cutting shoe and sample window in the side. The soil corer is advanced into the soil by applying downward pressure (body weight). The soil is unloaded by then forcing a ram towards the cutting shoe, which results in the discharge of the soil core through a window in the sleeve.

Use, application, and sample protocol is the same as for hand augering provided above, but without necessarily rotating the corer while advancing it.

SAFETY REMINDER

Hand augering and soil corer sampling can be physically demanding based on the type of geology and subsurface encumbrances encountered. Soil coring has some added hazards such the corer collapsing under your weight. To reduce the potential for muscle strain and damage, the following measures will be incorporated:

- Stretch and limber your muscles before heavy exertion. This hazard becomes more predominant in the early morning hours (prior to muscles becoming limber) and later in the day (as a result of fatigue).

- Job rotation – Share the duties so that repetitive actions do not result in fatigue and injury.

- Increase break frequencies as needed, especially as ambient conditions of heat and/or cold stress may dictate.

- Do not force the hand tools or use cheater pipes or similar devices to bypass an obstruction. Move to another location near the sampling point. Exerting additional forces on the sampling devices can result in damage and/or failure that could potentially injure someone in the immediate vicinity.

- Do not over compromise yourself when applying force to the soil corer or hand auger. If there is a sudden release, it could result in a fall or muscle injury due to strain.

6.6 Subsurface Soil Sampling with a Split-Barrel Sampler

A split-barrel (split-spoon) sampler consists of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment B). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-pound or larger casing driver.

Safety Reminder

It is intended through the Equipment Inspection for Drill Rigs form provided in the HASP that the hammer and hemp rope, where applicable, associated with this activity will be inspected (no physical damage is obvious), properly attached to the hammer (suitable knots or sufficient mechanical devices), and is in overall good condition.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (2-inch OD, 1-3/8-inch ID, either 20 inches or 26 inches long); Larger OD samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-pound weight, driving head, and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls or re-sealable plastic bags.
- Equipment listed in Section 6.3.

The following steps shall be followed to obtain split-barrel samples (Steps 1 through 4 are typically performed by the drilling subcontractor):

1. Attach the split-barrel sampler to the sampling rods.
2. Lower the sampler into the borehole inside the hollow stem auger bits.
3. Advance the split-barrel sampler by hammering the length (typically 18 or 24 inches) of the split-barrel sampler into the soil using 140-pound or larger hammer.
4. When the desired depth is achieved, extract the drill rods and sampler from the augers and/or borehole.
5. Detach the sampler from the drill rods.
6. Place the sampler securely in a vise so it can be opened using pipe wrenches.

CAUTION

Pipe wrenches are used to separate the split spoon into several components. The driller's helper should not apply excessive force through the use of cheater pipes or push or pull in the direction where, if the wrench slips, hands or fingers will be trapped against an immovable object.

7. Remove the drive head and nosepiece with the wrenches, and open the sampler to reveal the soil sample.

8. Immediately scan the sample core with a real-time air monitoring instrument (e.g., FID, PID, etc.) (as project-specific planning documents dictate). Carefully separate (or cut) the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.

9. If elevated vapor readings were observed, collect the sample scheduled for volatile analysis from the center of the core where elevated readings occurred. If no elevated readings where encountered, the sample material should be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact) (refer to Section 6.2.1).

10. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl or re-sealable plastic bag.

11. Homogenize the sample material as thoroughly as practicable then fill the remaining sample containers (refer to Section 6.2.2).

12. Follow steps 4 through 7 in Section 6.3.

6.7 Subsurface Soil Sampling Using Direct-Push Technology

Subsurface soil samples can be collected to depths of 40+ feet using DPT. DPT equipment, responsibilities, and procedures are described in SOP SA-2.5.

6.8 Excavation and Sampling of Test Pits and Trenches

6.8.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

CAUTION

During the excavation of trenches or pits, several health and safety concerns arise from the method of excavation. No personnel shall enter any test pit or excavation over 4 feet deep except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart P - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden, steel, or aluminum support structures or through sloping and benching. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments; therefore, monitoring will be conducted by the Competent Person to determine if it is safe to enter. Any entry into a trench greater than 4 feet deep will constitute a Confined Space Entry and must be conducted in conformance with OSHA standard 29 CFR 1910.146. In all cases involving entry, substantial air monitoring, before entry, appropriate respiratory gear and protective clothing determination, and rescue provisions are mandatory. There must be at least three people present at the immediate site before entry by one of the field team members. This minimum number of people will increase based on the potential hazards or complexity of the work to be performed. The reader shall refer to OSHA regulations 29 CFR 1926.650, 29 CFR 1910.120, 29 CFR 1910.134, and 29 CFR 1910.146. High-hazard entries such as this will be supported by members of the Health Sciences Group professionally trained in these activities.

Excavations are generally not practical where a depth of more than about 15 to 20-feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If soil data at depths greater than 15-feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

6.8.2 Test Pit and Trench Excavation

Test pits or trench excavations are constructed with the intent that they will provide an open view of subsurface lithology and/or disposal conditions that a boring will not provide. These procedures describe the methods for excavating and logging test pits and trenches installed to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented (see Attachment C).

Test pits and trenches may be excavated by hand or power equipment to permit detailed descriptions of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration.
- The space required for efficient excavation.
- The chemicals of concern.
- The economics and efficiency of available equipment.

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table provides guidelines for design consideration based on equipment efficiencies.

Equipment	Typical Widths, in Feet
Trenching machine	0.25 to 1.0
Backhoe/Track Hoe	2 to 6

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, the following field conditions may necessitate revisions to the initial plans:

- Subsurface utilities.
- Surface and subsurface encumbrances.
- Vehicle and pedestrian traffic patterns.
- Purpose for excavation (e.g., the excavation of potential ordnance items).

The final depth and construction method shall be collectively determined by the FOL and designated Competent Person. The actual layout of each test pit, temporary staging area, and spoils pile may further be predicated based on site conditions and wind direction at the time the test pit is excavated. Prior to excavation, the area may be surveyed by magnetometer or metal detector or other passive methods specified in SOP HS1.0, Utility Location and Excavation Clearance, to identify the presence of underground utilities or drums. Where possible, the excavator should be positioned upwind and preferably within an enclosed cab.

No personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is required, OSHA requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be placed for every 25 feet of lateral travel and extended 3 feet above ground surface). A temporary guard rail or vehicle stop must be placed along the surface of the hole before entry in situations where the excavation may be approached by traffic. Spoils will be stockpiled no closer than 2 feet from the sidewall of the excavation. The excavation equipment operator shall be careful not to undercut sidewalls and will, where necessary, bench back to increase stability. The top cover, when considered clean, will be placed separately from the subsurface materials to permit clean cover. It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example, samples of leachate, groundwater, or sidewall soil can be collected with telescoping poles or similar equipment.

Dewatering and watering may be required to ensure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation stable. This is an important consideration for excavations in cohesionless material below the groundwater table and for excavations left open greater than a day. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

Where possible, excavations and test pits shall be opened and closed within the same working day. Where this is not possible, the following engineering controls shall be put in place to control access:

- Trench covers/street plates.
- Fences encompassing the entire excavation intended to control access.

- Warning signs warning personnel of the hazards.
- Amber flashing lights to demarcate boundaries of the excavation at night.

Excavations left open will have emergency means to exit should someone accidentally enter.

6.8.3 Sampling in Test Pits and Trenches

6.8.3.1 General

Log test pits and trenches as they are excavated in accordance with the Test Pit Log presented in Attachment C. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable health and safety and OSHA requirements have been met as stated above. These provisions will be reiterated as appropriate in the project-specific HASP.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information includes soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples that can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

6.8.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks, hand augers, and stainless steel trowels/disposable trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottle ware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.
- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps, and right angle adapter for conduit (see Attachment D).

6.8.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 6.8.3.4.

- Excavate the trench or pit in several 0.5- to 1.0-foot depth increments. Where soil types support the use of a sand bar cutting plate, use of this device is recommended to avoid potentially snagging utilities with the excavator teeth. It is recommended that soil probes or similar devices be employed where buried items or utilities may be encountered. This permits the trench floor to be probed prior to the next cut.
- After each increment:

  - The operator shall wait while the sampler inspects the test pit from grade level.

  - The sampler shall probe the next interval where this is considered necessary. Practical depth increments for lithological evaluations may range from 2 to 4 feet or where lithological changes are noted.

- The backhoe operator, who will have the best view of the test pit, shall immediately cease digging if:

  - Any fluid phase, including groundwater seepage, is encountered in the test pit.

  - Any drums, other potential waste containers, obstructions, or utility lines are encountered.

  - Distinct changes of material being excavated are encountered.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending on the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Use the backhoe to remove loose material from the excavation walls and floor to the greatest extent possible.

- Secure the walls of the pit, if necessary. (There is seldom any need to enter a pit or trench that would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)

- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material after it has been deposited on the ground, as follows:

  a. The sampler or FOL shall direct the backhoe operator to remove material from the selected depth or location within the test pit/trench.

  b. The backhoe operator shall bring the bucket over to a designated location on the sidewall a sufficient distance from the pit (at least 5 feet) to allow the sampler to work around the bucket.

  c. After the bucket has been set on the ground, the backhoe operator shall either disengage the controls or shut the machine down.

  d. When signaled by the operator that it is safe to do, the sampler will approach the bucket.

  e. The soil shall be monitored with a PID or FID as directed in the project-specific planning documents.

f. The sampler shall collect the sample from the center of the bucket or pile in accordance with surface soil sampling procedures of Section 6.3 or 6.4, as applicable. Collecting samples from the center of a pile or bucket eliminates cross-contamination from the bucket or other depth intervals.

- If a composite sample is desired, several depths or locations within the pit/trench will be selected, and the bucket will be filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket or re-sealable plastic bag and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

CAUTION

Care must be exercised when using the remote sampler described in the next step because of potential instability of trench walls. In situations where someone must move closer than 2 feet to the excavation edge, a board or platform should be used to displace the sampler's weight to minimize the chance of collapse of the excavation edge. Fall protection should also be employed when working near the edges or trenches greater than 6 feet deep. An immediate means to extract people who have fallen into the trench will be immediately available. These means may include ladders or rope anchor points.

- Using the remote sampler shown in Attachment D, samples can be taken at the desired depth from the sidewall or bottom of the pit as follows:

a. Scrape the face of the pit/trench using a long-handled shovel or hoe to remove the smeared zone that has contacted the backhoe bucket.

b. Collect the sample directly into the sample jar, by scraping with the jar edge, eliminating the need for sample handling equipment and minimizing the likelihood of cross-contamination.

c. Cap the sample jar, remove it from the remote sampler assembly, and package the sample for shipment in accordance with SOP SA-6.3.

- Complete documentation as described in SOP SA-6.3 and Attachment C of this SOP.

6.8.3.4 In-Pit Sampling

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soil or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There are no practical alternative means of obtaining such data.
- The SSO and Competent Person determine that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of oxygen concentration, flammable gases, and toxic compounds, in that order). Action levels will be provided in project-specific planning documents.

- A company-designated Competent Person determines that the pit/trench is stable through soil classification evaluation/inspections or is made stable (by cutting/grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements shall be strictly observed.

If these conditions are satisfied, only one person may enter the pit/trench. On potentially hazardous waste sites, this individual shall be dressed in selected PPE as required by the conditions in the pit. He/she shall be affixed to a harness and lifeline and continuously monitored while in the pit.

A second and possible third individual shall be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations to support self-rescue or assisted self-rescue. The individual entering the pit shall remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon.

6.8.3.5 Geotechnical Sampling

In addition to the equipment described in Section 6.8.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., thin-walled tube samplers), that can be pushed or driven into the floor of the test pit.
- Suitable driving (e.g., sledge hammer) or pushing (e.g., backhoe bucket) equipment used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soil in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification: larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soil using thin-walled tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability, and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe, rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the tube when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 6.8.3.4 shall be followed. The thin-walled tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate because the sample will not have the correct orientation.

A sledge hammer or backhoe may be used to drive or push the tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. When using a sledge hammer, it is recommended that the sampler be stabilized using a rope/strap wrench or pipe wrench to replace the person's hands holding the sampler from the strike zone. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hook the sampler to the excavator or backhoe and extract. This means an alternative head will be used as a connection point or that multiple choke hitches will be applied to extract the sampler. If this fails and the excavator can dig deeper without potentially impacting subsurface utilities, excavate the sampler. If this fails or if the excavator cannot be used due to subsurface utilities, hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry into the test pit, the requirements in Section 6.8.3.4 must be followed. Prepare the sample as described in Steps 9 through 13 in Section 6.2.3, and label, pack and transport the sample in the required manner, as described in SOPs SA-6.3 and SA-6.1.

6.8.4 Backfilling of Trenches and Test Pits

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non-working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew may photograph, if required by the project-specific work plan, all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL. Backfill should be returned to the trench or test pit in 6-inch to 1-foot lifts and compacted with the bucket. Remote controlled tampers or rollers may be lowered into the trench and operated from top side. This procedure will continue to the grade surface. It is recommended that the trench be tracked or rolled in. During excavation, clean soil from the top 2 feet may have been separated to be used to cover the last segments. Where these materials are not clean, it is recommended that clean fill be used for the top cover.

If a low-permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

6.9 Records

The appropriate sample log sheet (see Attachment A of this SOP) must be completed by the site geologist/sampler for all samples collected. All soil sampling locations should be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) or obtaining global positioning system (GPS) coordinates; and shall be noted on the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see Attachment C of this SOP) shall contain a sketch of pit conditions. If the project-specific work plan requires photographs, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits, and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.
Other data to be recorded in the field logbook include the following:

- Name and location of job

- Date of boring and excavation
- Approximate surface elevation
- Total depth of boring and excavation
- Dimensions of pit
- Method of sample acquisition
- Type and size of samples
- Soil and rock descriptions
- Photographs, if required
- Groundwater levels
- PID/FID/LEL/O_2 meter readings
- Other pertinent information, such as waste material encountered

In addition, site-specific documentation to be maintained by the SSO and/or Competent Person will be required including:

- Calibration logs
- Excavation inspection checklists
- Soil type classification

7.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

NUS Corporation, 1986. Hazardous Material Handling Training Manual.

NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

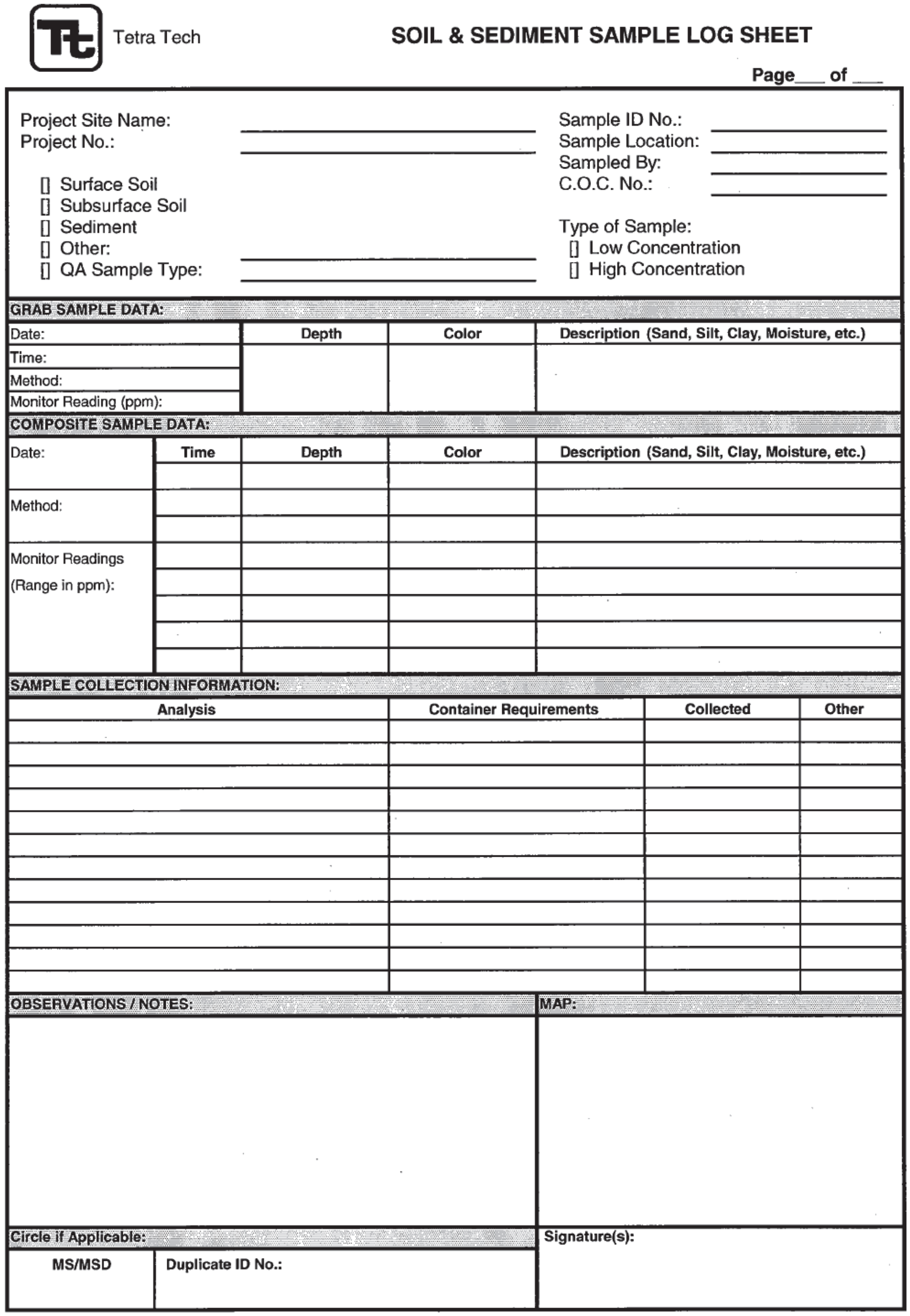
OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

OSHA, Confined Space Entry 29 CFR 1910.146.

U.S. EPA, 1992. Specifications and Guidance for Contaminant-Free Sample Containers. EPA-540/R-93/051.

USEPA, November 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.

ATTACHMENT A
SOIL & SEDIMENT SAMPLE LOG SHEET (EXAMPLE)



Tetra Tech

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: ____________________
Project No.: ____________________

☐ Surface Soil
☐ Subsurface Soil
☐ Sediment
☐ Other: ____________________
☐ QA Sample Type: ____________________

Sample ID No.: ____________
Sample Location: ____________
Sampled By: ____________
C.O.C. No.: ____________

Type of Sample:
☐ Low Concentration
☐ High Concentration

GRAB SAMPLE DATA:

Date:	**Depth**	**Color**	**Description (Sand, Silt, Clay, Moisture, etc.)**
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	**Time**	**Depth**	**Color**	**Description (Sand, Silt, Clay, Moisture, etc.)**
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	**Container Requirements**	**Collected**	**Other**

OBSERVATIONS / NOTES:

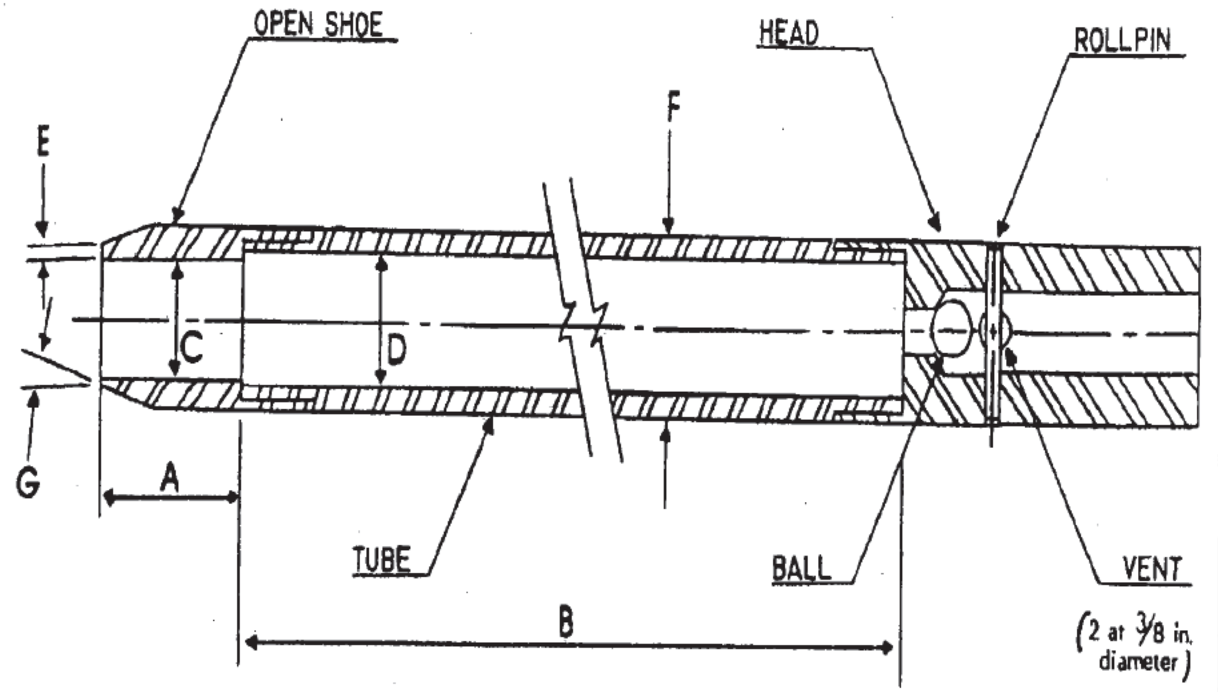
MAP:

Circle if Applicable:

MS/MSD	**Duplicate ID No.:**

Signature(s):

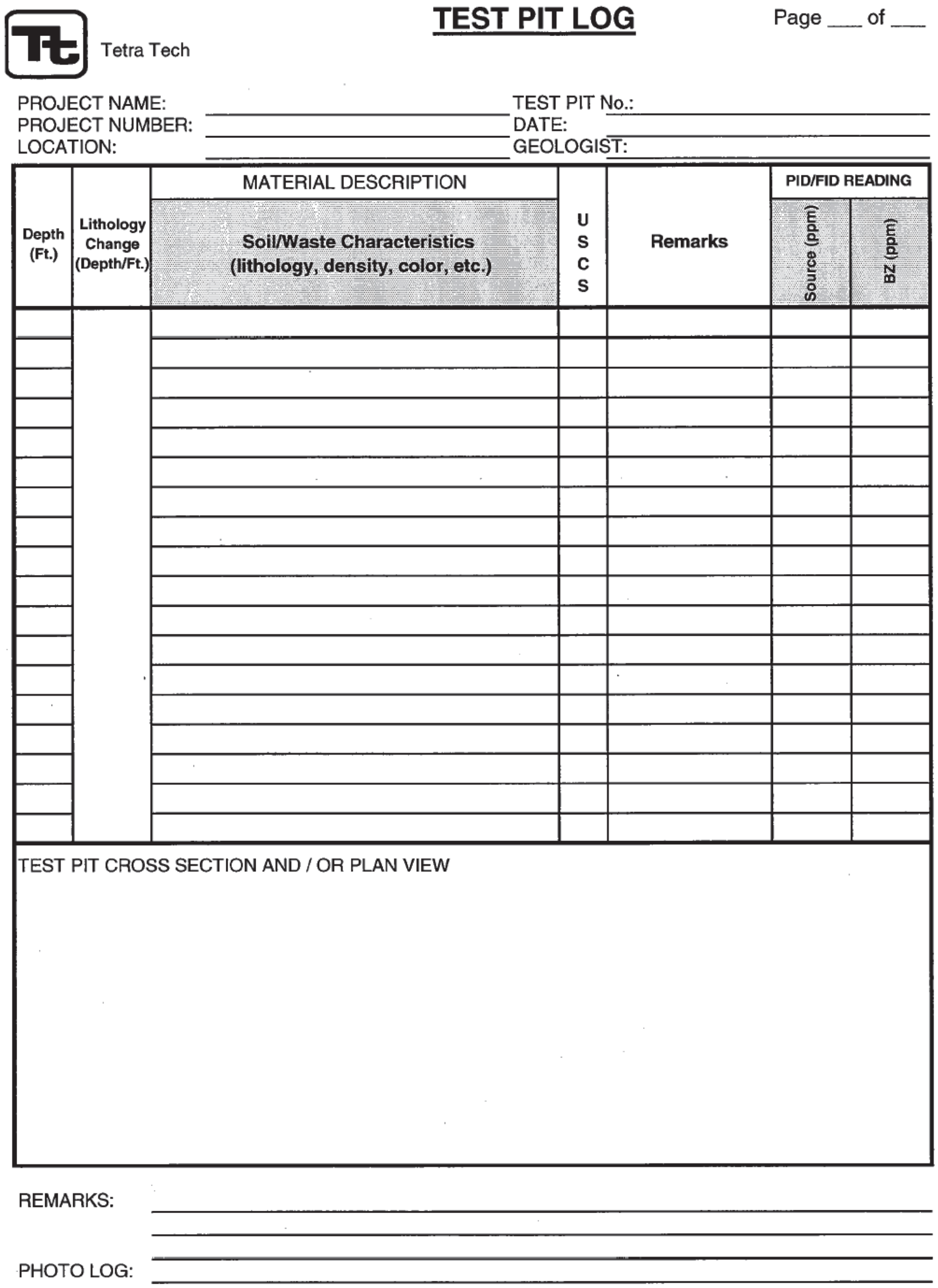
ATTACHMENT B
SPLIT-SPOON SAMPLER (EXAMPLE)



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

ATTACHMENT C
TEST PIT LOG (EXAMPLE)



Tetra Tech

TEST PIT LOG

Page ___ of ___

PROJECT NAME: ______________________
PROJECT NUMBER: ______________________
LOCATION: ______________________
TEST PIT No.: ______________________
DATE: ______________________
GEOLOGIST: ______________________

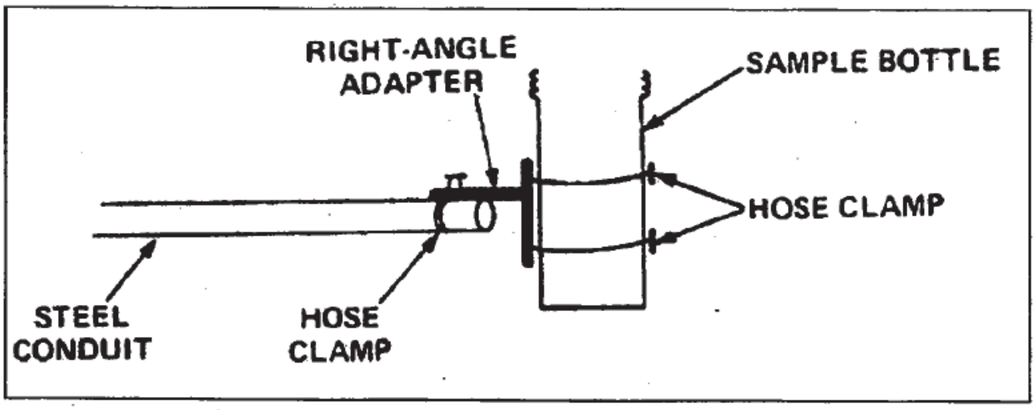
Depth (Ft.)	Lithology Change (Depth/Ft.)	MATERIAL DESCRIPTION	U S C S	Remarks	PID/FID READING	
		Soil/Waste Characteristics (lithology, density, color, etc.)			Source (ppm)	BZ (ppm)

TEST PIT CROSS SECTION AND / OR PLAN VIEW

REMARKS: ______________________

PHOTO LOG: ______________________

ATTACHMENT D
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING (EXAMPLE)



APPENDIX D
STANDARD OPERATING PROCEEDURES
SA-1.8 - PFAS Sample Acquisition

TETRA TECH

STANDARD OPERATING PROCEDURE

Number SA-1.8	Page 1 of 12
Effective Date 01/25/2018	Revision 3
Applicability Tetra Tech, Inc., NUS Operating Unit	
Prepared Earth Sciences Department	

Subject
SAMPLE ACQUISITION FOR PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES (PFAS) ANALYSIS

Approved
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Date: 2018.01.25 14:21:16 -05'00'

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1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the methods and protocols to be used for collecting and handling samples to be analyzed for polyfluoroalkyl and perfluoroalkyl substances (PFAS). PFAS are present in many consumer products including some typical sampling equipment and are widely present in the environment.

Low regulatory criteria and high contamination potential require special precautions to be implemented to avoid compromising sample integrity. Instructions are provided herein for collection of environmental samples without contaminating them. This SOP is designed to supplement but not replace existing sampling SOPs SA-1.1, SA-1.2, SA-1.3, SA-1.7, and SA-5.1. In addition, some clients and/or projects may have specific PFAS-related sampling requirements that extend beyond the procedures described in this SOP. Such additional requirements typically are documented in work plans or similar documents.

2.0 SCOPE AND APPLICABILITY

This document provides information on selection of proper sampling equipment and techniques for groundwater, surface water, sediment, soil, and water supply sampling for PFAS analysis. Sampling of air or biota is not addressed in this SOP, but the same principles would apply for those media.

3.0 BACKGROUND

PFAS have been used since the 1940s as manufacturer-applied oil and water repellants on products such as clothing, upholstery, paper, and carpets and in making fluoropolymers for non-stick cookware. They are found in textiles and leather products, mist suppressants for metal plating, materials used in the photography industry, photolithography, semi-conductors, paper and packaging, coatings, cleaning products, pesticides, and cosmetics. They have been used in well-known consumer products including Teflon, StainMaster, Scotchgard, and GoreTex. In the 1960s, aqueous film-forming foam (AFFF) containing PFASs was developed for fighting flammable liquid fires, particularly petroleum-fueled (Class B) fires (ATSDR, 2009). The two most researched and most prevalent PFAS in the environment are perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) (ATSDR, 2009).

Military uses of PFAS have been primarily related to fire fighting and electroplating. AFFF meeting MIL-F-24385 specifications was developed by various manufacturers for use in extinguishing fires at military bases, airports, commercial facilities, and fire-fighting training facilities throughout the United States. Beginning in the late 1960s the United States Department of Defense (DoD) used large quantities of AFFF for shipboard and shore facility fire-suppression systems, on fire-fighting vehicles, and at fire-training facilities. AFFF concentrate that contains PFAS may still be in use at DoD facilities, and large quantities of AFFF may have been released to the environment at some facilities.

PFAS are persistent in the environment, tend to bioaccumulate, and demonstrate toxicity in laboratory animals, enough to raise concerns about their presence in the environment. Some areas where PFAS may have been released to the environment include the following:

- Fire-fighting training areas
- Areas where fire-fighting products/materials are stored
- Aircraft crash sites
- Metal coating and plating facilities
- Water treatment systems and receiving water bodies
- Airport hangars and other facilities storing fire-fighting foams
- Fluorochemical manufacturing, use, and disposal facilities

PFAS are ubiquitous in consumer products and are present in or on some materials used in environmental sampling (e.g., Teflon tubing, waterproof logbooks, and GoreTex field clothing). Laboratory detection limits are low for PFAS, and contact of sample material or sampling equipment with any one of the multitude of PFAS sources could result in detectable contamination. In addition, PFAS tend to adsorb to glass and some plastics, so certain glass or plastic sample collection containers are inappropriate for use in PFAS sample collection. Adsorption to sample containers may result in a low bias for measured PFAS concentrations.

Collection and analysis of quality control blanks is an important aspect of verifying that samples have not been contaminated during sample collection and handling. Use of additional blanks or blanks of a different type than usual may be required in some circumstances, and the governing project planning documents should be consulted. Consult Section 7.7 of this SOP for instructions regarding collection of field reagent blanks (FRBs).

4.0 DEFINITIONS AND ABBREVIATIONS

AFFF – Aqueous film-forming foam.

Emerging Contaminant – An emerging contaminant is a chemical or material that is characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards (U.S. EPA, 2014). A contaminant may also be “emerging” because a new source or a new pathway for human exposure has been discovered or a new detection method or treatment technology has been developed (DoD, 2011).

FRB – Field Reagent Blank. A blank sample prepared in the field by transferring laboratory-supplied, chemically preserved, deionized water to an empty, laboratory-supplied, collection bottle. FRBs are typically analyzed only for PFAS and are treated as site samples in all respects, including shipment to the sampling site, exposure to sampling site conditions, storage, preservation, and all PFAS analytical procedures. The purpose of FRBs is to indicate whether PFAS measured in corresponding site samples may have been introduced during sample collection and handling.

PFAS – Per- and Polyfluoroalkyl Substances. A reference term currently in use, replacing “PFCs” in recent scientific and other technical literature. The term is inclusive of both perfluorinated chemicals like PFOA and PFOS and polyfluoroalkyl substances like fluorinated telomers.

PFCs – Perfluorinated Compounds or Chemicals. PFCs are a family of man-made chemicals that have been used for commercial, industrial, and military applications because they resist thermal degradation and repel oil, stains, grease, and water.

PFOA – Perfluorooctanoic Acid. PFOA is used as an aqueous dispersion agent and in the manufacture of fluoropolymers (including Teflon) used in industrial components such as electrical wire casings, fire- and chemical-resistant tubing, and plumbing seal tape. PFOA is used in surface treatment products to impart oil, stain, grease, and water resistance. PFOA can also be produced by the breakdown of some fluorinated telomers.

PFOS – Perfluorooctane Sulfonate. PFOS was a key ingredient in Scotchgard and used in the manufacture of Class B AFFF used per DoD military specifications. Phase out of AFFF by 3M occurred in 2002.

5.0 SAFETY PRECAUTIONS

Sample acquisition activities shall be conducted in accordance health and safety requirements identified in the project-specific Health and Safety Plan (HASP), Accident Prevention Plan (APP), and corporate health and safety policies. Alteration may be necessary to allow sample collection without cross contamination as dictated by site-specific conditions.

Caution

The use of personal protective equipment (PPE) containing PFAS (e.g., some insect repellants, sunscreens, traffic safety vests, etc.) should be avoided if possible or, if deemed necessary to control hazards, should be carefully considered as they can pose a potential cross-contamination risk for samples. Extra care (e.g., changing outer gloves) must be exercised to ensure that PFAS is not transferred directly or indirectly from PPE to samples or sample containers.

The Tetra Tech Project Manager (PM), in coordination with the Tetra Tech NUS Operating Unit Health and Safety Group, shall ensure that the development of project-specific plans balances the need to control exposure to safety hazards as well as address PFAS contamination risks.

6.0 PERSONNEL RESPONSIBILITIES, QUALIFICATIONS, AND TRAINING

Project Manager (PM) – The PM along with the management team are responsible for determining sampling objectives, initial sampling locations, and field procedures used in the collection of samples of environmental media. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the PM is responsible for selecting and detailing the specific sampling techniques and equipment to be used and for providing detailed input in this regard to the project planning documents. The PM has the overall responsibility for ensuring that sampling activities are properly conducted by appropriately trained staff.

Site Safety and Health Officer (SSHO) – The SSHO (or a qualified designee) is responsible for providing the technical support necessary to implement the project HASP, APP, or equivalent. The SSHO or SSHO designee may also be required to advise the Field Operations Leader (FOL) on safety-related matters regarding sampling, such as measures to mitigate potential hazards, hazardous objects, or conditions.

Project Geologist/Sampler – The project geologist/sampler is responsible for proper acquisition of samples in accordance with this SOP or other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, boring logs, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

Field Operations Leader (FOL) – This individual is primarily responsible for the execution of the field sampling program in accordance with the project planning documents. This is accomplished through management of a field sampling team for the proper acquisition of samples.

Personnel implementing this SOP must read and understand this SOP prior to collection of samples designated for PFAS analysis.

7.0 PROCEDURES

The following sampling procedure establishes requirements for collection of samples designated for PFAS analysis while minimizing potential cross contamination of the samples and other materials.

7.1 Selection of Equipment

It is important to research available equipment and materials at the project planning stage to avoid last-minute problems in the field, for example, ensuring compatibility of high-density polyethylene (HDPE) tubing with fittings for use in a peristaltic or other pump, or ensuring that equipment (e.g., a bladder pump) does not contain Teflon.

Sampling Equipment:

Note: PFAS cross-contamination of samples can be minimized through decontamination or conditioning of equipment left in a well. Use of dedicated equipment also is helpful so that handling during decontamination is unnecessary.

- Decontamination – All reusable equipment used in sample acquisition should be adequately decontaminated prior to use.
- Unless project requirements indicate otherwise, use sampling equipment made of stainless steel, acetate, silicone, or HDPE. This applies to tubing, pumps and pump components, tape for plumbing fittings, trowels, mixing bowls, or other equipment that could contact the sample media. Gasket and O-ring components of sampling equipment may also contain fluoropolymers.

Note: PFAS on purchased or rented items is likely to occur predominantly in newly manufactured or rented items treated with chemicals containing PFAS. Therefore, all rental equipment that will make direct contact with the material being sampled must be thoroughly decontaminated prior to use, especially if the equipment items are new.

- Use sampling equipment that does not include or containing polytetrafluoroethylene (PTFE) or Teflon (DuPont brand name) or fluorinated ethylene propylene (FEP) during sample handling or mobilization/demobilization.
- Use products that are not made of low-density polyethylene products (LDPE) if contamination from those products can be transferred to environmental samples or QC samples.
- For collecting drinking water samples to be analyzed using United States Environmental Protection Agency (U.S. EPA) Method 537, use polypropylene sample bottles with a polypropylene screw cap; for all other samples, use HDPE containers with unlined plastic screw caps.

Non-Sampling Field Equipment:

- Non-waterproof loose-leaf paper or notebooks are acceptable. Avoid using waterproof field books or paper during sampling activities, although “Rite in the Rain” books have been found empirically to be acceptable. Do not use plastic clipboards, binders, or spiral hard-cover notebooks that may be coated; use Masonite or aluminum clipboards instead.
- Avoid using Post-it notes or similar removable notes during sample handling or mobilization/demobilization activities.
- Use ballpoint pens or pencils for note taking and sample bottle labeling. Avoid using Sharpies or similar indelible markers.
- Avoid the use of aluminum foil.

Field Personnel Clothing and Protective Gear:

- Wear clothing that has been washed at least six times without fabric softener to remove possible stain-resistant coatings. Clothing made of natural fibers such as cotton is preferred to other fabrics. Protective clothing must be washed in accordance with manufacturer recommendations to ensure that the protective properties necessary to control safety hazards (e.g., fire-retardant clothing) are not compromised.

- Avoid unnecessary contact with upholstery in vehicles because many such fabrics may be treated with stain-resistant materials that could contain PFAS. Typically, rental vehicles are newer and more likely to pose a contamination risk to samples. Well-washed towels or rags may be placed on the seats to prevent contact with car seats and other materials that could transfer PFAS to clothing worn by samplers. If practical, cover clothing and skin that has been in contact with such upholstery with non-fluorinated clothing.

- During wet weather, use rain gear made from polyurethane or wax-coated materials.

- Avoid wearing water-resistant (e.g., Gore-Tex or similar material) clothing or footwear (e.g., boots) immediately prior to or during sample collection and management.

- Avoid wearing coated Tyvek or similar coated PPE suits.

- Wear un-powdered nitrile gloves at all times while collecting and handling samples, and change gloves often. Anecdotal evidence indicates that changing gloves is one of the most effective methods of reducing or eliminating sample contamination potential; therefore, change to a new pair of gloves prior to collecting each sample.

- Avoid wearing cosmetics, shampoos, moisturizers, hand cream, or other similar personal care products on the day of sampling.

- When expected to be effective, use sunscreens and insect repellants that are made with 100-percent natural ingredients and that the Air Force Civil Engineer Center has identified as acceptable for use. ***These products must be used in accordance with manufacturer recommendations and in combination with controls in the project-specific HASP, APP, and corporate health and safety policies*. *Multiple applications of these products per work shift may be required to ensure their effectiveness.***

  - Sunscreens: Alba Organics Natural Sunscreen, Yes To Cucumbers, Aubrey Organics, Jason Natural Sun Block, Kiss My Face, baby sunscreens that are “free” or “natural.”

  - Sunscreen and insect repellant: Avon Skin So Soft Bug Guard Plus – SPF 30 Lotion

  - Insect Repellent: Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus Insect Repellant, Herbal Armor, California Baby Natural Bug Spray, BabyGanics.

Note: The suitability of these items has not been independently verified. Products containing N-diethyl-meta-toluamide (DEET), picaridin, and IR3535 and some oil of lemon eucalyptus (OLE) and para-menthane-diol products are known to provide longer-lasting protection than others. One of the products recommended by the Air Force Civil Engineer Center and listed above, Repel Lemon Eucalyptus Insect Repellant, contains OLE and is most likely to be effective.

Sample Containers and Shipping Materials:

- Avoid the use of glass sample containers, which are believed to result in loss of PFAS through adsorption to the container inner walls.

- Collect samples in clean, laboratory-supplied, plastic bottles only, typically polypropylene for drinking water or HDPE for other matrices.

- Confirm that Teflon-lined caps are not used in sample containers; unlined polypropylene screw caps must be used. It is best to segregate sample containers with Teflon components (e.g., Teflon-lined septa) from PFAS sample containers.

- Avoid using Blue Ice or similar items to cool samples and avoid placing such items in sample coolers for shipping. Use commercially available (e.g., from convenience stores or supermarkets) double-bagged ice instead.

Caution: Samples designated for PFAS analysis must be cooled to achieve a storage temperature of less than 6 °C. Cooling to this temperature may take several hours, and sample temperatures may not achieve 6 °C by the time they arrive at the laboratory. If sample temperatures upon arrival at the laboratory are not less than 10 °C, the laboratory may conclude that sample preservation was compromised and may reject the samples. Therefore, place samples on ice as soon after collection as possible. On warm days, or when a representative from a nearby laboratory picks up the samples, take extra care (e.g., use more ice or delay shipment, if necessary) to ensure that sample temperatures will not exceed 10 °C when the samples arrive at the laboratory.

- Use of commercially available plastic bags (e.g., 3-mil-thick trash can liners) for lining coolers to prevent leakage and to separate potential melt water from chain-of-custody forms is allowed.

7.2 Other Precautions for Sample Handling

- Wash hands thoroughly before sampling and after handling fast food, carryout food, snacks, or other items that may contain PFAS. Do not carry pre-packaged food items such as candy bars or microwave popcorn into sampling areas.

- Assume that shipping tape used for securing coolers could contain PFAS; therefore, take care not to transfer PFAS from tape to samples.

- Minimize exposure of samples to light. This can be done by placing the collected samples into a cooler (with ice) and closing the cooler lid.

- If in doubt about a particular product or item that comes into contact with environmental media to be sampled or is in close proximity to sampling operations, consider collecting and analyzing a rinsate blank using laboratory-supplied PFAS-free water to test the item for contamination potential. Consult the Tetra Tech PM in these cases to verify whether collection of additional blanks is warranted.

- Support personnel that are within 2 to 3 meters of the sample processing area are considered subject to the same restrictions related to precautionary measures for clothing and food as applied to sampling personnel.

These precautions must be observed during sampling activities, especially during water sample collection (groundwater, water supply, and surface water), given the high solubilities of PFAS in water. Examples of how these precautions may be applied to sampling of specific media are provided in the following sections.

7.3 Groundwater Sample Acquisition

The precautions and requirements identified in Sections 7.1 and 7.2 must be observed for groundwater sampling. Do not proceed any further without reviewing each of those precautions and requirements.

- Collect groundwater samples for PFAS analyses in accordance with this SOP, SOP SA-1.1, and/or project- or client-specific requirements.

- If non-dedicated non-disposable equipment is used between sampling locations, it should be decontaminated with Alconox or Liquinox, unless 1,4-dioxane (a potential component of Liquinox) is also a contaminant of concern. In that case, Liquinox should not be used. Products such as Decon 90, which contains fluorosurfactants, should not be used. Alconox or Liquinox rinses should be followed by a potable water rinse then deionized water rinse.

- If Teflon or LDPE materials are required for the non-PFAS analytes, use multiple sets of containers. Collect samples for PFAS analysis last to ensure adequate purging and conditioning of sampling equipment. If practical to do so, suitable PPE (especially gloves) may also be changed out for PFAS sampling. For example, purge and sample a monitoring well for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals using a peristaltic pump with HDPE and silicone tubing, then collect the material for PFAS analysis or switch to a stainless steel bailer to collect the PFAS samples. If either the proper sampling sequence or proper equipment is unclear, consult the FOL or Tetra Tech PM and record the actual sequence in the field notes.

- If sampling wells that have or had dedicated Teflon or FEP tubing that potentially contained PFAS, remove the dedicated tubing and, using silicone or HDPE tubing, remove at least one well volume from the target sampling interval prior to sampling. Accomplish this removal in a manner that is rigorous enough to remove the entire water column from the well and not just a limited vertical interval of the water column. This will minimize the potential for collecting a sample that was in contact with the Teflon/FEP tubing.

- The use of detergents must be avoided during decontamination of drilling equipment. All equipment must be scrubbed with a plastic brush or steam cleaned and rinsed thoroughly in potable water to clean away any debris or material on exposed surfaces and then triple-rinsed in distilled (American Society for Testing and Materials Grade 3 or better) or deionized water (or Millipore water).

- Sample(s) representing any water collected at the point of use (e.g., water truck or tank on site) used by the driller for drilling purposes must be analyzed for PFAS. See Section 7.8 for guidance on waste management.

- Collect drinking water samples to be analyzed using U.S. EPA Method 537 in clean polypropylene sample bottles with a polypropylene screw cap; for all other samples, use clean, laboratory-supplied, HDPE bottles with unlined plastic screw caps.

7.4 Soil Sample Acquisition

The precautions and requirements identified in Sections 7.1 and 7.2 must be observed for soil sampling. Do not proceed any further without reviewing each of those precautions and requirements.

- Collect soil samples for PFAS analyses in accordance with this SOP, SOP SA-1.3, and/or project- or client-specific requirements. Review client–specific (e.g., DoD component) guidance or previously approved Sampling and Analysis Plans (SAPs).

- Soil sampling equipment should not be constructed of or contain Teflon or other materials likely to contain or be coated with PFAS. Acceptable materials for sampling include stainless steel, acetate, and HDPE.

- If non-dedicated non-disposable equipment is used between sampling locations, it should be decontaminated with Alconox or Liquinox, unless 1,4-dioxane (a potential component of Liquinox) is also a contaminant of concern. In that case, Liquinox should not be used. Products such as Decon 90, which contains fluorosurfactants, should not be used. Alconox or Liquinox rinses should be followed by a potable water rinse then deionized water rinse.

- Collect samples in laboratory-provided HDPE containers specifically designated for PFAS analysis. Do not use glass jars typically used for soil sample collection because some PFAS may irreversibly adsorb to the glass and could create a negative bias in the measured PFAS concentrations. Also consult Section 7.6 if sampling a water supply.

7.5 Surface Water and Sediment Sample Acquisition

The precautions and requirements identified in Sections 7.1 and 7.2 must be observed for surface water and sediment sampling. Do not proceed any further without reviewing each of those precautions and requirements.

- Collect surface water and sediment samples for PFAS analysis in accordance with this SOP, SOP SA-1.2, and/or project- or client-specific requirements.

- Surface water and sediment sampling equipment should not be constructed of or contain Teflon or LDPE materials. Acceptable materials for sampling include HDPE, small amounts of silicone, stainless steel, and acetate. Do not use glass. The bottleware should be supplied clean by the laboratory and specifically designated for PFAS analysis. If transfer bottles are required for collection of surface water samples, the transfer bottles used should be of the same material as the containers designated for submission to the laboratory.

- For surface water sample collection, invert the capped sample bottle, with the opening pointing downward, at least 10 cm below the water surface, 10 cm above the bottom of the water body, and as close to the center of the channel or water body as practical. To collect the sample, uncap the bottle underneath the water surface and point the bottle upward so that gloved hands, sample container, and sampler are downstream of where the sample is being collected.

- For aquatic samples collected from the shoreline or via wading, ensure that waders are constructed of fabric that has not been treated with waterproofing coatings.

- If non-dedicated non-disposable sampling equipment is used between sampling locations, it should be decontaminated with Alconox or Liquinox, unless 1,4-dioxane (a potential component of Liquinox) is also a contaminant of concern. In that case, Liquinox should not be used. Products such as Decon 90, which contains fluorosurfactants, also should not be used. Alconox or Liquinox rinses should be followed by a potable water rinse then deionized water rinse.

7.6 Water Supply Sampling

This section applies to sampling from taps, spigots, faucets, or similar devices for PFAS analysis. The precautions and requirements identified in Sections 7.1 and 7.2 must be observed for water supply sampling. Do not proceed any further without reviewing each of those precautions and requirements.

- Collect water supply samples for PFAS analysis in accordance with applicable portions of SOP SA-1.7 and/or project- or client-specific requirements.
- Water supply sampling equipment (if needed) should not be constructed of or contain Teflon or LDPE materials. Acceptable materials for sampling include HDPE, polypropylene (drinking water sampling only), small amounts of silicone (e.g., short runs of silicone tubing used in peristaltic pumps), stainless steel, and acetate. Non-drinking water supply samples should be collected in clean, laboratory-supplied, HDPE bottleware specifically designated for PFAS analysis (not glass). Collect drinking water samples in clean polypropylene bottles supplied by the laboratory.
- Ensure that sample bottles used to collect chlorinated water samples contain the proper Trizma preservative (5 g/L to preserve and remove chlorine). Non-chlorinated water does not require chemical preservatives designed to remove chlorine.
- If non-dedicated non-disposable equipment is used between sample locations, it should be decontaminated with Alconox or Liquinox.
- Locate the sampling point. If a specific sampling point has already been designated (e.g., a kitchen tap), plan to collect the sample from that point. Otherwise, identify a location in the water supply line that is as close as possible to the water's point of origination (e.g., a well or other water source) and upstream of any local water treatment unit(s) that could affect PFAS levels (e.g., water softeners, activated carbon, or reverse osmosis treatment units). If a treatment unit is in use, a post-treatment sample may also be required in some cases, per project requirements.

  Note: If treatment that could affect PFAS levels (e.g., carbon filtration or reverse osmosis) is part of the water distribution system, often a spigot will be present in the plumbing line between the water source and the treatment unit, and this spigot should be used for sample collection.
- Remove any aerator/diffuser from the faucet, if possible. If removal is not possible, record this observation in the field notes.
- Allow the water to run freely from the tap until water quality parameter stabilization per project-specific requirements is achieved, or as otherwise required by project-specific requirements. This will often require purging for 3 to 5 minutes.
- Reduce the water flow rate to minimize aeration of the sample. The water stream should be no wider than the diameter of a pencil.
- Fill the sample bottle (typically 250 mL) directly from the tap to the bottom of the neck of the bottle, and cap the bottle immediately.
- After collecting the sample, cap the bottle and, if preservative is included, agitate by hand until the preservative is dissolved.
- Do not use filters when collecting samples because the filters may introduce PFAS contamination or absorb PFAS and thus reduce PFAS concentrations in the samples.

7.7 Field Reagent Blank Collection

Note: If PFAS are detected in site samples, FRBs may be analyzed to assess whether PFAS in site samples could be non-site-related contamination and whether resampling is necessary. U.S. EPA Method 537 and modifications thereof for PFAS analysis require an FRB to be handled along with each sample set. A sample set is described as samples collected from the same sample site and at the same time, but "sample site" and "same time" are not precisely defined. Therefore, it is important to verify that the correct number of FRBs will be collected. The intent is to be able to verify whether samples have been contaminated and to help identify the source of contamination. In general, collecting one FRB at each sampling point is recommended when sampling drinking water; fewer FRBs are recommended when sampling non-drinking water matrices. The actual number will depend on project needs. *Collection of an FRB at every sampling point may be required.*

- Verify the number of FRBs to be collected for the project and where those samples must be collected. This should be described in the project planning documents such as work plans or SAPs. If it is not, consult the PM.

- At the sampling site, when ready to collect an FRB, open the bottle of chemically preserved FRB reagent water provided by the laboratory and a corresponding clean empty bottle, also provided by the laboratory.

- Pour the preserved FRB reagent water into the empty sample bottle, close the cap, and label this filled bottle as the FRB.

- Pack and ship the FRB along with site samples and required documentation (e.g., chain-of-custody form) to the laboratory.

Note: Although chain-of-custody forms will indicate that FRBs must be analyzed for PFAS, analysis of an FRB will be required only if site samples contain PFAS greater than a certain concentration. If an FRB is analyzed and any PFAS concentration in the FRB exceeds one-third of the laboratory minimum reporting limit (or equivalent), all samples collected with that FRB may be considered invalid and may require recollection and reanalysis. Consult the project planning documents governing sample collection for specifics as to whether resampling is necessary. Care in collection and handling of site samples and FRBs in a way that avoids contamination cannot be overemphasized.

Note: It will be necessary to associate individual FRBs with corresponding site samples; otherwise, decisions about which samples to recollect (if recollection is indicated) could be compromised. Associations between FRBs and corresponding site samples may be accomplished by marking chain-of-custody forms with the associations, but other methods also may be useful. Consult the governing planning document or the PM for guidance, if necessary.

7.8 Disposal of Investigation-Derived Waste Potentially Containing PFAS

PFAS are not hazardous wastes as defined in the Resource Conservation and Recovery Act and Comprehensive Environmental Response, Compensation, and Liability Act. It may be possible to dispose of PFAS-containing solid waste as non-hazardous, but sampling solid waste material for PFAS analysis is not advised. Consult the client PM or on-site point of contact to verify their current disposal acceptance criteria, and indicate on waste manifests that the waste potentially contains PFAS. Waste water potentially containing PFAS should be analyzed for PFAS to determine the appropriate disposal option. If the sum of PFOS and PFOA concentrations is less than 70 µg/L the water may be disposed of without special handling if no other enforceable regulations apply; otherwise, the water should be treated to reduce the PFOA + PFOS concentration to an acceptable level or should be directed to an appropriate treatment facility for disposal. On-site treatment (e.g., granular activated carbon filtration) may be appropriate. Consult the client PM or on-site point of contact for direction regarding disposal.

Note: If aqueous investigation-derived waste (IDW) is expected to contain much greater than 70 ng/L (e.g., captured residual from an accidental release in a hangar), special actions may be necessary and the client PM should be consulted. For wastes that are dewatered and potentially contain PFAS, containerize the waste water and analyze it for PFAS prior to disposal.

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APPENDIX D

STANDARD OPERATING PROCEEDURES

SA-2.5 - Direct Push Technology

TETRA TECH	**STANDARD OPERATING PROCEDURE (GUIDANCE)**	Number SA-2.5	Page 1 of 8
		Effective Date 05/12/2017	Revision 5
		Applicability Tetra Tech, Inc. NUS Operating Unit	
		Prepared Earth Sciences Department	
Subject DIRECT PUSH TECHNOLOGY		Approved T. Johnston	tom. johnston @tetratech.com Digitally signed by: tom. johnston@tetratech.com DN: CN = tom. johnston@tetratech.com Date: 2017.05.09 16:17:09 -05'00'

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1.0 PURPOSE

This guidance document provides information on how to perform subsurface investigations using Direct Push Technology (DPT) drilling methods.

2.0 SCOPE

This guidance document addresses standard DPT methodologies, and their benefits and drawbacks. It provides standardized instructions for using this type of drilling. Project Managers should consult Staff Geologists and prospective DPT Subcontractors to determine if DPT drilling can meet the project objectives.

3.0 GLOSSARY

Direct Push Technology (DPT) – DPT refers to a drilling method that uses hydraulic pressure and/or percussion hammers to advance sampling tools directly into the ground without the use of rotary type drilling equipment. DPT drilling is restricted to unconsolidated materials.

Geoprobe® – Geoprobe® is a manufacturer of DPT drilling rigs capable of multiple types of drilling methods; DPT, HSA, rotary, and sonic drilling see SOP GH-1.3 for addition guidance for these other drilling methods.

Halogenated Hydrocarbons – Hydrocarbon compounds containing atoms of elements such as bromine, chlorine, or fluorine (called halogens).

Gas Chromatography (GC) – A technique for analyzing a mixture of volatile substances in which the mixture is carried by an inert gas through a column packed with a selective material.

Flame Ionization Detector (FID) – An instrument for the measurement of combustible organic compounds and inorganic compounds in air at parts-per million levels. The basis for detection is the ionization of gaseous species using a hydrogen flame as the energizing source.

Photo Ionization Detector (PID) – An instrument for the measurement of combustible organic compounds and inorganic compounds in air at parts-per million levels. The basis for detection is the ionization of gaseous species using ultraviolet radiation as the energizing source.

Halogen Specific Detector (XSD) – A device for detecting halogenated hydrocarbons in a carrier gas using an electron emitter anode and cathode transducer. The XSD is less prone to non-halogen interferences than ionization detectors.

Dual Tube Soil Sampling System – This sampling system is used for collecting continuous soil core samples. The system uses inner sampling string of tools and an outer casing which is advanced to keep the hole open. The system is susceptible to sandy material entering into the outer casing (heaving or running sands) when the inner string is extracted. For more details click on the following Web link: - Dual Tube Soil Sampling System | Geoprobe® Systems.

Macro-Core®® Sampling System – This sampling system is a single tube, discrete or continuous sampling tool for use when running sands are to be expected. For more details click on the following link: Macro-Core® Geoprobe® Systems.

Pre-packed Screen – Pre-packed screens consist of slotted PVC well screen pipe surrounded by a stainless steel mesh or slotted PVC. Sand is packed between the slotted PVC and the outer screen material. Since the sand is packed around the slotted PVC before the well screen is installed it ensures proper sand pack emplacement.

Membrane Interface Probe (MIP) – This tool is a semi-quantitative, field-screening tool that can detect volatile organic compounds (VOCs) in soil and sediment.

4.0 RESPONSIBILITIES

Project Manager – The Project Manager (PM) is responsible for overall planning, staffing, and execution of a field project. The PM is also responsible to ensure that a Site Specific Health and Safety Plan (or equivalent) is generated by Health and Safety department for the site specific field investigation activities.

Project Geologist – The Project Geologist, with input from the PM, is responsible for selecting the appropriate drilling methods and technical approach required to meet project objectives. He is also responsible for providing input to the field team regarding daily activities on an as-needed basis.

Field Operations Leader (FOL) – The FOL responsibilities include but are not limited to:

- Serving as a liaison with facility and subcontractor personnel.
- Ensuring and enforcing compliance with the health and safety plan for all personnel involved in the execution of the field investigation activities.
- Coordinating field investigation activities such that they may be performed in an effective, efficient, and safe manner consistent with the governing planning documents.
- Supporting the utility clearance process. Refer to SOP HS-1.0 for additional guidance.
- Supporting logistics including access to items such as, but not limited to:
  - Potable water for decontamination operations
  - Areas for equipment lay down and storage

Site Geologist – The Site Geologist is responsible for verifying that the standard and approved DPT procedures are followed while working onsite. The Site Geologist will generate a detailed boring log for each borehole drilled in accordance to SOP GH-1.5. The Site Geologist will inspect the drill rig and components to ensure that it is in safe operating condition. These responsibilities may be assigned to other Tetra Tech personnel with the PM approval.

Proposed boring locations should be shown on a site map provided in the governing planning documents such as a Work Plan or Sampling and Analysis Plan. The Site Geologist or the FOL is responsible to finalize the exact drilling location. The drilling location may need to be moved slightly for a variety of reasons such as: utility avoidance, trees, or physical barriers, etc. If the proposed drilling location needs to be moved a significant distance (e.g., more than 10 feet), as determine by communiques between the FOL and the project manager, possible options need to be discussed with the project team based on field observations. A map sketch showing the drill location(s) relative to a permanent site feature(s) should be made in the field note book.

DPT Subcontractor – The DPT Subcontractor is responsible for obtaining required drilling permits, and supplying all labor, equipment, and material required to perform the drilling tasks as specified in the subcontract documents. The DPT Subcontractor is also responsible for equipment maintenance and quality control of their operation. The DPT Subcontractor shall be licensed in the State/Territory where the DPT work is to occur. The DPT Subcontractor maybe required by State law to complete the state utility clearance One-Call process; however, this requirement may vary from state to state. Therefore, check with the state One -Call requirements. Tetra Tech should determine who will be responsible to initiate the One-Call process prior to contracting a drilling company (see SOP HS-1.0 for additional guidance).

The DPT Subcontractor must report to the FOL within 24 hours any major technical or analytical problems encountered in the field, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager). Depending on the subcontract, the Project Manager may need to obtain written authorization from appropriate administrative personnel before approving any changes.

5.0 METHODS

This sections provides an overview of the common DPT drilling procedures and associated sampling systems.

5.1 General

DPT is a recommended drilling method for subsurface investigations when other drilling methods are not required. For additional guidance regarding other drilling methods see SOP GH-1.3. The DPT investigation methods described herein include the following:

- Soil sampling, surface and subsurface
- Groundwater grab or single point samplers
- Monitoring well installation (temporary and permanent)
- Screening tools (MIP/EC)

Soil gas sampling is discussed in SOP SA-2.4.

The advantage of using DPT over other drilling methods includes:

- Fewer drill cuttings.
- Lower decontamination fluid volumes.
- Smaller and lighter track mounted rigs providing a wide range of access capabilities.
- Lower overhead clearance requirements.
- Lower mobilization costs.

Disadvantages include:

- Limited penetration depth, this is becoming less of a concern with bigger and stronger DPT rigs.
- Limited well diameter size, 2-inch inside diameter (ID) or less.
- Limited to unconsolidated material.
- The rig may have difficulties penetrating gravelly material, again this is less of a concern with the larger DPT rigs.
- Not recommended when drilling beyond a confining unit requiring dual cased installation.

5.2 Soil Sampling Methods

There are two common types of DPT soil sampling methods: Macro-Core® and dual tube. Both sampling methodologies use plastic liners or tubes to retrieve the soil sample for processing. The plastic liners are extracted from the sample barrel and cut by the driller for processing in accordance with SOPs GH-1.5 and SA-1.3. The driller is responsible to use the proper cutting tools to ensure that the plastic liners are cut safely.

5.2.1 Macro Core Methodology

Macro-Core® is a single tube, discrete interval or continuous soil sampling system. There are two types of Macro-Core® systems, 1) the light-weight center rod (LWCR), and 2) the stop-pin. These systems use different tools to unlock a piston point allowing soil to enter the sample barrel at the desired sample interval.

The LWCR system uses center rods within the tool string to keep the piston point inside the cutting shoe and preventing soil from entering the sample barrel. When the desired sampling depth is reached, the center rods are removed. Then the tool string is advanced to the sampling depth allowing the center piston to be displaced by the in-coming soil filling the plastic liner. The Geoprobe® SOP is provide here (Macro-Core® LWCR) for more details.

The stop-pin system uses a locking pin and a piston rod to hold the center piston in the cutting shoe till the sample depth is reached. The piston rod extends down through the sample barrel into the drive head. When the desired depth is reached, extension rods are sent down through the tool string to release the stop pin and piston. Then the tool string is advanced allowing the soil to enter the plastic liner. Additional Geoprobe® guidance is provided at this link: Macro-Core® stop-pin.

5.2.2 Dual Tube Methodology

The dual tube system uses two sets of probe rods to retrieve soil sample core. An outer casing (pipe) and the inner sampling rod. A plastic sample tube is attached to the inner rods and is advanced with the outer casing into undisturbed soil filling the plastic tube. The plastic tube is then withdrawn from the outer casing using the inner rods while the outer casing with a cutting shoe remains in the ground. The sampling method should be changed to Macro-Core® when loose sand enters and heaves upward by several feet (running sands) into the otter casing. The Geoprobe® SOP for dual tube sampling is provided at this link: dual tube sampling system.

5.3 Groundwater Sampling Methods

Groundwater sampling generally occurs after a soil boring has been completed characterizing the subsurface material and identifying the water producing zones. There are two types of groundwater sampling methods used with DPT: 1) groundwater grab samplers and 2) monitoring wells (permanent or temporary). Groundwater sampling guidance is provided in SOP SA-1.1. Monitoring well installation guidance is provided in SOP GH-2.8.

5.3.1 Groundwater Grab Samplers

Groundwater grab samplers are used for screening purposes during one field event. The sampling device is removed from the ground and the hole is abandoned after the sampling is completed. There are two common systems used to collect groundwater grab samples, 1) screen-point samplers and 2) PVC slotted-screen and riser (1-inch nominal diameter).

Screen-Point Samplers

Screen-point samplers consist of a wire-wound stainless steel screen or slotted PVC screen sealed within a steel pipe with an expendable tip. The sampler is driven to the sampling depth and deployed by retracting upward the steel pipe to expose the screen to the formation material. The screen has a nominal diameter of 1 inch. The screen interval can be adjusted depending on the distance the steel pipe is retracted, from a few inches to 4 feet. Additional information for the Geoprobe® screen-point sampler is provided at the following link: Geoprobe® groundwater sampler.

When using screen-point samplers in aquifers with low yields the following problems may be encountered:

- Being sampled without purging or development resulting in high turbidity.
- High sample volume requirements, causing the point sampler to go dry. Well recovery and resampling can be time consuming.

PVC Slotted-Screen and Riser

The PVC slotted-screen and riser sampler can mitigate the screen-point sampler problems. This type of grab sampler is installed using DPT drill pipe with an expendable tip. The drill pipe is pushed to the desired depth, and the screen and riser are lowered into the drill pipe. The expendable tip is knocked out while the pipe is pulled out of the ground, exposing the screen to the formation material. The PVC slotted screen grab sampler can be installed and sampled over a period of days allowing for recovery prior to removal and abandonment. This approach enables the driller to proceed to other well point installations. If metals are to be analyzed and low turbidity samples are desired, a filter pack can be installed provided proper size pipe is used to accommodate the filter pack. The PVC material is discarded or decontaminated once the sample is collected to minimize cross contamination. This type of grab sampler can be converted to a monitoring well by placing the proper back fill materials above the filter pack in accordance with State regulations, and client and project requirements. Monitoring well installation is discussed in more detail in the following section.

5.3.2 Monitoring Well Installation

There are two types of monitoring well installations: temporary and permanent. Pre-packed screens are recommended for both types to expedite and ensure proper installation of the filter sand. However, PVC slotted screen cost less, and can provide equivalent data quality. The most common well diameter for DPT installation is 1-inch inside diameter. The steel pipe used for the installation has a nominal inside diameter of 3 inches allowing for backfill materials to be installed and measured during the installation.

The definition of a temporary well can vary depending on State regulations, client or project requirements, and budgetary concerns. For example, in accordance with South Carolina regulations, a temporary well is to be abandoned within 5 days of installation. Temporary wells can provide groundwater level and chemical data of the same quality as permanent wells. A temporary well is installed with the intent of easy abandonment and not intended for long term monitoring. A permanent well is installed for long term use with durable surface seal and protection.

Temporary Well

The well riser and screen are joined and lowered to the desired depth inside the drill pipe. The expendable tip can be knocked out with the PVC well riser and screen. However, in some cases, light weight DPT rod string is needed to knock out the expendable tip. The well filter pack is installed while the drill pipe is withdrawn from the ground. The annular space around the screen is filled with silica sand to at least 1 to 2 feet above the screen. A bentonite seal is installed above the filter pack with a nominal thickness of 2 to 4 feet, or the project may require that the bentonite be installed up to the ground surface. The riser pipe is capped and the annulus covered with plastic sheeting to prevent rain water from entering into the well.

Permanent Well

Permanent monitoring wells are installed in the same manner as the temporary wells except that the proper back fill materials (some type of grout) are installed above the bentonite seal. In addition, a surface protection cover and bollards (if required) are installed in accordance with the State regulations, and client and project specifications. Comprehensive procedures regarding well installation and completion are provided in SOP GH-2.8.

5.4 Membrane Interface Probe/Electrical Conductivity Probe

The Membrane Interface Probe/Electrical Conductivity (MIP/EC) probe is a semi-quantitative field screening tool developed by Geoprobe® for vertical profiling of volatile organic compounds (VOCs) and soil conductivity for lithologic characterization. A permeable membrane device is driven into the subsurface. The membrane is heated to approximately 250 degrees Fahrenheit (°F) which leads to diffusion of VOCs across the membrane into a carrier gas stream which is transported to a laboratory grade GC. Various detectors are used: PID, FID, and XSD in the GC instrument to detect VOCs. An EC probe on the device measures the soil conductivity. A depth transducer is attached to the direct push drive head to track the depth of the probe. The MIP/EC profile response can be viewed while the probe in advancing downward allowing the user to determine the completion depth of the MIP/EC point. Hard copy of the MIP/EC results are provided when the MIP/EC point is completed. The real time data can be used:

- To determine plume size.
- To determine placement of temporary wells or permanent monitoring wells.
- For a one-phase investigation (eliminating a multiple phased effort).
- To determine quickly if contamination is present or not.
- To large sites where the MIP cost would offset taking numerous samples.
- To determine if there are contamination pathways present.
- To define contamination in fine-grained saturated material which doesn’t yield water into a well.
- To characterize the lithology and the extent of contamination to provide support for remediation system installation (i.e., which zones would most significantly benefit from chemical treatment injection).

For additional MIP/EC operational guidance go to this link: Geoprobe® MIP SOP.

6.0 RECORDS

A record of all field procedures, tests, and observations must be recorded in the field logbook, boring logs, and sample log sheets. Entries should include all pertinent data regarding the investigation. The use of sketches and field landmarks will help to supplement the investigation and evaluation. Comprehensive guides and procedures regarding records and documentation are provided in the following SOPs:

- GH-1.5 – Borehole and Sample Logging
- GH-2.8 – Groundwater Monitoring Well Installation

- SA-1.3 – Soil Sampling
- SA-1.1 – Groundwater sampling and Onsite Testing