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FINAL BASEWIDE PER AND POLYFLUOROALKYL SUBSTANCES SITE INSPECTION REPORT NAS OCEANA VA

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CH2M HILL

Mid-Atlantic
Virginia Beach, Virginia

Final

Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report

Naval Air Station Oceana
Virginia Beach, Virginia

August 2018

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Prepared for NAVFAC Mid-Atlantic
by CH2M HILL, Inc.
Virginia Beach, Virginia
Contract N62470-16-D-9000
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Executive Summary

Historical use of aqueous film-forming foam (AFFF) at Naval Air Station (NAS) Oceana during fire and emergency response, testing, and training activities, has prompted the Department of the Navy (the Navy) to conduct a per- and polyfluoroalkyl substances (PFAS) Site Inspection at the installation. The United States Environmental Protection Agency (USEPA) has described PFAS as "emerging contaminants," and established USEPA lifetime health advisories (L-HAs) for two PFAS compounds (perfluorooctanoic acid [PFOA] and perfluorooctane sulfonate [PFOS]). A Regional Screening Level (RSL) is also published for perfluorobutane sulfonate (PFBS). There are currently no legally enforceable federal or Virginia standards for PFAS constituents.

The objectives of the NAS Oceana Site Inspection for PFAS were identified in *Final Sampling and Analysis Plan, Basewide Site Inspection for Perfluorinated Compounds, Naval Air Station Oceana, Virginia Beach, Virginia* (CH2M, 2017), hereinafter referred to as the "SAP." Objectives were to:

- Determine if PFAS are present in suspected source areas at NAS Oceana.
- Determine whether PFAS are present at levels posing potentially unacceptable human health risks in groundwater at NAS Oceana.
- Determine whether PFAS have migrated offsite and are present at levels exceeding screening criteria (RSL and L-HAs) in private potable water within 1 mile downgradient of suspected source areas.

Preliminary investigation activities included a desktop study and interviews with Base personnel to determine potential source areas of PFAS. The field investigation was initiated in October of 2016 (Phase I) and consisted of the installation of shallow monitoring wells (screened in the Columbia aquifer) in locations where AFFF may have been used or released; groundwater sampling of newly installed and existing monitoring wells screened in the Columbia aquifer; sampling of potable wells located off-Base; and sampling of a non-potable well located on-Base. Based on the results from Phase I, additional investigation activities were initiated in March 2017 (Phase II), which included the installation of deep monitoring wells (screened in the Yorktown aquifer) and groundwater sampling in the Columbia and Yorktown aquifers. Groundwater sampling was also conducted in February 2017 to evaluate the effect of Oxygen Release Compound (ORC) socks on PFOS/PFOA concentrations in monitoring wells at Solid Waste Management Units (SWMUs) 2C and 2E. In addition, aquifer variable-head testing (slug test) in monitoring wells screened in the Columbia aquifer and measurement of groundwater elevations in the Columbia and Yorktown aquifers were performed to define the hydraulic characteristics of both aquifers. Investigations were performed in accordance with the SAP.

Laboratory analysis of groundwater samples collected in the Columbia aquifer indicate that PFAS are present in the majority of the monitoring wells sampled (31 out of 34 monitoring wells) with concentrations of PFOA and PFOS exceeding the USEPA L-HA of 70 nanograms per liter in the Columbia aquifer at Site 11 (Fire Training Area), Solid Waste Management Unit (SWMU) 26 (Burn Pit), in the vicinity of the aircraft hangars, and the Hush House (Jet Test Cell). One exceedance was also measured in the Yorktown aquifer in the vicinity of Site 11 (OW11-MW10D), which indicates that the contamination has migrated vertically from the Columbia aquifer to the Yorktown aquifer in that area. Results from the Human Health Risk Screening (HHRS) Analysis suggest that potable use of groundwater from the Columbia aquifer at Site 11, SWMU 26, the Aircraft Hangars and Maintenance Buildings site, and the Hush House may result in potential unacceptable human health risks associated with PFOA and PFOS.

There was no detection of PFAS in five of the six groundwater samples collected off-Base from private potable wells. The remaining sample did not exceed screening criteria. In addition, analysis of groundwater in shallow and deep monitoring wells located near the installation boundary (perimeter wells) showed that PFAS were not present or were present at concentrations below the screening standards. The HHRS suggests that potable use of groundwater from potable wells sampled off-Base and the perimeter wells would not result in unacceptable human health risks associated with PFAS at the wells sampled.

This investigation demonstrated that four source areas of PFAS were present at the installation. However, the investigation did not result in the full delineation of the horizontal and vertical extent of the contamination, did not fully assess the fate and transport of the contamination, and did not fully quantify whether PFAS are present at levels posing unacceptable human health risks in groundwater at NAS Oceana.

It is recommended that an Expanded Site Inspection (ESI) for PFAS be conducted at NAS Oceana to assess these data gaps and others (e.g., ecological risk screening, should screening values become available). As part of the ESI, it is recommended that additional monitoring wells be installed in the Columbia and Yorktown aquifers to better define the contamination extent and to monitor the horizontal and vertical migration of the contamination. New monitoring wells will also provide groundwater elevation data which will help better characterize the hydraulic characteristics of the Yorktown aquifer. Based on this data, a preliminary Conceptual Site Model (CSM) should be developed to fully define the fate and transport of the contamination.

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Acronyms and Abbreviations

°C	degree Celsius
AFFF	aqueous film-forming foam
amsl	above mean sea level
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-term Environmental Action—Navy
COC	constituent of concern
COPC	constituent of potential concern
CSM	conceptual site model
DI	deionized
DO	dissolved oxygen
ER	Environmental Restoration
ESI	Expanded Site Inspection
ft/min	foot per minute
HARN	High Accuracy Reference Network
HHRS	Human Health Risk Screening
HI	hazard index
HSA	Hollow Stem Auger
IDW	investigation-derived waste
L-HA	lifetime health advisory
MDC	Maximum Detected Concentration
mg/L	milligram per liter
MS	matrix spike
MSD	matrix spike duplicate
mS/cm	milliSiemen per centimeter
MSA	Miller Stephenson and Associates
mV	millivolt
NAVFAC	Naval Facilities Engineering Command
NAS	Naval Air Station
NAVD	North American Vertical Datum
Navy	Department of the Navy
ng/L	nanogram per liter
NTU	nephelometric turbidity units
ORC	oxygen release compound
ORP	oxidation-reduction potential
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutanesulfonic acid
PFHpA	perfluoroheptanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
POL	petroleum, oil, and lubricants

ppm	part per million
ppt	part per trillion
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SI	Site Inspection
SOP	Standard Operating Procedure
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit
TCLP	Toxicity Characteristic Leaching Procedure
USEPA	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compound

SECTION 1

Introduction

This Site Inspection (SI) Report presents the data and findings obtained from a per- and polyfluoroalkyl substances (PFAS) investigation conducted at Naval Air Station (NAS) Oceana. In October 2014, the Assistant Secretary of the Navy, Energy, Installations and Environment issued a statement requiring evaluation of sites with the potential for PFAS contamination under the Defense Environmental Restoration (ER) Program (Navy, 2014). In January 2015, the Department of the Navy issued a Perfluorinated Compounds (PFCs) Interim Guidance/Frequently Asked Questions which main objective was to "*assist Remedial Project Managers with programmatic and technical issues related to PFCs at Naval ER sites*" (Navy, 2015)[1] PFAS are described as emergent contaminants by the United States Environmental Protection Agency (USEPA) and have not been previously evaluated at Navy sites (USEPA, 2016a).

Overall objectives of the SI were defined in the *Final Sampling and Analysis Plan, Basewide Site Inspection for Perfluorinated Compounds, Naval Air Station Oceana, Virginia Beach, Virginia* (CH2M, 2017), hereinafter referred to as the "SAP." Objectives were to:

- Determine if PFAS are in suspected source areas at the installation.
- Determine whether PFAS are present at levels posing potentially unacceptable human health risks in groundwater at NAS Oceana.
- Determine whether PFAS have migrated offsite and are present at levels exceeding screening criteria in private potable water within 1 mile downgradient of suspected source areas.

This SI Report outlines the approach taken to achieve the listed objectives and provides conclusions of data collected and recommendations for further study. This report was prepared for the Department of the Navy (Navy), Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic, under the Comprehensive Long-term Environmental Action— Navy (CLEAN) 9000, Contract N62470-16-D-9000, Contract Task Order WE14, for submittal to NAVFAC Mid-Atlantic, USEPA Region 3, and the Virginia Department of Environmental Quality (VDEQ). The Navy, USEPA, and VDEQ work jointly as the NAS Oceana/Naval Auxiliary Landing Field Fentress Tier 1 Partnering Team (Team).

The SI Report is organized as follows:

- **Section 1** – Introduction
- **Section 2** – Site Background and Physical Setting
- **Section 3** – Investigation Methodology
- **Section 4** – Investigation Results
- **Section 5** – Human Health Risk Screening
- **Section 6** – Conclusions and Recommendations
- **Section 7** – References

Tables and figures are provided at the end of each respective section. Appendices are included at the end of the report.

[1] In September 2017, the Department of the Navy issued an interim PFAS Site Guidance which assists in "*identifying sampling methodologies, and promoting a consistent approach for dealing with PFAS at Navy ER Sites"* (Navy, 2017). The 2015 guidance was revised and superseded by 2017 guidance. However, since the 2017 guidance was issued after this investigation was complete, the 2015 guidance was followed for this investigation.

SECTION 2

Site Background and Physical Setting

This section presents background information on NAS Oceana including site history, potential sources of PFAS, and relevant information on the physical and hydrogeologic setting at the site.

2.1 Site Background

NAS Oceana is located in Virginia Beach, Virginia and was established in 1940 as a small auxiliary airfield. Since 1940, NAS Oceana has grown to more than 16 times its original size and is now a 6,000-acre master jet base supporting a community of more than 9,100 Navy personnel and 11,000 dependents. The primary mission of NAS Oceana is to provide the personnel, operations, maintenance, and training facilities to ensure that fighter and attack squadrons on aircraft carriers of the U.S. Atlantic Fleet are ready for deployment. **Figure 2-1** provides a location map of NAS Oceana.

During the desktop review of historical documents and interviews with the NAS Oceana Fire Department, potential PFAS source areas were identified. **Appendix A** provides the record of these interviews. **Figure 2-1** depicts the locations of potential aqueous film-forming foam (AFFF) release areas evaluated in this SI. Available site histories of these areas are described below.

2.1.1 Site 11 (Fire Training Area)

Site 11 was used for firefighting training twice per week from the 1960s to the 1980s. Initially, training exercises were performed on the abandoned runway. Waste fuel and oil were dumped onto the abandoned runway, ignited, and extinguished with AFFF. In 1969, the annual usage of AFFF was estimated to be 2,000 gallons. In the mid-1970s, the first fire training ring (Solid Waste Management Unit [SWMU] 62, the Old Fire Station Burn Pit) was installed with an earthen berm to contain runoff. After construction of the first ring, training exercises were performed within the earthen berm and runoff would occasionally flow onto surrounding soils. In the early 1980s, a second fire training ring (SWMU 63, the New Burn Pit) was installed on a concrete pad with a concrete berm and an oil/water separator to contain petroleum, oil, and lubricants (POL). In the 1990s, a third training ring was built to the north as a jet mock-up on a concrete pad with runoff collection devices. Historical use does not indicate that AFFF was used at the jet mock-up, but trucks were tested quarterly in the past near this area by spraying AFFF onto the grass near the ring. In 2001, Site 11 (referred to as SWMU 11 in that the 2001 report) was closed (CH2M, 2001). The 2001 Decision Document, which has received USEPA concurrence, establishes No Further Action as the selected remedy for Site 11 (referred to as SWMU 11 in the 2001 report) (CH2M, 2001). Site 11 was identified as requiring evaluation for PFAS due to firefighting training activities historically conducted at the site.

2.1.2 SWMU 26 (Fire Station Burn Pit)

SWMU 26, located southeast of Building 220 (Fire Station), was used for firefighting training activities from the 1960s to the 1980s and consisted of a partially buried tank that was filled with waste fuel and oil, ignited, and extinguished with AFFF. The tank was removed from the ground by 1990. In 2001, SWMU 26 was closed (CH2M, 2001). The 2001 Decision Document, which has received USEPA concurrence, establishes No Further Action as the selected remedy for SWMU 26 (CH2M, 2001). SWMU 26 was identified as requiring evaluation for PFAS due to firefighting training activities historically conducted at the site.

2.1.3 Aircraft Hangars and Maintenance Buildings

Several aircraft hangars and maintenance buildings were identified as potential AFFF release areas during NAS Oceana Fire Department interviews (**Appendix A**). In Building 145, AFFF was accidentally released into the parking lot (**Figure 2-1**). Personnel were advised to cover the storm drains and spray water to wash the AFFF onto the grass. A contractor was brought in to vacuum up any remaining foam. The date of this release is unknown. In Hangar 111, a release occurred during retrofit of the floor nozzles. The date of this release is unknown. In Hangar

500, accidental “activations” (which are technically not considered “spills”) used to occur approximately on a monthly basis due to sensitive sensors. The sensors have been adjusted and there have been no additional activations. The date range of the monthly activations is unknown. In Building 139, there was a spill at the corrosion control facility in 2010. There are no drains in that area and the foam was pushed outside to the grass swale on the southeast side of the building, and then cleaned up with a vacuum truck. In Building 139, there have been multiple releases, but the dates of these releases are unknown. In Hangar 122, a very large storm caused stormwater to back up and fill the overflow tanks in July 2011, releasing AFFF to the environment, including the storm drain and storm ditch. The Hampton Roads Sanitation District was notified of this release.

2.1.4 1986 Crash Site

In 1986, a plane crashed off Oceana Boulevard near the Base boundary. Interviewees indicated that AFFF was probably used for this crash.

2.1.5 1996 Crash Site

Interviewees indicated that a plane crashed in the woods on the installation in 1995. However, a local newspaper article indicated that the crash was in 1996 (Sizemore, 2012). Interviewees could not recall whether there was an associated fire and were uncertain whether AFFF was used for this crash.

2.1.6 2007 Crash Site

In 2007, a civilian plane crashed during an air show practice, right off Runway 5L. Interviewees were not sure whether AFFF was used.

2.1.7 Hush House (Jet Test Cell)

The Hush House (also referred to as the Jet Test Cell) was first investigated in December 2003 as a result of a fuel release on November 24, 2003 (VDEQ, 2004). The Hush House was used for testing jet engines in an enclosed area for the purpose of noise control. It is being evaluated for PFAS due to an accidental AFFF release in that area which occurred at an unknown date. Personnel called Oceana Base Environmental personnel and were told to spray down the concrete area into the grass.

2.1.8 POL Fuel Tank (Site F8-F9)

Trucks carrying AFFF would connect to the fire suppressing system piping adjacent to the POL Fuel Tank area near monitoring well OC-F8F9-MW-4. Releases of AFFF to the ground may have occurred when connecting and disconnecting from the pipes.

2.2 Physical Setting

This section describes the site setting, including geologic features relevant to this investigation.

2.2.1 Climate

NAS Oceana is located in an area where temperature extremes are moderated by the Atlantic Ocean. The average yearly temperature is 60.0 degrees Fahrenheit with an annual precipitation of 45.7 inches. Winds on average blow from a northerly direction from January through March and again in September and October. During the remaining months, winds generally blow from a southerly direction (INRMP, 2017).

2.2.2 Topography and Surface Drainage Features

The topography of the station is generally flat, with elevations ranging from 1 to 31 feet above mean sea level (amsl) (INRMP, 2017). The highest elevations occur in the eastern portion of the station along a relic sand dune, the Punto Ridge. Elevations in the developed area of the station range from 10 to 25 feet amsl. Surface runoff from the station is facilitated by a system of drainage ditches and surface canals that flow south and west to West

Neck Creek, north to London Bridge and Great Neck Creek, and east to Owls Creek and Lake Rudee (**Figure 2-1**). These drainage ditches are engineered, maintained structures and are cleaned periodically. Surface water bodies on the station are limited to these drainage ditches and a number of manmade ponds.

2.2.3 Land Use

More than 40 percent of NAS Oceana is urbanized including commercial, residential, and operations buildings and runways, hangars, and similar structures. The undeveloped areas of NAS Oceana consist of farmland, open land, forest, and wetlands. Approximately 646 acres of land are farmed by private producers under the Navy's agricultural outlease program (INRMP, 2017). The facility is restricted to the general public by a locked, chain-link fence; however, with the exception of the runway and flight line areas, it is unrestricted to Navy personnel. Land use at NAS Oceana is not expected to change in the foreseeable future.

2.2.4 Water Use

Groundwater is not currently used as a potable water supply on NAS Oceana. The Base and most private properties surrounding the Base have access to water provided by the City of Virginia Beach although some private properties are not connected to the municipal water supply and use groundwater as a potable water source. Non-potable wells are also present in private properties in the vicinity of the NAS Oceana and the possibility exists that people will accidentally use the water from these wells for potable purposes or incidentally ingest it during non-potable use.

On-Base non-potable wells are located on the north side of the Base at the Skeet and Trap Range. Multiple irrigation wells are also present at the Base Golf Course. Based on conversations with NAS Oceana personnel, only one well extracts groundwater. Other Golf Course extraction points referred to as "wells" are suspected to pump from irrigation ponds. Two wells, one to the north of the Base and one to the south of the Base, pump water for use in concrete manufacturing operations. In addition, there is a supply well on the east side of the Base at the Natural Resources Building.

Bottled water is provided to the Skeet and Trap Range for reasons unrelated to the potential presence of PFAS in groundwater in that area of the base.

2.2.5 Geologic Setting

NAS Oceana is on the outer edge of the Atlantic Coastal Plain physiographic province. The Atlantic Coastal Plain is a broad wedge of unconsolidated sediments that dip and thicken to the east. In the vicinity of NAS Oceana these sediments consist of several thousand feet of unconsolidated sand, clay, silt, and gravels and are underlain by granite basement rock. The sediments range in age from late Cretaceous to Recent. From oldest to youngest, the five principal geologic units are the Potomac Formation, the Unnamed Upper Cretaceous deposits, the Pamunkey Group, the Chesapeake Group, and the Columbia Group. The Chesapeake Group has been differentiated further into five formations, which are, from oldest to youngest: the Calvert, Choptank, St. Marys, Eastover, and Yorktown Formations. The Columbia Group sediments overlying the Yorktown Formation have also been differentiated into several units.

The geologic units of concern in the environmental investigations at NAS Oceana are the Yorktown Formation and the Columbia Group. The Columbia Group is present at the ground surface in the vicinity of the Base and generally extends to approximately 20 feet bgs. The Yorktown Formation underlies the Columbia Group. The upper Yorktown Formation consists of interbedded layers of shelly, very fine to coarse sands, clayey sands and sandy clay of Tertiary age. Regionally, the uppermost of these silt and clay beds separates the Yorktown Formation from the sediments of the Columbia Group that overlie it. This uppermost bed consists of massive, well-bedded yellow-gray to greenish-gray clays and silty clays, commonly containing shells, fine sand, and mica. This unit is absent across much of NAS Oceana. The clay layers within the confining bed are generally extensive but are a series of coalescing clay beds rather than a single deposited unit. This unit was deposited in a shallow open-marine environment of broad lagoons and quiet bays (Meng and Harsh, 1984). The sediments of the Columbia Group consist of interbedded gravels, sands, silts, and clays of Pleistocene and Holocene age. The Pleistocene and

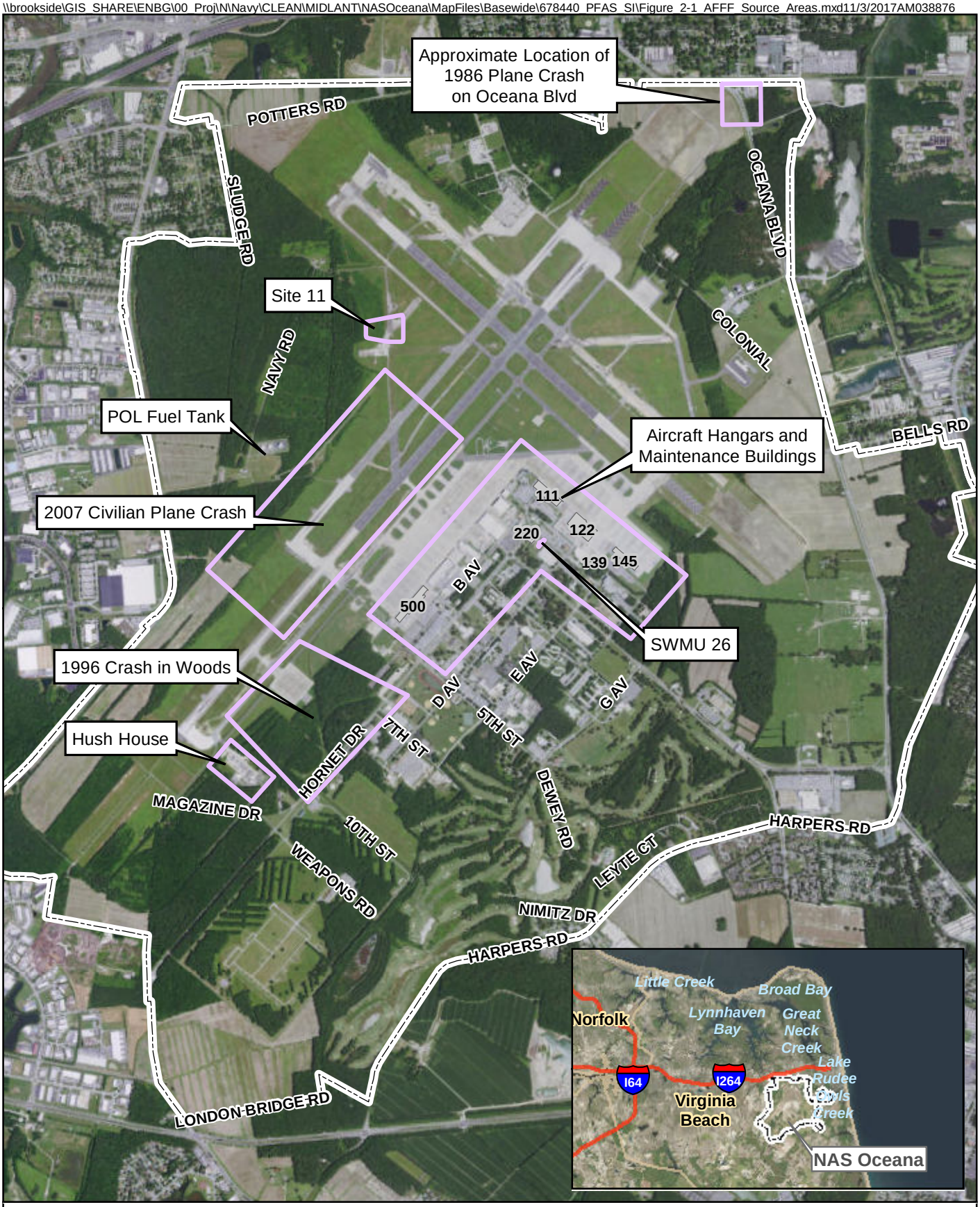
Holocene sediments were deposited in fluvial-marine terrace and near-shore marine environments such as lagoons, beaches, tidal flats and barrier islands (CH2M, 1991).

2.2.6 Groundwater Flow

Groundwater at NAS Oceana is generally within 4 to 10 feet of the land surface. Aquifer conditions are unconfined in the Columbia Group and unconfined to semiconfined within the upper Yorktown Formation. When the clay confining unit overlying the Yorktown is absent, the upper Yorktown and Columbia aquifers act as a single, unconfined, hydrogeologic unit. Groundwater flow directions in the Columbia aquifer are variable and generally flow to the north at the northern half of the Base, to the south-southwest at the southern half of the Base, and to the west-northwest at the eastern portion of the Base. The Yorktown aquifer appears to follow the flow patterns of the Columbia aquifer at the Base with flow to the north at the northern half of the Base and to the southwest at the southern half of the Base. Groundwater flow data collected as part of this investigation is discussed in more detail in **Sections 3.5 and 3.6**.

2.2.7 Hydrogeologic Setting

The surficial hydrogeologic unit at NAS Oceana consists of the Columbia aquifer, which extends to a depth of approximately 17 to 30 feet bgs at the installation. This unit is underlain by the Yorktown confining unit across much of coastal Virginia; however, this unit is absent across most of NAS Oceana. Where present, the confining unit is underlain by the Yorktown aquifer. No monitoring wells or water supply wells at the Base have been installed to the total depth of the Yorktown aquifer, but the approximate thickness of the unit is 100 feet based on *The Virginia Coastal Plain Hydrogeologic Framework* (USGS, 2006).



Legend

- Potential AFFF Release Areas
- Installation Boundary

N
W E
S

0 1,375 2,750
Feet

Imagery and Basemap Source: ©2017 Esri

Figure 2-1
AFFF Source Areas
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

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SECTION 3

Investigation Methodology

3.1 Objectives and Approach

The field activities discussed in this report were performed in accordance with the SAP. The initial phase of field activities (Phase I) was conducted from October to December of 2016 and included on-Base monitoring well installation in the Columbia aquifer, on-Base groundwater sampling, aquifer variable-head testing (slug test) in monitoring wells screened in the Columbia aquifer, and off-Base private potable well sampling. Based on the results of Phase I, CH2M performed an additional investigation (Phase II) from March to May of 2017, which included the installation of additional monitoring wells in the Columbia and Yorktown aquifers, and associated groundwater sampling. Additional groundwater sampling was conducted in February 2017 to evaluate the effect of oxygen release compound (ORC) socks on PFOS/PFOA concentrations. A summary of the technical approach for conducting these activities is provided below.

3.2 Site Preparation and Utility Location

Prior to installation of new monitoring wells, utilities within 10 feet of proposed well locations were marked by Advanced Infrastructure Mapping, a licensed utility locator. Miss Utility of Virginia was also contacted to clear utilities in the vicinity of borings. While some locations required minor adjustment to account for buried utility lines, no significant changes to locations were necessary.

3.3 Monitoring Well Installation

In October 2016 and May 2017, 12 monitoring wells were installed to depths of approximately 20 feet below ground surface (bgs) and screened within the Columbia aquifer (from 10 to 20 feet bgs) (**Figures 3-1, 3-2, and 3-3**). In addition, in August 2017, 1 monitoring well that had collapsed (MW-BG04) was abandoned and replaced by a new monitoring well (MW-BG04R). Monitoring wells were installed at Site 11, SWMU 26, the Hush House site, and the 1986 and 1996 airplane crash sites. For other potential source areas (**Figure 2-1**) existing wells were present at the site that could be sampled in lieu of installing new monitoring wells. In May 2017, five monitoring wells were installed to depths of 60 feet bgs and screened within the Yorktown aquifer at depths ranging from 50 to 60 feet bgs (**Figure 3-4**) and one additional shallow well was installed in the southern portion of the Base to better assess offsite migration in that area. Monitoring wells were installed near the Base boundary, at Site 11, and south of the 1986 Crash Site.

Each monitoring well was installed in accordance with the standard operation procedures (SOPs) titled *General Guidance for Monitoring Well Installation, Installation of Shallow Monitoring Wells, and Installation of Deep Monitoring Wells*, provided in the SAP (CH2M, 2017).

Parratt-Wolff, Inc., of Hillsborough, North Carolina, provided hollow-stem auger (HSA) well drilling and installation services using a 4.25-inch-inside-diameter HSA. During the lithologic logging of soil cores (collected using 4-foot-long acetate sleeves), soil descriptions were recorded, including grain size, color, moisture content, relative density, consistency, soil structure, mineralogy, and other relevant information, such as possible evidence of contamination. **Appendix B** and **Appendix C** present the construction details and soil boring logs for each Columbia monitoring well and Yorktown monitoring well.

Each new monitoring well was constructed with 2-inch-inside-diameter Schedule 40 polyvinyl chloride (PVC) screen and riser with a 10-foot-long, 0.010-inch machine-slotted screen. A silica filter pack (Industrial Quartz #1 or #1A) was placed around the annular space of the well screen from the bottom of the boring extending to a depth of 2 feet above the top of the screen. The filter pack was installed in a manner that prevents bridging. The depth to the top of the sand filter pack was measured periodically using a weighted measuring tape. A minimum of a 2-foot bentonite layer of pure, additive-free chips was placed at the top of the sand pack. The bentonite was

allowed to hydrate for 45 minutes before a cement-bentonite grout was placed in the remaining annular space. All monitoring wells were completed with a bolt down flush-mounted or stick-up cover. A locking, watertight cap was placed on the top of each casing, and the well identification numbers were clearly marked on the well with etched well identification tags. Well construction details are summarized in **Table 3-1**.

3.4 Monitoring Well Development

Prior to sampling, all newly installed monitoring wells were developed in order to restore the permeability of the aquifer material immediately surrounding the well, which may have been reduced by the drilling operations, and to remove fine-grained materials that may have collected inside the well during installation. Monitoring well development was performed after the grout used to construct the new monitoring wells was allowed to adequately set (at least 24 hours or more) to prevent grout contamination of the screened interval. Monitoring wells were developed with a submersible pump using a combination of pumping and surging throughout the length of the well screen.

Between 36 and 78 gallons of water were evacuated from each well, with a total of 850 gallons of water purged during the entire monitoring well development event. During monitoring well development, in accordance with the SOPs provided in the SAP (CH2M, 2017), water quality parameters (pH, oxidation-reduction potential [ORP], temperature, specific conductivity, salinity, turbidity, and dissolved oxygen [DO]) were recorded approximately every 5 minutes using a YSI water-quality meter. The YSI instrument was calibrated daily, and calibration results were recorded in the field notebook.

Generally, development continued until at least three well volumes were removed and the water produced was free of turbidity, sand, and silt (to the maximum extent practicable). The water quality meter was used to determine when the turbidity was low (preferably less than 20 nephelometric turbidity units [NTU]). If turbidity continued to decrease after the removal of three well volumes, development was continued until turbidity readings stabilized (that is, until turbidity readings were within 10 percent of each other for three consecutive readings). In addition, development typically ended once three successive measurements of pH, specific conductivity, and temperature within 10 percent of each other were achieved.

3.5 Groundwater Elevation Measurement

Groundwater elevation surveys were conducted in October of 2016 for 38 monitoring wells (11 new and 27 existing monitoring wells) in the Columbia aquifer (**Table 3-2**). In May of 2017 a survey was conducted for 37 new and existing monitoring wells in the Columbia aquifer (**Table 3-3**) and four new monitoring wells in the Yorktown aquifer (**Table 3-4**). In November 2017, a survey was conducted for 40 monitoring wells in the Columbia aquifer and five (**Table 3-5**) in the Yorktown aquifer (**Table 3-6**) An electronic water-level meter was used to measure the depth to water from the surveyed marking on the top of the well casing to the nearest 0.01 foot. Based on the groundwater elevations measured in October 2016, and May and November 2017, groundwater contour maps for the Columbia aquifer were prepared (**Figures 3-1, 3-2, and 3-3**). Groundwater contour maps based on groundwater elevations measured in May and November 2017 for the Yorktown aquifer (**Figures 3-4 and 3-5**) were also prepared. However, the groundwater contour map for the Yorktown aquifer had to be extrapolated in the southwestern portion of the site and could not be drawn in the southern portion of the site due to the limited number of monitoring wells installed in that aquifer.

Vertical gradients were calculated for paired wells in the Columbia and Yorktown aquifers and are included in Table 3-7. Water elevations were very similar between well pairs in the two aquifers, as expected since a confining unit is not present at the site. Vertical gradient information indicates a weak downward gradient between the Surficial/Columbia and Yorktown aquifer wells (between -0.003 and -0.036 ft/ft with a mean of 0.0132 ft/ft).

3.6 Aquifer Variable-head Testing

On November 10 and 11, 2016, falling- and rising-head slug tests were conducted in monitoring wells OW2B-MW14, OW2C-MW19, OW11-MW04, OW11-MW07, OW11-MW09, and OW26-MW01 to quantify spatial variations of the hydraulic properties of the shallow aquifer unit at the Aircraft Hangars and Maintenance Buildings site, SWMU 26, and Site 11 (**Figure 3-6**).

Three rising-head and three falling-head slug tests were performed in each monitoring well. The static depth to water was manually measured and recorded before each slug test. A digital data logger (Level Troll 700™) was submerged in the monitoring well to a depth of several feet below the static water level. The data logger was programmed to logarithmically record the depth of water above the sensor at 0.25-second intervals. The slug used for all test consisted of a 5-foot-long, 1.5-inch-diameter section of solid PVC.

For each falling-head test the slug was rapidly lowered into the well and held steady while the digital data logger measured the changing depth of water. The slug remained in place until the static water level recovered to 90 percent of the pre-test level.

A rising-head test was conducted by rapidly removing the slug while the digital data logger measured the changing depth of water. The test continued until the water level recovered to 90 percent of the pre-test level.

All equipment that entered the well was decontaminated before testing was started and before the equipment was moved to test a new well. After each test, the data logger was downloaded and the test results were examined.

The slug test data sets were analyzed using the Bouwer-Rice solution method (Bouwer and Rice, 1976). The graphical analysis sheets are presented in **Appendix D**, and the hydraulic conductivity estimates are summarized in **Table 3-8**. The Bouwer-Rice solution was developed to accommodate the analysis of slug tests in unconfined aquifers and is theoretically appropriate for these slug tests. The estimated hydraulic conductivity for the Columbia Aquifer ranged from 4.00×10^{-3} feet per minute (ft/min) to 9.53×10^{-3} ft/min. These values are consistent with moderate to rapid saturated hydraulic conductivity as indicated in the *National Soil Survey Handbook, Part 618* (U.S. Department of Agriculture, 2017). Some uncertainty exists with respect to the validity of the falling-head tests because the static water level in some of the screens were within the well screen interval. However, because falling- and rising-head test results were similar, results are believed to be valid.

For the shallow aquifer at the Aircraft Hangars and Maintenance Buildings site, SWMU 26, and Site 11, the groundwater flow velocity was calculated using the following equation:

$$V=Ki/N_e$$

Where:

V= the estimated groundwater flow velocity
K= the average hydraulic conductivity
i = the groundwater gradient
N_e = the estimated effective porosity, as a decimal fraction

Site specific parameters are as follows:

K = 6.765×10^{-3} ft/min (average of values calculated during slug tests)
i = 0.0008 ft/ft (based on the May 2017 groundwater levels)
N_e = 0.25 (estimated effective porosity of silty sand)

In consideration of these parameter, the groundwater velocity at the Aircraft Hangars and Maintenance Buildings site, SWMU 26, and Site 11 is estimated to be 0.0312 ft/day or approximately 11.37 ft/year.

3.7 Groundwater Sampling

Between October 2016 and May 2017, 35 samples from 34 Columbia aquifer wells were collected on-Base. Additionally, five wells in the Yorktown aquifer were sampled.

All samples were collected in accordance with the SOP *Low-Flow Groundwater Sampling from Monitoring Wells – EPA Region I and III* provided in the SAP (CH2M, 2017) in order to minimize drawdown and to obtain samples representative of groundwater conditions in the surrounding geologic formation. Cross-contamination of PFAS was considered during sampling in accordance with the SOP *OPNAV PFC Sampling Policy* provided in the SAP (CH2M, 2017). Prior to groundwater sample collection, monitoring wells were purged in order to remove any stagnant water and to collect a representative sample from the aquifer. Groundwater samples were collected from monitoring wells using a peristaltic pump and disposable tubing. Groundwater quality parameters, including pH, ORP, temperature, specific conductivity, salinity, turbidity, and DO, were measured during the purging of each well using a YSI water-quality meter and a flow-through cell to prevent the purged groundwater from contacting the atmosphere during parameter measurement.

Purging continued until water quality readings collected 5 minutes apart stabilized to within 10 percent of one another. Following parameter stabilization, a CHEMet test kit was used to confirm DO readings measured by the water-quality meter (Model Numbers K-7501 for 0 to 1 part per million [ppm] and K-7512 for 1 to 12 ppm). Once DO confirmation was recorded, the flow-through cell was disconnected and samples were collected directly into laboratory-provided sample bottles. The final set of groundwater quality measurements recorded before sample collection for each monitoring well is presented in **Tables 3-9** through **3-11** for the Columbia aquifer, and in **Table 3-12** for the Yorktown aquifer.

Groundwater samples were analyzed for six PFAS: perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and perfluorobutanesulfonic acid (PFBS) in accordance with the USEPA's Third Unregulated Contaminant Monitoring Rule (USEPA, 2012). Groundwater for the analytical samples was pumped through the tubing directly into the appropriate laboratory-provided bottleware. To avoid cross-contamination of PFAS, Teflon tubing was not utilized during sampling. After collection in sampling containers, and at the end of each day, the samples were packed on ice and shipped via overnight service to the laboratory for analysis.

3.8 Off-Base Potable Water Sampling

In accordance with the *Perfluorinated Compounds Interim Guidance and Frequently Asked Questions (*Navy, 2015)[1], all parcels located within 1 mile of potential PFAS source areas were evaluated to determine whether groundwater was used as a potential potable water source. A record search showed that 470 parcels were located within the 1-mile radius, and that only 15 parcels had a potable water well installed. A survey of the parcels' owners/residents with a potable well was performed to determine the actual type and usage of well, and a request to collect a water sample from the well was sent. Six residents/homeowners requested that their well be sampled. Samples were taken in accordance with the SOP *Drinking Water Sampling when Analyzing for Per- and Polyfluoroalklyl Substances (PFASs)* and the SOP *OPNAV PFC Sampling Policy*, both provided in the SAP (CH2M, 2017).

Prior to potable well sample collection, the tap or spigot was opened and water was purged for at least 10 minutes in order to flush the system of stagnant water and collect a sample representative of the aquifer. Homeowner questionnaires were also completed to determine well construction details, if known. Depth and screen interval information of the wells, which was provided by homeowners or residents, could not be obtained for some wells and could not be verified. Potable well samples were collected directly from the tap or spigot, depending on location, from a collection point upstream from any treatment system installed by the homeowner (such as granular activated carbon filter). A field reagent blank was collected at each sampling location. After collection in sampling containers, and at the end of each day, the samples were packed on ice and shipped via overnight service to the laboratory for analysis. The potable water samples were analyzed for the same six PFAS that the groundwater samples were analyzed for: PFOS, PFOA, PFNA, PFHxS, PFHpA, and PFBS.

3.9 Surveying

Miller Stephenson and Associates (MSA), and Pennoni Associates, of Virginia Beach, Virginia (both Virginia-licensed and registered surveyors), conducted a survey of the monitoring wells installed during the Phase I and II investigations, respectively. Each of the monitoring wells was surveyed for vertical and horizontal control to an accuracy of ±0.01 foot and ±0.1 foot, respectively (**Appendix E**). Monitoring wells were surveyed at the top of the PVC casing (where marked) and at the ground surface. The vertical elevations were referenced to National American Vertical Datum of 1988 (NAVD 88) to remain consistent with the coordinate system and datum currently in use on the project site. Horizontal coordinates were referenced to the Virginia State Plane Coordinate System, South Zone, NAD83/94 HARN. Discrepancies were noted in the Pennoni Associates survey report. The wells contained in that report may be resurveyed during additional investigations.

3.10 Quality Assurance and Quality Control

Drinking water samples were collected according to the Navy CLEAN SOP *Drinking Water Sampling when Analyzing for Per-and Polyfluoroalkyl Substances (PFAS)* referenced in the SAP (CH2M, 2017). Groundwater and drinking water samples collected for this field investigation were analyzed using USEPA 537 Modification analytical method as identified in the SAP (CH2M, 2017).

Field quality assurance/quality control (QA/QC) samples were collected during the sampling program. These samples were obtained to:

- Ensure that disposable and reusable sampling equipment were free of contaminants
- Evaluate field methodology
- Establish ambient field background conditions
- Evaluate whether cross-contamination occurred during sampling and/or shipping

Several types of field QA/QC samples that were collected and analyzed are defined as follows:

- **Equipment Rinsate Blank (decontaminated equipment):** Equipment blanks were collected at the frequency of one per day of sampling. These samples were obtained by running laboratory-grade deionized (DI) water over or through sample collection equipment after the decontamination procedures had been conducted. These samples, which were collected during groundwater sampling only, were used to determine whether decontamination procedures for reusable equipment were adequate.
- **Equipment Rinsate Blank (disposable equipment):** Equipment blanks were collected at the frequency of one per lot. These samples were obtained by running laboratory-grade DI water over or through sample collection equipment prior to the equipment's use. These samples, which were collected during groundwater sampling only, were used to determine whether disposable, one-time-use equipment was contaminant-free prior to use.
- **Field Reagent Blank:** Field blanks were collected at the frequency of one per week for groundwater monitoring and one per residence for drinking water sampling. These samples were collected by pouring the laboratory-provided preserved reagent blank water from the preserved bottle into the unpreserved blank container. The purpose of these samples is to assess the potential for field contamination.
- **Duplicate Sample:** Duplicate samples were collected at the same time and under identical conditions as their respective associated sample at the frequency of one per 10 field samples of similar matrix. These samples were collected to evaluate the field and laboratory reproducibility of sample results and are one way to evaluate field methodology.

In addition to samples collected to monitor field QC, samples were also collected to monitor quality within the laboratory. These included the following:

- **Matrix Spike (MS):** An aliquot of a matrix (that is, groundwater) was spiked with known quantities of analytes of interest and subjected to the entire analytical procedure. By measuring the recovery of these spiked quantities, the appropriateness of the method for the matrix was demonstrated.
- **Matrix Spike Duplicate (MSD):** These samples were collected as second aliquots of the same matrix as the MS to determine the precision of the method.

One MS sample and one MSD sample were collected for every 20 environmental samples collected (or greater than or equal to 5 percent of the samples collected) per medium including field duplicates.

3.11 Decontamination Procedures

All decontamination activities were conducted in accordance with the SOPs *Decontamination of Drilling Rigs* and *Equipment* and *Decontamination of Personnel and Equipment* provided in the SAP, as applicable (CH2M, 2017). In addition, cross-contamination of PFAS was considered during decontamination in accordance with the SOP titled *OPNAV PFC Sampling Policy* provided in the SAP (CH2M, 2017).

Nondisposable equipment was decontaminated using the following solutions in this order:

1. Distilled water (laboratory certified PFAS-free) and Liquinox solution
2. Distilled water (laboratory certified PFAS-free) rinse 10 percent isopropanol and distilled water solution (laboratory certified PFAS-free) and air-dried
3. Laboratory grade DI water (laboratory certified PFAS-free)

Water generated during decontamination of sampling equipment was collected and transferred to an approved 55-gallon drum to await characterization and disposal.

No equipment decontamination was required for the drinking water sampling event.

Disposable sampling equipment and personal protective equipment, such as Masterflex tubing and nitrile gloves, were not decontaminated after use and instead were disposed as nonhazardous solid waste. After use, disposable equipment was placed in plastic contractor bags and disposed in an onsite trash dumpster.

Reusable heavy equipment, such as drilling rods and augers, was decontaminated before and in between the collection of each sample using a high-pressure steam cleaner with potable-grade water. Pressure washing was conducted at the temporary decontamination pad, which had been constructed prior to the start of drilling activities. The decontamination pad consisted of a raised wood frame lined with a high-density polyethylene tarp, which acted as a basin to collect fluids. These fluids were then pumped into approved 55-gallon drums to await characterization and disposal. All heavy equipment decontamination procedures were conducted in accordance with the SOP *Decontamination of Drilling Rigs and Equipment* provided in the SAP (CH2M, 2017).

3.12 Investigation-derived Waste Management

Investigation-derived waste (IDW) generated during the SI included soil cuttings, well development groundwater, groundwater sampling purge-water, as well as decontamination rinse-water from all nondisposable sampling equipment and heavy equipment. The IDW was containerized in approved 55-gallon drums that were properly labeled and stored within secondary containment at NAS Oceana. A total of 24 drums of solid IDW (17 drums associated with Phase I and 7 drums associated with Phase II) and 33 drums of aqueous IDW (13 drums associated with the Phase I SI and 20 drums associated with the Phase II SI) were generated during the field activities.

Prior to disposal, CH2M field staff collected three composite samples from all aqueous IDW drums (two associated with Phase I and one associated with Phase II) and eight composite sample from all solid IDW drums (seven associated with Phase I and one associated with Phase II). The IDW samples were analyzed for full Toxicity Characteristic Leaching Procedure (TCLP) analyses (volatile organic compounds [VOCs], semivolatile organic compounds [SVOCs], pesticides, and inorganic constituents), ignitability, reactive cyanide, reactive sulfide, and corrosivity. Phase II aqueous samples were additionally analyzed for PFAS in accordance with a more recent Navy

policy. Based on the analytical results, all IDW was identified as nonhazardous and PFAS results for the Phase II aqueous samples were less than the USEPA lifetime health advisory (L-HA) of 70 nanograms per liter (ng/L) for the sum of PFOA and PFOS. As such, waste was disposed as nonhazardous by Clearfield MMG within 90 days of generation at the company's approved disposal facility in Chesapeake, Virginia.

All IDW management activities were conducted in accordance with the SAP (CH2M, 2017). **Tables F-1**, and **F-2** of **Appendix F** provide an analytical summary for the Phase I IDW samples and **Tables F-3** and **F-4** of **Appendix F** provide an analytical summary for the Phase II IDW samples. **Appendix F** also includes all IDW handling and disposal information.

3.13 Data Quality Evaluation

The data quality evaluation and validation is a multitiered approach. The process begins with an internal laboratory review, continues with an independent review by a third-party validator, and ends with an overall review by the CH2M project chemistry team. The data validation reports are included as **Appendix G**.

TABLE 3-1
Well Construction Detail Table
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Monitoring Well	Installation Date	Ground Elevation (feet amsl)	Top of Casing Elevation (feet amsl)	Wellhead protection	Total Well Depth (feet bgs)	Length of Screen (feet)	Elevation of Top of Screen (feet amsl)	Elevation of Bottom Screen (feet amsl)
Columbia Aquifer Monitoring Wells								
OW11-MW4	10/6/2016	15.89	18.89	Aluminum standpipe	19.68	10	25.24	35.24
OW11-MW5	10/6/2016	16.87	20.05	Aluminum standpipe	18.81	10	25.5	35.5
OW11-MW6	10/6/2016	18.2	17.89	Flush mount	20.48	10	28.35	38.35
OW11-MW7	10/6/2016	17.47	17.15	Flush mount	20.56	10	27.7	37.7
OW11-MW8	10/6/2016	15.81	18.88	Aluminum standpipe	19.61	10	25.24	35.24
OW11-MW9	10/6/2016	15.84	18.65	Aluminum standpipe	20.54	10	26.44	36.44
OW26-MW1	10/11/2016	18.33	18.13	Flush mount	19.3	10	27.45	37.45
OC-MW01	10/12/2016	19.22	18.98	Flush mount	20.04	10	28.93	38.93
OC-MW02	10/13/2016	22.43	22.22	Flush mount	20.63	10	32.73	42.73
OC-MW03	10/14/2016	13.91	13.58	Flush mount	20.38	10	23.96	33.96
OC-MW04	10/13/2016	14.26	17.45	Aluminum standpipe	21.11	10	25.04	35.04
W-BG04R	8/8/2017	25.25	24.99	Flush mount	20	10	36.03	46.03
Yorktown Aquifer Monitoring Wells								
OC-MW07D *	3/13/2017	9.6	13.59	Steel standpipe	60	10	20.38	30.38
OC-MW02D *	3/20/2017	22.9	22.79	Flush mount	60	10	33.68	43.68
OC-MW05D *	3/16/2017	16.6	16.28	Steel standpipe	60	10	27.38	37.38
OW11-MW10D *	3/14/2017	17.4	17.11	Flush mount	56	10	28.18	38.18
OW26-MW1D *	3/8/2017	18.6	18.35	Flush mount	60	10	29.38	39.38

Notes:
amsl = above mean sea level
bgs = below ground surface
* Discrepancies were noted in the survey report. These wells may be resurveyed during additional investigations.

TABLE 3-2

Groundwater Elevations in the Columbia Aquifer (October 2016)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Well ID	Total Depth (feet bgs)	Well Screen Interval (feet bgs)	Top of Casing Elevation (feet amsl)	Depth to Water (feet below measuring point)	Groundwater Elevation (feet amsl)
OW11-MW1	18	8-18	19.25	8.12	11.13
OW11-MW4	20	10-20	18.89	7.36	11.53
OW11-MW5	21	10-21	20.05	8.54	11.51
OW11-MW6	22	10-22	17.89	6.54	11.35
OW11-MW7	23	10-23	17.15	6.00	11.15
OW11-MW8	24	10-24	18.88	8.12	10.76
OW11-MW9	25	10-25	18.65	8.13	10.52
DT-03	21	10-21	16.74	5.71	11.03
1-MW06	21	5-20.5	18.18	8.09	10.09
OW26-MW1	20	10-20	18.13	4.46	13.67
OC-MW01	20	10-20	18.98	9.54	9.44
OC-MW03	20	10-20	13.58	4.40	9.18
JTC-MW-B	13	3-13	15.63	5.81	9.82
OC-MW04	23	13-23	17.45	7.35	10.10
OW2C-MW19	20	10-20	20.56	7.90	12.66
OW2C-MW05	16	6-16	20.42	5.27	15.15
OW2C-MW11	23	13-23	18.47	4.75	13.72
OW2C-MW24	23	13-23	18.72	5.17	13.55
OW2E-MW09R	19	4-19	19.88	5.51	14.37
OW2E-MW18	19	4-19	18.36	4.40	13.96
OW2E-MW19	19	9-19	19.67	5.22	14.45
OW2E-MW03	18	8-18	19.61	3.73	15.88
OW2B-MW41	20	10-20	21.59	6.86	14.73
OW2B-MW14	20	10-20	19.47	5.81	13.66
MW-D	14	4-14	17.83	4.39	13.44
203MW-19	20	10-20	18.97	6.01	12.96
MW-C	11	1.7-11.7	17.47	3.07	14.40
TL-D*	12	2-12	19.25	7.52	11.73
OC-MW02	20	10-20	22.22	9.45	12.77
MW-BG01	20	10-20	17.27	6.54	10.73
MW-BG04R**	20	10-20	24.99	NM	NM
MW-BG05	20	10-20	24.79	7.03	17.76
MW-BG06	20	10-20	18.73	6.74	11.99
MW-BG07	20	10-20	17.06	5.51	11.55
MW-BG09	20	10-20	16.00	4.50	11.50
MW-BG10	20	10-20	13.96	3.55	10.41
MW-BG11	20	10-20	15.42	6.2	9.22
MW-BG12	20	10-20	17.82	4.24	13.58
MW-BG13	20	10-20	15.97	3.31	12.66

Notes:

* Approximately 0.04 feet of free product was measured in this monitoring well. This monitoring well was gauged as part of the groundwater level survey and was not analyzed during this investigation. It is currently monitored under the Virginia Department of Environmental Quality's Petroleum Oil and Lubricant program. TL-D is associated with the underground transmission line (T-Line) site and is reported to be sampled annually for TPH-DRO, BTEX and naphthalene.

** Monitoring well was installed after this gauging event

amsl = above mean sea level

bgs = below ground surface

NA = Not available

NM = Not measured

TOC = Top of casing

TABLE 3-3
Groundwater Elevations in the Columbia Aquifer (May 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Well ID	Total Depth (feet bgs)	Well Screen Interval (feet bgs)	TOC Elevation (feet amsl)	Depth to Water (feet below TOC)	Groundwater Elevation (feet amsl)
OW11-MW1	18	8-18	19.25	7.98	11.27
OW11-MW4	20	10-20	18.89	7.03	11.86
OW11-MW5	21	10-21	20.05	8.32	11.73
OW11-MW6	22	10-22	17.89	6.38	11.51
OW11-MW7	23	10-23	17.15	5.82	11.33
OW11-MW8	24	10-24	18.88	8.01	10.87
OW11-MW9	25	10-25	18.65	8.11	10.54
DT-03	21	10-21	16.74	2.11	14.63
1-MW06	21	5-20.5	18.18	8.09	10.09
OW26-MW1	20	10-20	18.13	5.03	13.10
OC-MW01	20	10-20	18.98	6.70	12.28
OC-MW03	20	10-20	13.58	5.34	8.24
JTC-MW-B	13	3-13	15.63	6.32	9.31
OC-MW04	23	13-23	17.45	8.25	9.20
OW2C-MW04	23	13-23	19.56	6.29	13.27
OW2C-MW18	23	13-23	18.23	5.01	13.22
OC-MW07	20	10-20	13.96	7.20	6.76
OW2C-MW19*	20	10-20	20.56	NA	NA
OW2C-MW05*	16	6-16	20.42	NA	NA
OW2C-MW11	23	13-23	18.47	5.24	13.23
OW2C-MW24*	23	13-23	18.72	NA	NA
OW2E-MW09R*	19	4-19	19.88	NA	NA
OW2E-MW18	19	4-19	18.36	4.18	14.18
OW2E-MW19	19	9-19	19.67	5.54	14.13
OW2E-MW03	18	8-18	19.61	5.38	14.23
OW2B-MW41	20	10-20	21.59	6.65	14.94
OW2B-MW14	20	10-20	19.47	5.89	13.58
MW-D	14	4-14	17.83	5.62	12.21
203MW-19	20	10-20	18.97	5.63	13.34
MW-C	11	1.3-11.3	17.47	1.58	15.89
TL-D	12	2-12	19.25	7.89	11.36
OC-MW02	20	10-20	22.22	10.59	11.63
OC-F8F9-MW-F4	30	unknown	17.64	4.90	12.74
MW-BG01	20	10-20	17.27	7.07	10.20
MW-BG04R**	20	10-20	24.99	NM	NM
MW-BG05	20	10-20	24.79	8.18	16.61
MW-BG06	20	10-20	18.73	7.50	11.23
MW-BG07	20	10-20	17.06	6.17	10.89
MW-BG09	20	10-20	16	5.46	10.54
MW-BG10	20	10-20	13.96	3.74	10.22
MW-BG11	20	10-20	15.42	6.68	8.74
MW-BG12	20	10-20	17.82	6.49	11.33
MW-BG13	20	10-20	15.97	4.41	11.56

Notes:
*Could not gauge due to presence of Oxygen Release Compound Socks
** Monitoring well was installed after this gauging event
amsl = above mean sea level
bgs = below ground surface
NA = Not available

TABLE 3-4

Groundwater Elevations in the Yorktown Aquifer (May 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Well ID	Total Depth (feet bgs)	Well Screen Interval (feet bgs)	TOC Elevation (feet amsl)	Depth to Water (feet below TOC)	Groundwater Elevation (feet amsl)
OW11-MW10D *	58.73	50-60	17.11	5.90	11.21
OC-MW05D *	59.30	50-60	16.28	6.45	9.83
OC-MW02D *	58.25	50-60	22.79	12.59	10.20
OW26-MW1D *	59.03	50-60	18.35	5.36	12.99
OC-MW07D *	63.87	50-60	13.59	7.46	6.13

Notes:

amsl = above mean sea level

bgs = below ground surface

TOC = top of casing

* Discrepancies were noted in the survey report. These wells may be resurveyed during additional investigations.

TABLE 3-5
Groundwater Elevations in the Columbia Aquifer (November 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Well ID	Total Depth (feet bgs)	Well Screen Interval (feet bgs)	TOC Elevation (feet amsl)	Depth to Water (feet below TOC)	Groundwater Elevation (feet amsl)
OW11-MW1	18	8-18	19.25	8.12	11.13
OW11-MW4	20	10-20	18.89	7.35	11.54
OW11-MW5	21	10-21	20.05	8.55	11.50
OW11-MW6	22	10-22	17.89	6.61	11.28
OW11-MW7	23	10-23	17.15	6.06	11.09
OW11-MW8	24	10-24	18.88	8.22	10.66
OW11-MW9	25	10-25	18.65	8.27	10.38
DT-03	21	10-21	16.74	2.80	13.94
1-MW06	21	5-20.5	18.18	8.21	9.97
OW26-MW1	20	10-20	18.13	5.53	12.60
OC-MW01	20	10-20	18.98	11.33	7.65
OC-MW03	20	10-20	13.58	6.20	7.38
JTC-MW-B*	13	3-13	15.63	8.10	7.53
OC-MW04	23	13-23	17.45	10.98	6.47
OC-MW07	20	10-20	13.96	10.53	3.43
OW2C-MW19	20	10-20	20.56	9.03	11.53
OW2C-MW05	16	6-16	20.42	6.81	13.61
OW2C-MW11	23	13-23	18.47	5.91	12.56
OW2C-MW24	23	13-23	18.72	6.10	12.62
OW2E-MW09R	19	4-19	19.88	6.31	13.57
OW2E-MW18	19	4-19	18.36	4.81	13.55
OW2E-MW19	19	9-19	19.67	6.11	13.56
OW2E-MW03	18	8-18	19.61	5.88	13.73
OW2B-MW41	20	10-20	21.59	7.05	14.54
OW2B-MW14	20	10-20	19.47	6.52	12.95
MW-D	14	4-14	17.83	7.72	10.11
203MW-19	20	10-20	18.97	8.09	10.88
MW-C	11	1.3-11.3	17.47	2.64	14.83
TL-D**	12	2-12	19.25	NM	NA
TL-7	12	2-12	15.91	4.39	11.52
OC-MW02	20	10-20	22.22	11.11	11.11
OC-MW-F4***	30	unknown	17.64	8.22	9.42
MW-BG01	20	10-20	17.27	7.75	9.52
MW-BG04R	20	10-20	24.99	10.27	14.72
MW-BG05****	20	10-20	24.79	NM	NA
MW-BG06	20	10-20	18.73	7.90	10.83
MW-BG07	20	10-20	17.06	6.40	10.66
MW-BG09	20	10-20	16	7.31	8.69
MW-BG10	20	10-20	13.96	5.59	8.37
MW-BG11	20	10-20	15.42	9.6	5.82
MW-BG12	20	10-20	17.82	8.85	8.97
MW-BG13	20	10-20	15.97	5.15	10.82

Notes:

* Approximately 0.01 feet of free product measured in well. This Monitoring well was gauged and only sampled for PFAS during this investigation. It is currently monitored under the Virginia Department of Environmental Quality's Petroleum Oil and Lubricant program. JTC-MW-B is associated with the Jet Test Cell and is reported to be monitored annually for TPH-DRO and naphthalene.

** Well was locked and could not be measured, TL-7 was collected instead

*** Approximately 0.7 feet of free product measured in well. This monitoring well was gauged and only sampled for PFAS during this investigation. It is currently monitored under the Virginia Department of Environmental Quality's Petroleum Oil and Lubricant program. OC-MW-F4 is associated with the F8/F9 site and is reported to be monitored annually for TPH-DRO and naphthalene.

**** Well is collapsed at 8.65 feet BTOC

amsl = above mean sea level

bgs = below ground surface

NA = Not available

TABLE 3-6

Groundwater Elevations in the Yorktown Aquifer (November 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Well ID	Total Depth (feet bgs)	Well Screen Interval (feet bgs)	TOC Elevation (feet amsl)	Depth to Water (feet below TOC)	Groundwater Elevation (feet amsl)
OW11-MW10D *	58.73	50-60	17.11	5.96	11.15
OC-MW05D *	59.3	50-60	16.28	7.36	8.92
OC-MW02D *	58.25	50-60	22.79	13.00	9.79
OW26-MW1D *	59.03	50-60	18.35	5.49	12.86
OC-MW07D *	63.87	50-60	13.59	9.63	3.96

Notes:

amsl = above mean sea level

bgs = below ground surface

TOC = top of casing

* Discrepancies were noted in the survey report. These wells may be resurveyed during additional investigations.

TABLE 3-7

Vertical Gradient Evaluation

Basewide Per- and Poly-fluoroalkyl Substances Site Inspection Report

NAS Oceana, Virginia Beach, Virginia

Well ID	Reference Point Elevation[1] (ft msl)	Screened Interval (ft bgs)	Aquifer	Depth to Water (ft btoc)	Groundwater Elevation (ft msl)	Vertical Gradient (ft/ft)	Upward or Downward Gradient
OW11-MW7	17.15	10.23-20.23	Columbia/Surficial Aquifer	5.82	11.33	-0.003	Downward
OW11-MW10D[2]	17.11	50 - 60	Yorktown Aquifer	5.90	11.21		
OC-MW02	22.22	10.3-20.3	Columbia/Surficial Aquifer	10.59	11.63	-0.036	Downward
OC-MW02D[2]	22.79	50 - 60	Yorktown Aquifer	12.59	10.20		
OW26-MW1	18.13	9.12-19.12	Columbia/Surficial Aquifer	5.03	13.10	-0.003	Downward
OW26-MW01D[2]	18.35	50 - 60	Yorktown Aquifer	5.36	12.99		
OC-MW07	13.96	10-20	Columbia/Surficial Aquifer	7.20	6.76	-0.016	Downward
OC-MW07D[2]	13.59	50 - 60	Yorktown Aquifer	7.46	6.13		
MW-BG01	17.27	4 - 19	Columbia/Surficial Aquifer	7.07	10.20	-0.009	Downward
OC-MW05D[2]	16.28	50 - 60	Yorktown Aquifer	6.45	9.83		

Notes:

ft bgs - feet below ground surface

ft msl - feet (relative) mean sea level

ft btoc - feet below top of casing

Vertical gradient indicated is between identified and next lowest screen interval. Negative values indicate a downward vertical gradient.

1. Reference Point Elevation = top of casing elevation

2. Discrepancies were noted in the survey report. These wells may be resurveyed during additional investigations.

TABLE 3-8
Hydraulic Conductivity Summary
Basewide PFAS Site Inspection
NAS Oceana. Virginia Beach, VA

Site	Well ID	Test Date	Aquifer	Test Type/ID	Horizontal Hydraulic Conductivity, K (ft/min)	Average Aquifer Hydraulic Conductivity, K (ft/min)
Site 11	OW11-MW04	11/10/2016	Columbia	Falling Head #1	5.76E-03	6.08E-03
				Falling Head #2	6.96E-03	
				Falling Head #3	7.15E-03	
				Rising Head #1	5.59E-03	
				Rising Head #2	5.26E-03	
				Rising Head #3	6.01E-03	
	OW11-MW07	11/10/2016	Columbia	Falling Head #1	8.13E-03	8.72E-03
				Falling Head #2	7.98E-03	
				Falling Head #3	8.68E-03	
				Rising Head #1	9.91E-03	
				Rising Head #2	9.51E-03	
				Rising Head #3	8.30E-03	
	OW11-MW09	11/10/2016	Columbia	Falling Head #1	4.47E-03	4.00E-03
				Falling Head #2	4.48E-03	
				Falling Head #3	4.25E-03	
				Rising Head #1	2.96E-03	
				Rising Head #2	4.92E-03	
				Rising Head #3	3.31E-03	
SWMU 2B	OW2B-MW14	11/11/2016	Columbia	Falling Head #1	9.33E-03	8.95E-03
				Falling Head #2	8.56E-03	
				Falling Head #3	9.10E-03	
				Rising Head #1	8.20E-03	
				Rising Head #2	9.31E-03	
				Rising Head #3	9.24E-03	
SWMU 2C	OW2C-MW19	11/11/2016	Columbia	Falling Head #1	7.45E-03	6.54E-03
				Falling Head #2	7.50E-03	
				Falling Head #3	6.25E-03	
				Rising Head #1	5.19E-03	
				Rising Head #2	7.30E-03	
				Rising Head #3	5.90E-03	

TABLE 3-8
Hydraulic Conductivity Summary
Basewide PFAS Site Inspection
NAS Oceana. Virginia Beach, VA

Site	Well ID	Test Date	Aquifer	Test Type/ID	Horizontal Hydraulic Conductivity, K (ft/min)	Average Aquifer Hydraulic Conductivity, K (ft/min)
SWMU 26	OW26-MW1	11/11/2016	Columbia	Falling Head #1	6.25E-03	9.53E-03
				Falling Head #2	9.36E-03	
				Falling Head #3	9.67E-03	
				Rising Head #1	1.18E-02	
				Rising Head #2	9.23E-03	
				Rising Head #3	1.21E-02	

Notes
ft /min = feet per minute
Average hydraulic conductivity calculated using the geometric mean

TABLE 3-9

Groundwater Quality Parameters in the Columbia Aquifer
(October - November 2016)

Basewide PFAS Site Inspection
NAS Oceana. Virginia Beach, VA

Sample ID **Sample Date**	203MW-19-1116 11/1/16	JTC-MW-B-1116 11/1/16	MW-BG01-1016 10/31/16	MW-BG05-1016 10/28/16	MW-BG06-1016 10/28/16	MW-BG07-1016 10/28/16	MW-BG09-1016 10/31/16	MW-BG10-1116 11/2/16	MW-BG11-1016 10/31/16
Groundwater Quality Parameters									
pH	5.85	6.24	5.65	5.54	4.94	5.12	5.09	5.53	5.50
Oxygen Reduction Potential (mV)	9.6	-55.9	77.6	124.4	204.5	221.0	134.0	97.6	88.5
Temperature (°C)	19.3	23.8	16.1	20.4	18.7	19.8	19.1	19.9	18.7
Specific Conductivity (mS/cm)	0.219	0.63	0.199	0.154	0.107	0.110	0.152	0.057	0.153
Salinity (ppt)	NM	0.31	0.09	0.07	0.05	0.06	0.08	NM	0.07
Turbidity (NTU)	21.7	2.7	18.5	0.93	9.93	20.2	34.4	309	173
Dissolved Oxygen (mg/L) by WQM	0.02	0.03	0.17	1.29	0.10	0.35	0.41	0.62	0.05
Dissolved Oxygen (mg/L) by Chemets®	NM	NM	NM	NM	NM	NM	NM	NM	NM

Notes:
*Monitoring was collapsed at the time of the event and data may not be representative of aquifer parameters
°C = degrees Celsius
mg/L = milligram per liter
mS/cm = millisiemen per centimeter
mV = millivolt
NM = not measured
NTU = nephelometric turbidity unit
ppt = parts per thousand
WQM = water quality meter

TABLE 3-9

Groundwater Quality Parameters in the Columbia Aquifer
(October - November 2016)

Basewide PFAS Site Inspection
NAS Oceana. Virginia Beach, VA

Sample ID **Sample Date**	MW-BG12-1016 10/26/16	MW-BG13-1016 10/26/16	OC-MW01-1116 11/1/16	OC-MW02-1116 11/1/16	OC-MW03-1116 11/1/16	OC-MW04-1016 10/31/16	OW2B-MW41-1116 11/1/16	OW2C-MW19-1116 11/1/16	OW2E-MW19-1116 11/1/16
Groundwater Quality Parameters									
pH	5.17	4.46	6.04	5.11	5.91	5.76	5.53	6.55	6.33
Oxygen Reduction Potential (mV)	230.3	293.8	-19.0	192.5	34.9	79.9	51.4	-55.5	-26.0
Temperature (°C)	17.4	18.8	20.6	19.8	18.4	18.2	24.3	23.9	23.0
Specific Conductivity (mS/cm)	0.131	0.188	5.59	0.102	0.404	0.149	0.79	0.65	0.74
Salinity (ppt)	0.06	0.09	3.03	0.05	0.19	0.07	NM	NM	NM
Turbidity (NTU)	15.1	6.94	1.82	0.62	2.91	7.13	14.2	3.55	197
Dissolved Oxygen (mg/L) by WQM	0.14	3.51	0.10	7.67	0.11	0.36	0.06	0.40	0.03
Dissolved Oxygen (mg/L) by Chemets®	NM	3	1	6	1	NM	NM	NM	NM

Notes:
*Monitoring was collapsed at the time of the event and data may not be representative of aquifer parameters
°C = degrees Celsius
mg/L = milligram per liter
mS/cm = millisiemen per centimeter
mV = millivolt
NM = not measured
NTU = nephelometric turbidity unit
ppt = parts per thousand
WQM = water quality meter

TABLE 3-9

Groundwater Quality Parameters in the Columbia Aquifer
(October - November 2016)

Basewide PFAS Site Inspection
NAS Oceana. Virginia Beach, VA

Sample ID **Sample Date**	OW11-MW1-1016 10/25/16	OW11-MW4-1016 10/26/16	OW11-MW5-1016 10/25/16	OW11-MW6-1016 10/26/16	OW11-MW7-1016 10/25/16	OW11-MW8-1016 10/25/16	OW11-MW9-1016 10/25/16	OW26-MW1-1116 11/1/16
Groundwater Quality Parameters								
pH	5.53	5.81	5.99	6.36	5.83	6.73	6.10	5.90
Oxygen Reduction Potential (mV)	132.3	83.2	32.7	-10.7	66.9	-37.8	6.6	18.5
Temperature (°C)	19.5	18.4	19.4	19.9	20.9	19.6	19.0	21.0
Specific Conductivity (mS/cm)	0.179	0.249	0.180	0.522	0.282	0.441	0.331	0.372
Salinity (ppt)	0.08	0.12	0.08	0.25	0.13	0.21	0.16	0.18
Turbidity (NTU)	9.06	2.39	5.52	3.12	1.59	5.34	2.62	5.25
Dissolved Oxygen (mg/L) by WQM	0.08	0.05	0.07	0.12	0.05	0.04	0.08	0.20
Dissolved Oxygen (mg/L) by Chemets®	1	1	1	1	0.6	1	0.4	1.0

Notes:
*Monitoring was collapsed at the time of the event and data may not be representative of aquifer parameters
°C = degrees Celsius
mg/L = milligram per liter
mS/cm = millisiemen per centimeter
mV = millivolt
NM = not measured
NTU = nephelometric turbidity unit
ppt = parts per thousand
WQM = water quality meter

TABLE 3-10

Groundwater Quality Parameters in the Columbia Aquifer (February 2017)

Basewide PFAS Site Inspection

NAS Oceana. Virginia Beach, Virginia

Sample ID **Sample Date**	OW2C-MW05-0217 2/23/17	OW2E-MW09R-0217 2/23/17	OW2C-MW19-0217 2/23/17	OW2C-MW24-0217 2/23/17	OW2C-MW25-0217 2/23/17
Groundwater Quality Parameters					
pH	7.08	7.10	7.66	6.94	7.27
Oxygen Reduction Potential (mV)	-41.9	-89.7	-100.7	-61.4	-83.9
Temperature (°C)	17.7	18.7	19.3	18.1	17.6
Specific Conductivity (mS/cm)	0.41	0.43	0.41	0.58	0.578
Salinity (ppt)	0.20	0.21	0.20	0.28	0.28
Turbidity (NTU)	9.02	3.3	49.3	10.0	12.9
Dissolved Oxygen (mg/L)	0.14	0.19	0.15	0.09	0.11
Dissolved Oxygen (mg/L) by Chemets®	0.6	0.2	0.4	0.6	0.3

Notes:

°C = degrees Celsius

mg/L = milligram per liter

mS/cm = millisiemen per centimeter

mV = millivolt

NM = not measured

NTU = nephelometric turbidity unit

ppt = parts per thousand

TABLE 3-11
Groundwater Quality Parameters in the Columbia Aquifer (April 2017)
Basewide PFAS Site Inspection
NAS Oceana. Virginia Beach, VA

Sample ID **Sample Date**	OC-MW07-0417 4/4/17	OC-F8F9-MW-F4-0417 4/4/17
Groundwater Quality Parameters		
pH	7.01	5.47
Oxygen Reduction Potential (mV)	7.9	72.7
Temperature (°C)	16.9	16.0
Specific Conductivity (mS/cm)	0.94	0.116
Salinity (ppt)	0.46	0.05
Turbidity (NTU)	11.9	27.6
Dissolved Oxygen (mg/L) by WQM	0.15	0.17
Dissolved Oxygen (mg/L) by Chemets®	NM	1

Notes:
°C = degrees Celsius
mg/L = milligram per liter
mS/cm = millisiemen per centimeter
mV = millivolt
NTU = nephelometric turbidity unit
ppt = parts per thousand
WQM = water quality meter

TABLE 3-12

Groundwater Quality Parameters in the Yorktown Aquifer (April 2017)

Basewide PFAS Site Inspection

NAS Oceana. Virginia Beach, VA

Sample ID **Sample Date**	OC-MW02D-0417 4/3/17	OC-MW05D-0417 4/3/17	OC-MW07D-0417 4/4/17	OW11-MW10D-0417 4/4/17	OW26-MW1D-0417 4/3/17
Groundwater Quality Parameters					
pH	6.44	7.57	6.91	7.95	7.22
Oxygen Reduction Potential (mV)	27.6	96.6	16.4	118.3	21.0
Temperature (°C)	17.0	16.6	17.3	17.7	18.9
Specific Conductivity (mS/cm)	0.147	0.564	0.72	0.96	0.473
Salinity (ppt)	0.07	NM	0.35	0.48	0.23
Turbidity (NTU)	46.2	58.3	23.5	22.0	7.19
Dissolved Oxygen (mg/L)	0.17	0.19	0.21	0.26	0.17
Dissolved Oxygen (mg/L) by Chemets®	0.8	0.4	0.6	0.4	0.8

Notes:

°C = degrees Celsius

mg/L = milligram per liter

mS/cm = millisiemen per centimeter

mV = millivolt

NM = not measured

NTU = nephelometric turbidity unit

ppt = parts per thousand

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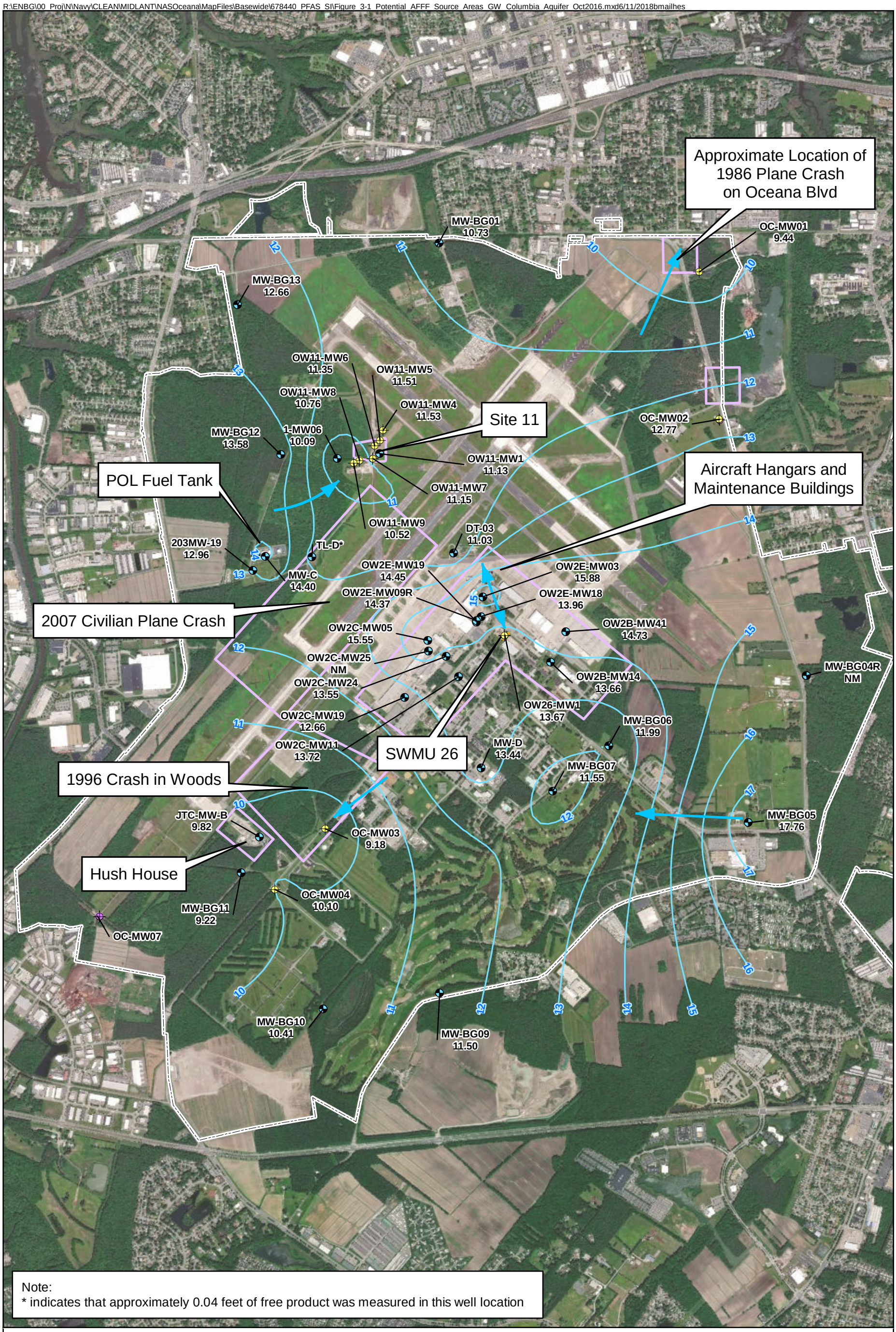

Note:
* indicates that approximately 0.04 feet of free product was measured in this well location

Legend

- Existing Monitoring Well
- Monitoring Well installed during the Phase I activities
- Monitoring Well installed during the Phase II activities
- Groundwater Elevation Contour (dashed where inferred)
- Direction of Groundwater Flow
- Potential AFFF Release Areas
- Installation Boundary

N
W E
S

0 1,000 2,000 Feet

1 inch = 2,000 feet

Imagery Source: ©2017 Esri

Figure 3-1
Groundwater Contours Measured in the Columbia Aquifer in October 2016
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

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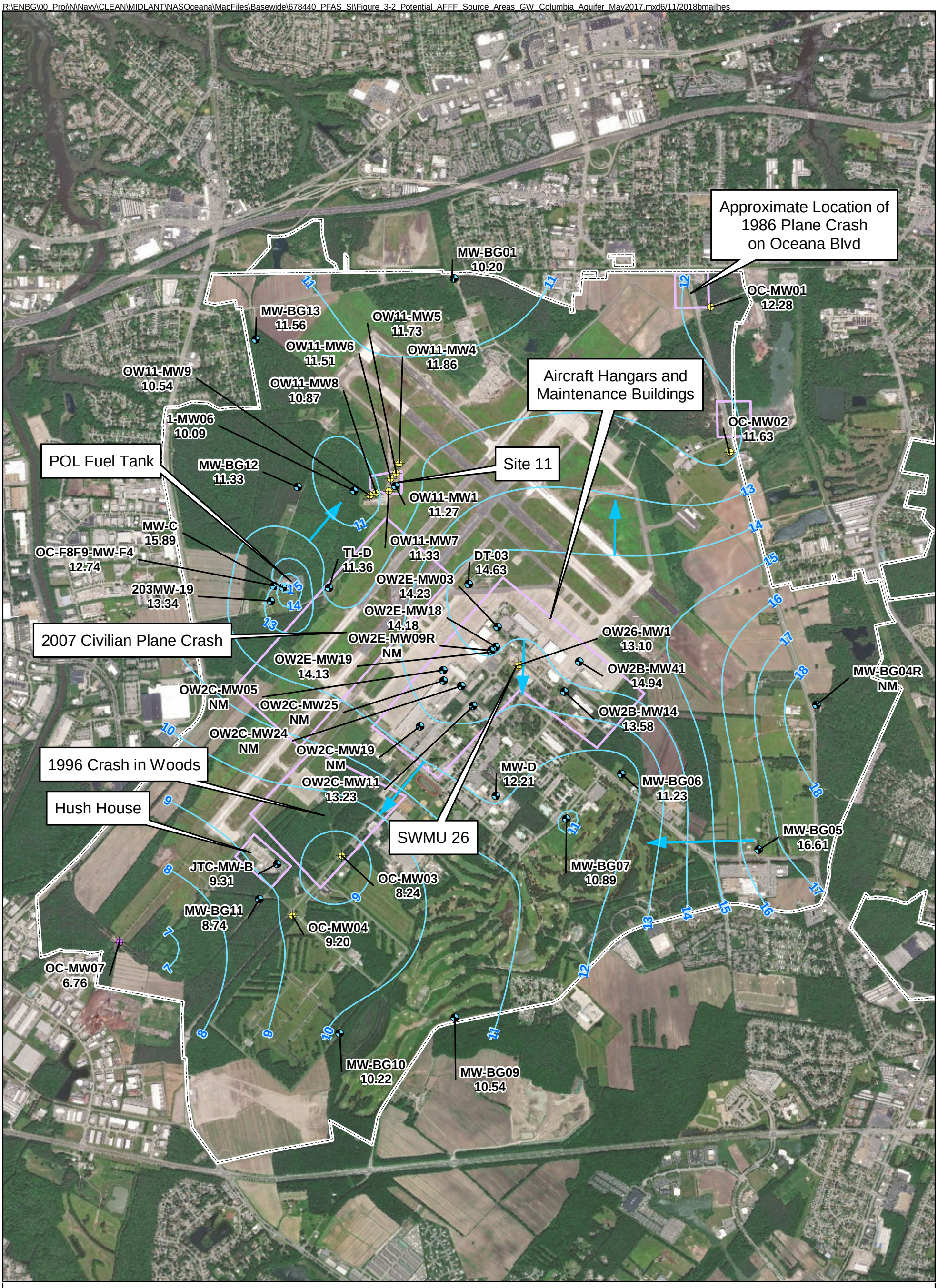

Legend

- Existing Monitoring Wells
- Monitoring Well installed during the Phase I activities
- Monitoring Well installed during the Phase II activities
- Groundwater Elevation Contour - May 2017 (dashed where inferred)
- Direction of Groundwater Flow
- Potential AFFF Release Areas
- Installation Boundary

N
W E
S

0 1,000 2,000
Feet

1 inch = 2,000 feet

Imagery Source: ©2017 Esri

Figure 3-2
Groundwater Contours Measured in the Columbia Aquifer in May 2017
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

ch2m.

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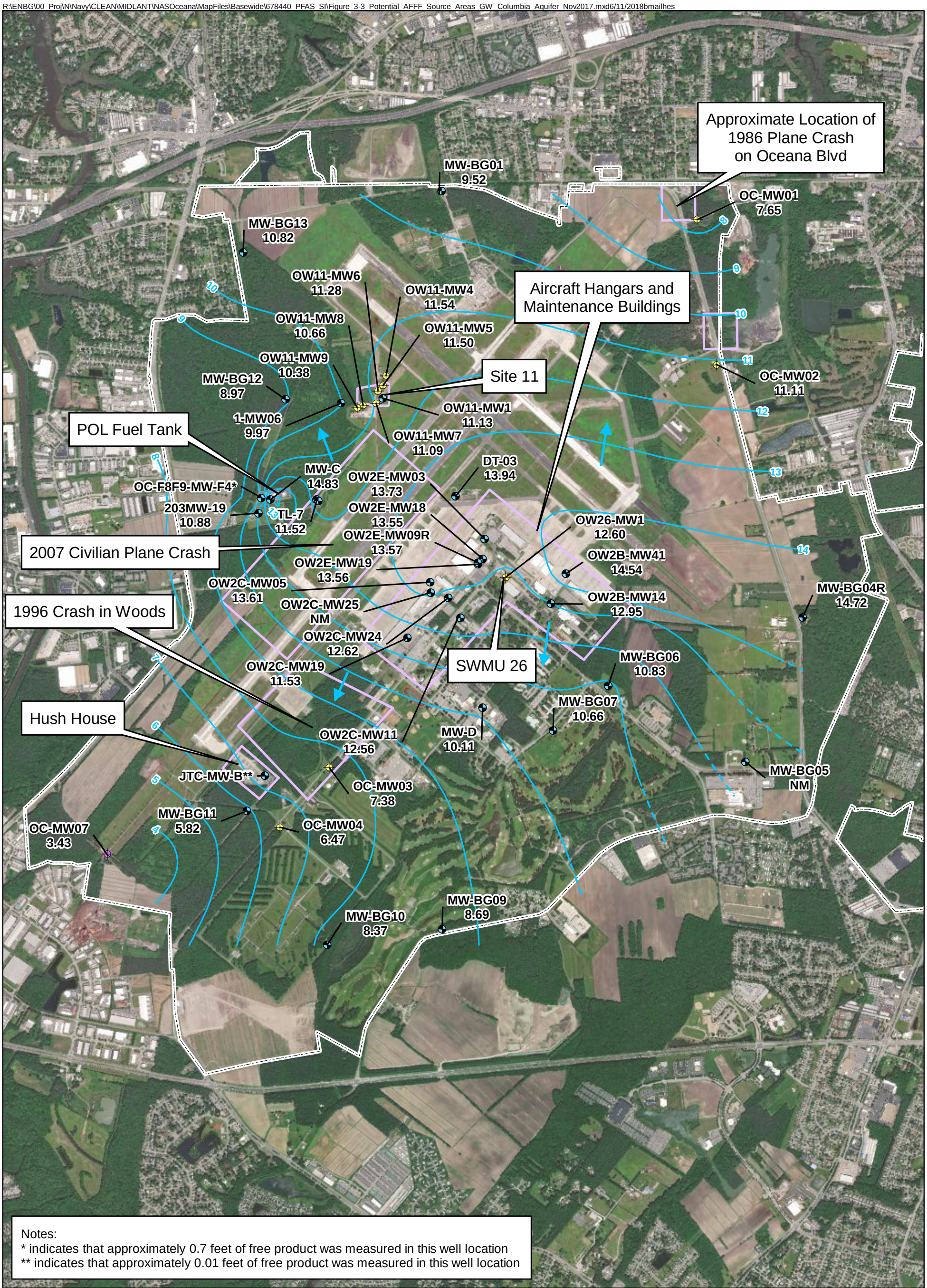

Notes:
* indicates that approximately 0.7 feet of free product was measured in this well location
** indicates that approximately 0.01 feet of free product was measured in this well location

Legend
- Existing Monitoring Well
- Monitoring Well installed during the Phase I activities
- Monitoring Well installed during the Phase II activities
- Groundwater Elevation Contour (dashed where inferred)
- Direction of Groundwater Flow
- Potential AFFF Release Areas
- Installation Boundary

N
W E
S

0 1,000 2,000
Feet

1 inch = 2,000 feet

Imagery Source: ©2017 Esri

Figure 3-3
Groundwater Contours Measured in the Columbia Aquifer (November 2017)
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

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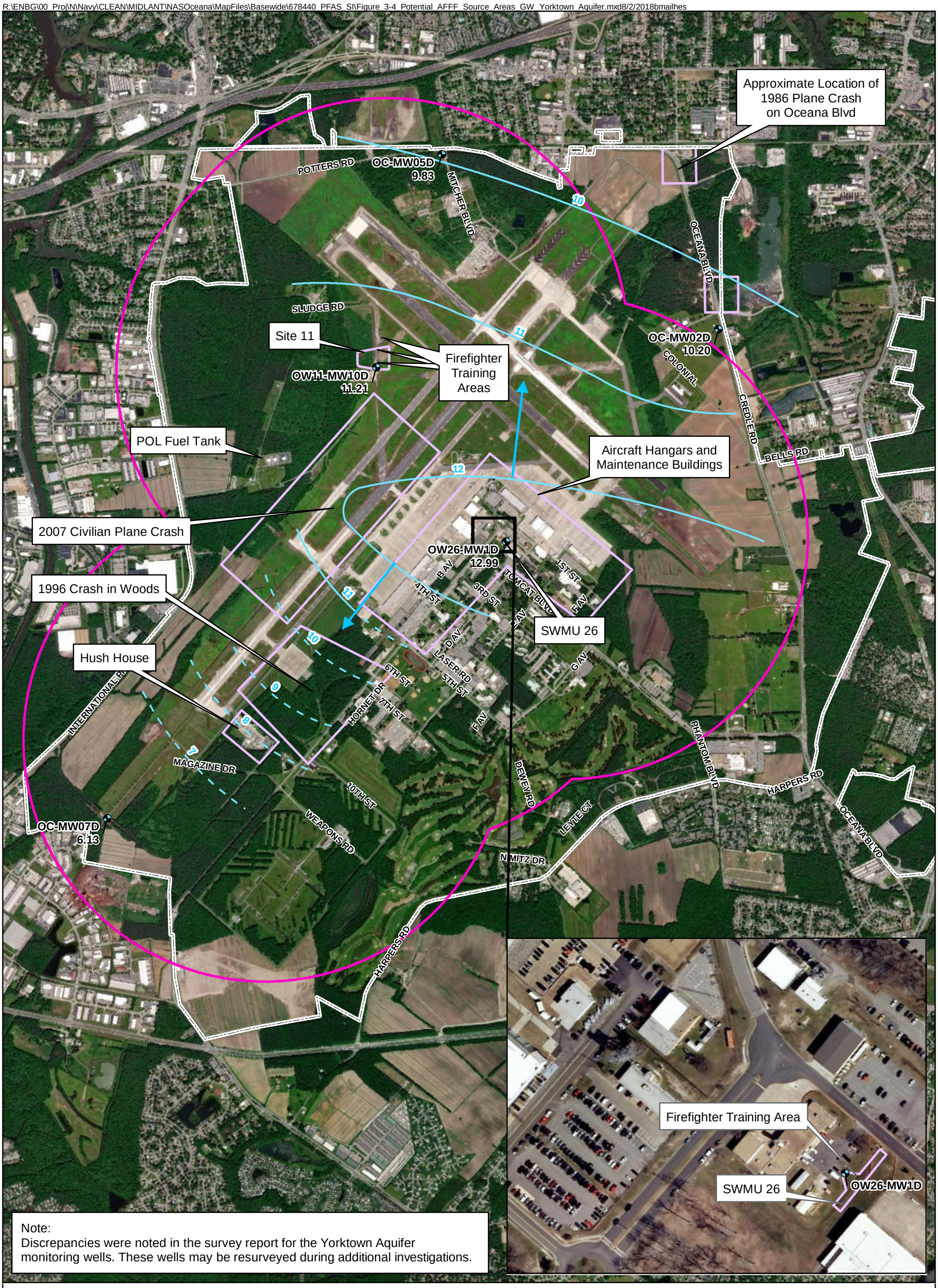

Note:
Discrepancies were noted in the survey report for the Yorktown Aquifer monitoring wells. These wells may be resurveyed during additional investigations.

Legend

- Monitoring Wells Installed in the Yorktown Aquifer during Site Investigation
- Direction of Groundwater Flow
- Groundwater Elevation Contour (dashed where inferred)
- Potential AFFF Release Areas
- Sampling Area
- Installation Boundary

N
W E
S

0 1,000 2,000
Feet

Imagery Source: ©2017 Esri

Figure 3-4
Groundwater Contours Measured in the Yorktown Aquifer (May 2017)
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

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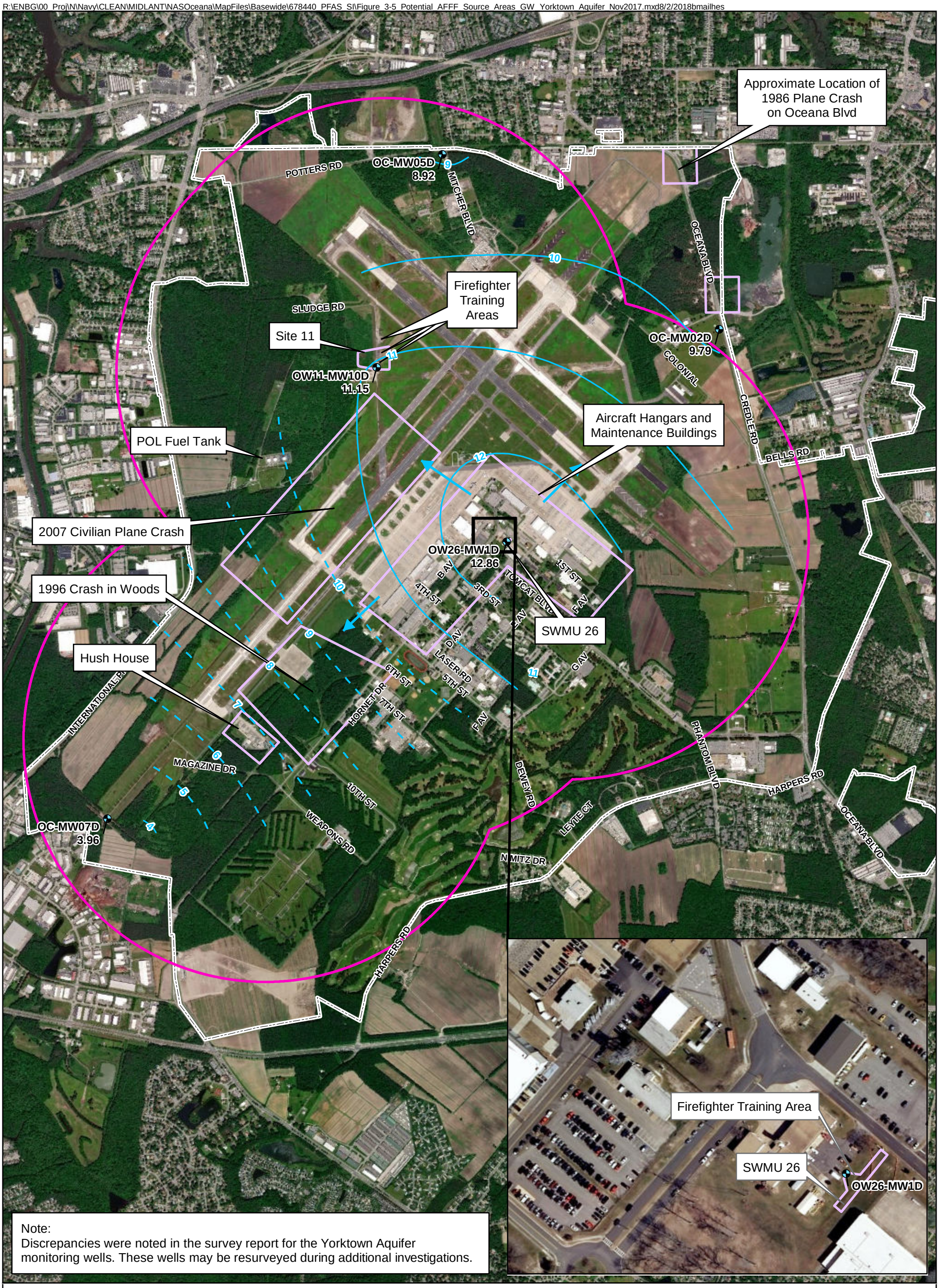

Note:
Discrepancies were noted in the survey report for the Yorktown Aquifer monitoring wells. These wells may be resurveyed during additional investigations.

Legend

- Monitoring Wells Installed in the Yorktown Aquifer during Site Investigation
- Direction of Groundwater Flow
- Groundwater Elevation Contour (dashed where inferred)
- Potential AFFF Release Areas
- Sampling Area
- Installation Boundary

N
W E
S

0 1,000 2,000 Feet

1 inch = 2,000 feet

Imagery Source: ©2017 Esri

Figure 3-5
Groundwater Contours Measured in the Yorktown Aquifer (November 2017)
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

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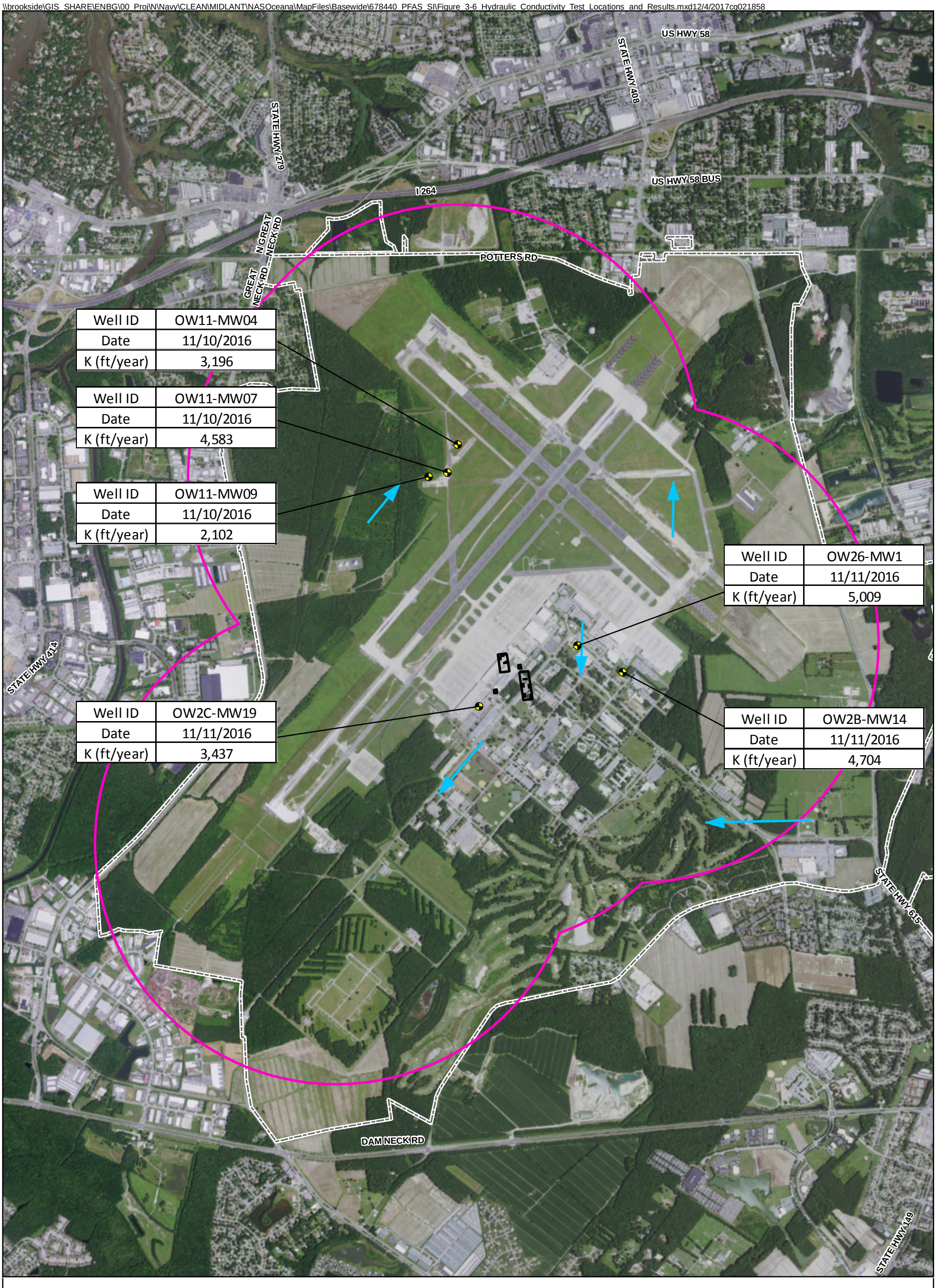

Legend

- Monitoring Well
- Non-Core Target Treatment Area (2004)
- Core Target Treatment Area (2004) (Core)
- Direction of Groundwater Flow
- Sampling Area
- Installation Boundary

N
W E
S

0 1,000 2,000 4,000
Feet

Imagery Source: ©2017 Esri

Figure 3-6
Hydraulic Conductivity Test Locations and Results
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

ch2m.

SECTION 4

Investigation Results

This section presents the results of the investigation described in **Section 3**.

To evaluate the extent of contamination, analytical data for PFOS and PFOA were screened against the USEPA L-HA (70 ng/L) and the analytical data for PFBS were screened against the USEPA Regional Screening Levels (RSLs) (400,000 ng/L). Determination of exceedances were only made based on PFAS with screening criteria, which include PFOS, PFOA, and PFBS. Analysis was also conducted for PFAS which do not have screening criteria (PFNA, PFHxS, PFHpA), the results of which may be consulted in the future, if criteria are established.

Laboratory analytical results for groundwater samples collected in the Columbia and Yorktown aquifers are summarized respectively in **Tables 4-1** and **4-2**. Laboratory analytical results for off-Base drinking water samples collected from potable wells and one on-Base water sample collected from a non-potable water supply well are summarized in **Table 4-3**. Per the Interim PFAS Site Guidance established in 2017 by the Navy, Tables 4-1 through 4-3 only present PFOA, PFOS, and PFBS data, while Appendix H presents data for PFHpA, PFHxS, and PFNA (Navy, 2017). **Figures 4-1** and **4-2** show constituents of concern (COC) exceedances respectively in the Columbia and Yorktown aquifers from samples taken on-Base. **Figure 4-3** shows detections in drinking water samples collected off-Base.

4.1 Groundwater

A summary of the results of the water quality parameters and a discussion of the extent of contamination are presented in the following subsections.

4.1.1 General Groundwater Geochemistry

Measurements of DO, ORP, pH, temperature, specific conductivity, salinity, and turbidity were collected at each monitoring well following purging and immediately prior to sampling. **Tables 3-6** through **3-10**, show the groundwater parameters measured in the Columbia and Yorktown aquifers.

Columbia Aquifer

The DO readings collected from samples taken in the Columbia aquifer during purging activities ranged between 0.2 milligram per liter (mg/L) and 1 mg/L (as recorded using the CHEMet test kits), which are indicative of anaerobic conditions. However, two monitoring wells, MW-BG13 and OC-MW02, were showing respective DO concentration of 3 and 6 mg/L, an indication of moderately aerobic to aerobic conditions. The ORP values, which indicate the potential for redox conditions in groundwater, ranged between -100.7 millivolts (mV) and 293 mV, also indicating that conditions at the site vary from moderately reducing to strongly oxidizing. Temperature readings ranged between 16 degrees Celsius (°C) and 24.3°C. pH values were generally slightly acidic to neutral, ranging between 4.28 and 7.66. Specific conductivity values, which provide an indication of the concentration of total dissolved solids within groundwater, ranged between 0.057 millisiemens per centimeter (mS/cm) and 0.79 mS/cm, which are indicative of freshwater conditions. However, specific conductivity in one monitoring well (OC-MW01) was measured at 5.59 mS/cm. Salinity values ranged between 0.05 part per trillion (ppt) and 3.3 ppt, also indicative of freshwater conditions. Turbidity measurements, which indicate the presence of suspended colloidal matter in water, were generally low (below 20 NTU), with the exception of monitoring wells OW2E-MW19, MW-BG11, and MW-BG10 where turbidity was measured at above 100 NTU.

Yorktown Aquifer

The DO readings collected from samples taken in the Yorktown aquifer during purging activities ranged between 0.4 mg/L and 0.8 mg/L (as recorded using the CHEMet test kits), which are indicative of slightly anaerobic conditions. The ORP values ranged between 16.4 millivolts (mV) and 118.3 mV, indicative of mildly oxidizing conditions. Temperature readings ranged between 16.6°C and 18.9°C. pH values were neutral, ranging between 6.44 and 7.95. Specific conductivity values ranged between 0.147 mS/cm and 0.96 mS/cm, which are indicative of

freshwater conditions. Salinity values ranging between 0.07 ppt and 0.48 ppt are also indicative of freshwater conditions. Turbidity measurements were generally moderate (below 60 NTU).

4.1.2 Overview of Groundwater Analytical Results

Analytical results from on-Base groundwater samples collected are presented **in Table 4-1** and **Figure 4-1** for the Columbia aquifer, and in **Table 4-2** and **Figure 4-2** for the Yorktown aquifer. A summary is presented below.

Columbia Aquifer

Analysis of the 34 groundwater samples collected in the Columbia aquifer, indicates the following:

- Seventeen samples indicate PFOS or PFOA concentration exceeding the L-HA screening criteria of 70 ng/L.
- Fifteen samples were showing detections for PFOS or PFOA below the L-HA.
- Two samples were showing no detection of PFOS or PFOA.
- Exceedances of the L-HA were observed in the southwestern portion of the Base (Hush House site), in the Aircraft Hangars and Maintenance Buildings area, at SWMU 26, and at Site 11.
- Concentrations were the highest at SWMU 26, with a PFOA concentration of 22,600 ng/L, a PFOS concentration of 471,000 ng/L and a total PFOA and PFOS concentration of 493,600 ng/L at monitoring well OW26-MW1.
- All seven monitoring wells sampled at Site 11 were showing exceedances of the L-HA for PFOS, PFOA, and total PFOS and PFOA.
- None of the samples exceeded the RSL for PFBS.
- Delineation of the COC exceedances in the groundwater indicate the presence of three on-Base COC plumes exceeding the L-HA, located at Site 11, the Aircraft Hangars and Maintenance Buildings site (including SWMU 26), and the Hush House site **(Figure 4-4).**
- The nature, extent, and location of the contamination is consistent with the historical activities at the site that have involved the use of AFFF during firefighting and training activities, and intentional or unintentional AFFF releases.
- Relatively high concentrations of PFAS at SWMU 26, the Aircraft Hangars and Maintenance Buildings, Site 11, and the Hush House site indicate that these four locations are groundwater COC source areas.
- COCs detected below the L-HA in the southern portion of the installation, could indicate a southward dispersion and advective transport of PFAS from the Hush House and the Aircraft Hangars and Maintenance Buildings sites. This observation is consistent with the direction of the Columbia groundwater flow in that portion of the Base.
- Detections of PFAS east and north of Site 11 may indicate migration of the COCs from that source area. However, the monitoring well network does not provide sufficient resolution to fully determine groundwater flow direction in the northwestern quadrant of the installation; therefore, a correlation between the groundwater flow and the detection of PFAS could not be fully established.
- The absence of PFAS detections in samples collected near the eastern boundary of the installation (monitoring wells OC-MW02 and MW-BG04) tends to indicate that the COCs have not migrated off-Base, in the Columbia aquifer in this area. This observation is consistent with the westward and northward groundwater flow in that part of the installation, which places both monitoring wells upgradient from on-Base source areas. As a result, the groundwater flow in the Columbia aquifer may effectively prevent off-Base migration of COCs in the eastern and northeastern portions of the installation.

Yorktown Aquifer

Analysis of the five groundwater samples collected from monitoring wells screened in the Yorktown indicates the following:

- One sample (OW11-MW10D) was showing a total PFOS and PFOA concentration of 639.3 ng/L, exceeding the USEPA L-HA screening criteria of 70 ng/L.
- Three samples were showing detections for PFOS or PFOA but with concentrations below the L-HA.
- One sample was showing no detections of PFOS or PFOA.
- The PFAS exceedance observed at Site 11 is an indication that the COCs have migrated vertically from the Columbia aquifer to the Yorktown aquifer (**Figure 4-5**). The absence of monitoring wells in the vicinity of OW11-MW10D; however, prevents the delineation of the COC plume exceeding the L-HA to its full extent in the Yorktown aquifer.
- COCs detected below the L-HA near the northern (OC-MW05D) and northeastern (OC-MW02D) boundaries of the installation, could indicate a northeastward dispersion and advective transport of PFAS from Site 11 and SWMU 26 source areas. This observation is consistent with the direction of the Yorktown groundwater flow in that portion of the Base. However, because the extent of the contamination at the source areas is not fully defined, it is unclear if these detections can be fully attributed to the source areas, or are just a manifestation of sporadic and localized uses or releases of AFFF in the northern and northeastern portions of the installation.
- COCs detected below the L-HA at SWMU 26 (monitoring well OW26-MW1D) indicate that vertical migration of PFAS from the Columbia to the Yorktown aquifer has been restricted in that area of the installation, possibly due to the 1.5-foot clay layer encountered at 40 feet bgs in the Yorktown aquifer as noted on the boring log for OW26-MW1D.
- The absence of PFAS detection in monitoring well OC-MW07D indicate that PFAS have not migrated from the Hush House PFAS source area to the Yorktown aquifer in the southwestern portion of the Base, even though this monitoring well is located downgradient of the Hush House. The Yorktown confining unit encountered at 25 feet bgs, at a thickness of 2 feet, may restrict vertical migration of PFAS at this location.

4.2 Potable and Non-Potable Water

Analytical results from potable water samples collected off-Base and for the non-potable water sample collected on-Base are presented in **Table 4-3** and **Figure 4-3**. A summary is presented below.

4.2.1 Off-Base Potable Well Results

Six drinking water samples were collected from off-Base potable wells ranging from 30 feet to 140 feet bgs.

Results of tests conducted on the drinking samples indicate the following:

- One potable water sample east of the Base (OC-RW01) detected PFOS (9.24 ng/L) and PFOA (24.6 ng/L), but the concentrations were below the L-HA of 70 ng/L. The homeowner indicated that this well was not used for drinking water. The well was approximately 30 feet deep bgs, which is representative of the Columbia aquifer.
- The other five potable water samples were showing no detections for PFOS or PFOA.
- None of the samples exceeded the RSL for PFBS.

4.2.2 On-Base Non-Potable Well Results

One sample (OCSTR-WL01) was collected from a well which supplies water to the Skeet and Trap Range (**Figure 4-2**). This well is 140 feet deep with an unknown screen interval. Analytical results indicate that PFOS, PFOA, and PFBS were not detected in that well. Although OCSTR-WL01 may be representative of the deeper

portion of the Yorktown aquifer and is potentially downgradient of Site 11, further investigation is required to determine if COCs have migrated from the upper to lower portions of the Yorktown aquifer.

TABLE 4-1
Columbia Aquifer Groundwater Analytical Data
(October and November 2016, February, May, and August 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	203MW-19-1116	FTWG-MW-02-1116	JTC-MW-B-1116	MW-BG01-1016	MW-BG04R-0817	MW-BG05-1016	MW-BG05P-1016
Sample Date			11/1/16	11/8/16	11/1/16	10/31/16	8/10/17	10/28/16	10/28/16
Chemical Name									
Semivolatile Organic Compounds (ng/L)									
Perfluorobutanesulfonic acid (PFBS)	400,000	--	4.03 U	7.94 J	4.27 J	4.07 U	8.67	3.94 U	4.03 U
Perfluorooctane Sulfonate (PFOS)	--	70	7.17 J	40.1	**4,020**	20.2	5.39 U	1.36 U	4.27 U
Perfluorooctanoic acid (PFOA)	--	70	5.75 J	**90.3**	12.6	13.5	4.72 J	1.26 J	2.02 J
Total PFOS + PFOA*	--	70	12.92	**130.4**	**4033**	33.7	4.72	1.26	2.02

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ = Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-1
Columbia Aquifer Groundwater Analytical Data
(October and November 2016, February, May, and August 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	MW-BG06-1016	MW-BG07-1016	MW-BG09-1016	MW-BG10-1116	MW-BG11-1016	MW-BG12-1016	MW-BG13-1016	MW-BG13P-1016
Sample Date			10/28/16	10/28/16	10/31/16	11/2/16	10/31/16	10/26/16	10/26/16	10/26/16
Chemical Name										
Semivolatile Organic Compounds (ng/L)										
Perfluorobutanesulfonic acid (PFBS)	400,000	--	4.03 U	3.97 U	4 U	4.2 U	4.1 U	6.95 J	4.1 U	3.94 UJ
Perfluorooctane Sulfonate (PFOS)	--	70	11.4	29.2	4.98 U	1.23 J	15.6	46.5	28.7 J	15.6 J
Perfluorooctanoic acid (PFOA)	--	70	2.02 U	1.65 J	3.15 J	2.1 U	2.05 U	10.2	2.6 U	1.97 UJ
Total PFOS + PFOA*	--	70	11.4	30.85	3.15	1.23	15.6	56.7	28.7	15.6

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ = Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-1
Columbia Aquifer Groundwater Analytical Data
(October and November 2016, February, May, and August 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	OC-F8F9-MW-F4-0417	OC-MW01-1116	OC-MW02-1116	OC-MW03-1116	OC-MW04-1016	OC-MW07-0417	OC-MW07D-0417
Sample Date			4/4/17	11/1/16	11/1/16	11/1/16	10/31/16	4/4/17	4/4/17
Chemical Name									
Semivolatile Organic Compounds (ng/L)									
Perfluorobutanesulfonic acid (PFBS)	400,000	--	4.13 UJ	4.13 J	4.03 U	6.89 J	4.03 J	4.03 U	4.24 U
Perfluorooctane Sulfonate (PFOS)	--	70	20.8 J	8.16 J	0.907 U	33.4	39.6	3.63 J	0.953 U
Perfluorooctanoic acid (PFOA)	--	70	8.35 J	4.92 J	2.02 U	15.6	6.84 J	0.685 J	2.12 U
Total PFOS + PFOA*	--	70	29.15	13.08	2.927 U	49	46.44	4.315	3.073 U

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ = Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-1
Columbia Aquifer Groundwater Analytical Data
(October and November 2016, February, May, and August 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	OW11-MW1-1016	OW11-MW4-1016	OW11-MW5-1016	OW11-MW6-1016	OW11-MW7-1016	OW11-MW8-1016	OW11-MW9-1016
Sample Date			10/25/16	10/26/16	10/25/16	10/26/16	10/25/16	10/25/16	10/25/16
Chemical Name									
Semivolatile Organic Compounds (ng/L)									
Perfluorobutanesulfonic acid (PFBS)	400,000	--	1,520	5,270	3,330	3,580	2,290	1,700	2,150
Perfluorooctane Sulfonate (PFOS)	--	70	**217,000 J**	**33,200 J**	**69,500 J**	**101,000 J**	**296,000 J**	**18,800**	**91,000 J**
Perfluorooctanoic acid (PFOA)	--	70	**11,600**	**1,540**	**4,100**	**11,300**	**18,700**	**5,360**	**8,550 J**
Total PFOS + PFOA*	--	70	**228600**	**34740**	**73600**	**112300**	**314700**	**24160**	**99550**

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ = Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-1
Columbia Aquifer Groundwater Analytical Data
(October and November 2016, February, May, and August 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	OW11-MW9P-1016	OW26-MW1-1116	OW26-MW1P 1116	OW2B-MW41-1116	OW2C-MW05-0217	OW2C-MW19-1116	OW2C-MW19-0217
Sample Date			10/25/16	11/1/16	11/1/16	11/1/16	2/23/17	11/1/16	2/23/17
Chemical Name									
Semivolatile Organic Compounds (ng/L)									
Perfluorobutanesulfonic acid (PFBS)	400,000	--	1,930	4,950	4,740	51.7	9.86	195	97.9
Perfluorooctane Sulfonate (PFOS)	--	70	**116,000 J**	**471,000**	**471,000**	63.1	**249**	**2,430**	**1,340**
Perfluorooctanoic acid (PFOA)	--	70	**10,100**	**22,600**	**21,200 J**	**222**	42.9	**546**	**268**
Total PFOS + PFOA*	--	70	**126100**	**493600**	**492200**	**285.1**	**291.9**	**2976**	**1608**

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ = Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-1
Columbia Aquifer Groundwater Analytical Data
(October and November 2016, February, May, and August 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	OW2C-MW24-0217	OW2C-MW25-0217	OW2E-MW09R-0217	OW2E-MW09RP-0217	OW2E-MW19-1116	OW2E-MW19-1116	MW-BG04R-0817	
Sample Date			2/23/17	2/23/17	2/23/17	2/23/17	11/1/16	11/1/16	8/10/17	
Chemical Name										
Semivolatile Organic Compounds (ng/L)										
Perfluorobutanesulfonic acid (PFBS)	400,000	--	16.1	310 J	48.3	48.2	43.4	43.4	8.67	
Perfluorooctane Sulfonate (PFOS)	--	70	**78.7**	**44,500 J**	**103**	**95.7**	**263**	**263**	5.39	U
Perfluorooctanoic acid (PFOA)	--	70	**1,540**	**1,100**	**134**	**130**	**413**	**413**	4.72	J
Total PFOS + PFOA*	--	70	**1619**	**45600**	**237**	**226**	**676**	**676**	4.72	

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ = Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-2
Yorktown Aquifer Groundwater Analytical Data April 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID / **Sample Date**	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	OC-MW02D-0417 4/3/17	OC-MW05D-0417 4/3/17	OC-MW05DP-0417 4/3/17	OC-MW07D-0417 4/4/17	OW11-MW10D-0417 4/4/17	OW26-MW01D-0417 4/3/17
Chemical Name								
Semivolatile Organic Compounds (ng/L)								
Perfluorobutanesulfonic acid (PFBS)	400,000	--	4.1 U	4.24 U	4.1 U	4.24 U	8.13 J	4.2 U
Perfluorooctane Sulfonate (PFOS)	--	70	0.922 U	1.01 J	2.42 J	0.953 U	**578**	10.1
Perfluorooctanoic acid (PFOA)	--	70	8.98	2.12 U	2.05 U	2.12 U	61.3	2.1 U
Total PFOS + PFOA*	--	70	8.98	1.01	2.42	3.073 U	**639.3**	10.1

Notes:
*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

TABLE 4-3

Production Well Analytical Data (Potable and Non-Potable Supply Wells) (December 2016 and January 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (November 2017)**	**USEPA Lifetime Health Advisory (May 2016)**	OC-RW01-1216	OC-RW03-1216	OC-RW03P-1216	OC-RW04-1216	OC-RW10-0117	OC-RW12-1216	OC-RW13-1216	OCSTR-WL01-1216
Sample Date			12/16/16	12/16/16	12/16/16	12/19/16	1/3/17	12/16/16	12/21/16	12/22/16
Chemical Name										
Semivolatile Organic Compounds (ng/L)										
Perfluorobutanesulfonic acid (PFBS)	400,000	--	2.21 J	3.88 U	3.97 U	3.94 U	3.94 U	3.91 U	4 U	3.91 U
Perfluorooctane Sulfonate (PFOS)	--	70	9.24	0.872 U	0.893 U	0.886 U	0.886 U	0.879 U	0.9 U	0.879 U
Perfluorooctanoic acid (PFOA)	--	70	24.6	0.721 B	0.887 B	1.97 U	1.97 U	1.02 B	2 U	1.95 U
Total PFOS + PFOA*	--	70	33.8	1.593 U	1.78 U	2.856 U	2.856 U	1.899 U	2.9 U	2.829 U

Notes:

*In cases when both PFOA and PFOS are non-detect, non-detect limits of detection were added together to provide the total PFOA + PFOS limit of detection and the total was considered a non-detect. In cases when either PFOA or PFOS was not detected, but the other of the two compounds was detected, only the detection was used to determine the total of PFOA and PFOS. Based on this dataset, there were no instances in which adding a concentration at the limit of detection of the non-detected compound to the detected concentration of the detected compound would have resulted in an exceedance of the L-HA, so there are no impacts to data usability.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise

ng/L = nanogram per liter

U = The material was analyzed for, but not detected

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

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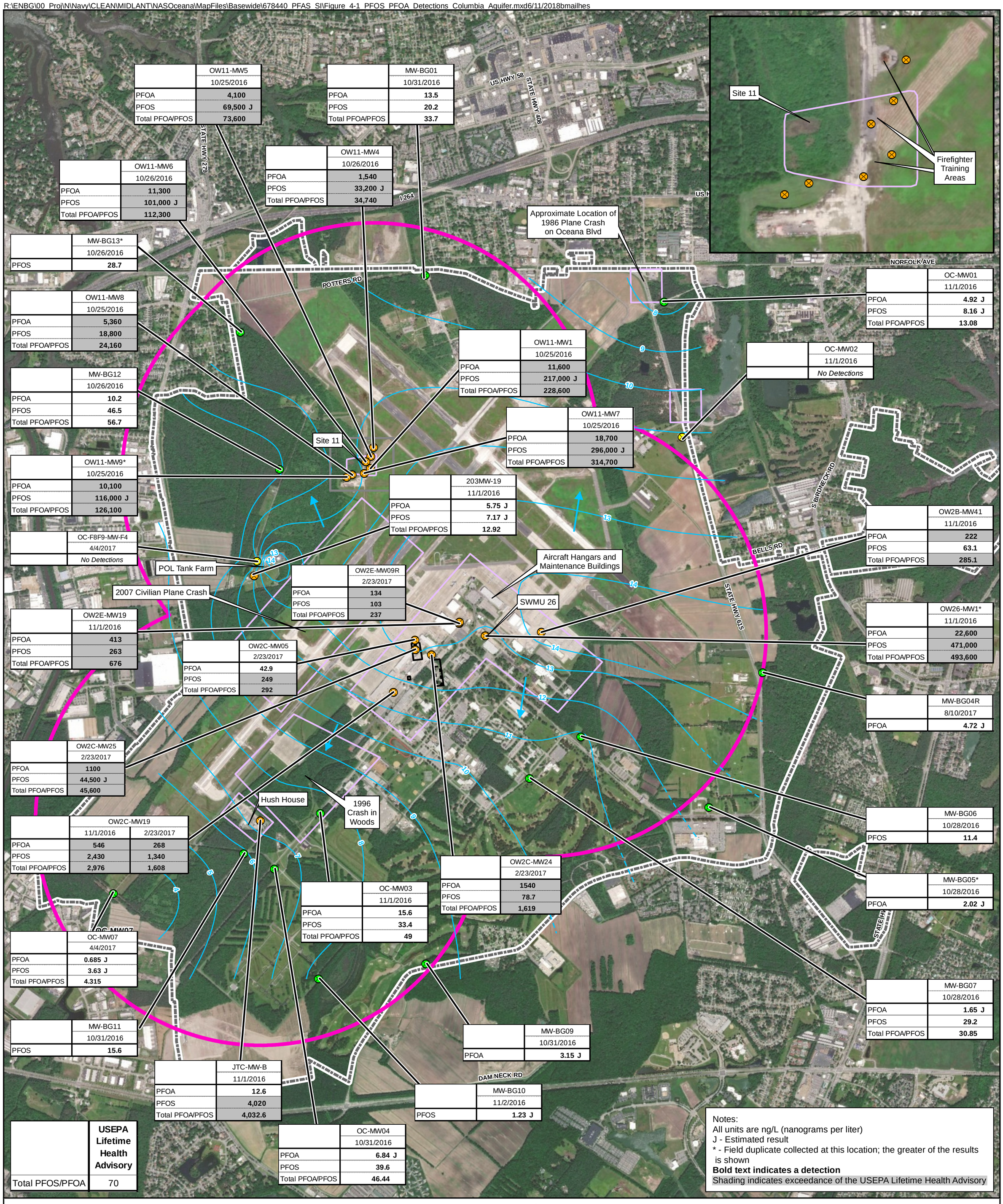

Figure 4-1
COCs Concentrations in the Columbia Aquifer
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

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	OC-MW05D*
	4/3/2017
PFOS	**2.42 J**

	OCSTR-WL01
	12/22/2016
	No Detections

	OC-MW02D
	4/3/2017
PFOA	**8.98**

	OW11-MW10D
	4/4/2017
PFOA	**61.3**
PFOS	**578**
Total PFOA/PFOS	**639.3**

	OW26-MW01D
	4/3/2017
PFOS	**10.1**

	OC-MW07D
	4/4/2017
	No Detections

Approximate Location of 1986 Plane Crash on Oceana Blvd

Firefighting Training Areas

Site 11

POL Fuel Tank

2007 Civilian Plane Crash

1996 Crash in Woods

Hush House

Aircraft Hangars and Maintenance Buildings

SWMU 26

US HWY 58

I 264

STATE HWY 279

N GREAT NECK RD

GREAT NECK RD

POTTERS RD

US HWY 58 BUS

BIRDNECK RD

N BIRDNECK RD

NORFOLK AVE

S BIRDNECK RD

BELLS RD

STATE HWY 615

STATE HWY 149

DAM NECK RD

	USEPA Lifetime Health Advisory
Total PFOS/PFOA	70

Notes:
All units are ng/L (nanograms per liter)
J - Estimated result
* - Field duplicate collected at this location; the greater of the results is shown
Bold text indicates a detection
Shading indicates exceedance of the USEPA Lifetime Health Advisory

Legend

- On-Base Non-Potable Well
- Monitoring Wells with PFOS/PFOA Detections
- Monitoring Wells with PFOS/PFOA Exceedances
- Monitoring Wells with No PFOS/PFOA Detections
- Non-Core Target Treatment Area (2004)
- Core Target Treatment Area (2004) (Core)
- Direction of Groundwater Flow
- Groundwater Elevation Contour - November 2017 (dashed where inferred)
- Sampling Area
- Potential AFFF Release Areas
- Installation Boundary

N W E S

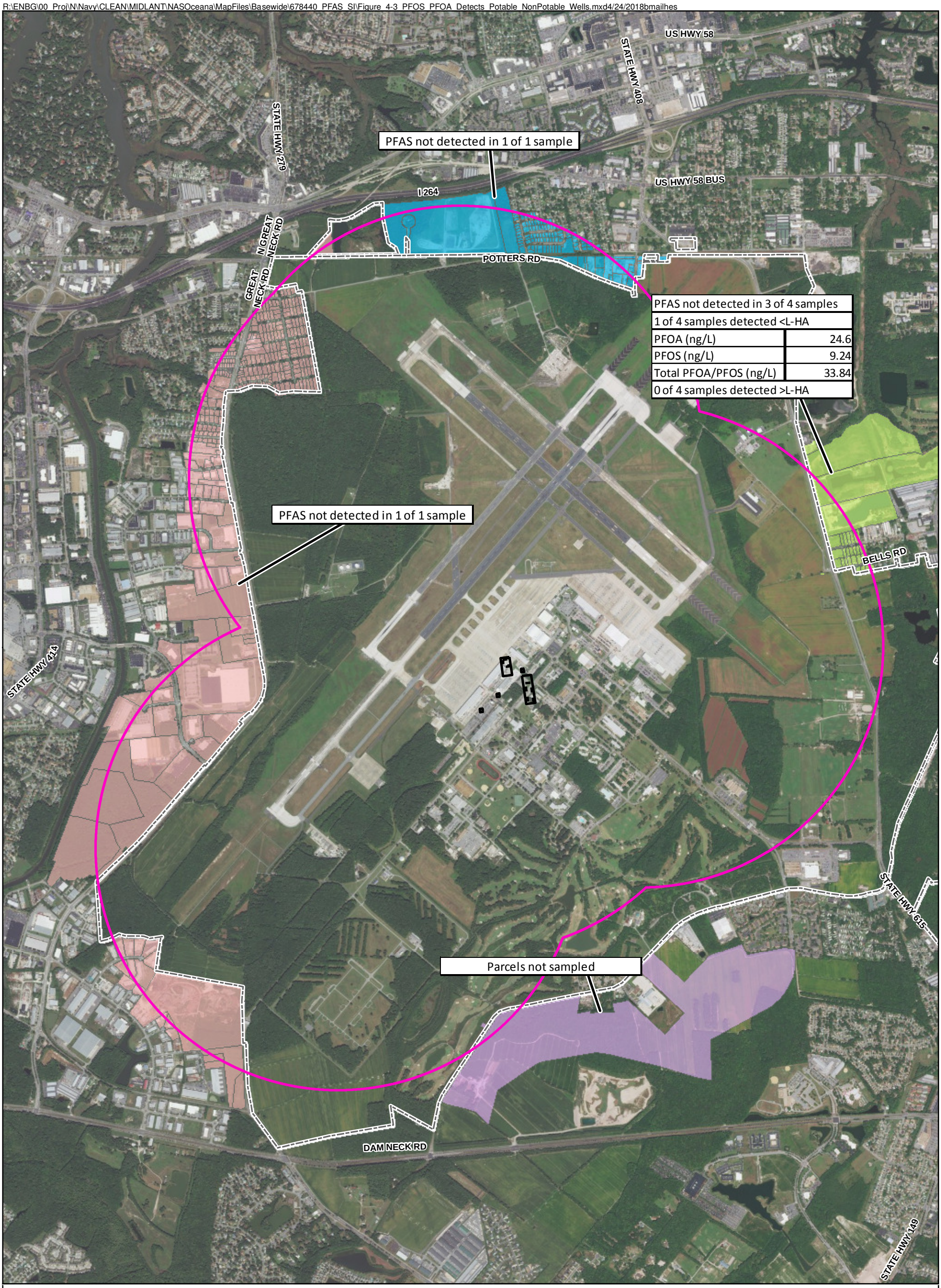
0 750 1,500 3,000 Feet

Imagery Source: Esri, 2016

Figure 4-2
COCs Concentrations in the Yorktown Aquifer
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

ch2m.

R:\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\Basewide\678440_PFAS_SI\Figure_4-3_PFOS_PFOA_Detects_Potable_NonPotable_Wells.mxd4/24/2018bmailhes



Legend

- Non-Core Target Treatment Area (2004)
- Core Target Treatment Area (2004) (Core)
- Sampling Area
- Installation Boundary

Off-Base Parcels

- East
- North
- South
- West

N
W E
S

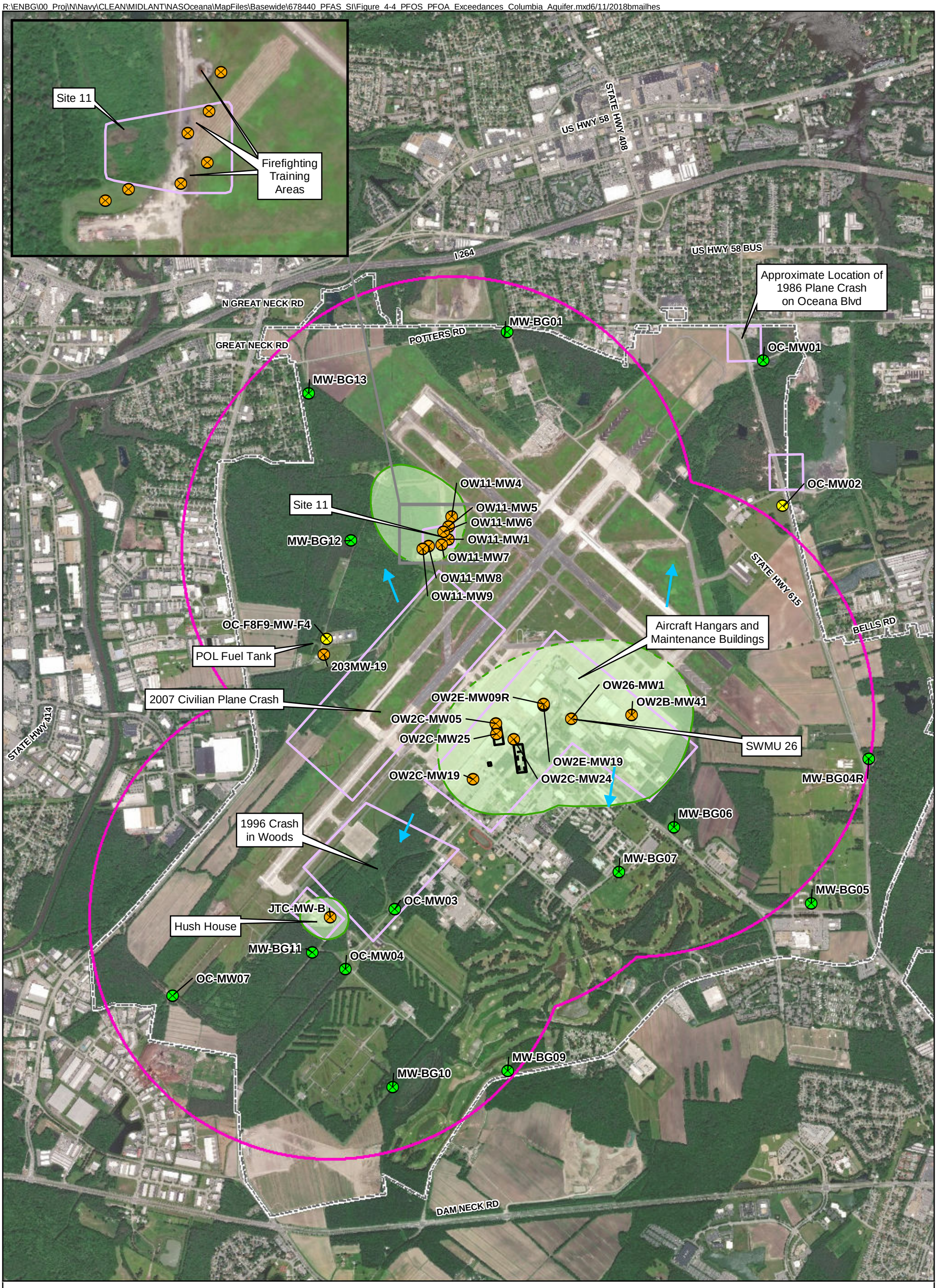
0 1,000 2,000 4,000 Feet

Imagery Source: ©2017 Esri

Figure 4-3
COCs Detections in Potable Wells Sampled from Parcels Located Off-Base
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

ch2m

R:\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\Basewide\678440_PFAS_SI\Figure_4-4_PFOS_PFOA_Exceedances_Columbia_Aquifer.mxd6/11/2018bmailhes



Legend

- Monitoring Wells with PFOS/PFOA Detections
- Monitoring Wells with PFOS/PFOA Exceedances
- Monitoring Wells with No PFOS/PFOA Detections
- Direction of Groundwater Flow
- Non-Core Target Treatment Area (2004)
- Core Target Treatment Area (2004) (Core)
- Total PFOA/PFOS above USEPA Lifetime Health Advisory of 70 ng/L.
- Sampling Area
- Potential AFFF Release Areas
- Installation Boundary

N
W E
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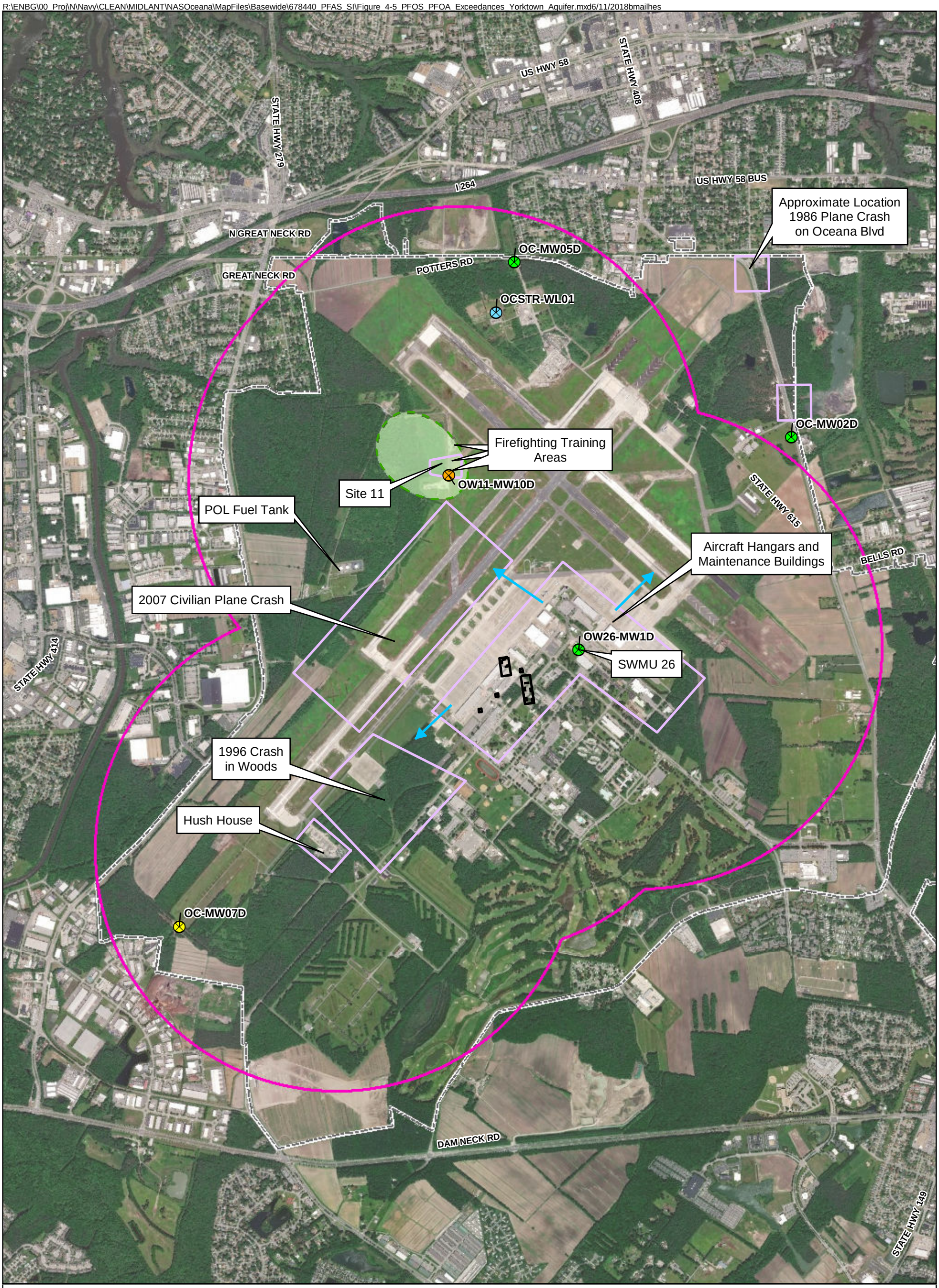
0 1,000 2,000 4,000 Feet

Imagery Source: ©2017 Esri

Figure 4-4
COCs Plume Delineation in the Columbia Aquifer
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

ch2m

R:\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\Basewide\678440_PFAS_SI\Figure_4-5_PFOS_PFOA_Exceedances_Yorktown_Aquifer.mxd6/11/2018bmailhes



Legend

- On-Base Non-Potable Well
- Monitoring Wells with PFOS/PFOA Detections
- Monitoring Wells with PFOS/PFOA Exceedances
- Monitoring Wells with No PFOS/PFOA Detections
- Direction of Groundwater Flow
- Non-Core Target Treatment Area (2004)
- Core Target Treatment Area (2004) (Core)
- Total PFOA/PFOS above USEPA Lifetime Health Advisory of 70 ng/L.
- Potential AFFF Release Areas
- Sampling Area
- Installation Boundary

N
W E
S

0 1,000 2,000 4,000 Feet

Imagery Source: ©2017 Esri

Figure 4-5
COCs Plume Delineation in the Yorktown Aquifer
Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report
NAS Oceana, Virginia Beach, Virginia

ch2m

SECTION 5

Human Health Risk Screening

A human health risk screening (HHRS) evaluation was performed to assess potential human health risks associated with exposure to PFAS in groundwater at NAS Oceana. The results of the HHRS provide a preliminary indication of potential risks from exposure to PFAS in groundwater, and are used to help evaluate whether future unrestricted use of the site is acceptable (i.e., residential, including potable use of groundwater), or if the site requires further evaluation. Although the groundwater on-Base is not used as a potable water supply, human health risk-based levels based on potable use were used for the screening evaluation.

5.1 Data Evaluation

The groundwater samples collected at each of the potential PFAS source areas were assessed separately in the HHRS. The off-Base residential water supplies were evaluated together as one exposure area. Groundwater samples collected from Columbia aquifer and Yorktown aquifer wells were evaluated separately. The following areas were evaluated in the HHRS:

- Site 11 (Columbia aquifer and Yorktown aquifer)
- SWMU 26 (Columbia aquifer and Yorktown aquifer)
- 1986 Crash Site (Columbia aquifer)
- 1996 Crash Site (Columbia aquifer)
- Hush House (Columbia aquifer)
- Aircraft Hangars and Maintenance Buildings (Columbia aquifer)
- 2007 Crash Site (Columbia aquifer)
- POL Fuel Tank Site (Columbia aquifer)
- Perimeter Wells (Columbia aquifer and Yorktown aquifer)
- Offsite Residential Potable Water and on-Base non-potable water supply wells

The groundwater PFAS data evaluated in the HHRS were validated. Validation of the data identified the following criteria for data usability:

- Estimated values flagged with a J qualifier were treated as unqualified detected concentrations.
- Values flagged with a B qualifier (indicating blank contamination) were considered non-detected values.
- Values flagged with a UJ qualifier indicate an analyte was not detected and the quantitation limit was estimated.
- The maximum concentration between a primary and a duplicate sample was used as the sample concentration. If the analyte was only detected in one of the samples, the detected concentration was used as the sample concentration.

5.2 Human Health Risk Screening Methodology

The HHRS was conducted in two steps using the risk ratio technique described in *Overview of Screening, Risk Ratio, and Toxicological Evaluation. Procedures for Northern Division Human Health Risk Assessments* (Navy, 2000).

Step 1

The maximum detected PFAS concentrations in groundwater within each area were compared to the USEPA tap water RSLs from the current RSL table (USEPA, 2017). RSLs based on noncarcinogenic effects were based on a hazard quotient of 0.1 to account for exposure to multiple constituents with the same target organ/target effect. RSLs based on carcinogenic endpoints were based on a carcinogenic risk of 1×10^{-6}. The tap water RSLs for PFOA and PFOS were calculated using the USEPA Risk Screening Level Calculator (USEPA, 2017) since they are not

included in the most recent RSL table (USEPA, 2017). RSL values are included in HHRS screening tables for PFBS, PFOA, and PFOS, the only PFAS with available toxicity values. As discussed in previous sections of the SI Report, three additional PFAS (PFNA, PFHxS, PFHpA) were also analyzedby the laboratory in the groundwater samples; however, as there are no current screening values or toxicity values for these PFAS they are not compared to human health risk-based concentrations. They were analyzed by the laboratory for comparison to screening levels that may be developed in the future.

If the maximum detected concentration (MDC) exceeded the RSL, the constituent was identified as a Step 1 constituent of potential concern (COPC) and carried forward to Step 2. In addition to comparing the MDC of PFOA and PFOS to the RSL, if the sum of the PFOA and PFOS concentrations exceeded the RSL, they were both identified as COPCs. This was done following the PFOA and PFOS drinking water health advisories (USEPA, 2016a, 2016b, 2016c) which indicate that the combined concentration of PFOA and PFOS should be compared to the L-HA.

The drinking water L-HAs for PFOA and PFOS are also included on the Step 1 screening tables. Drinking water L-HAs provide information on pollutants that can affect drinking water quality, but that are not regulated under the Safe Drinking Water Act. The health advisory levels are developed to provide a margin of protection against adverse health effects to the most sensitive population (fetuses during pregnancy and breastfed infants). The health advisory levels for PFOA and PFOS are calculated based on drinking water intake of lactating women and are based on exposure from drinking water ingestion only, and do not consider exposure from dermal contact or inhalation. The L-HA also factors in other sources of exposure (for example, food and soil). The toxicity values presented in the health advisories are those used in the RSL calculator to calculate the drinking water RSL for PFOA and PFOS. The difference between the tap water RSL values and the L-HA values for PFOA and PFOS are due to the different exposure assumptions used to calculate each, and the incorporation of the relative source contribution factor used in the calculation of the health advisory.

Step 2

A risk level was calculated for the constituents identified as COPCs in Step 1 following the approach discussed in *Overview of Screening, Risk Ratio, and Toxicological Evaluation. Procedures for Northern Division Human Health Risk Assessments* (Navy, 2000):

For carcinogenic chemicals identified as COPCs in Step 1, carcinogenic risk was calculated using the following equation:

$$\textit{Carcinogenic risk} = \frac{\textit{MDC x acceptable risk level}}{\textit{RSL}}$$

Where:

MDC = Maximum detected concentration (ng/L)
acceptable risk level = $1x10^{-6}$ (unitless)
RSL = USEPA Regional Screening Level based on carcinogenic risk of $1x10^{-6}$ (ng/L)

For noncarcinogenic chemicals identified as COPCs in Step 1, a hazard index (HI) was calculated using the following equation:

$$\textit{HI} = \frac{\textit{MDC x acceptable HI}}{\textit{RSL}}$$

Where:

MDC = Maximum detected concentration (ng/L)
acceptable HI = 1 (unitless)
RSL = USEPA Regional Screening Level based on HI of 1 (ng/L)

Both carcinogenic risk and HI were calculated for COPCs that act through carcinogenic and noncarcinogenic effects. The carcinogenic risks for each chemical within an area were summed to calculate the cumulative carcinogenic risk, and the HIs for each area were summed to calculate the cumulative HI. A cumulative HI was also

calculated for each target organ/effect. If the cumulative HI for a target organ/effect was greater than 0.5, or the cumulative carcinogenic risk was greater than 5×10^{-5} (the target hazard and risk levels presented in the Navy risk ratio guidance document [Navy, 2000]), the chemicals contributing to these values were identified as COPCs.

5.3 Human Health Risk Screening Results

The HHRS results are presented in this section for each area evaluated.

5.3.1 Site 11 (Fire Training Area)

Both Columbia aquifer and Yorktown aquifer groundwater samples were collected at Site 11.

Tables 5-1 and **5-2** present the HHRS for Columbia aquifer groundwater. The MDCs of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were identified as COPCs.

Tables 5-3 and **5-4** present the HHRS for the Yorktown aquifer groundwater. The MDCs of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were identified as COPCs.

Potable use of groundwater from the Columbia aquifer or the Yorktown aquifer at Site 11 may result in potential unacceptable human health risks associated with PFOA and PFOS. It should be noted that the concentrations detected in the Columbia aquifer groundwater were two to three orders of magnitude higher than the concentrations detected in the Yorktown aquifer groundwater.

5.3.2 SWMU 26 (Fire Station Burn Pit)

Both Columbia aquifer and Yorktown aquifer groundwater samples were collected at the SWMU 26 site.

Tables 5-5 and **5-6** present the HHRS for Columbia aquifer groundwater. The MDCs of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were identified as COPCs.

Table 5-7 presents the HHRS for the Yorktown aquifer groundwater. The MDCs of the PFAS with RSLs were below the RSLs.

Potable use of groundwater from the Columbia aquifer may result in potential unacceptable human health risks associated with PFOA and PFOS. Potable use of groundwater from the Yorktown aquifer would not result in unacceptable human health risks associated with PFAS.

5.3.3 1986 Crash Site

Columbia aquifer groundwater samples were collected at the 1986 Crash Site.

Table 5-8 presents the HHRS for the 1986 Crash Site groundwater. The MDCs of the PFAS with RSLs were below the RSLs.

Potable use of groundwater from the Columbia aquifer at the 1986 Crash Site would not result in unacceptable human health risks associated with PFAS based on current toxicity data.

5.3.4 1996 Crash Site

Columbia aquifer groundwater samples were collected at the 1996 Crash Site.

Tables 5-9 and **5-10** present the HHRS for the 1996 Crash Site groundwater. The combined detected concentration of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were not identified as COPCs.

Potable use of groundwater from the Columbia aquifer at the 1996 Crash Site would not result in unacceptable human health risks associated with PFAS based on current toxicity data.

5.3.5 Hush House

Columbia aquifer groundwater samples were collected at the Hush House site. **Tables 5-11** and **5-12** present the HHRS for the Hush House site groundwater. The MDC of PFOS and the combined MDC of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were identified as COPCs.

Potable use of groundwater from the Columbia aquifer at the Hush House may result in potential unacceptable human health risks associated with PFOA and PFOS.

5.3.6 Aircraft Hangars and Maintenance Buildings

Columbia aquifer groundwater samples were collected at the Aircraft Hangars and Maintenance Buildings site.

Tables 5-13 and **5-14** present the HHRS for Aircraft Hangars and Maintenance Buildings site groundwater. The MDC of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were identified as COPCs.

Potable use of groundwater from the Columbia aquifer at the Aircraft Hangars and Maintenance Buildings site may result in potential unacceptable human health risks associated with PFOA and PFOS.

5.3.7 2007 Crash Site

Columbia aquifer groundwater samples were collected at the 2007 Crash Site.

Tables 5-15 and **5-16** present the HHRS for 2007 Crash Site groundwater. The detected concentration of PFOA and the combined detected concentration of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were not identified as COPCs.

Potable use of groundwater from the Columbia aquifer at the 2007 Crash Site would not result in unacceptable human health risks associated with PFAS based on current toxicity data.

5.3.8 POL Fuel Tank Site

Columbia aquifer groundwater samples were collected at the POL Fuel Tank site.

Table 5-17 presents the HHRS for the POL Fuel Tank site groundwater. The detected concentrations of the PFAS with RSLs were below the RSLs.

Potable use of groundwater from the Columbia aquifer at the POL Fuel Tank site would not result in unacceptable human health risks associated with PFAS based on current toxicity data.

5.3.9 Perimeter Wells

Both Columbia aquifer and Yorktown aquifer groundwater samples were collected from the perimeter monitoring wells.

Tables 5-18 and **5-19** present the HHRS for Columbia aquifer groundwater. The MDC of PFOS and the combined MDC of PFOA and PFOS exceeded the RSL, and therefore, PFOA and PFOS were evaluated in Step 2. Based on Step 2, PFOA and PFOS were not identified as COPCs.

Table 5-20 presents the HHRS for the Yorktown aquifer groundwater. The MDCs of the PFAS with RSLs were below the RSLs.

Potable use of groundwater from the Columbia aquifer or Yorktown aquifer from the perimeter monitoring wells would not result unacceptable human health risks associated with PFAS based on current toxicity data.

5.3.10 Off-Base Residential Potable Water and on-Base Non-Potable Water Supply Well

Groundwater samples were collected from the tap or spigot (prior to any water treatment system installed by the homeowner) at six off-Base residential properties that do not have access to city water and are located within 1 mile downgradient of potential PFAS source areas and the one on-Base non-potable water supply well at the Skeet and Trap Range.

Table 5-21 presents the HHRS for the residential drinking water samples and on-Base non-potable water supply well sample. The MDCs of all of the PFAS with RSLs were below the RSLs.

Potable use of groundwater at any of these residences and from the on-Base non-potable water supply well would not result in unacceptable human health risks associated with PFAS based on current toxicity data.

5.4 Human Health Risk Screening Findings

The HHRS identified potential unacceptable risks associated with PFAS in groundwater for the following areas:

- Site 11, Columbia aquifer and Yorktown aquifer
- SWMU 26, Columbia aquifer
- Hush House, Columbia aquifer
- Aircraft Hangars and Maintenance Buildings site, Columbia aquifer

TABLE 5-1

Occurrence, Distribution, and Selection of Constituents of Potential Concern, Site 11 Fire Training Area, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Site 11	375-73-5	Perfluorobutanesulfonic acid (PFBS)	1.5E+03	5.3E+03	NG/L	OW11-MW4-1016	7/7	N/A	5.3E+03	N/A	4.0E+04 N	N/A		NO	BSL
Fire Training Area	375-85-9	Perfluoroheptanoic acid (PFHpA)	2.5E+03	1.0E+04	NG/L	OW11-MW7-1016	7/7	N/A	1.0E+04	N/A	N/A	N/A		NO	NTX
Columbia Aquifer	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	1.7E+04	3.9E+04	NG/L	OW11-MW6-1016	7/7	N/A	3.9E+04	N/A	N/A	N/A		NO	NTX
Groundwater	375-95-1	Perfluorononanoic acid (PFNA)	1.0E+02	2.7E+03	NG/L	OW11-MW7-1016	7/7	N/A	2.7E+03	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**1.9E+04**	**3.0E+05 J**	**NG/L**	**OW11-MW7-1016**	**7/7**	**N/A**	**3.0E+05**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**1.5E+03**	**1.9E+04**	**NG/L**	**OW11-MW7-1016**	**7/7**	**N/A**	**1.9E+04**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-2

Risk Ratio Screening, Site 11 Fire Training Area, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS	7 / 7	3.0E+05 J	OW11-MW7-1016	N/A			4.0E+02	1	740	Developmental
Perfluorooctanoic acid (PFOA)	7 / 7	1.9E+04	OW11-MW7-1016	1.1E+03	1E-06	2E-05	4.0E+02	1	47	Developmental
Cumulative Hazard Index[c]									**787**	
Cumulative Cancer Risk[d]						**2E-05**				
								Total Developmental HI =	**787**	

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

J = Estimated Value

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

TABLE 5-3

Occurence, Distribution, and Selection of Constituents of Potential Concern, Site 11 Fire Training Area, Yorktown Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Site 11	375-73-5	Perfluorobutanesulfonic acid (PFBS)	8.1E+00 J	8.1E+00 J	NG/L	OW11-MW10D-0417	1/1	N/A	8.1E+00	N/A	4.0E+04 N	N/A		NO	BSL
Fire Training Area	375-85-9	Perfluoroheptanoic acid (PFHpA)	2.2E+01	2.2E+01	NG/L	OW11-MW10D-0417	1/1	N/A	2.2E+01	N/A	N/A	N/A		NO	NTX
Yorktown Aquifer	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	1.2E+02	1.2E+02	NG/L	OW11-MW10D-0417	1/1	N/A	1.2E+02	N/A	N/A	N/A		NO	NTX
Groundwater	375-95-1	Perfluorononanoic acid (PFNA)	5.2E+00 J	5.2E+00 J	NG/L	OW11-MW10D-0417	1/1	N/A	5.2E+00	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**5.8E+02**	**5.8E+02**	**NG/L**	**OW11-MW10D-0417**	**1/1**	**N/A**	**5.8E+02**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**6.1E+01**	**6.1E+01**	**NG/L**	**OW11-MW10D-0417**	**1/1**	**N/A**	**6.1E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-4

Risk Ratio Screening, Site 11 Fire Training Area, Yorktown Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	1 / 1	5.8E+02	OW11-MW10D-0417	N/A			4.0E+02	1	1.4	Developmental
Perfluorooctanoic acid (PFOA)	1 / 1	6.1E+01	OW11-MW10D-0417	1.1E+03	1E-06	6E-08	4.0E+02	1	0.2	Developmental
Cumulative Hazard Index[c]									**2**	
Cumulative Cancer Risk[d]						**6E-08**				
								Total Developmental HI =	**2**	

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

TABLE 5-5

Occurrence, Distribution, and Selection of Constituents of Potential Concern, SWMU 26, Fire Station Burn Pit, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
SWMU 26	375-73-5	Perfluorobutanesulfonic acid (PFBS)	5.0E+03	5.0E+03	NG/L	OW26-MW1-1116	1/1	N/A	5.0E+03	N/A	4.0E+04 N	N/A		NO	BSL
Fire Station Burn Pit	375-85-9	Perfluoroheptanoic acid (PFHpA)	1.4E+04	1.4E+04	NG/L	OW26-MW1-1116	1/1	N/A	1.4E+04	N/A	N/A	N/A		NO	NTX
Columbia Aquifer	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	5.2E+04 J	5.2E+04 J	NG/L	OW26-MW1-1116	1/1	N/A	5.2E+04	N/A	N/A	N/A		NO	NTX
Groundwater	375-95-1	Perfluorononanoic acid (PFNA)	1.7E+03	1.7E+03	NG/L	OW26-MW1-1116	1/1	N/A	1.7E+03	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**4.7E+05**	**4.7E+05**	**NG/L**	**OW26-MW1-1116**	**1/1**	**N/A**	**4.7E+05**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**2.3E+04**	**2.3E+04**	**NG/L**	**OW26-MW1-1116**	**1/1**	**N/A**	**2.3E+04**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites. Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-6

Risk Ratio Screening, SWMU 26, Fire Station Burn Pit, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	1 / 1	4.7E+05	OW26-MW1-1116	N/A			4.0E+02	1	1178	Developmental
Perfluorooctanoic acid (PFOA)	1 / 1	2.3E+04	OW26-MW1-1116	1.1E+03	1E-06	2E-05	4.0E+02	1	57	Developmental
Cumulative Hazard Index[c]									**1234**	
Cumulative Cancer Risk[d]						**2E-05**				
								Total Developmental HI =		**1234**

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

TABLE 5-7

Occurrence, Distribution, and Selection of Constituents of Potential Concern, SWMU 26, Fire Station Burn Pit, Yorktown Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
SWMU 26 Fire Station Burn Pit Yorktown Aquifer Groundwater	355-46-4 1763-23-1	Perfluorohexanesulfonic acid (PFHxS) Perfluorooctane Sulfonate (PFOS)	2.4E+00 J 1.0E+01	2.4E+00 J 1.0E+01	NG/L NG/L	OW26-MW01D-0417 OW26-MW01D-0417	1/1 1/1	N/A N/A	2.4E+00 1.0E+01	N/A N/A	N/A 4.0E+01 N	N/A 7.0E+01	 HA	NO NO	NTX BSL

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)

Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-8

Occurrence, Distribution, and Selection of Constituents of Potential Concern, 1986 Crash Site, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
1986 Crash Site Columbia Aquifer Groundwater	375-73-5	Perfluorobutanesulfonic acid (PFBS)	4.1E+00 J	4.1E+00 J	NG/L	OC-MW01-1116	1/1	N/A	4.1E+00	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	2.7E+00 J	2.7E+00 J	NG/L	OC-MW01-1116	1/1	N/A	2.7E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	1.9E+01	1.9E+01	NG/L	OC-MW01-1116	1/1	N/A	1.9E+01	N/A	N/A	N/A		NO	NTX
	375-95-1	Perfluorononanoic acid (PFNA)	1.8E+00 J	1.8E+00 J	NG/L	OC-MW01-1116	1/1	N/A	1.8E+00	N/A	N/A	N/A		NO	NTX
	1763-23-1	Perfluorooctane Sulfonate (PFOS)	8.2E+00 J	8.2E+00 J	NG/L	OC-MW01-1116	1/1	N/A	8.2E+00	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL
	335-67-1	Perfluorooctanoic acid (PFOA)	4.9E+00 J	4.9E+00 J	NG/L	OC-MW01-1116	1/1	N/A	4.9E+00	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

COPC = Constituent of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
J = Estimated Value
C = Carcinogenic
N = Noncarcinogenic
N/A = Not available
HA = USEPA Lifetime Health Advisory (May 2016)
NG/L = Nanograms/Liter

TABLE 5-9

Occurrence, Distribution, and Selection of Constituents of Potential Concern, 1996 Crash Site, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
1996 Crash Site Columbia Aquifer Groundwater	375-73-5	Perfluorobutanesulfonic acid (PFBS)	6.9E+00 J	6.9E+00 J	NG/L	OC-MW03-1116	1/1	N/A	6.9E+00	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	9.6E+00	9.6E+00	NG/L	OC-MW03-1116	1/1	N/A	9.6E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	4.7E+01	4.7E+01	NG/L	OC-MW03-1116	1/1	N/A	4.7E+01	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**3.3E+01**	**3.3E+01**	**NG/L**	**OC-MW03-1116**	**1/1**	**N/A**	**3.3E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**PFOS+PFOA**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**1.6E+01**	**1.6E+01**	**NG/L**	**OC-MW03-1116**	**1/1**	**N/A**	**1.6E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**PFOS+PFOA**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Combined concentration of PFOS and PFOA exceeds the RSL (PFOS+PFOA)

Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-10

Risk Ratio Screening, 1996 Crash Site, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	1 / 1	3.3E+01	OC-MW03-1116	N/A			4.0E+02	1	0.08	Developmental
Perfluorooctanoic acid (PFOA)	1 / 1	1.6E+01	OC-MW03-1116	1.1E+03	1E-06	1E-08	4.0E+02	1	0.04	Developmental
Cumulative Hazard Index[c]									**0.1**	
Cumulative Cancer Risk[d]						**1E-08**				
								Total Developmental HI =	**0.1**	

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

N/A = Not available/not applicable

NG/L = nanogram/liter

RSL = Regional Screening Level

TABLE 5-11

Occurrence, Distribution, and Selection of Constituents of Potential Concern, Hush House, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Accidental Release at Hush House Columbia Aquifer Groundwater	375-73-5	Perfluorobutanesulfonic acid (PFBS)	4.0E+00 J	4.3E+00 J	NG/L	JTC-MW-B-1116	2/2	N/A	4.3E+00	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	6.3E+00 J	6.4E+00 J	NG/L	OC-MW04-1016	2/2	N/A	6.4E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	4.3E+01	2.1E+02	NG/L	JTC-MW-B-1116	2/2	N/A	2.1E+02	N/A	N/A	N/A		NO	NTX
	375-95-1	Perfluorononanoic acid (PFNA)	6.1E+00 J	6.1E+00 J	NG/L	JTC-MW-B-1116	1/2	N/A	6.1E+00	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**4.0E+01**	**4.0E+03**	**NG/L**	**JTC-MW-B-1116**	**2/2**	**N/A**	**4.0E+03**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**6.8E+00 J**	**1.3E+01**	**NG/L**	**JTC-MW-B-1116**	**2/2**	**N/A**	**1.3E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**PFOS+PFOA**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites. Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Combined concentration of PFOS and PFOA exceeds the RSL (PFOS+PFOA)

Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-12

Risk Ratio Screening, Hush House, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	1 / 1	4.0E+03	JTC-MW-B-1116	N/A			4.0E+02	1	10	Developmental
Perfluorooctanoic acid (PFOA)	1 / 1	1.3E+01	JTC-MW-B-1116	1.1E+03	1E-06	1E-08	4.0E+02	1	0.03	Developmental
Cumulative Hazard Index[c]									**10**	
Cumulative Cancer Risk[d]						**1E-08**				
									Total Developmental HI =	**10**

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

TABLE 5-13

Occurrence, Distribution, and Selection of Constituents of Potential Concern, Aircraft Hangars and Maintenance Buildings, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Aircraft Hangars and Maintenance Buildings Columbia Aquifer Groundwater	375-73-5	Perfluorobutanesulfonic acid (PFBS)	9.9E+00	3.1E+02 J	NG/L	OW2C-MW25-0217	8/8	N/A	3.1E+02	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	2.6E+01	5.3E+02	NG/L	OW2C-MW25-0217	8/8	N/A	5.3E+02	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	7.9E+01	3.6E+03	NG/L	OW2C-MW25-0217	8/8	N/A	3.6E+03	N/A	N/A	N/A		NO	NTX
	375-95-1	Perfluorononanoic acid (PFNA)	3.2E+00	2.5E+02	NG/L	OW2C-MW25-0217	8/8	N/A	2.5E+02	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**6.3E+01**	**4.5E+04 J**	**NG/L**	**OW2C-MW25-0217**	**8/8**	**N/A**	**4.5E+04**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**4.3E+01**	**1.5E+03**	**NG/L**	**OW2C-MW24-0217**	**8/8**	**N/A**	**1.5E+03**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites. Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens). RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-14

Risk Ratio Screening, Aircraft Hangars and Maintenance Buildings, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	8 / 8	4.5E+04 J	OW2C-MW25-0217	N/A			4.0E+02	1	111	Developmental
Perfluorooctanoic acid (PFOA)	8 / 8	1.5E+03	OW2C-MW24-0217	1.1E+03	1E-06	1E-06	4.0E+02	1	3.9	Developmental
Cumulative Hazard Index[c]									**115**	
Cumulative Cancer Risk[d]						**1E-06**				
								Total Developmental HI =	**115**	

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

J = Estimated Value

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

TABLE 5-15

Occurence, Distribution, and Selection of Constituents of Potential Concern, 2007 Crash Site, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
2007 Crash Site Columbia Aquifer Groundwater	375-73-5	Perfluorobutanesulfonic acid (PFBS)	7.9E+00 J	7.9E+00 J	NG/L	FTWG-MW-02-1116	1/1	N/A	7.9E+00	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	8.4E+00 J	8.4E+00 J	NG/L	FTWG-MW-02-1116	1/1	N/A	8.4E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	1.1E+01	1.1E+01	NG/L	FTWG-MW-02-1116	1/1	N/A	1.1E+01	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**4.0E+01**	**4.0E+01**	**NG/L**	**FTWG-MW-02-1116**	**1/1**	**N/A**	**4.0E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**PFOS+PFOA**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**9.0E+01**	**9.0E+01**	**NG/L**	**FTWG-MW-02-1116**	**1/1**	**N/A**	**9.0E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Combined concentration of PFOS and PFOA exceeds the RSL (PFOS+PFOA)

Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-16

Risk Ratio Screening, 2007 Crash Site, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	1 / 1	4.0E+01	FTWG-MW-02-1116	N/A			4.0E+02	1	0.1	Developmental
Perfluorooctanoic acid (PFOA)	1 / 1	9.0E+01	FTWG-MW-02-1116	1.1E+03	1E-06	8E-08	4.0E+02	1	0.2	Developmental
Cumulative Hazard Index[c]									**0.3**	
Cumulative Cancer Risk[d]						**8E-08**				
								Total Developmental HI =		**0.3**

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

TABLE 5-17

Occurrence, Distribution, and Selection of Constituents of Potential Concern, POL Fuel Tank Site, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
POL Fuel Tank Columbia Aquifer Groundwater	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	2.7E+00 J	2.7E+00 J	NG/L	OC-F8F9-MW-F4-0417	1/1	N/A	2.7E+00	N/A	N/A	N/A		NO	NTX
	375-95-1	Perfluorononanoic acid (PFNA)	1.8E+00 J	1.8E+00 J	NG/L	OC-F8F9-MW-F4-0417	1/1	N/A	1.8E+00	N/A	N/A	N/A		NO	NTX
	1763-23-1	Perfluorooctane Sulfonate (PFOS)	2.1E+01 J	2.1E+01 J	NG/L	OC-F8F9-MW-F4-0417	1/1	N/A	2.1E+01	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL
	335-67-1	Perfluorooctanoic acid (PFOA)	8.4E+00 J	8.4E+00 J	NG/L	OC-F8F9-MW-F4-0417	1/1	N/A	8.4E+00	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL

[1] Minimum/Maximum detected concentrations.
[2] Maximum detected concentration is used for screening,.
[3] Background values not available
[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.
[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Combined concentration of PFOS and PFOA exceeds the RSL (PFOS+PFOA)
Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-18

Occurrence, Distribution, and Selection of Constituents of Potential Concern, Perimeter Wells, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Perimeter Wells Columbia Aquifer Groundwater	375-73-5	Perfluorobutanesulfonic acid (PFBS)	7.0E+00 J	7.0E+00 J	NG/L	MW-BG12-1016	1/13	N/A	7.0E+00	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	6.7E-01 J	2.7E+00 J	NG/L	MW-BG12-1016	4/13	N/A	2.7E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	1.1E+00 J	8.0E+01	NG/L	MW-BG12-1016	10/13	N/A	8.0E+01	N/A	N/A	N/A		NO	NTX
	375-95-1	Perfluorononanoic acid (PFNA)	1.4E+00 J	1.4E+00 J	NG/L	MW-BG12-1016	1/13	N/A	1.4E+00	N/A	N/A	N/A		NO	NTX
	1763-23-1	**Perfluorooctane Sulfonate (PFOS)**	**1.2E+00 J**	**4.7E+01**	**NG/L**	**MW-BG12-1016**	**9/13**	**N/A**	**4.7E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**ASL**
	335-67-1	**Perfluorooctanoic acid (PFOA)**	**6.9E-01 J**	**1.4E+01**	**NG/L**	**MW-BG01-1016**	**7/13**	**N/A**	**1.4E+01**	**N/A**	**4.0E+01 N**	**7.0E+01**	**HA**	**YES**	**PFOS+PFOA**

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Combined concentration of PFOS and PFOA exceeds the RSL (PFOS+PFOA)

Deletion Reason: Below Screening Level (BSL)
No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-19

Risk Ratio Screening, Perimeter Wells, Columbia Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Analyte	Detection Frequency	Maximum Detected Concentration (Qualifier) (NG/L)	Sample Location of Maximum Detected Concentration	Carcinogenic Tap Water RSL (NG/L)	Acceptable Risk Level	Cancer Risk[a]	Non-carcinogenic Tap Water RSL (NG/L)	Acceptable Hazard Level	Hazard Index[b]	Target Organ
Perfluorooctane Sulfonate (PFOS)	9 / 13	4.7E+01	MW-BG12-1016	N/A			4.0E+02	1	0.1	Developmental
Perfluorooctanoic acid (PFOA)	7 / 13	1.4E+01	MW-BG01-1016	1.1E+03	1E-06	1E-08	4.0E+02	1	0.03	Developmental
Cumulative Hazard Index[c]									**0.2**	
Cumulative Cancer Risk[d]						**1E-08**				
								Total Developmental HI =		**0.2**

Notes:

[a] Cancer Risk equals maximum detected concentration divided by the RSL divided by the acceptable risk level.

[b] Hazard Index equals maximum detected concentration divided by the RSL divided by the acceptable hazard level.

[c] Cumulative Hazard Index equals sum of Hazard Indices for each constituent.

[d] Cumulative Cancer Risk equals sum of Cancer Risks for each constituent.

Constituent selected as COPC if it contributes to an overall Hazard Index by target organ greater than 0.5 or Cumulative Cancer Risk greater than 5E-05, otherwise, constituent not selected as COPC.

Constituents selected as COPCs are indicated by shading.

COPC = Constituent of Potential Concern

HI = Hazard Index

N/A = Not available/not applicable

NG/L = Nanograms/Liter

RSL = Regional Screening Level

UG/L = micrograms/liter

TABLE 5-20

Occurrence, Distribution, and Selection of Constituents of Potential Concern, Perimeter Wells, Yorktown Aquifer

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Perimeter Wells Yorktown Aquifer Groundwater	375-85-9	Perfluoroheptanoic acid (PFHpA)	3.4E+00 J	3.4E+00 J	NG/L	OC-MW02D-0417	1/3	N/A	3.4E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	1.0E+01	1.0E+01	NG/L	OC-MW02D-0417	1/3	N/A	1.0E+01	N/A	N/A	N/A		NO	NTX
	1763-23-1	Perfluorooctane Sulfonate (PFOS)	2.4E+00 J	2.4E+00 J	NG/L	OC-MW05D-0417	1/3	N/A	2.4E+00	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL
	335-67-1	Perfluorooctanoic acid (PFOA)	9.0E+00	9.0E+00	NG/L	OC-MW02D-0417	1/3	N/A	9.0E+00	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason:	Above Screening Levels (ASL)
Deletion Reason:	Below Screening Level (BSL)
	No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

TABLE 5-21

Occurrence, Distribution, and Selection of Constituents of Potential Concern, Off-Base Residential Drinking Water and On-Base Non-Potable Water Supply Well

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Off-Base Residential Drinking Water and On-Base Non-Potable Water Supply Well	375-73-5	Perfluorobutanesulfonic acid (PFBS)	2.2E+00 J	2.2E+00 J	NG/L	OC-RW01-1216	1/7	N/A	2.2E+00	N/A	4.0E+04 N	N/A		NO	BSL
	375-85-9	Perfluoroheptanoic acid (PFHpA)	8.5E+00	8.5E+00	NG/L	OC-RW01-1216	1/7	N/A	8.5E+00	N/A	N/A	N/A		NO	NTX
	355-46-4	Perfluorohexanesulfonic acid (PFHxS)	3.3E+01	3.3E+01	NG/L	OC-RW01-1216	1/7	N/A	3.3E+01	N/A	N/A	N/A		NO	NTX
	375-95-1	Perfluorononanoic acid (PFNA)	1.2E+00 J	1.2E+00 J	NG/L	OC-RW01-1216	1/7	N/A	1.2E+00	N/A	N/A	N/A		NO	NTX
	1763-23-1	Perfluorooctane Sulfonate (PFOS)	9.2E+00	9.2E+00	NG/L	OC-RW01-1216	1/7	N/A	9.2E+00	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL
	335-67-1	Perfluorooctanoic acid (PFOA)	2.5E+01	2.5E+01	NG/L	OC-RW01-1216	1/7	N/A	2.5E+01	N/A	4.0E+01 N	7.0E+01	HA	NO	BSL

[1] Minimum/Maximum detected concentrations.

[2] Maximum detected concentration is used for screening,.

[3] Background values not available

[4] Oak Ridge National Laboratory (ORNL). June 2017. Regional Screening Levels for Chemical Contaminants at Superfund Sites.
Tap Water RSLs (based on 10^{-6} for carcinogens and HQ of 0.1 for noncarcinogens).
RSL values were calculated using the RSL calculator tool.

[5] Rationale Codes

Selection Reason:	Above Screening Levels (ASL)
Deletion Reason:	Below Screening Level (BSL)
	No toxicity value (NTX)

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
To Be Considered
C = Carcinogenic
COPC = Constituent of Potential Concern
HA = USEPA Lifetime Health Advisory (May 2016)
J = Estimated Value
N = Noncarcinogenic
N/A = Not available
NG/L = Nanograms/Liter

SECTION 6

Conclusions and Recommendations

This section summarizes the major conclusions of the Basewide PFAS SI conducted at NAS Oceana. It also presents proposed recommendations to address the PFAS contamination at the installation.

6.1 Conclusions

6.1.1 Hydraulic Characteristics

Groundwater flow in the Columbia aquifer generally radiates from the center of the installation to the north and to the south. In the eastern part of the installation, the flow follows a west-northwestward pattern. Groundwater flow in the Yorktown aquifer generally mimics the flow in the Columbia aquifer (northward and southward from the center of the installation) although the interpretation of the flow is incomplete due to the limited number of data points, especially in the southern and western portions of the installation. Similarly, the flow patterns of the two aquifers indicate that the confining unit may be absent or have a limited effect on the hydrology in some areas of the installation. Vertical gradient calculations indicate a weak downward gradient between the Columbia aquifer and the Yorktown aquifer.

Slug tests conducted in monitoring wells screened in the Columbia aquifer estimated that hydraulic conductivity ranged from 4.00×10^{-3} ft/min to 9.53×10^{-3} ft/min and a flow velocity of 0.0312 ft/day or approximately 11.37 ft/year.

6.1.2 Contaminant Distribution

Based on total concentrations of PFOA and PFOS exceeding the USEPA L-HA, four main PFAS source areas have been defined: Site 11, SWMU 26, the Aircraft Hangars and Maintenance Buildings, and the Hush House. These findings are consistent with the historical activities reported at each site which involved the use or release of AFFF. Maximum exceedances reached concentrations 7000 times the L-HA at SWMU 26, 4,500 times the L-HA at Site 11, 600 times the L-HA at the Aircraft Hangars and Maintenance Buildings, and 50 times the L-HA at the Hush House. However, the extent of the contamination could not be fully defined due to insufficient monitoring well coverage at each of the plumes.

Groundwater analysis for PFAS in the vicinity of plane crash sites where AFFF was potentially used did not show exceedances above the L-HA. However, PFAS detected below the L-HA in a deep eastern boundary well (OC-MW02D) and in an eastern off-Base potable well sample in the same area do not appear to be downgradient of an identified source area. No PFAS constituents were detected in the shallow boundary well (OC-MW02) in this area.

Exceedances above the USEPA L-HA in the Yorktown aquifer in the vicinity of Site 11 indicate that the contamination has migrated vertically from the Columbia to the Yorktown aquifer in that portion of the installation. However, lack of exceedances in the Yorktown aquifer at SWMU 26 and the Hush House are indicative that clay layers within the aquifers and the confining unit, where present, may be protective of the lower aquifer at these two sites.

There were no exceedances of the USEPA L-HA in water samples collected from off-Base potable water wells and there were detections of PFOA and PFOS below standard at a private potable well located just east of the installation.

6.1.3 Human Health Risk Screening Results

The HHRS which was performed to evaluate potential human health risks associated with exposure to PFAS in groundwater indicated that:

- Potable use of groundwater from the Columbia aquifer at Site 11, SWMU 26, the Aircraft Hangars and Maintenance Buildings site, and the Hush House may result in potential unacceptable human health risks associated with PFOA and PFOS.
- Potable use of groundwater from the Yorktown aquifer at Site 11 may result in potential unacceptable human health risks associated with PFOA and PFOS.
- Potable use of groundwater at any of the residences adjacent to the Base, where a potable well was sampled, would not result in unacceptable human health risks associated with PFAS.
- Potable use of groundwater from the well supplying non-potable water to the Skeet and Trap Range in the northern portion of the installation, and from the perimeter monitoring wells, would not result in unacceptable human health risks associated with PFAS.

6.1.4 Contamination Fate and Transport

Interpretation of analytical results indicates that PFAS contamination has migrated from the Columbia aquifer to the Yorktown aquifer at Site 11, but not at SWMU 26 and the Hush House, which may give an indication that the vertical transport of PFAS is not consistent throughout the installation. The Yorktown confining unit, where present, may slow the vertical transport of PFAS from the Columbia aquifer to the Yorktown aquifer. Downward migration from the upper Yorktown aquifer to the lower Yorktown aquifer has not been investigated as part of this SI and should be explored further. Finally, contamination appears to have dispersed northward and southward from the four PFAS source areas, in a manner consistent with the groundwater flow observed at the site. However, since the plumes' extents have not been fully defined, it is unclear whether the presence of PFAS observed throughout the Base could be attributed in parts to sporadic usage or release of AFFF in non-source areas.

6.2 Proposed Actions

An Expanded Site Inspection is recommended to refine understanding of the hydraulic characteristics at the site and the extent of the contamination, to establish the fate and transport of the COCs, and to further assess risks posed by exposure to contamination for human receptors. Specifically, the following actions are proposed:

1. Install new monitoring wells in the Yorktown aquifer in the eastern, southern, and western portions of the installation to better define the hydraulic characteristics at the site.
2. Install new monitoring wells to better define the extent of the contamination in the Columbia aquifer downgradient of the source areas (Site 11, Aircraft Hangars and Maintenance Buildings, SWMU 26, and the Hush House) and in the Yorktown aquifer downgradient of Site 11.
3. Install additional wells to determine the source of contamination near the 1986 Crash Site, to evaluate downgradient concentrations, and to determine if there are higher concentrations in the area exceeding the L-HA.
4. Install new monitoring wells at Site 11, screened in the lower portion of the Yorktown aquifer (100 feet bgs or deeper) to determine vertical extent of contamination.
5. Perform aquifer variable-head testing in the Yorktown aquifer to define the hydraulic characteristics of this aquifer.
6. Collect additional data on the presence/absence of the Yorktown confining unit beneath NAS Oceana.
7. Establish long-term monitoring of the groundwater to monitor the vertical and horizontal migrations of PFAS in the Columbia and the Yorktown aquifers to ensure long-term protectiveness to potential receptors off-Base.
8. Update the CSM based on new data collected.

9. Perform a supplemental Human Health Risk Screening to further evaluate risks to human health associated with exposure to PFAS detected in groundwater.
10. Perform an Ecological Risk Screening, should ecological toxicity data for PFAS become available.
11. Assess the potential for implementation of land use controls within the boundary of the contaminant plume with concentrations greater than the L-HA to prevent use of groundwater as a drinking water source.
12. Future analysis will include the expanded analyte list of 14 PFAS as per the 2017 Navy Guidance (Navy, 2017).

SECTION 7

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Appendix A
Fire Department Interviews

Interview to Evaluate Use of Aqueous Film-Forming Foam Use at NAS Oceana

ATTENDEES:	Capt. Vincent Jackson/NALF Fentress Chief Kenny Russell/NAS Oceana	Angela Jones/NAVFAC Amy Brand/CH2M
COPY TO:	Laura Cook/CH2M	
PREPARED BY:	Amy Brand/CH2M	
MEETING DATE:	November 2, 2015	

In November, 2015, Ms. Jones and Ms. Brand interviewed Captain Vincent Jackson of Naval Auxiliary Landing Field (NALF) Fentress and Assistant Fire Chief Kenny Russell of Naval Air Station (NAS) Oceana about use of Aqueous Film-Forming Foams (AFFFs) in firefighter training and emergency operations at NAFL Fentress and NAS Oceana. This report summarizes the information regarding use of AFFF at NAS Oceana only. A separate memo was generated for NALF Fentress.

AFFF Use at NAS Oceana

Captain Jackson reported that firefighter training activities at NAS Oceana are currently conducted only using water; no AFFF is used in training. AFFF is currently used in crash trucks in preparation for emergency use. In addition, automated fire suppression systems in the aircraft hangars are charged with AFFF; these systems are maintained by a contractor, Kinetix.

AFFF Use by the NAS Oceana Fire Department

AFFF is ordered at NAS Oceana following current military specifications. Only 3-percent AFFF is used. 3M and Ansul brands have been used previously, but headquarters is using primarily Chemguard brand now.

AFFF is stored in Building 118 at NAS Oceana. A total 3350 gallons is stored in 54 five-gallon cans and 28 55-gallon drums. To load the crash trucks, the trucks are brought to Building 118 and AFFF is replenished manually from the 5-gallon cans. Empty AFFF cans are disposed of as Hazardous Materials (at Building 1114 at NAS Oceana.) Occasionally, AFFF is pumped from 55-gallon drums into 5-gallon cans. When that occurs, the pump is not cleaned; but rather, is kept in the can for future use. There is secondary containment in the area in front of Building 118 where the trucks are filled with AFFF.

Four trucks are kept supplied with AFFF at NAS Oceana, with tanks ranging from 200 to 405 gallons each. Spray tests are performed quarterly at Site 11 (Figure 1). This site has been approved for spray testing. The spray test involves checking the roof turret, pumper turret, and hand lines under the truck nozzles to ensure the foam is the right consistency and to test the distance and width of the spray pattern. Plans for spray testing are coordinated in advance, and spray testing is not conducted if it is raining or if rain is predicted within the new few days. Old foam is flushed at the site where spray testing is done – in the grassy area near Site 11, with care to avoid any storm drains or ditches. Valves are only cleaned if there is a problem with the metering valve; this maintenance, which is rare, is performed by the Public Works and Transportation Department at NAS Oceana.

All current firefighter training areas are mobile, using water only. Firefighter training is conducted quarterly, using propane to create the fire.

AFFF Use in Fire Suppression Systems in the Hangars

AFFF storage for fire suppression in the hangars is handled by a contractor, Kinetix. The automated fire suppression systems in the hangars are currently charged with AFFF. Kinetix brings in 55-gallon drums of AFFF and pumps it into plastic holding tanks, located within the mechanical rooms in the hangars. The tanks are not leak-tested. There is concentrated AFFF in the pipes up to the mixing valve. Interviewees reported never having seen the system flushed; however, flushing the line is part of the cleanup process if there is an activation. When the system is flushed, there is a holding tank, which is checked for adequate capacity. The holding tank has an overflow to the storm sewer system.

If AFFF gets on airplane parts, the parts are discarded (rather than washed) because AFFF is very corrosive.

AFFF Releases

AFFF was reportedly used or presumed to have been used during several emergency response incidents (Figure 1):

- In 1986, a plane crashed off Oceana Boulevard, killing a pregnant woman on the ground. Interviewees indicated that AFFF was probably used for this crash.
- In 1995, a plane crashed in the woods on the installation, but interviewees could not recall whether there was an associated fire.
- 1n 2007, a civilian plane crashed during an air show practice, right off runway 5L. Interviewees were not sure whether AFFF was used.
- In April, 2012, an F18 crashed into the Mayview Apartments. Interviewees believed that AFFF was used on the subsequent fire.

An accidental release has occurred once during firefighter training activities (Figure 1):

- During training in the 1100 area near the Hush House, a person accidentally pressed the wrong button, releasing AFFF. Personnel called Environmental and were told to spray down the concrete area into the grass. There is an underground storage tank at Hush House that acts as a holding tank if there is a discharge.

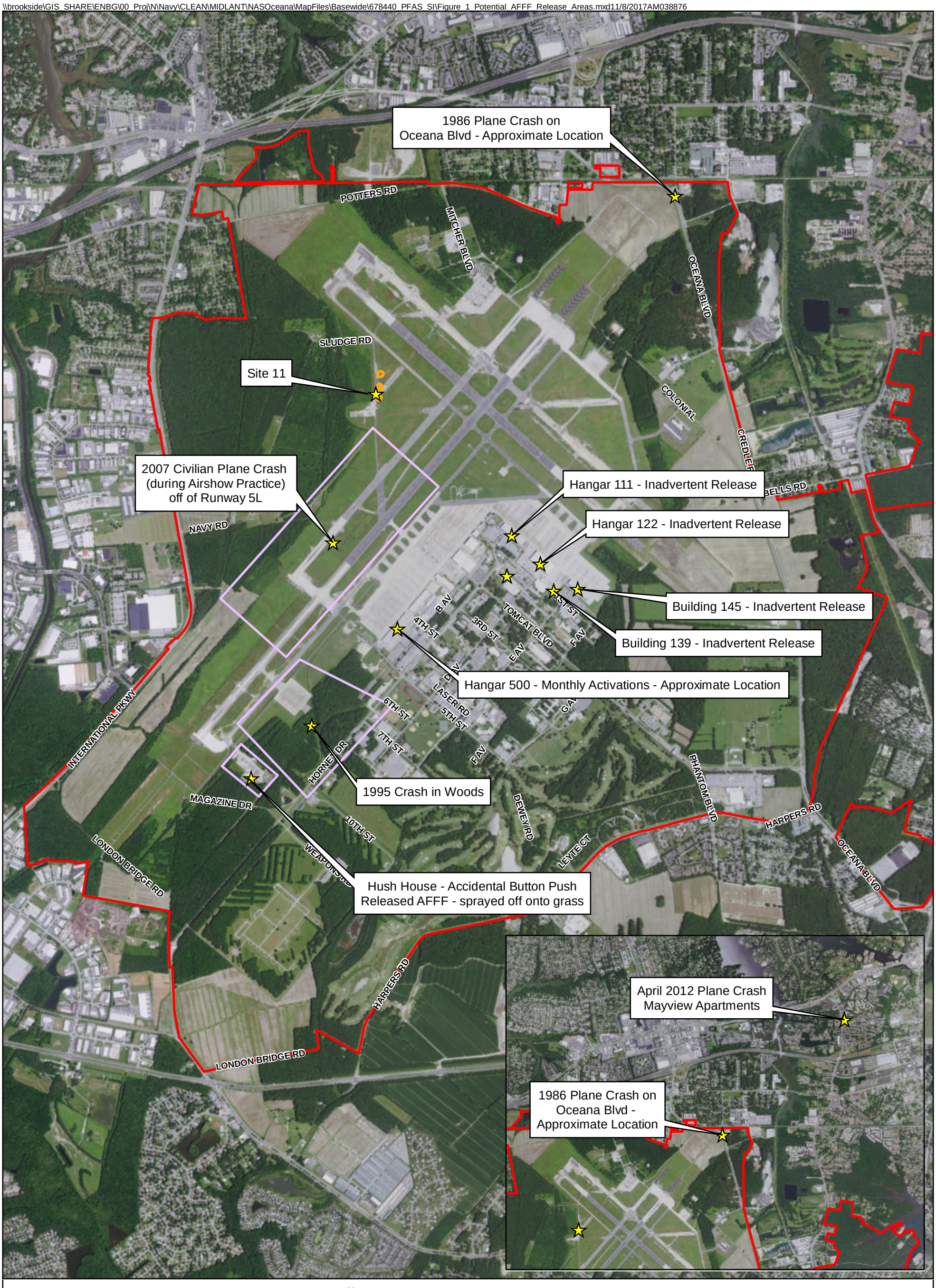
While AFFF has not been used in the hangars for a fire, there have also been several inadvertent releases (Figure 1):

- In Building 145, a worker accidentally pushed the wrong button, releasing AFFF which went into the parking lot. Personnel were advised to cover the storm drains as well as they could, and then spray water to wash the AFFF onto the grass. A contractor was brought in to vacuum up any remaining foam. The buttons have now been covered with plastic to avoid similar accidents.
- A release reportedly occurred in Hangar 111 during retrofit of the floor nozzles.
- An “activation” (which is technically not considered a “spill”) used to occur monthly in Hangar 500 due to sensitive sensors. The sensors have been adjusted and there have been no additional activations.
- In 2010, there was a spill at the corrosion control facility (Building 139). There are no drains in that area. The foam was pushed outside to the grass swale on the southeast side of the building, and then cleaned up with a vacuum truck. An interviewee noted that there have been multiple previous releases at Building 139.
- In July, 2011, a very large storm caused stormwater to back up and fill the overflow tanks in Hangar 122, releasing AFFF to the environment, including the storm drain and storm ditch.

Information about this release is well-documented in the spill log, and the Hampton Roads Sanitation District was notified.

When AFFF releases have occurred, the cleanup has been focused on avoiding any release into water or storm drains. Releases of AFFF into the environment have been documented in spill logs for the past 6-7 years.

\\brookside\GIS_SHARE\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\Basewide\678440_PFAS_SI\Figure_1_Potential_AFFF_Release_Areas.mxd11/8/2017AM038876



Legend

- AFFF Release Locations
- Potential AFFF Release Areas
- Firefighting Areas
- Installation Boundary

N
W E
S

0 1,000 2,000
Feet

Imagery Source: ©2016 Esri

Figure 1
Potential AFFF Release Areas
NAS Oceana, Virginia Beach, Virginia

ch2m

Appendix B
Columbia Monitoring Well Completion Diagrams and Soil Boring Logs

PROJECT NUMBER	WELL NUMBER	
678440	OW11-MW4	SHEET 1 OF 1

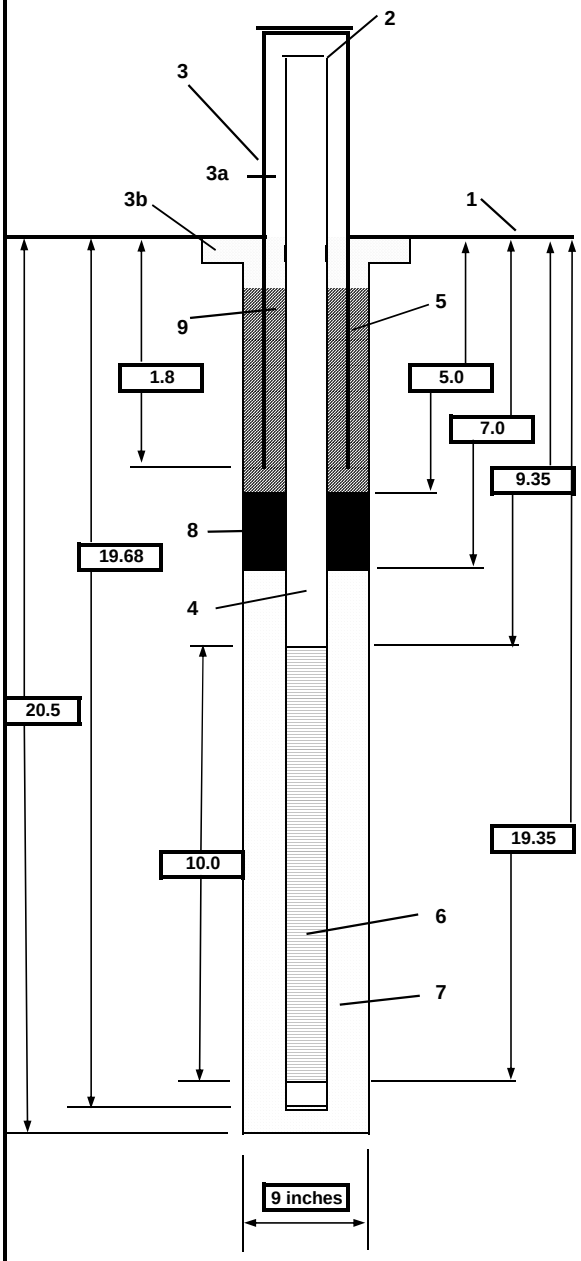
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 3.37 ft BGS (10/6/16) START : 10/4/2016 END : 10/6/2016 LOGGER : **L. Baerga**



NOT TO SCALE

1- Ground elevation at well	15.89	
2- Top of casing elevation	18.89	
3- Wellhead protection cover type	4.5-inch square Aluminum Standpipe	
a) drain tube?	No	
b) concrete pad dimensions	2.5 ft diameter x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	4.5-inch x 5-ft square Aluminum	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/12/2016	9:50
Estimated purge volume	50 gallons	

Comments

PROJECT NUMBER	WELL NUMBER	
678440	OW11-MW5	SHEET 1 OF 1

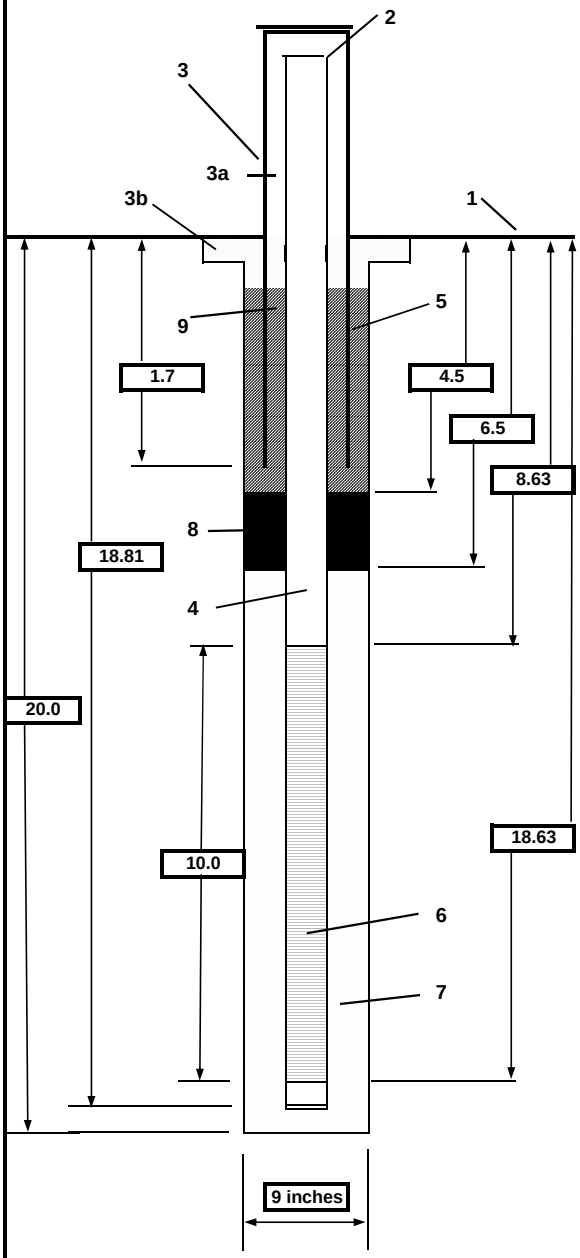
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 4.38 ft BGS (10/6/16) START : 10/4/2016 END : 10/6/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	16.87	
2- Top of casing elevation	20.05	
3- Wellhead protection cover type	4.5-inch square Aluminum Standpipe	
a) drain tube?	No	
b) concrete pad dimensions	2.5 ft diameter x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	4.5-inch x 5-ft square Aluminum	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	14	Gallons
d) Vol. of well casing grout	1.5	Cubic ft
Development method	Submersible Pump	
Development time	10/12/2016	10:50
Estimated purge volume	50 gallons	

Comments

PROJECT NUMBER	WELL NUMBER	
678440	OW11-MW6	SHEET 1 OF 1

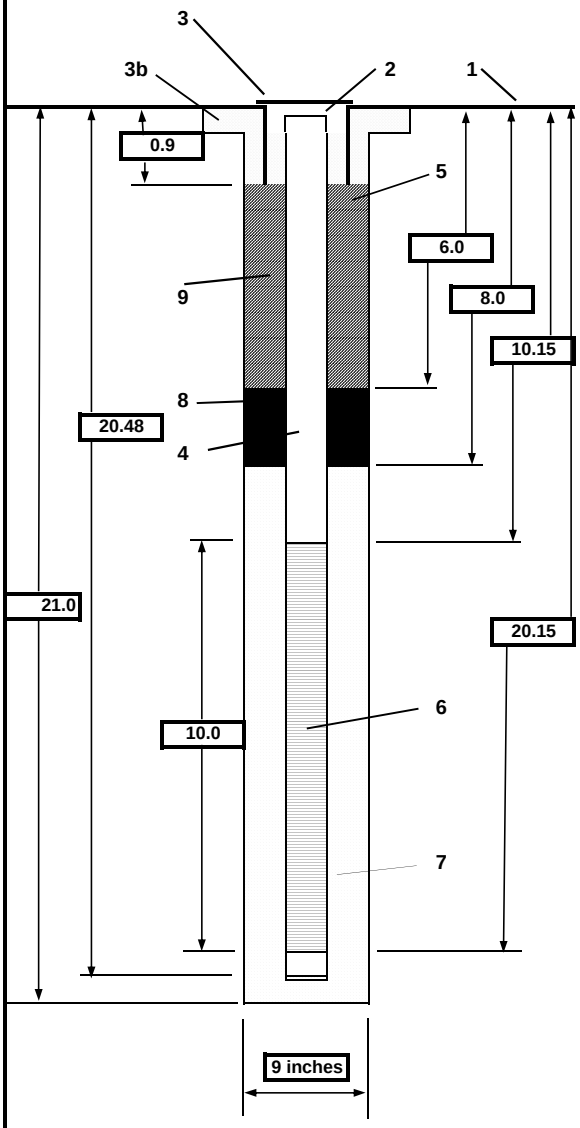
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 5.85 ft BGS (10/6/16) START : 10/6/2016 END : 10/6/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	18.2	
2- Top of casing elevation	17.89	
3- Wellhead protection cover type	Flush Mount Steel Bolt-Down Roadbox	
a) drain tube?	No	
b) concrete pad dimensions	1 ft diameter x 0.3 ft in pavement	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	8.0-inch I.D. Steel	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	22	Gallons
d) Vol. of well casing grout	2.9	Cubic ft
Development method	Submersible Pump	
Development time	10/12/2016	12:00
Estimated purge volume	50 gallons	

Comments

NOT TO SCALE

PROJECT NUMBER	WELL NUMBER	
678440	OW11-MW7	SHEET 1 OF 1

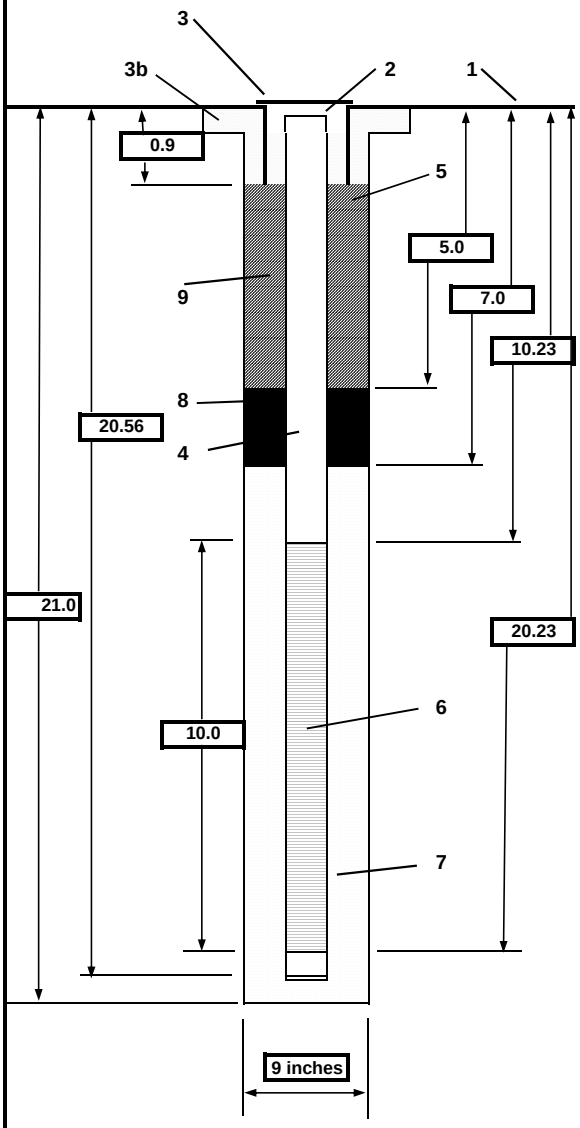
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 5.59 ft BGS (10/6/16) START : 10/5/2016 END : 10/6/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	17.47	
2- Top of casing elevation	17.15	
3- Wellhead protection cover type	Flush Mount Steel Bolt-Down Roadbox	
a) drain tube?	No	
b) concrete pad dimensions	1 ft diameter x 0.3 ft in pavement	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	8.0-inch I.D. Steel	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.0	50 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/12/2016	12:30
Estimated purge volume	58 gallons	

Comments

NOT TO SCALE

PROJECT NUMBER	WELL NUMBER	
678440	OW11-MW8	SHEET 1 OF 1

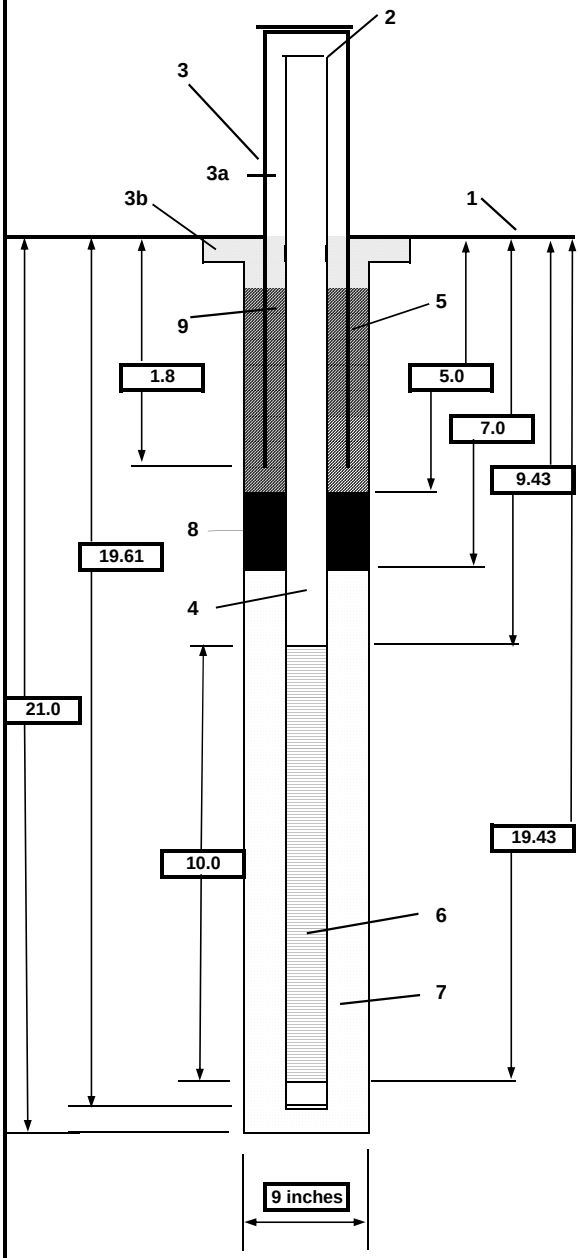
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 4.40 ft BGS (10/6/16) START : 10/5/2016 END : 10/6/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	15.81	
2- Top of casing elevation	18.88	
3- Wellhead protection cover type	4.5-inch square Aluminum Standpipe	
a) drain tube?	No	
b) concrete pad dimensions	2.5 ft diameter x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	4.5-inch x 5-ft square Aluminum	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	5 Bags	250 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/12/2016	10:48
Estimated purge volume	76 gallons	

Comments

PROJECT NUMBER	WELL NUMBER	
678440	OW11-MW9	SHEET 1 OF 1

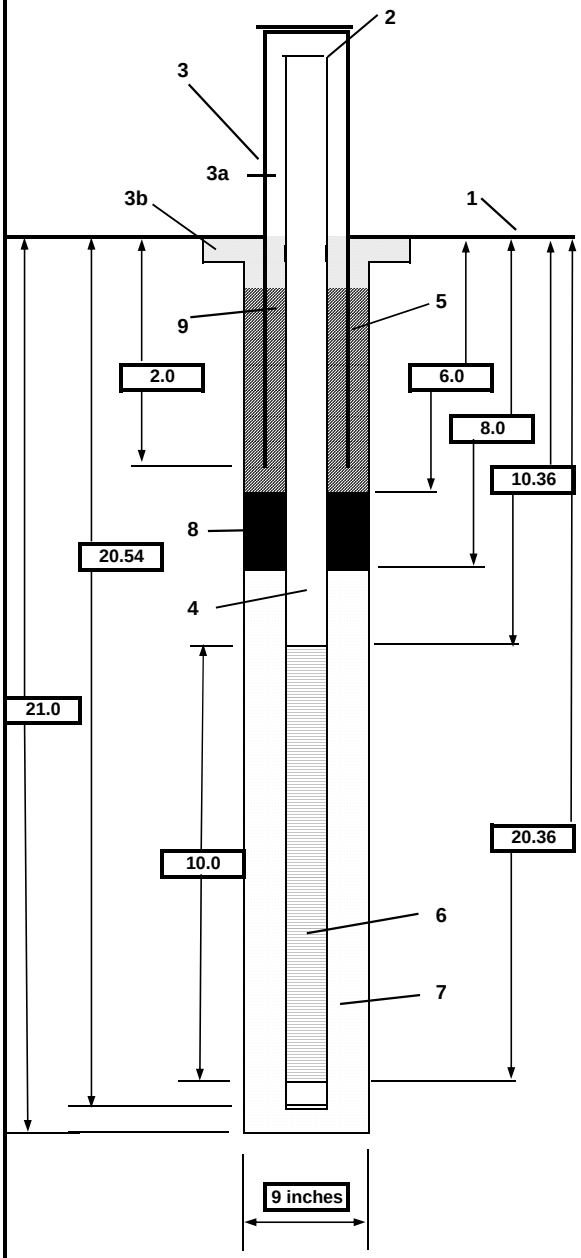
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 4.84 ft BGS (10/6/16) START : 10/4/2016 END : 10/6/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	15.84	
2- Top of casing elevation	18.65	
3- Wellhead protection cover type	4.5-inch square Aluminum Standpipe	
a) drain tube?	No	
b) concrete pad dimensions	2.5 ft diameter x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	4.5-inch x 5-ft square Aluminum	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	4 Bags	200 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	22	Gallons
d) Vol. of well casing grout	2.9	Cubic ft
Development method	Submersible Pump	
Development time	10/12/2016	10:00
Estimated purge volume	40 gallons	

Comments

PROJECT NUMBER	WELL NUMBER	
678440	OW26-MW1	SHEET 1 OF 1

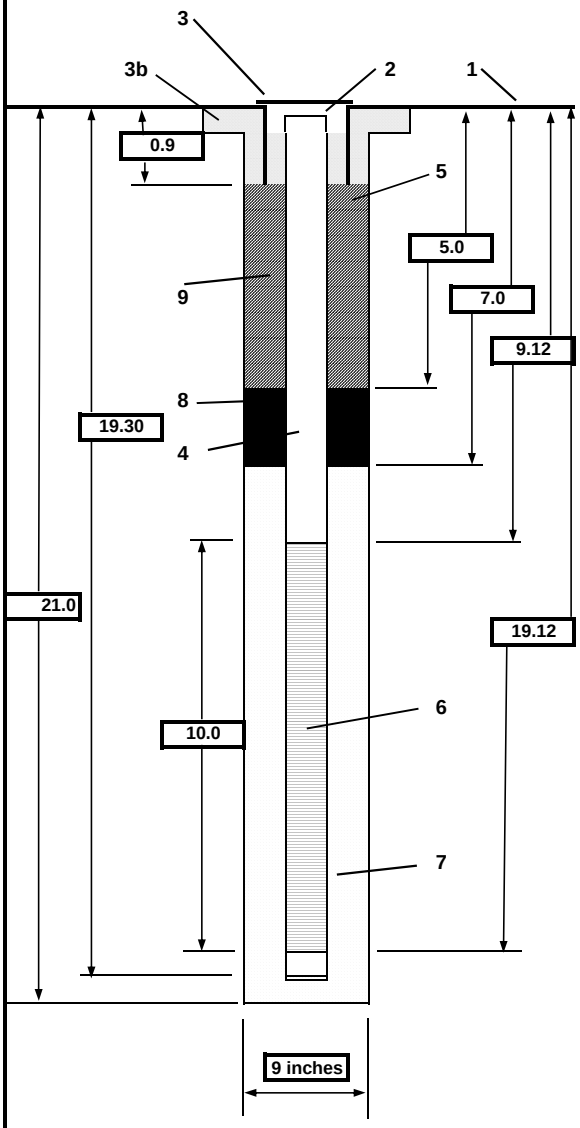
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 3.33 ft BGS (10/11/16) START : 10/11/2016 END : 10/11/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	18.33	
2- Top of casing elevation	18.13	
3- Wellhead protection cover type	Flush Mount Steel Bolt-Down Roadbox	
a) drain tube?	No	
b) concrete pad dimensions	2.5 ft diameter x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	8.0-inch I.D. Steel	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	7 Bags	350 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1 Bag	50 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/13/2016	10:35
Estimated purge volume	58 gallons	

Comments

NOT TO SCALE

PROJECT NUMBER	WELL NUMBER	
678440	OC-MW01	SHEET 1 OF 1

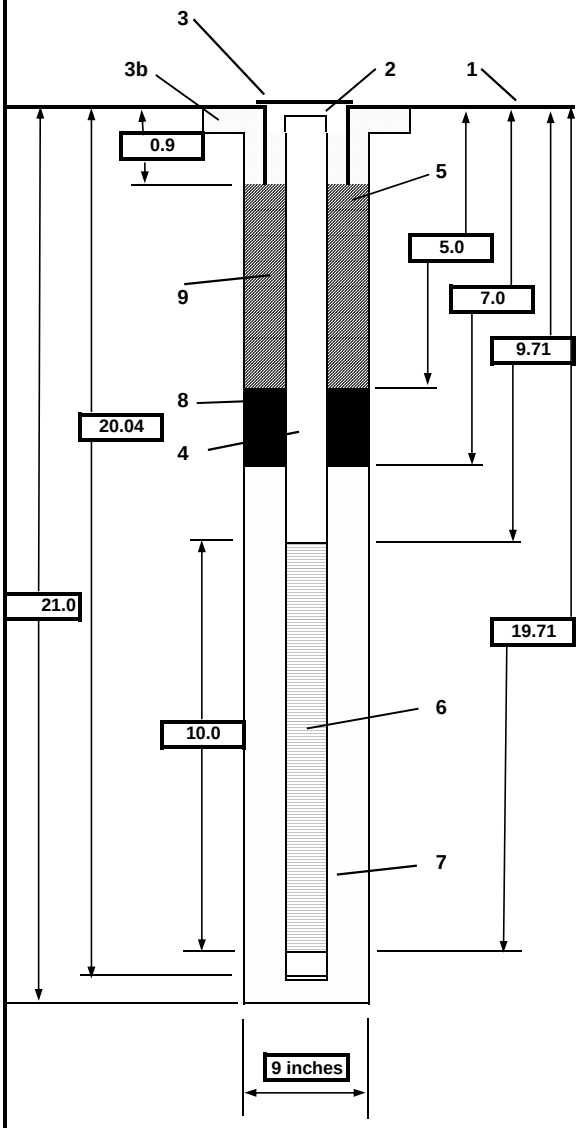
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 9.15 ft BGS (10/13/16) START : 10/11/2016 END : 10/11/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	19.22	
2- Top of casing elevation	18.98	
3- Wellhead protection cover type	Flush Mount Steel Bolt-Down Roadbox	
a) drain tube?	No	
b) concrete pad dimensions	2 ft x 2 ft x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	8.0-inch I.D. Steel	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/13/2016	8:25
Estimated purge volume	52 gallons	

Comments

NOT TO SCALE

PROJECT NUMBER	WELL NUMBER	
678440	OC-MW02	SHEET 1 OF 1

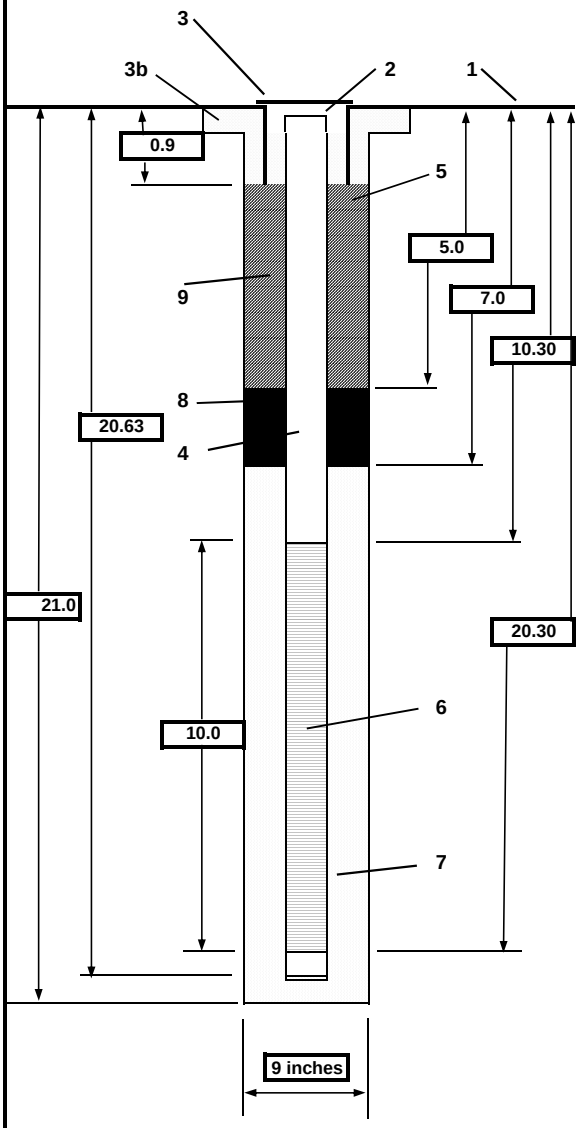
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 6.79 ft BGS (10/13/16) START : 10/12/2016 END : 10/12/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	22.43	
2- Top of casing elevation	22.22	
3- Wellhead protection cover type	Flush Mount Steel Bolt-Down Roadbox	
a) drain tube?	No	
b) concrete pad dimensions	2 ft x 2 ft x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	8.0-inch I.D. Steel	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/13/2016	9:15
Estimated purge volume	54 gallons	

Comments

NOT TO SCALE

PROJECT NUMBER	WELL NUMBER	
678440	OC-MW03	SHEET 1 OF 1

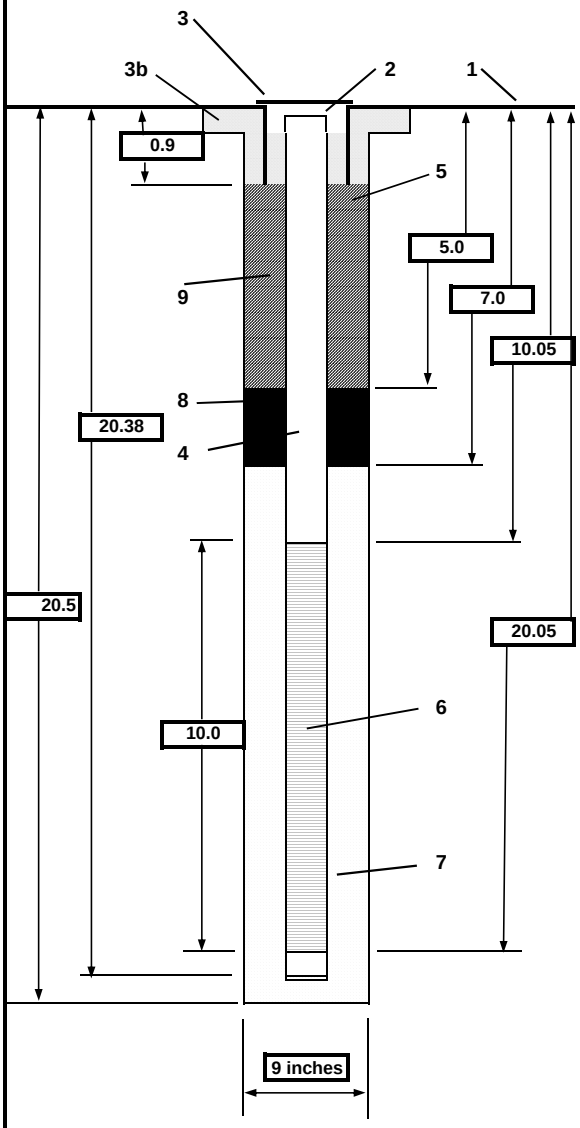
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 3.05 ft BGS (10/14/16) START : 10/13/2016 END : 10/13/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	13.91	
2- Top of casing elevation	13.58	
3- Wellhead protection cover type	Flush Mount Steel Bolt-Down Roadbox	
a) drain tube?	No	
b) concrete pad dimensions	2 ft x 2 ft x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	8.0-inch I.D. Steel	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/14/2016	7:55
Estimated purge volume	58 gallons	

Comments

NOT TO SCALE

PROJECT NUMBER	WELL NUMBER	
678440	OC-MW04	SHEET 1 OF 1

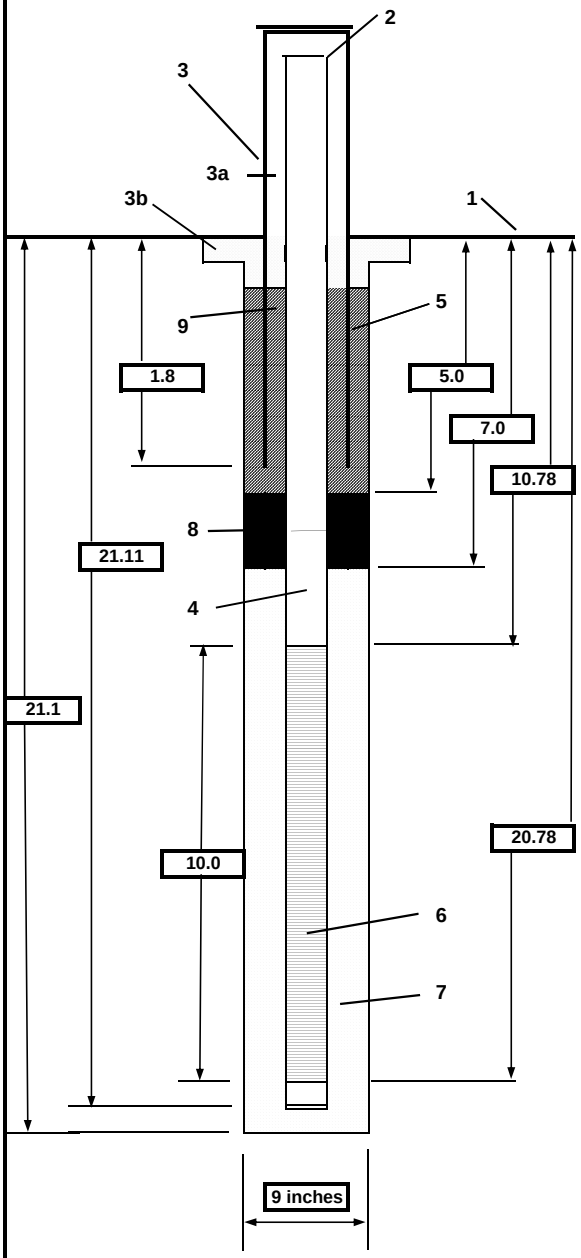
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 1.83 ft BGS (10/13/16) START : 10/12/2016 END : 10/12/2016 LOGGER : **L. Baerga**



1- Ground elevation at well	14.26	
2- Top of casing elevation	17.45	
3- Wellhead protection cover type	4.5-inch square Aluminum Standpipe	
a) drain tube?	No	
b) concrete pad dimensions	2.5 ft diameter x 0.3 ft	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	4.5-inch x 5-ft square Aluminum	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	6 Bags	300 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1.5 Bags	75 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	15	Gallons
d) Vol. of well casing grout	1.7	Cubic ft
Development method	Submersible Pump	
Development time	10/13/2016	11:45
Estimated purge volume	58 gallons	

Comments

PROJECT NUMBER	WELL NUMBER	
678440.SI.SI	OC-MW07	SHEET 1 OF 1

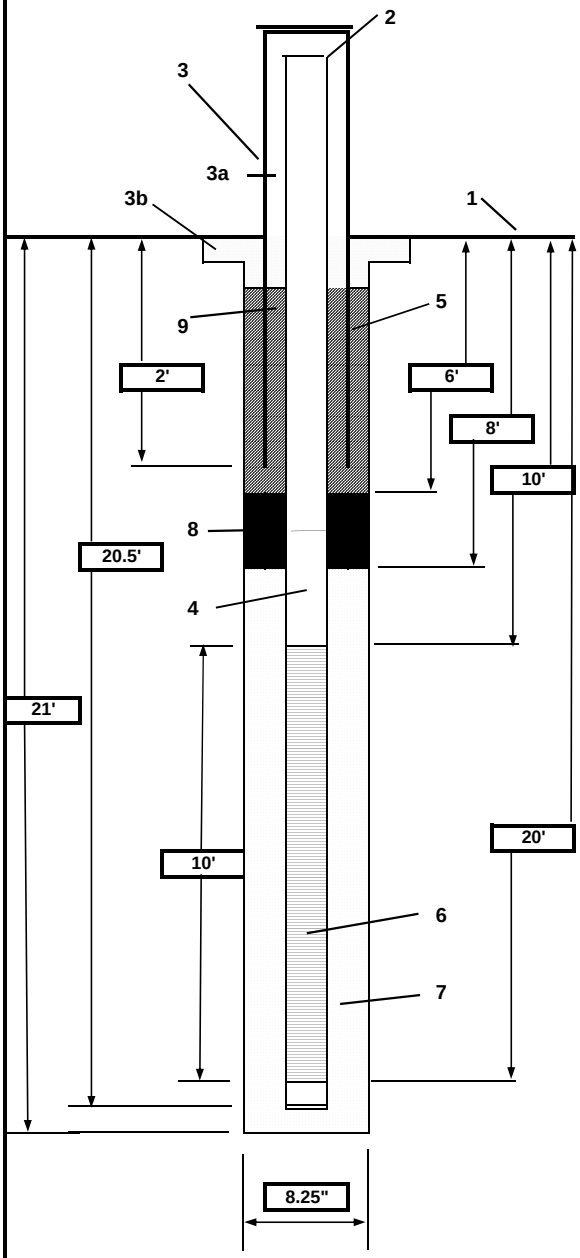
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC Investigation** LOCATION : **Virginia Beach, VA**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell**

WATER LEVELS : 6.0' bgs START : 3/13/2017 END : 3/13/2017 LOGGER : **M. Ost**



1- Ground elevation at well	TBD	
2- Top of casing elevation	TBD	
3- Wellhead protection cover type	4" steel square	
a) drain tube?	No	
b) concrete pad dimensions	2' x 2' square	
4- Dia./type of well casing	2.0-inch I.D. / 2.375-inch O.D.	
	Sched 40 PVC, flush thread w/ o-rings	
5- Dia./type surface casing	4" steel square cover, 3' stickup	
6- Type/slot/size of screen	0.010-inch (10-slot) x 10 ft length	
	Sched 40 PVC, flush thread w/ o-rings	
7- Type screen filter	DSI Well Gravel #1A Silica Sand	
a) Quantity used	5 Bags	250 Lbs.
8- Type of seal	Holeplug 3/8-inch WY Bentonite Chips	
a) Quantity used	1/2 Bag	25 Lbs.
9- Grout		
a) Grout mix used	Portland Cement/Bentonite	
b) Method of placement	Tremie Pump	
c) Quantity used	10	Gallons
d) Vol. of well casing grout	1.33	Cubic ft
Development method	Submersible Pump	
Development time	3/16/2017	8:55
Estimated purge volume	50 gallons	

Comments

PROJECT NUMBER	WELL NUMBER		
678440.SI.SI.02	MW-BG04R	SHEET 1	OF 1

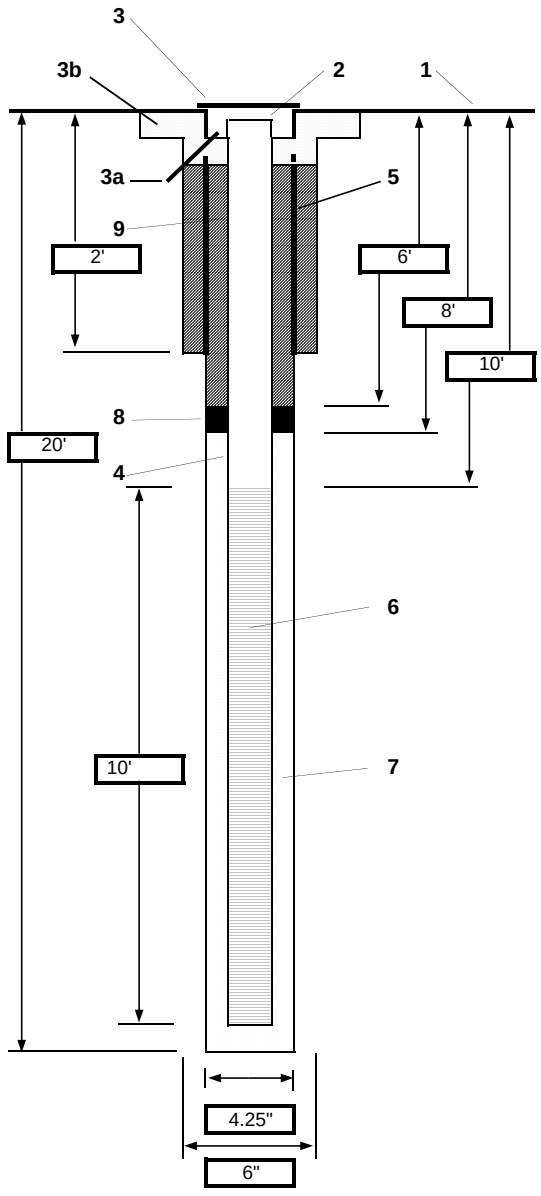
WELL COMPLETION DIAGRAM

PROJECT : NAS Oceana NRB Source Investigation LOCATION : NAS Oceana

DRILLING CONTRACTOR : Geo Explorations

DRILLING METHOD AND EQUIPMENT USED : 4.25" HAS

WATER LEVELS : 9.8' START : 8/8/17 1310 END : 8/8/17 1500 LOGGER : M.L.Ost



1-	Ground elevation at well	25.25
2-	Top of casing elevation	24.99
3-	Wellhead protection cover type	Flush Mount
	a) drain tube?	NA
	b) concrete pad dimensions	2x2" Concrete
4-	Dia./type of well casing	2" Schedule 40 PVC
5-	Dia./type surface casing	NA
6-	Type/slot/size of screen	0.010 Machine Slot Schedule 40 PVC
7-	Type screen filter	#1 Drillers Sand
	a) Quantity used	2 50# Bags
8-	Type of seal	3/8" Bentonite Chips
	a) Quantity used	1 Bag
9-	Grout	
	a) Grout mix used	Portland Cemet Bentonite Mixture
	b) Method of placement	Tremie
	c) Vol.of surface casing grout	NA
	d) Vol. of well casing grout	20 Gallons
	Development method	Whale Pump
	Development time	1 Hour
	Estimated purge volume	55 Gallons

Comments Replacement Well for BG04.

PROJECT NUMBER	BORING NUMBER	
678440	OC-MW01	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 9.15 ft BGS (10/12/16) **START :** 10/11/2016 **END:** 10/11/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION		COMMENTS
						SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
	0	C1	2.8		0.0 - 0.6	Sandy SILT (ML-SM), slightly damp, crumbly, roots 7.5YR 6/6 reddish yellow	
1				FILL	0.6 - 1.8	Asphalt mixed with coarse to fine gravel and sand (GW) dry, crumbly	
2				CL	1.8 - 2.8	CLAY with fine sand, silt (CL), crumbly, damp, mottled 10YR 5/2 grayish brown to 4/1 dark gray	
3				NR	2.8 - 5.0	NO RECOVERY	
4							
5	5						
	5	C2	2.0		5.0 - 7.0	SILT, little fine sand, clay (MH), cohesive, dry crumbly to malleable, cohesive, mottled 5Y 4/1 dark gray with 5/1 gray	
6				MH			
7					7.0 - 10.0	NO RECOVERY	
8							
9							
10	10						
	10	C3	3.0		10.0 - 10.6	Fine SAND, trace silt, poorly graded (SP), damp 2.5Y 6/2 light brownish gray	
11					10.6 - 13.0	Fine SAND, trace coarse to medium sand (SP), moist medium dense, 2.5Y 7/2 light gray	
12				SP			
13					13.0 -15.0	NO RECOVERY	
14							
15	15						
	15	C4	4.3		15.0 - 17.3	Fine SAND, trace coarse to medium sand (SP), moist medium dense, faint layering and oxidation staining 10YR 6/4 light yellowish brown	
16							
17							
18				MH	17.3 - 18.6	Clayey SILT, little fine sand (MH), soft, cohesive, wet 10YR 5/4 yellowish brown	
19				SM	18.6 - 19.3	Fine SAND, some silt, trace medium sand (SM), loose, wet 10YR 6/4 light yellowish brown to 6/6 brownish yellow	
					19.3 - 20.0	NO RECOVERY	Heaving fine sands
20	20					Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OC-MW02	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 6.79 ft BGS (10/12/16) **START :** 10/12/2016 **END:** 10/12/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
0	0	C1	3.7	SM	0.0 - 0.2 Fine SAND, silt loam topsoil (SM), damp, 7.5YR 4/3 brown	
					0.2 - 1.2 SILT, trace to little clay (ML-MH), soft, cohesive, damp dry, crumbly, 7.5YR 5/4 brown	
1					1.2 - 3.2 SILT, trace to little clay (ML-MH), soft, cohesive, damp dry, crumbly, 7.5YR 5/6 strong brown	
2				ML-MH		
3						
4					3.7 - 5.0 NO RECOVERY	
5	5					
5	5	C2	3.6		5.0 - 5.5 Fine SAND, trace silt (SP), loose, damp, faint layering 7.5YR 7/6 reddish yellow	
6					5.5 - 6.1 Fine SAND, trace medium sand (SP), damp 7.5YR 7/6 reddish yellow	
				SP	6.1 - 7.0 Medium SAND, little fine sand, poorly graded (SP), wet 7.5YR 5/3 brown	
7					7.0 - 7.7 Medium SAND, little fine sand, poorly graded (SP), wet faint 2-inch layering, 10YR 5/3 brown	
8					7.7 - 8.6 Medium SAND, trace fine sand, poorly graded (SP), wet 10YR 6/4 light yellowish brown	
9					8.6 - 10.0 NO RECOVERY	
10	10					
10	10	C3	3.0		10.0 - 12.3 Coarse SAND, little medium sand, trace fine sand (SW) dense, wet 10YR 6/4 light yellowish brown	
11				SW		
12						
13					12.3 - 13.0 Fine SAND, trace medium sand, poorly graded (SP), wet medium dense, 10YR 8/4 very pale brown	
					13.0 -15.0 NO RECOVERY	
14						
15	15			SP		
15	15	C4	4.8		15.0 - 16.8 Fine SAND (SP), medium dense, wet oxidation staining, 10YR 7/3 very pale brown	
16						
17				SW	16.8 - 17.6 Medium SAND, trace coarse, fine sand and gravel (SW) wet, mottled with strong oxidation staining 7.5YR 6/6 reddish yellow	
18				CL	17.6 - 18.8 CLAY (CL), little silt, soft, wet, finely laminated 10YR 6/3 pale brown with 10YR 6/6 brownish yellow	
19				SW	18.8 - 19.8 Medium SAND, little coarse, trace fine sand (SW) wet, faint layering, strong oxidation staining 7.5YR 6/4 light brown with 6/8 reddish yellow	
20	20				19.8 - 20.0 NO RECOVERY Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OC-MW03	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 3.05 ft BGS (10/14/16) **START :** 10/13/2016 **END:** 10/13/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code		SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone / Headspace
0	0	C1	3.7	ML-SM	0.0 - 0.2	SILT, fine SAND topsoil (ML-SM), damp, 5YR 3/2 brown	
				ML	0.2 - 1.1	SILT, trace fine sand (ML), soft, crumbly, dry, mottled 7.5YR 5/1 gray with 5/2 brown and 5/6 strong brown	
1					1.1 - 1.7	Clayey SILT (MH), crumbly, hard, cohesive, damp mottled, 7.5YR 6/1 gray with 5/2 brown and 5/6 strong brown	
2				MH	1.7 - 3.0	SILT, little clay (MH), soft, crumbly damp, mottled 7.5YR 5/2 to 4/2 brown	
3							
				ML	3.0 - 3.7	SILT, little fine sand, trace clay (ML), crumbly, soft, damp mottled, 10YR 5/3 brown to 5/6 yellowish brown	
4					3.7 - 5.0	NO RECOVERY	
5	5						
	5	C2	3.7	SM	5.0 - 7.0	Fine sand, little silt (SM), loose, wet 5Y 4/1 dark gray	
6							
7							
				SP	7.0 - 7.5	Fine sand, trace silt (SP), loose, wet 5Y 4/1 to 5/1 dark gray to gray	
8					7.5 - 8.3	Fine sand, trace silt (SP), loose, wet 10YR 6/8 brownish yellow	
				SM	8.3 - 8.7	Fine sandy SILT (SM), soft, crumbly, wet, mottled 10YR 5/3 brown with 5/6 yellowish brown	
9					8.7 - 10.0	NO RECOVERY	Auger cuttings, liquified fine gray sands
10	10						
	10	C3	2.8		10.0 - 12.8	Fine SAND, poorly graded (SP), loose, wet no structure, 10YR 5/1 gray	
11							
12							
					12.8 -15.0	NO RECOVERY	Auger cuttings, liquified fine gray sands
13							
14							
				SP			
15	15						
	15	C4	0.3		15.0 - 15.3	Fine SAND (SP), loose, wet, 10YR 5/1 gray	Auger cuttings, liquified fine gray sands
					15.3 - 20.0	NO RECOVERY	
16							
17							
18							
19							
20	20					Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OC-MW04	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 1.83 ft BGS (10/14/16) **START :** 10/12/2016 **END:** 10/12/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
0	0	C1	5.0	ML	0.0 - 1.1	SILT, trace clay (ML), soft, crumbly, damp 10YR 6/3 pale brown	
1							
				MH	1.1 - 3.1	SILT, little clay (MH), medium stiff, malleable, damp 10YR 6/2 light brownish gray slightly oxidized from 1.6 to 1.7 ft	
2							
3				CL	3.1 - 3.9	CLAY (CL), little silt, dry-damp, stiff, crumbly 10YR 5/2 grayish brown	
4							
5	5				3.9 - 5.0	CLAY (CL), trace silt, dry-damp, stiff, crumbly, cohesive mottled, 2.5Y 7/2 light gray with 10YR 6/6 brownish yellow	
	5	C2	2.5		5.0 - 5.6	CLAY (CL), trace silt, dry-damp, stiff, crumbly, cohesive mottled, 2.5Y 7/2 light gray with 10YR 6/6 brownish yellow	
6				ML	5.6 - 6.2	SILT, trace fine sand (ML), moist, heavily oxidized, mottled faint seams, 10YR 7/2 light gray with 6/6 brownish yellow	
7				SP-SM	6.2 - 7.5	Fine SAND, trace to little silt (SP-SM), wet 10YR 5/1 gray	
8					7.5 - 10.0	NO RECOVERY	
9							
10	10						
	10	C3	4.7		10.0 - 10.7	Fine SAND, trace silt (SP), loose, wet no structure, 2.5Y 5/1 gray	
11					10.7 - 14.7	Fine SAND, poorly graded (SP), wet no structure, 2.5Y 6/1 gray	
12				SP			
13							Auger cuttings, liquified fine gray sands
14							
15	15				14.7 -15.0	NO RECOVERY	
	15	C4	4.4		15.0 - 15.9	Fine SAND, trace silt (SP), loose, wet no structure, 2.5Y 5/1 gray	
16							
17					15.9 - 19.4	Fine SAND, trace to little silt (SP-SM), wet interbedded with 1-2 inch layers of soft silt 10YR 4/1 dark gray	
18				SP-SM			
19							
20	20				19.4 - 20.0	NO RECOVERY Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440.SI.SI.01	OC-MW07	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation Phase II **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 6' bgs **START :** 3/13/2017 **END** 3/13/2017 **LOGGER :** M. Ost

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone / Headspace
0	0	C1	2.0	ML	0.0 - 2.0 SILT (ML), reddish brown (5YR 5/3), dry, loose	
1						
2				NR	2.0 - 5.0 NO RECOVERY	
3						
4						
5	5					
	5	C2	2.0	ML	5.0 - 6.0 SILT (ML), reddish brown (5YR 5/3), dry, loose	
6						
				SM	6.0 - 7.0 SANDY SILT (SM), wet at 6.0' bgs, dark gray (10YR 4/1) loose, fine grain	
7						
				NR	7.0 - 10.0 NO RECOVERY	
8						
9						
10	10					
	10	C3	2.0	CL	10.0 - 12.0 SILTY LEAN CLAY (CL), wet, gray (10YR 5/1), soft, plastic	
11						
12				NR	12.0-15.0 NO RECOVERY	
13						
14						
15	15					
	15	C4	3.0	SM	15.0 - 18.0 SILTY SAND (SM), wet, dark greenishe gray (GLEY 2 4/10BG), loose, fine grain	
16						
17						
18				NR	18.0 - 20.0 NO RECOVERY	
19						
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW11-MW4	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 3.37 ft BGS (10/6/16) **START :** 10/4/2016 **END:** 10/4/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION.
						OVM (ppm): Breathing Zone Headspace
	0	C1	4.3	FILL	0.0 - 0.3 Silt loam topsoil (OL), dry, crumbly, 10YR 4/2 dark grayish brown 0.3 - 0.6 Black asphalt fragments	Cored through buried asphalt to 0.6 ft with 12-inch diameter cutting bit, then advanced soil core barrel to 5 ft
1					0.6 - 1.8 CLAY (CH), stiff, dry, crumbly, 5Y 5/2 olive gray	
2				CH	1.8 - 2.8 CLAY (CH), stiff, slightly damp, massive structure, mottled 10YR 4/2 dark grayish brown with 10YR 6/6 brownish yellow	
3				CL	2.8 - 3.9 CLAY (CL), medium stiff, faint lamination, dry/damp, mottled 10YR 7/1 light gray with 10 YR 6/6 brownish yellow	
4				ML	3.9 - 4.3 SILT (ML), soft, wet, laminated 10YR 5/6 yellowish brown	
5	5				4.3 - 5.0 NO RECOVERY	
	5	C2	3.9		5.0 - 6.1 SILT (ML), trace fine sand, soft, wet, laminated, mottled 10 YR 5/6 yellowish brown with 10 YR 7/1 light gray	
6				SM	6.1 - 6.8 Fine SAND, some silt (SM), loose, wet, faint seams, mottled 10 YR 7/1 light gray with 10 YR 7/6 yellow	
7				SP	6.8 - 7.9 Fine SAND, trace medium sand, trace silt, poorly graded (SP) medium dense, wet, faint layering, 10 YR 7/4 very pale brown	
8					7.9 - 8.9 Fine SAND, trace medium sand, poorly graded (SP), medium dense wet, 10 YR 7/1 light gray	
9					8.9 - 10.0 NO RECOVERY	
10	10					
	10	C3	3.8		10.0 - 13.3 Fine SAND, trace silt, poorly graded (SP), medium dense, wet massive structure, 10 YR 6/1 gray	
11						
12						
13						
14				SM	13.3 - 13.8 Fine SAND, little-some silt (SM), loose, wet 2.5 YR 5/1 gray	
					13.8 - 15.0 NO RECOVERY	
15	15					
	15	C4	5.0	SM-ML	15.0 - 17.2 Fine SAND, little-some silt, interbedded with seams of silt (SM-ML) loose/soft, wet, 2.5 YR 5/1 gray	
16						
17					17.2 - 20.0 SILT, trace clay, trace fine sand (ML), soft, wet seamed/laminated, 2.5 YR 5/1 gray	
18				ML		
19						
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW11-MW5	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 4.38 ft BGS (10/6/16) **START :** 10/4/2016 **END:** 10/4/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
	0	C1	3.9	FILL	0.0 - 0.5 ORGANIC SILT, little fine sand (OL), damp, 5YR 3/1 very dark gray 0.5 - 0.8 Dense Black asphalt layer 0.8 - 1.5 Medium SAND, little coarse sand, trace fine sand (SW) dense, dry, 2.5Y 5/4 light olive brown 1.5 - 1.6 coarse gravel (GP)	
1						
2				MH	1.6 - 2.8 SILT (MH), crumbly, slightly cohesive, medium stiff, damp mottled, 7.5YR 5/2 brown	
3				CL	2.8 - 3.3 CLAY (CL), medium stiff, cohesive, dry/damp, mottled 7.5YR 5/2 brown with 7.5YR 6/6 reddish yellow	
4					3.3 - 3.9 CLAY (CL), medium stiff, cohesive, dry/damp, mottled 7.5YR 6/1 gray with 7.5YR 6/6 reddish yellow	
5	5				3.9 - 5.0 NO RECOVERY	
	5	C2	3.3	ML	5.0 - 5.2 SILT (ML), elastic and lean Clay (CL),damp, mottled 7.5YR 6/1 gray with 7.5YR 6/6 reddish yellow 5.2 - 6.5 SILT (ML),little fine sand, moist, 7.5YR 6/4 light brown	
6						
7				SP	6.5 - 7.6 Fine SAND, poorly graded (SP) loose, moist 2.5YR 7/2 light gray 7.6 - 8.3 Fine SAND, poorly graded (SP), trace silt, moist 2.5Y 5/1 gray	
8					8.3 - 10.0 NO RECOVERY	
9						
10	10					
	10	C3	4.2		10.0 - 14.2 Fine SAND, trace medium sand, poorly graded (SP), wet 2.5Y 7/1 light gray	
11						
12						
13						
14					14.2 - 15.0 NO RECOVERY	
15	15					
	15	C4	4.3		15.0 - 16.2 Fine SAND, trace silt, poorly graded (SP), faintly laminated wet, 2.5Y 5/1 gray	
16						
				SM	16.2 - 18.3 SILT, some fine sand (SM), laminated, soft, wet 5Y 4/1 dark gray	
17						
18				ML-MH	18.3 - 19.3 SILT, increasing clay content (ML-MH), very soft, wet some cohesivenss, laminated, 5Y 4/1 dark gray	
19					19.3 - 20.0 NO RECOVERY	
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW11-MW6	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 5.85 ft BGS (10/6/16) **START :** 10/6/2016 **END:** 10/6/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
	0	C1	3.4		0.0 - 0.6 Asphalt gravel, cobbles, coarse to fine sand (GW)	Cored through 12-inch concrete slab to 1.6 ft with 12-inch diameter cutting bit then advanced soil core barrell to 5 ft
					0.6 - 1.6 12 inch concrete slab	
1				FILL	1.6 - 1.9 SAND, coarse to fine grained, trace fine gravel (SW) black dry crumbly	
2					1.9 - 3.4 CLAY, trace silt (CL), damp, medium stiff 10YR 5/2 grayish brown	
3						
					3.4 - 5.0 NO RECOVERY	
4				CL		
5	5				5.0 - 5.1 CLAY (CH), damp, malleable, cohesive, medium stiff 10YR 5/2 grayish brown	
	5	C2	3.2		5.1 - 6.1 CLAY, trace silt (CL), damp, malleable, crumbly, mottled 10Y 5/2 grayish olive with 2.5Y 6/4 light yellowish brown	
6						
				ML	6.1 - 7.2 SILT, trace clay, trace fine sand (ML), moist, soft to medium dense, GLEY 1 5/1 greenish gray	
7				SM	7.2 - 8.1 Fine SAND, little silt (SM), wet, loose to medium dense GLEY 1 5/1 greenish gray	
8					8.1 - 8.2 Fine SAND, poorly graded (SP), wet 2.5Y 5/1 gray	
					8.2 - 10.0 NO RECOVERY	
9						
10	10					
	10	C3	3.5		10.0 - 13.5 Fine SAND, trace coarse to medium sand (SP), wet massive structure, medium dense, 2.5Y 5/1 to 6/1 gray	
11						
12						
13				SP		
					13.5 - 15.0 NO RECOVERY	Auger cuttings are gray, liquified fine sand
14						
15	15					
	15	C4	4.9		15.0 - 17.8 Fine SAND, trace silt, poorly graded (SP), wet loose to medium dense, 5Y 5/1 gray	
16						
17						
18				SM	17.8 - 18.8 Fine SILTY SAND (SM), laminated, soft, wet, liquified 5Y 4/1 dark gray	
19				ML	18.8 - 19.9 SILT, trace fine sand (ML), inclusions of red-brown peat very soft, wet	
					19.9 - 20.0 NO RECOVERY	Auger cuttings are gray, liquified fine sand, silt
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW11-MW7	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 5.59 ft BGS (10/6/16) **START :** 10/5/2016 **END:** 10/5/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone / Headspace
0	0	C1	2.0	FILL	0.0 - 1.2 Cobbles, coarse to fine gravel, coarse to fine sand (GW)	
1				CL	1.2 - 1.5 CLAY (CL), trace silt, fine sand, crumbly, dry, hard 2.5Y 5/2 grayish brown	
2				MH	1.5 - 2.0 SILT (ML), trace clay, crumbly, hard, dry 10YR 3/1 very dark gray	
3				CH	2.0 - 5.0 NO RECOVERY	Auger cuttings from 2.0 to 5.0 ft: CLAY (CH), moist, cuttings are cohesive, soft clumps 10YR 4/2 dark grayish brown to 3/1 very dark gray
4						
5	5					
6	5	C2	3.0	ML-SM	5.0 - 7.3 SILT, trace to little fine sand (ML-SM), medium dense, wet, 10Y 5/2 grayish olive grading to fine sand by 7.3 ft	
7						
8					7.3 - 8.0 Fine SAND, poorly graded (SP), loose, wet no bedding structure, 5Y 7/1 light gray	
9					8.0 - 10.0 NO RECOVERY	Auger cuttings are gray, wet fine sand
10	10					
11	10	C3	4.0	SP	10.0 - 14.0 Fine SAND, trace medium sand, poorly graded (SP), wet dense, 2.5Y 6/1 gray	
12						
13						
14					14.0- 15.0 NO RECOVERY	
15	15					
16	15	C4	0.0		15.0- 20.0 NO RECOVERY	Auger cuttings are liquified dark gray silt and fine sand, consistency of slurry
17				ML-SM		
18						
19						
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW11-MW8	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 4.40 ft BGS (10/6/16) **START :** 10/5/2016 **END:** 10/5/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
	0	C1	4.8	OL	0.0 - 0.3 SILT topsoil (OL), slightly damp, crumbly 7.5YR 3/2 dark brown	
				ML	0.3 - 0.9 SILT, trace clay (ML), dry, crumbly 7.5YR 5/2 brown	
1					0.9 - 3.4 CLAY (CL), damp, medium stiff, cohesive, mottled 7.5YR 5/2 brown with 7.5YR 6/6 reddish yellow	
2						
3				CL		
					3.4 - 4.6 CLAY (CL), damp, medium stiff, cohesive, mottled 10YR 7/1 light gray with 10YR 6/6 brownish yellow occassional lenses of dark brown silt	
4						
				ML	4.6 - 4.8 SILT (ML), trace fine sand, damp, crumbly 10YR 5/3 brown	
5	5				4.8 - 5.0 NO RECOVERY	
	5	C2	3.0	ML-SM	5.0 - 5.4 SILT, little very fine sand (ML-SM), damp 10YR 5/2 grayish brown	
6					5.4 - 6.6 Fine SAND, poorly graded (SP), damp, medium dense 10YR 7/3 very pale brown	
					6.6 - 6.9 Fine SAND, poorly graded (SP), damp, medium dense 10YR 6/6 brownish yellow	
7					6.9 - 8.0 Fine SAND, trace medium sand, poorly graded (SP), moist medium dense, 10YR 5/1 gray	
8						
					8.0 - 10.0 NO RECOVERY	Auger cuttings are gray, wet fine sand
9						
10	10			SP		
	10	C3	3.9		10.0 - 13.9 Fine SAND, trace medium sand, trace silt (SP), wet medium dense, no bedding structure 10YR 6/1 gray	
11						
12						
13						
						Auger duttings are gray, wet fine sand, silt
14					13.9 - 15.0 NO RECOVERY	liquified to a slurry consistency
15	15					
	15	C4	4.8	SP-SM	15.0 - 16.6 Fine SAND, trace to little silt (SP-SM), wet loose, no bedding structure 2.5Y 5/1 gray	
16						
					16.6 - 19.8 SILT, little very fine sand (ML-SM), soft, weak, wet, 2.5Y 4/1 dark gray	
17						
18				ML-SM		
19						
					19.8 - 20.0 NO RECOVERY	
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW11-MW9	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 4.84 ft BGS (10/6/16) **START :** 10/4/2016 **END:** 10/4/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
0	0	C1	4.1	OL-OH	0.0 - 0.4 SILT, clay topsoil (OL), slightly damp, crumbly, medium hard 10YR 4/2 dark grayish brown	
1					0.4 - 4.1 CLAY (CL), damp, medium to stiff, cohesive, mottled 10YR 5/2 grayish brown with 10YR 6/6 brownish yellow	
2				CL		
3						
4					4.1 - 5.0 NO RECOVERY	
5	5					
	5	C2	2.8		5.0 - 6.5 Medium SAND, trace fine sand and silt, poorly graded (SP) moist, medium dense, color changes with depth from 10YR 7/4 very pale brown to 10YR 7/6 yellow	
6						
7					6.5 - 7.8 Medium SAND, poorly graded (SP), wet, medium dense no bedding structure, 2.5Y 6/1 gray	
8					7.8 - 10.0 NO RECOVERY	Auger cuttings are gray, wet fine sand
9				SP		
10	10					
	10	C3	3.8		10.0 - 13.8 Medium SAND, poorly graded (SP), wet, grading to fine sand from 12.3 ft, no bedding structure 2.5Y 6/1 gray	
11						
12						
13						
14					13.8 - 15.0 NO RECOVERY	Auger duttings are gray, wet fine sand, silt liquified to a slurry consistency
15	15					
	15	C4	2.7		15.0 - 17.2 Fine SAND, little silt (SM), wet, loose, no bedding structure 2.5Y 4/1 dark gray	
16				SM		
17						
					17.2 - 17.7 SILT, some fine sand (ML-SM), soft, weak, wet, 2.5Y 4/1 dark gray	
18					17.7 - 20.0 NO RECOVERY	Auger duttings are gray, wet fine sand, silt liquified to a slurry consistency
19				ML-SM		
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OW26-MW1	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana PFC Investigation **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 9.0-in OD/4.25-in ID Augers, 2-inch x 5-ft sealed soil core barrell

WATER LEVELS: 3.32 ft BGS (10/12/16) **START :** 10/11/2016 **END:** 10/11/2016 **LOGGER :** L. Baerga

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): Breathing Zone Headspace
	0	H1	N/A	SM	0.0 - 0.3 Sandy loam topsoil (SM), slightly damp, crumbly, roots 5YR 3/2 dark reddish brown	Hand auger to 5 ft. Difficult to cut through soils from 0.3 to 4.0 ft (dense soils) Wet soil at 4.0 ft
1					0.3 - 3.3 Medium SAND, little fine sand, trace silt (SP), dense, wet 2.5Y 4/3 reddish brown	
2				SP		
3					3.3 - 4.0 Medium SAND, little fine sand, trace silt (SP), dense, wet 7.5YR 6/4 light brown	
4					4.0 - 5.0 SILT, little clay (MH),wet, soft 5YR 4/2 dark reddish gray	
5	5			MH		
	5	C2	3.1	SP	5.0 - 5.6 Fine SAND, trace medium sand, poorly graded (SP), wet medium dense, 7.5YR 5/2 brown	
6				CL	5.6 - 5.9 CLAY, trace silt (CL), damp, soft, cohesive 7.5YR 3/1 very dark gray	
					5.9 - 6.4 CLAY (CL), medium stiff, cohesive, damp, laminated Gley 1 8/1 light greenish gray and 2.5Y 6/6 olive yellow	
7					6.4 - 7.1 Fine SAND, trace to little silt (SP-SM), loose, wet 2.5Y 5/1 gray	
					7.1 - 8.1 Fine SAND, trace silt (SP), loose, wet 2.5Y 7/2 light gray	
8					8.1 - 10.0 NO RECOVERY	Auger cuttings are liquified fine gray sand
9						
10	10					
	10	C3	0.0		10.0 - 15.0 NO RECOVERY	Auger cuttings are liquified fine gray sand
11						
12						
13				SP		
14						
15	15					
	15	C4	4.3		15.0 - 16.0 Medium SAND, little fine sand (SP), wet, loose 2.5Y 6/1 gray	Auger duttings are gray, wet fine sand liquified to a slurry consistency
16					16.0 - 19.3 Fine SAND (SP), wet, loose 2.5Y 6/1 gray	
17						
18						
19					19.3 - 20.0 NO RECOVERY	
20	20				Bottom of Exploration: 20.0 ft	

PROJECT NUMBER	BORING NUMBER	
678440	OC-MW-BG04R	SHEET 1 OF 1

SOIL BORING LOG

PROJECT : NAS Oceana Natural Resources Building **LOCATION :** NAS Oceana

ELEVATION : **DRILLING CONTRACTOR :** Geologic Exploration

DRILLING METHOD AND EQUIPMENT USED : Hollow Stem Auger Drilling 6.0-in OD/4.25-in ID Augers

WATER LEVELS: 7.0 ft BGS (8/2/17) **START :** 8/2/2017 **END:** 8/2/2017 **LOGGER : M.Ost**

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SAMPLE RECOVERY (FT)	USCS Code	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. OVM (ppm): 3reathing Zon Headspace
	0	1	N/A		0.0 - 1.0 soil/dry wood material	
1						
					1.0-4.0 Silt, ML, reddish gray, dry, medium dense, some iron matte 5yr/5/2	
2						
				ML		
3						
4						
					4.0-5.0 SAND, SP, very pale brown, moist, loose 10yr/7/3	
5	5			SP		
	5	2			5.0-8.0 SAND, SP, very pale brown, water table at 7.0 ft bgs 10yr/7/3	
6						
7						
8						
					8.0-10.0 SAND, SP, light red, saturated, organic stain at bottom 2.5y/6/6	
9						
				SP		
10	10					
	10	3			10.0-14.0 SAND, SP, light red, saturated, organic stain at bottom 2.5y/6/6	
11						
12						
13						
14						
				CL	14.0-14.5 Clay, CL, light greenish gray, saturated Gley 1 7/5G soft	
					14.5-15.0 SAND, SP, light greenish gray, saturated, loose, mediium grain Gley 1 7/5G soft	
15	15					
	15	4			15.0-17.0 SAND, SP, pink, saturated, loose, mediium grain 7.5yr/7/4	
16				SP		
17						
					17.0-19.0 Clay, CL, bluish gray, saturated, soft Gley 2/5/10B	
18				CL		
19						
				SP	19.0-20.0 SAND, SP, bluish gray, saturated Gley 2/6/10B	
20	20					
	20	5			20.0-22.0 SAND, SP, bluish gray, saturated, coarse Gley 2/6/10B	
21						
22						
				CL	22.0-24.0 SAND, SP, bluish gray, saturated, very soft Gley 2/6/10B	
23						
24						
					24.0-25.0 SAND, SP, saturated, loose, medium grain	
25	25				Bottom of Exploration: 25.0 ft	

Appendix C
Yorktown Monitoring Well Completion Diagrams and Soil Boring Logs

PROJECT NUMBER	WELL NUMBER		
678440.SI.SI.01	OW11-MW10D	SHEET 1	OF 1

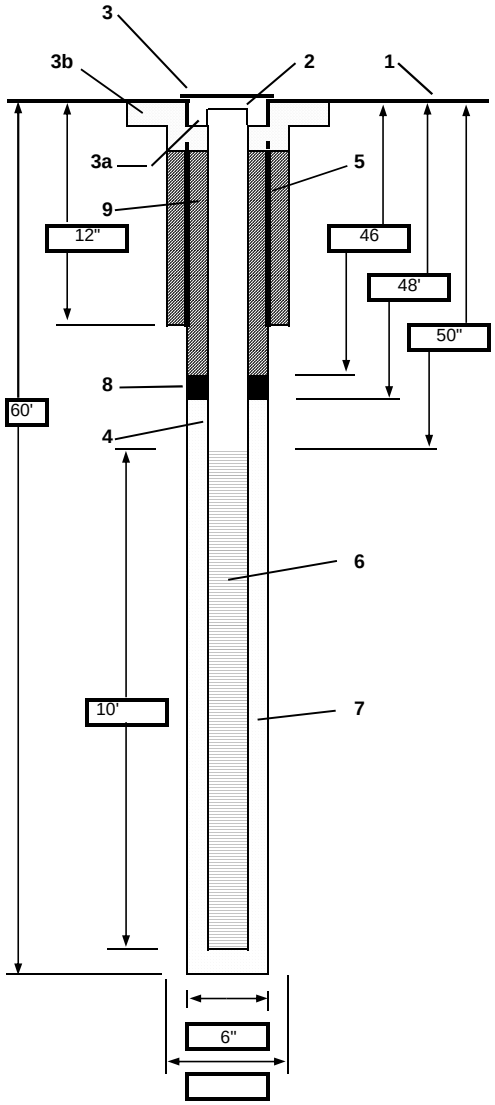
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC** LOCATION : **NAS Oceana**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **4.25" Hollow Stem Auger**

WATER LEVELS : 7 START : 1300 3/14/17 END : 1845 3/14/17 LOGGER : **M.L. Ost**



1- Ground elevation at well

2- Top of casing elevation

3- Wellhead protection cover type: Flush Mount
- a) drain tube?: NA
- b) concrete pad dimensions: 2x2 Concrete

4- Dia./type of well casing: 2" Schedule 40 PVC

5- Dia./type surface casing: NA

6- Type/slot/size of screen: 0.010 Machine Slot PVC. Schedule 40

7- Type screen filter: # 1 Drillers Sand
- a) Quantity used: 8. 50lbs. Bags

8- Type of seal: 3/8" Bentonite Chips
- a) Quantity used: 1 Bag

9- Grout
- a) Grout mix used: Portland and Bentonite
- b) Method of placement: Tremie
- c) Vol.of surface casing grout:
- d) Vol. of well casing grout: 75 Gallons

Development method: Whale Pump

Development time: 1 Hour

Estimated purge volume: 55 Gallons

Comments

PROJECT NUMBER	WELL NUMBER	
678440.SI.SI.01	OW26-MW1D	SHEET 1 OF 1

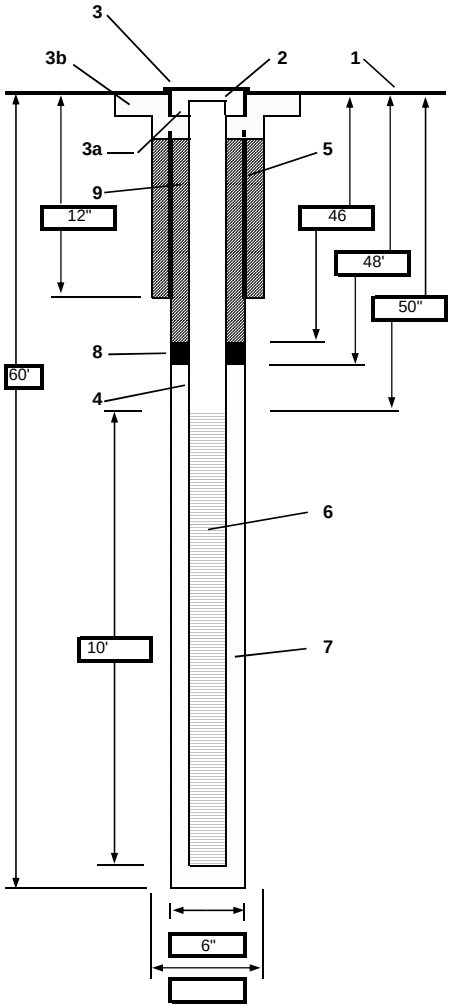
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC** LOCATION : **NAS Oceana**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **4.25" Hollow Stem Auger**

WATER LEVELS : 7 START : 0740 3/08/17 END : 1720 3/08/17 LOGGER : M.L. Ost



1- Ground elevation at well

2- Top of casing elevation

3- Wellhead protection cover type: Flush Mount
- a) drain tube? NA
- b) concrete pad dimensions: 2x2 Concrete

4- Dia./type of well casing: 2" Schedule 40 PVC

5- Dia./type surface casing: NA

6- Type/slot/size of screen: 0.010 Machine Slot PVC. Schedule 40

7- Type screen filter: # 1 Drillers Sand
- a) Quantity used: 8. 50lbs. Bags

8- Type of seal: 3/8" Bentonite Chips
- a) Quantity used: 1 Bag

9- Grout
- a) Grout mix used: Portland and Bentonite
- b) Method of placement: Tremie
- c) Vol.of surface casing grout:
- d) Vol. of well casing grout: 55 Gallons

Development method: Whale Pump

Development time: 1 Hour

Estimated purge volume: 55 Gallons

Comments: Fire Station Deep Well

PROJECT NUMBER	WELL NUMBER		
678440.SI.SI.01	OC-MW02D	SHEET 1	OF 1

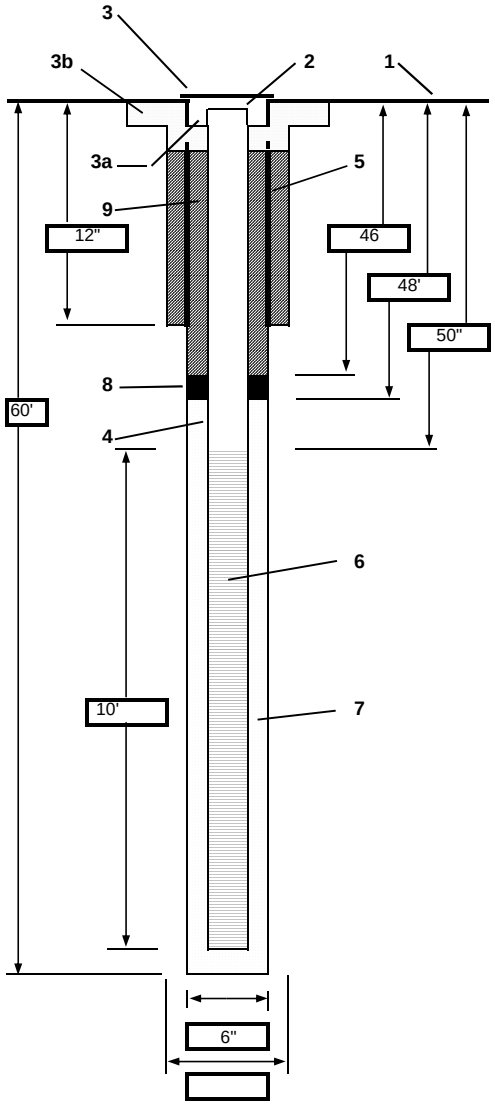
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC** LOCATION : **NAS Oceana**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : 4.25" **Hollow Stem Auger**

WATER LEVELS : 7 START : 1234 3/20/17 END : 0904 3/21/17 LOGGER : M.L. Ost



1- Ground elevation at well

2- Top of casing elevation

3- Wellhead protection cover type: Flush Mount
- a) drain tube?: NA
- b) concrete pad dimensions: 2x2 Concrete

4- Dia./type of well casing: 2" Schedule 40 PVC

5- Dia./type surface casing: NA

6- Type/slot/size of screen: 0.010 Machine Slot PVC. Schedule 40

7- Type screen filter: # 1 Drillers Sand
- a) Quantity used: 7. 50lbs. Bags

8- Type of seal: 3/8" Bentonite Chips
- a) Quantity used: 1 Bag

9- Grout
- a) Grout mix used: Portland and Bentonite
- b) Method of placement: Tremie
- c) Vol.of surface casing grout:
- d) Vol. of well casing grout: 70 Gallons

Development method: Whale Pump

Development time: 1 Hour

Estimated purge volume: 55 Gallons

Comments: Vacapes

PROJECT NUMBER	WELL NUMBER		
678440.SI.SI.01	OC-MW05D	SHEET 1	OF 1

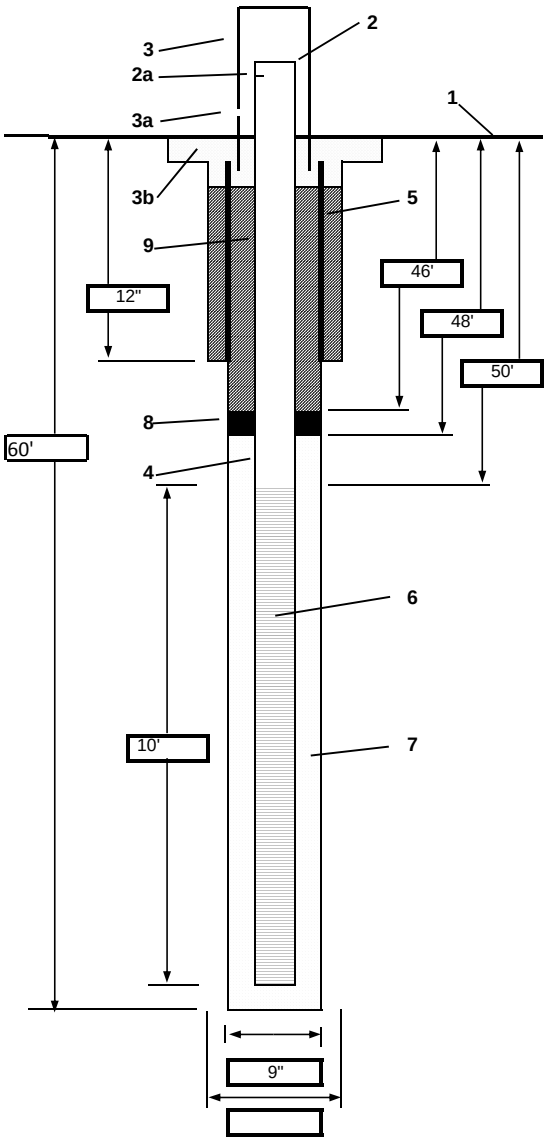
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC** LOCATION : **NAS Oceana - Potters Road**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **4.25" Hollow Stem Auger**

WATER LEVELS : 7 START : 1215 3/16/17 END : 1650 3/16/17 LOGGER : M.L. Ost



1- Ground elevation at well

2- Top of casing elevation
a) vent hole?

3- Wellhead protection cover type: Steel
a) weep hole?: No
b) concrete pad dimensions: 2x2

4- Dia./type of well casing: 2" schedule 40 PVC

5- Dia./type of surface casing: 4" Square

6- Type/slot size of screen: 0.010 machine slot schedule 40 PVC

7- Type screen filter: #1 Drillers Sand
a) Quantity used: 6 bags

8- Type of seal: 3/8" Bentonite Chip
a) Quantity used: 1 bag

9- Grout
a) Grout mix used: Portland/Bentonite High Yield Powder
b) Method of placement: Tremie
c) Vol. of surface casing grout
d) Vol. of well casing grout: 55 gallons

Development method: Whale pump

Development time: 1 hour

Estimated purge volume: 55 gallons

Comments: Potters Road

PROJECT NUMBER	WELL NUMBER		
678440.SI.SI.01	OC-MW07D	SHEET 1	OF 1

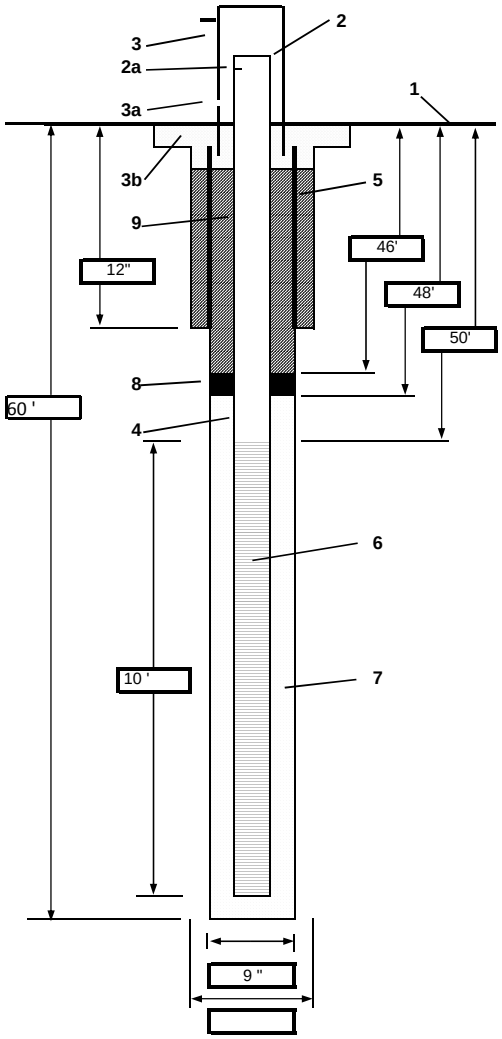
WELL COMPLETION DIAGRAM

PROJECT : **NAS Oceana PFC** LOCATION : **NAS Oceana - End of Runway**

DRILLING CONTRACTOR : **Parratt Wolff**

DRILLING METHOD AND EQUIPMENT USED : **4.25" Hollow Stem Auger**

WATER LEVELS : 7 START : 1145 3/13/17 END : 0930 3/14/17 LOGGER : M.L. Ost



1- Ground elevation at well

2- Top of casing elevation
a) vent hole?

3- Wellhead protection cover type: Steel
a) weep hole? No
b) concrete pad dimensions 2x2

4- Dia./type of well casing: 2" schedule 40 PVC

5- Dia./type of surface casing: 4" Square

6- Type/slot size of screen: 0.010 machine slot schedule 40 PVC

7- Type screen filter: #1 Drillers Sand
a) Quantity used: 6 bags

8- Type of seal: 3/8" Bentonite Chip
a) Quantity used: 1 bag

9- Grout
a) Grout mix used: Portland/Bentonite High Yield Powder
b) Method of placement: Tremie
c) Vol. of surface casing grout
d) Vol. of well casing grout: 55 gallons

Development method: Whale pump

Development time: 1 hour

Estimated purge volume: 55 gallons

Comments: End of Runway

PROJECT NUMBER	BORING NUMBER	
678440.SI.SI.01	OW26-MW01D	SHEET 1 OF 2

SOIL BORING LOG

PROJECT : Oceana PTC MW Install — LOCATION : Fire Station Well (Near OW26-MW1)

ELEVATION : — DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED :

WATER LEVELS : NA — START : 3/8/17 — END : 3/8/17 — LOGGER : M. Ost/VBO

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (FT)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENISTY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION.
0					Boring initiated at depth of paired shallow well	PID=0.0 ppm
20	20-25'	2'			**20.0 - 25.0':** SAND (SP), light gray (10YR 7/1), saturated, loose, fine	
25	25-30'	2.5'			**25.0-25.5':**SAND (SP), gray (10YR 5/1), saturated, fine, loose, thin layer clay **25.5-30':** Silty SAND (SM), dark grey (GLEY 4/N), saturated, fine, slightly plastic	
30	30-35'	0.5'			**30.0-30.5':** Silty SAND (SM), dark grey (GLEY 4/N), saturated, fine, not plastic **30.5-35.0':** no recovery	
35	35-40'	2'			**35.0-37.0':** Sandy SILT (ML), dark grey (GLEY 4/N), saturated, fine, loose, shelly material **38-40':** no recovery	
40						

					40.0-41.5': Silty CLAY (CL), dark grey (GLEY 4/N), saturated, fine, slightly plastic, shelly material	
	40-45'	1.5'			**41.5-45.0':** no recovery	
45						
					45.0-46.0': Sandy SILT (ML), dark gray (GLEY 4/N), saturated, very fine, loose	
	45-50'	1			**46.0-50.0':** no recovery	
50						

Bottom of boring at 50.0 ft bgs

Notes:

bgs - below ground surface

PID - photoionization detector

NA - not applicable

HA - hand auger

MC - macrocore sample

ppm - parts per million

NM - not measured

PROJECT NUMBER	BORING NUMBER	
678440.SI.SI.01	OW11-MW10D	SHEET 1 OF 2

SOIL BORING LOG

PROJECT : Oceana PTC MW Install | LOCATION : NW Site 11 Deep

ELEVATION : | DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED :

WATER LEVELS : NA | START : 3/14/17 | END : 3/14/17 | LOGGER : M. Ost/VBO

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (FT)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENISTY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION.
0					Boring initiated at depth of paired shallow well	PID=0.0 ppm
20	20-25'	2'			**20.0 - 21.0':** SAND (SP), yellow (10YR 8/5), saturated, loose	
					21.0 - 22.0': SAND (SP), very dark gray (10YR 3/1), loose, medium sand	
					22.0-25.0': no recovery	
25	25-30'	1'			**25.0-26.0':** SILT (ML), very dark greenish gray	
					26.0-30.0': No recovery	
30	30-35'	2'			**30.0-32.0':** SILT (ML), dark grey (5YR 4/1), saturated, loose, lens of very fine sand	
					32.0-35.0': no recovery	
35	35-40'	2'			**35.0-36.0':** SAND (SP), greenish gray (GLEY2 5/10GB), saturated, loose, fine	
					36.0-37.0': SILT (ML), gray (GLEY2 5/10GB), saturated, loose	
40					**37.0-40.0':** no recovery	

45	40-45'	1'			**40.0-41.0':** Sandy SILT (ML), greenish gray (GLEY2 5/10GB), loose, fine, shell	
					41.0-45.0': no recovery	
	45-50'	1'			**45.0-46.0':** Sandy SILT (ML), greenish gray (GLEY2 5/10GB), loose, fine, shell	
50					**46.0-50.0':** no recovery	
	50-55'	1'			**50.0-51.0'**: Sandy silt (ML), greenish gray (GLEY2 5/10GB), loose, fine, shell	
55					**51.0-55.0':** no recovery	
	55-60'	1'			**55.0-56.0'**: Sandy SILT (ML), greenish gray (GLEY2 5/10GB), loose, fine, shell	
60					**Bottom of boring at 56.0 ft bgs**	

Notes:

bgs - below ground surface

PID - photoionization detector

NA - not applicable

HA - hand auger

MC - macrocore sample

ppm - parts per million

NM - not measured

PROJECT NUMBER	BORING NUMBER	
678440.SI.SI.01	OC-MW02D	SHEET 1 OF 3

SOIL BORING LOG

PROJECT : Oceana PTC MW Install | LOCATION :

ELEVATION : | DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED :

WATER LEVELS : NA | START : 3/20/17 | END : 3/20/17 | LOGGER : M. Ost/VBO

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (FT)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENISTY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION.
0					Boring initiated at depth of paired shallow well	PID=0.0 ppm
20	20-25'	5'			**20.0-25.0':** SAND (SP), redddish yellow (7.5YR 8/6), saturated, loose, coarse sand, iron stain	
25	25-30'	5'			**25.0-30.0':** SAND (SP), redddish yellow (7.5YR 8/6), saturated, loose, very coarse sand, iron stain, thins lens of find sand	
30	30-35'	3'			**30.0-33.0':** SILT (ML), dark greenish grey (GLEY2 4/10BG), saturated, soft, some fine sand	
35					**33.0-35.0':** no recovery	
	35-40'	3'			**35.0-38.0':** Clayey SILT (ML), gray (10YR 5/1), saturated, soft, slight clay, not plastic	
40					**38.0-40.0':** no recovery	

45	40-45'	5'			**40.0-45.0':** Silty SAND (SM), dark gray (10YR 4/1), saturated, fine sand, no plasticity	
50	45-50'	2'			**45.0-46.0':** SAND (SP), yellow (10YR 7/6), saturated, loose, fine **46.0-47.0':** Silty SAND (SM), gray (10YR 6/3), saturated, soft, non-plastic, slight clay at bottom 1" **47.0-50.0':** no recovery	
55	50-55'	2'			**50.0-51.0'**: SILT (ML), gray (10YR 5/1), saturated, some fine sand, not plastic **51.0-52.0':** SAND (SP), gray, (10YR 5/1), saturated, loose, very fine **52.0-55.0':** no recovery	
60	55-60'	2'			**55.0-56.0'**: SAND (SP), gray (10YR 5/1), saturated, loose, fine **56.0-57.0'**: Silty SAND (SM), gray (10YR 5/1), saturated, loose, fine sand, no plasticity **57.0-60.0':** no recovery	

Bottom of boring at 60.0 ft bgs

Notes:

bgs - below ground surface

PID - photoionization detector

NA - not applicable

HA - hand auger

MC - macrocore sample

ppm - parts per million

NM - not measured

PROJECT NUMBER	BORING NUMBER	
678440.SI.SI.01	OC-MW05D	SHEET 1 OF 3

SOIL BORING LOG

PROJECT : Oceana PTC MW Install — LOCATION : Potters Road

ELEVATION : — DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED :

WATER LEVELS : NA — START : 3/16/17 — END : 3/16/17 — LOGGER : M. Ost/VBO

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (FT)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENISTY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION.
0	0-5'	5'			**0.0-1.0':** SOIL AND GRAVEL, dark brown (10YR 3/3), dry, loose **1.0-5.0':** SILT (ML), light gray (10YR 7/1), dry, dense, compacted, iron stain, mottles	PID=0.0 ppm
5	5-10'	5'			**5.0-6.0':** SILT(ML), light gray (10YR 7/1), dry dense, compacted, iron stain, mottles **6.0-7.0':** SILT (ML), very pale brown (10YR 7/4), saturated, loose **7.0-10.0':** SAND (SP), yellow (10YR 7/8), saturated, loose, fine	
10	10-15'	4'			**10.0-10.5':** SAND (SP), gray (10YR 6/1), saturated, loose, medium sand and gravel **10.5-14.0':** SAND (SP), ? Color, loose, fine **14.0-15.0':** no recovery	
15	15-20'	5'			**15.0-20.0':** SAND (SP), ? Color, loose, fine	
20	20-25'	1'			**20.0-21.0':** SAND (SP), gray (10YR 6/1), saturated, loose, fine, some silt at bottom **21.0-25.0':** no recovery	
25	25-30'	1'			**25.0-26.0':** SILT (ML), greenish gray (GLEY2 6/5GB), saturated, loose **26.0-30.0':** no recovery	
30	30-35'	5'			**30.0-35.0':** SAND (SP), gray (10YR 6/1), saturated, loose, very fine	
35	35-40'	5'			**35.0-40.0':** Clayey SILT (ML), greenish gray (GLEY2 6/5GB), saturated, soft, slightly plastic, shell material	
40						

45	40-45'	5'			**40.0-45.0':** Clayey SILT (ML), greensish gray (GLEY2 6/5GB, saturated, soft, plastic, shell material	
	45-50'	2'			**45.0-47.0':** SILT (ML), greenish gray (GLEY2 6/5GB), saturated, fine, no clay, no plasticity	
50					**47.0-50.0':** no recovery	
	50-55'	1'			**50.0-51.0**': SILT (ML), greenish gray (GLEY2 6/5GB), saturated, fine, no clay, no plasticity	
55					**51.0-55.0':** no recovery	
	55-60'	1'			**55.0-56.0**': SILT (ML), greenish gray (GLEY2 6/5GB), saturated, fine, no clay, no plasticity	
60					**56.0-60.0':** no recovery	

Bottom of boring at 60.0 ft bgs

Notes:

bgs - below ground surface

PID - photoionization detector

NA - not applicable

HA - hand auger

MC - macrocore sample

ppm - parts per million

NM - not measured

PROJECT NUMBER	BORING NUMBER	
678440.SI.SI.01	OC-MW07D	SHEET 1 OF 3

SOIL BORING LOG

PROJECT : Oceana PTC MW Install — LOCATION : End of Runway

ELEVATION : — DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED :

WATER LEVELS : NA — START : 3/13/17 — END : 3/13/17 — LOGGER : M. Ost/VBO

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)	RECOVERY (FT)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	CORE DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENISTY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION.
0	0-5'	2'			**0.0-2.0':** SILT (ML), brown (10YR 4/3), dry, loose	PID=0.0 ppm
					2.0-5.0': no recovery	
5	5-10'	2'			**5.0-6.0':** SILT (ML), brown (10YR 4/3), dry, loose	Water level at 6'
					6.0-7.0': Sandy SILT (SM), dark gray (10YR 4/1), saturated, loose, fine	
					7.0-10.0': no recovery	
10	10-15'	2'			**10.0-12':** Silty CLAY (CL), gray (10YR 5/1), saturated, lean, plastic, soft	
					12.0-15.0': no recovery	
15	15-20'	3'			**15.0-18.0':** Silty SAND (SM), dark green gray (GLEY1 4/10GB), saturated, soft, plastic	
					18.0-20.0': no recovery	
20	20-25'	3'			**20.0-23.0':** Silty SAND (SM), greenish gray (GLEY2 6/10G), saturated, soft, plant material	
					23.0-25.0': no recovery	
25	25-30'	2'			**25.0-27.0':** Silty CLAY (CL), gray (7.5YR 5/1), saturated, fat, plastic	
					27.0-30.0': no recovery	
30	30-35'	1'			**30.0-31.0':** SILT (ML), bluish gray (GLEY2 5/5BG), saturated, no plastic, medium dense	
					31.0-35.0': no recovery	
35	35-40'	1'			**35.0-36.0':** SILT (ML), bluish gray (GLEY2 5/5BG), saturated, no plastic, medium dense	
					36.0-40.0': no recovery	
40						

45	40-45'	1'			**40.0-41.0':** Clayey SILT (ML), bluish gray (GLEY2 5/5GB, saturated, plastic **41.0-45.0':** no recovery	
50	45-50'	5'			**45.0-50.0':** SAND (SP), gray (10YR 6/1) some gravel tightly packed, thin 1" clay lens at 47'	
55	50-55'	2'			**50.0-51.0'**: SAND (SP), gray (10YR 6/1) some gravel tightly packed **51.0-51.5':** CLAY (CL), dark yellow brown (10YR 3/6), saturated, soft **51.5-52.0':** SAND (SP), gray (10YR 6/1)some gravel tightly packed **52.0-55.0':** no recovery	
60	55-60'	3'			**55.0-58.0'**: SAND (SP), gray (10YR 5/1), loose, trace gravel **58.0-60.0':** no recovery	

Bottom of boring at 60.0 ft bgs

Notes:

bgs - below ground surface

PID - photoionization detector

NA - not applicable

HA - hand auger

MC - macrocore sample

ppm - parts per million

NM - not measured

Appendix D
Aquifer Variable-Head Testing Charts

Oceana PFC Investigation

11/10/16

0925 A. Wuebrenner arrives at London Bridge gate
Weather - low 50s, mostly cloudy, light NW wind
Objective - Slug testing at site 11 wells
Equipment - LevelTroll 700 # C102586, cable # C102981
using 5' long 1.5" diameter PVC slug
Rugged reader # C102728

1005 R. McElhinny onsite

1020 H+S meeting - ~~stop~~ footing with paddles

1025 Setup on OW11-MW4
DTW 6.97' DTB 22.79' Depth of probe reading 14.76', set 1' above bottom of well

1041 Start OW11 MW04 Slug in 1

1043 Stop OW11 MW04 Slug in 1 - DTW 6.96

1046 Start OW11 MW04 Slug out 1 DTW 6.97

1048 Stop OW11 MW04 Slug Out 1 DTW 6.97

1050 Start OW11 MW04 Slug In 2 DTW 6.97

1051 Stop OW11 MW04 Slug In 2 DTW 6.95

1055 Start OW11 MW04 Slug out 2 DTW 6.96

1056 Stop OW11 MW04 slug out 2 DTW 6.97

1058 Start OW11 MW04 Slug In 3 DTW 6.97

1059 Stop OW11 MW04 Slug In 3 DTW 6.95

1100 Start OW11 MW04 Slug out 3 DTW 6.97

1101 Stop " " DTW 6.99

Setup on OW11-MW07 DTW - 5.92' DTB 20.12'
Sensor set 1' above bottom - Probe reading 12.86'

1118 Start OW11 MW07 Slug In 1 5.92

1119 Stop OW11 MW07 Slug In 1 5.91

1122 Start OW11 MW07 Slug ~~in 2~~ out 1 DTW 5.92
1123 Stop " " DTW 5.93
1125 Start OW11 MW07 Slug In 2 DTW 5.92
1126 Stop OW11 MW07 Slug In 2 DTW 5.92
1128 Start OW11 MW07 Slug out 2 DTW 5.92
1129 Stop " " DTW 5.93
1130 Start OW11 MW07 Slug in 3 DTW 5.92
1131 Stop " " DTW 5.93
1132 Start OW11 MW07 Slug out 3 DTW 5.92
1133 Stop " " DTW 5.93

Setup on OW11-MW09 DTW 7.95' DTB 23.27'
Probe set 1' above bottom, reading 14.53'

1148 Start OW11 MW09 Slug In 1 DTW 7.95'
1150 Stop " " DTW 7.95'
1151 Start OW11 MW09 Slug out 1 DTW 7.98'
1153 Stop OW11 MW09 Slug out 1 DTW 7.98'
1155 Start OW11 MW09 Slug In 2 DTW 7.95'
1157 Stop " " DTW 7.93'
1159 Start OW11 MW09 Slug out 2 DTW 7.95'
1201 Stop " " DTW 7.96'
1202 Start OW11 MW09 Slug In 3 DTW 7.95'
1205 Stop OW11 MW09 Slug ~~in~~ 3 DTW 7.92'
1207 Start OW11 MW09 Slug Out 3 DTW 7.95'
1209 Stop OW11 MW09 Slug out 3 DTW 7.97'
1225 Offsite

Oceana PFC Investigation 11/11/16

0840 A. Winebrenner onsite
Weather - Clear, mid 50s, light NW wind
Objective - Slug testing at 3 wells
Equipment - Level troll 700 #C102728, cable # C102981
5' long x 1.5" diameter PVC slug

0850 Sign PTSP

0855 Setup on OW26-MW1 DTW 4.83' DTB 18.80'
Sensor reading depth of probe 13.00', ~1' off bottom

0908 Start OW26-MW1 Slug in 1 DTW 4.83
0910 Stop " " DTW 4.82
0912 Start OW26-MW1 Slug out 1 DTW 4.83
0913 Stop " " DTW 4.84
0915 Start OW26-MW1 Slug in 2 DTW 4.83
0916 Stop OW26-MW1 Slug in 2 DTW 4.82
0918 Start OW26-MW1 Slug out 2 DTW 4.83
0919 Stop " " DTW 4.84
0920 Start " Slug in 3 DTW 4.83
0921 Stop " " DTW 4.83
0922 Start " Slug out 3 DTW 4.83
0923 Stop " " DTW 4.84

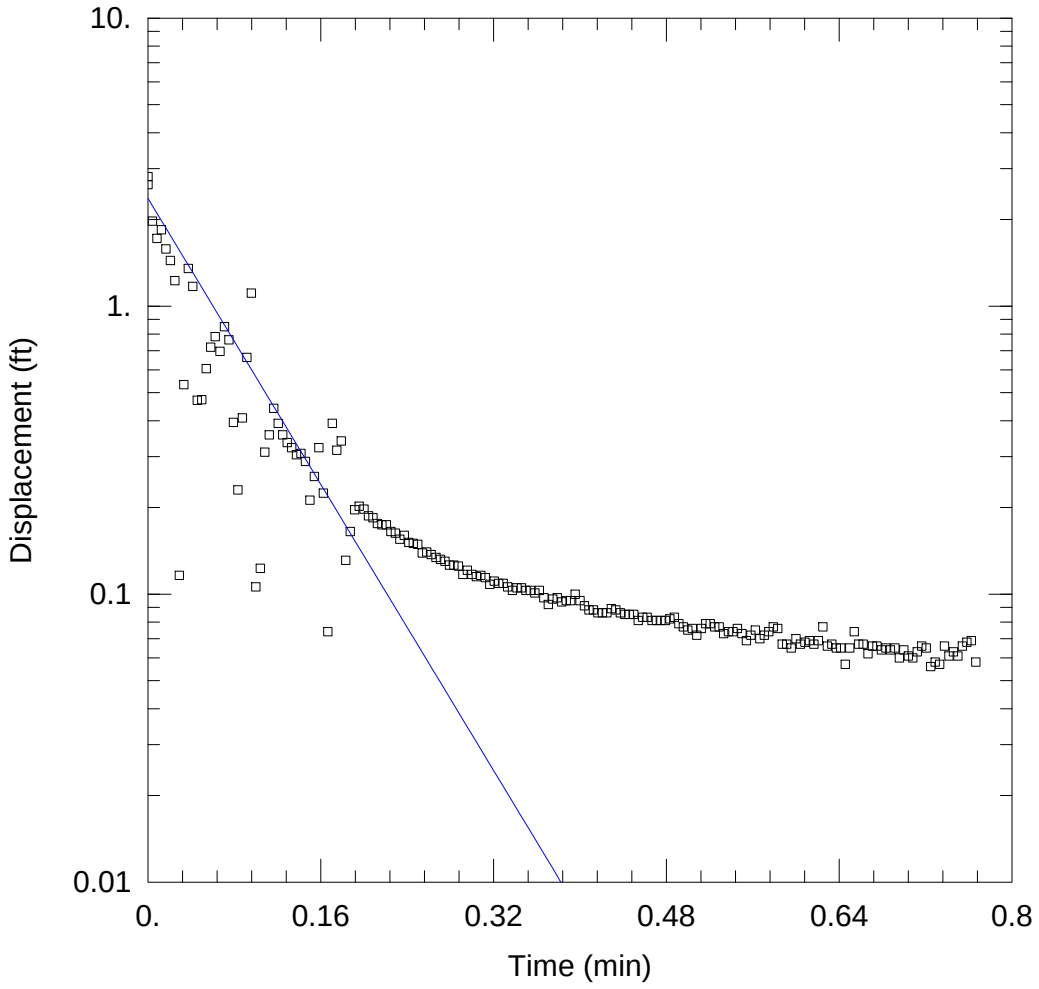
0945 Setup on OW28-MW14 DTW 5.87 DTB 22.35
0950 R. McElhinny onsite Sensor reading 15.58', ~1' off bottom
1010 Start OW28-MW14 Slug in 1 DTW 5.87
1012 Stop " " DTW 5.87
1015 Start " Slug out 1 DTW 5.87
1016 Stop " " DTW 5.88

1020	Start	OW2B-MW14	Slug In 2	DTW	5.87
1020	Stop	"	"	DTW	5.87
1022	Start	"	Slug Out 2	DTW	5.87
1023	Stop	"	"	DTW	5.88
1025	Start	"	Slug In 3	DTW	5.87
1026	Stop	"	"	DTW	5.87
1030	Start	"	Slug Out 3	DTW	5.87
1031	Stop	"	"	DTW	5.90
1033	Start	"	Slug In 4	DTW	5.87
1034	Stop	"	"	DTW	5.87

1048 Setup on OW2C-MW19. DTW 8.33' DTB 19.22
Sensor reading 9.54' about 1' above bottom

1055	Start	OW2C-MW19	Slug In 1	DTW	8.33
1056	Stop	"	"		8.30
1057	Start	"	Slug Out 1		8.33
1059	Stop	"	"		8.33
1100	Start	"	Slug In 2		8.33
1101	Stop	"	"		8.32
1103	Start	"	Slug Out 2		8.33
1104	Stop	"	"		8.35
1105	Start	"	Slug In 3		8.33
1106	Stop	"	"		8.33
1108	Start	"	Slug Out 3		8.33
1109	Stop	"	"		8.35

1120 Offbase



WELL TEST ANALYSIS

Data Set: \...\OW2B-MW14-Slug in 2.aqt
Date: 06/02/17 Time: 13:57:14

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

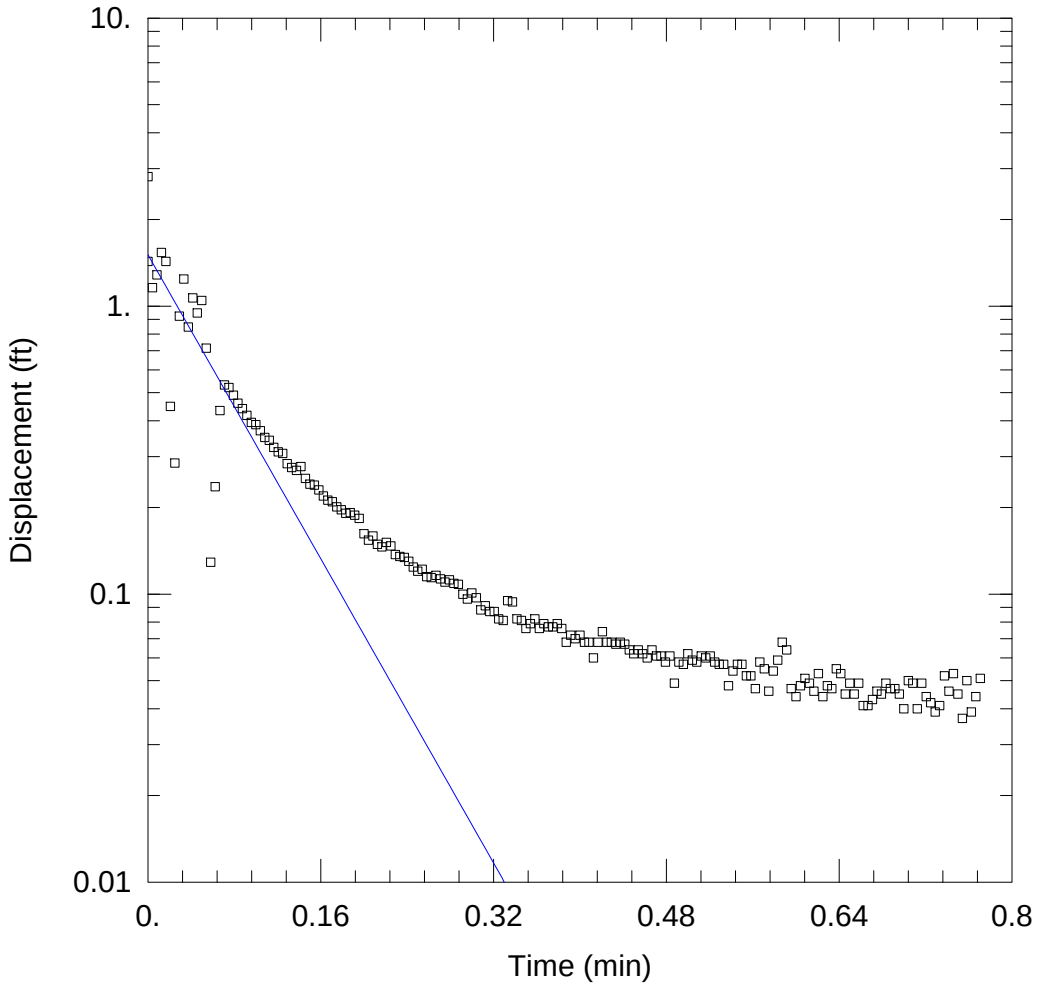
Saturated Thickness: 16.48 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 16.48 ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.48 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.008562 ft/min
y0 = 2.365 ft



WELL TEST ANALYSIS

Data Set: \...\OW2B-MW14-Slug in 3.aqt
Date: 06/02/17 Time: 13:58:23

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

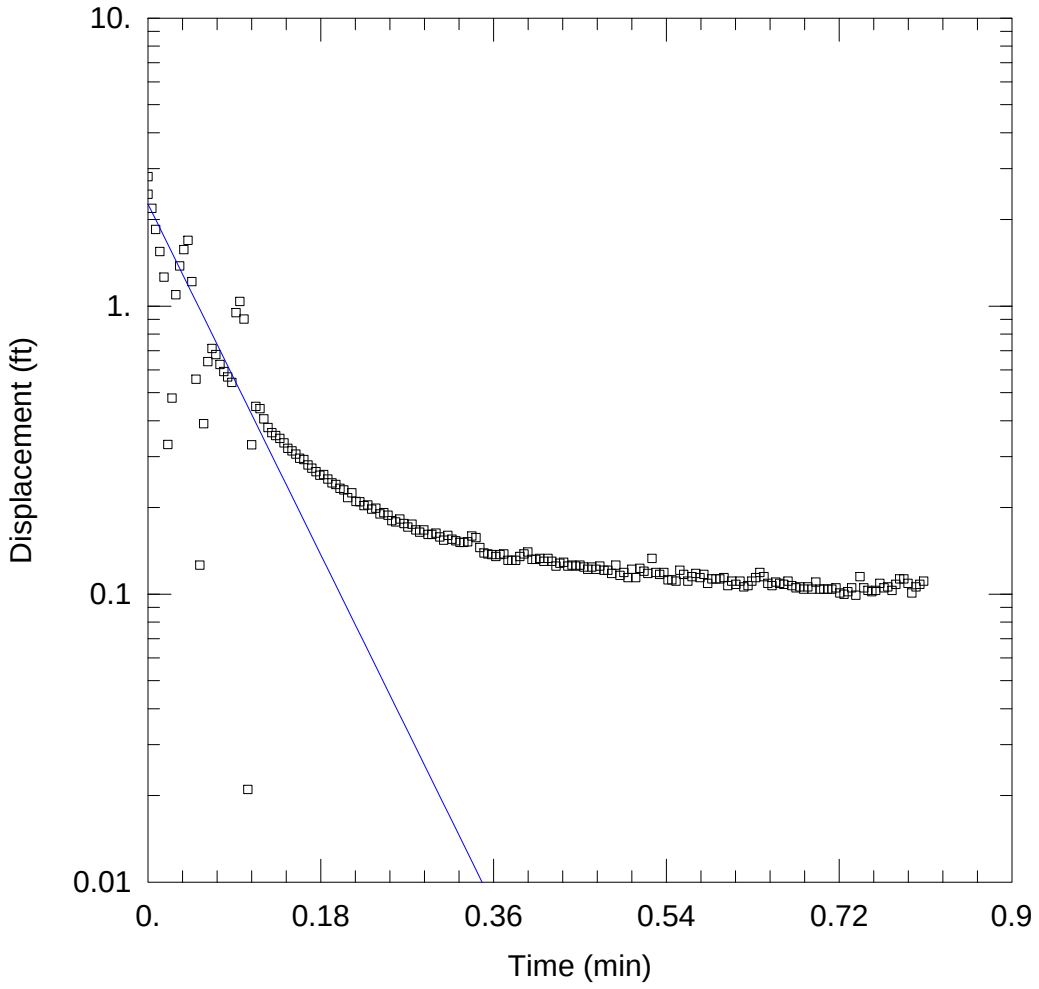
Saturated Thickness: 16.48 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 16.48 ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.48 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.009103 ft/min
y0 = 1.508 ft



WELL TEST ANALYSIS

Data Set: \...\OW2B-MW14-Slug in 4.aqt
Date: 06/02/17 Time: 13:58:44

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

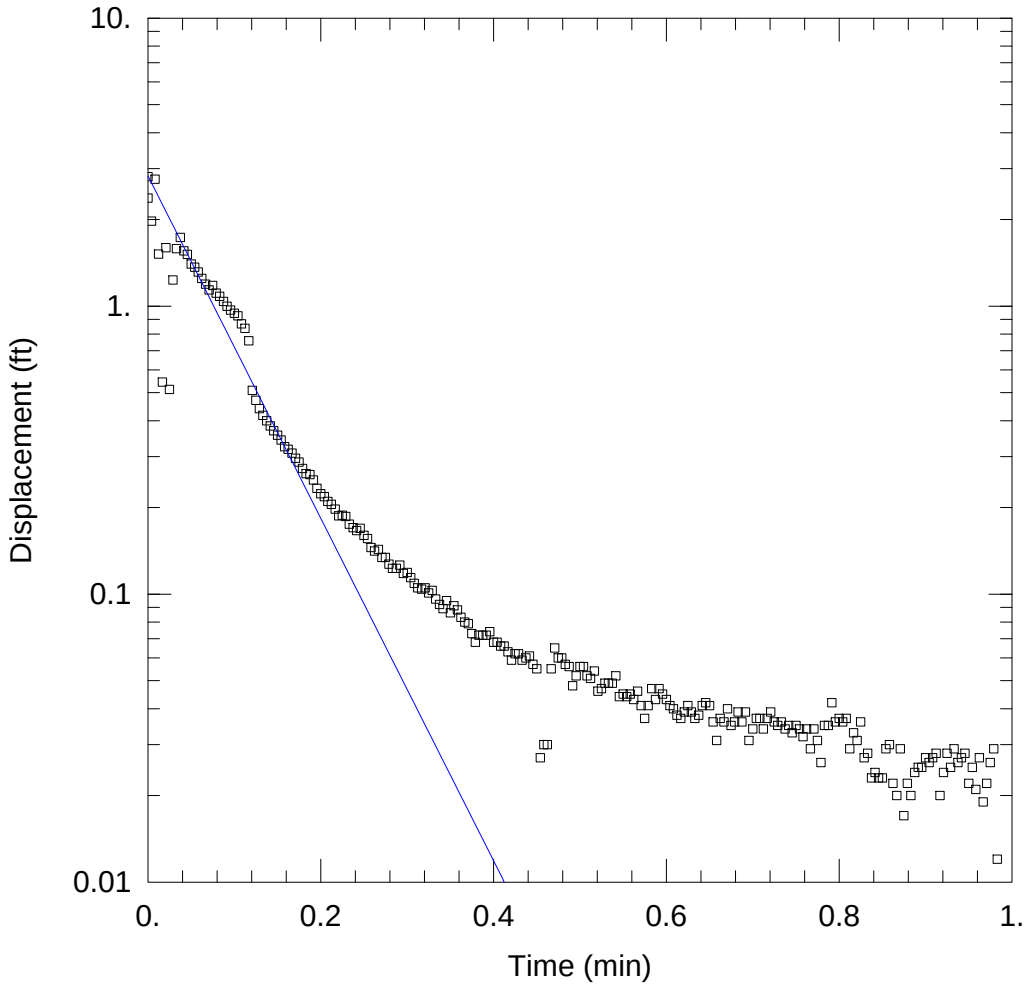
Saturated Thickness: 16.48 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 16.48 ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.48 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.009331 ft/min
y0 = 2.261 ft



WELL TEST ANALYSIS

Data Set: \...\OW2B-MW14-Slug out 1.aqt
Date: 06/02/17 Time: 13:59:17

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

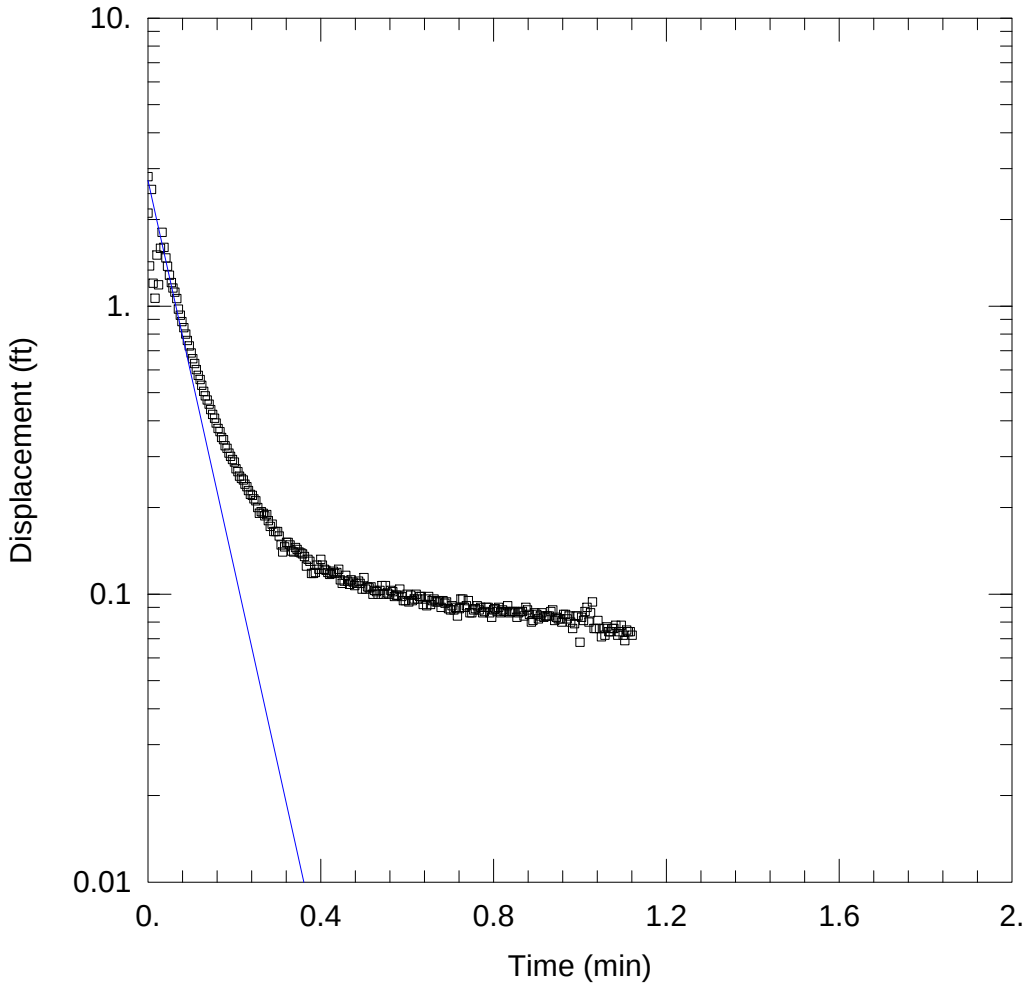
Saturated Thickness: 16.48 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 16.48 ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.48 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.008199 ft/min
y0 = 2.83 ft



WELL TEST ANALYSIS

Data Set: \...\OW2B-MW14-Slug out 2.aqt
Date: 06/02/17 Time: 13:59:38

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 16.48 ft Anisotropy Ratio (Kz/Kr): 1.

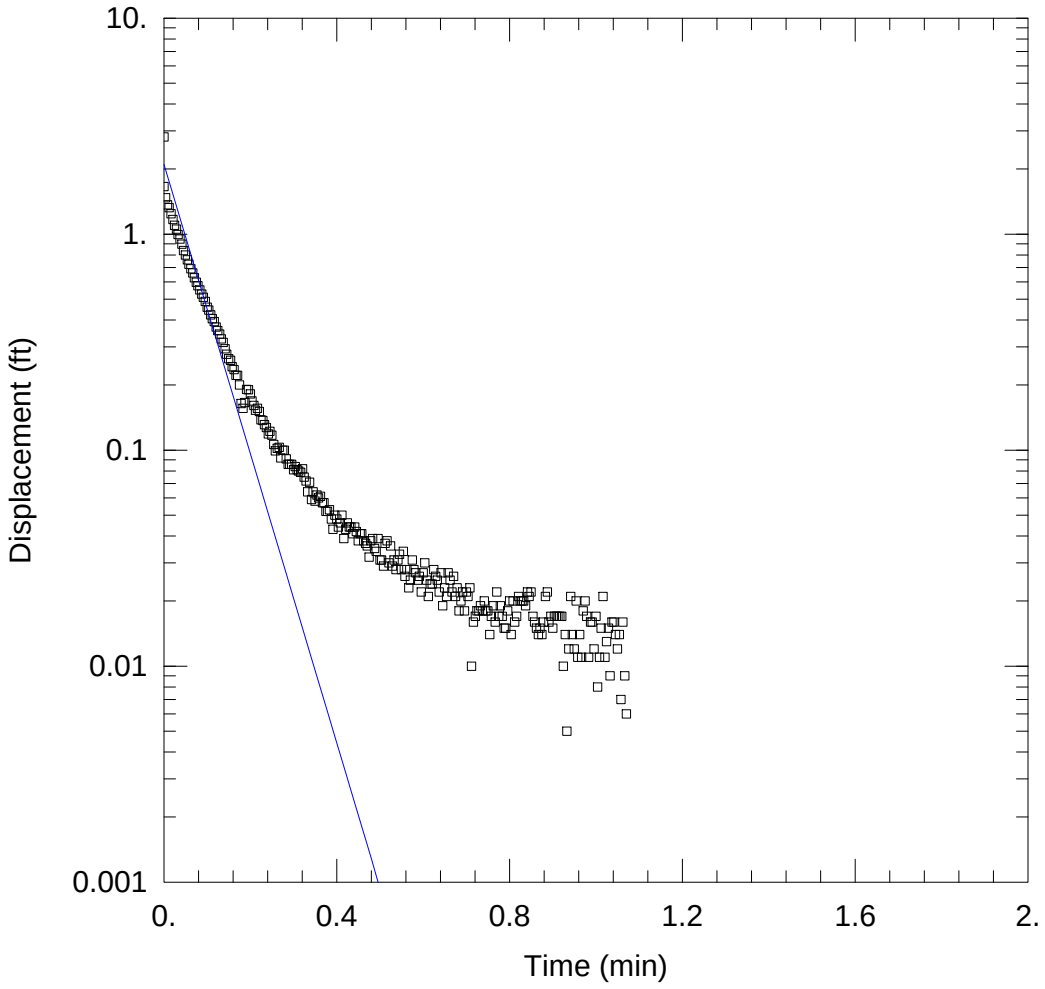
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 16.48 ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.48 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.009312 ft/min y0 = 2.728 ft



WELL TEST ANALYSIS

Data Set: \...\OW2B-MW14-Slug out 3.aqt
Date: 06/02/17 Time: 13:59:51

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 16.48 ft Anisotropy Ratio (Kz/Kr): 1.

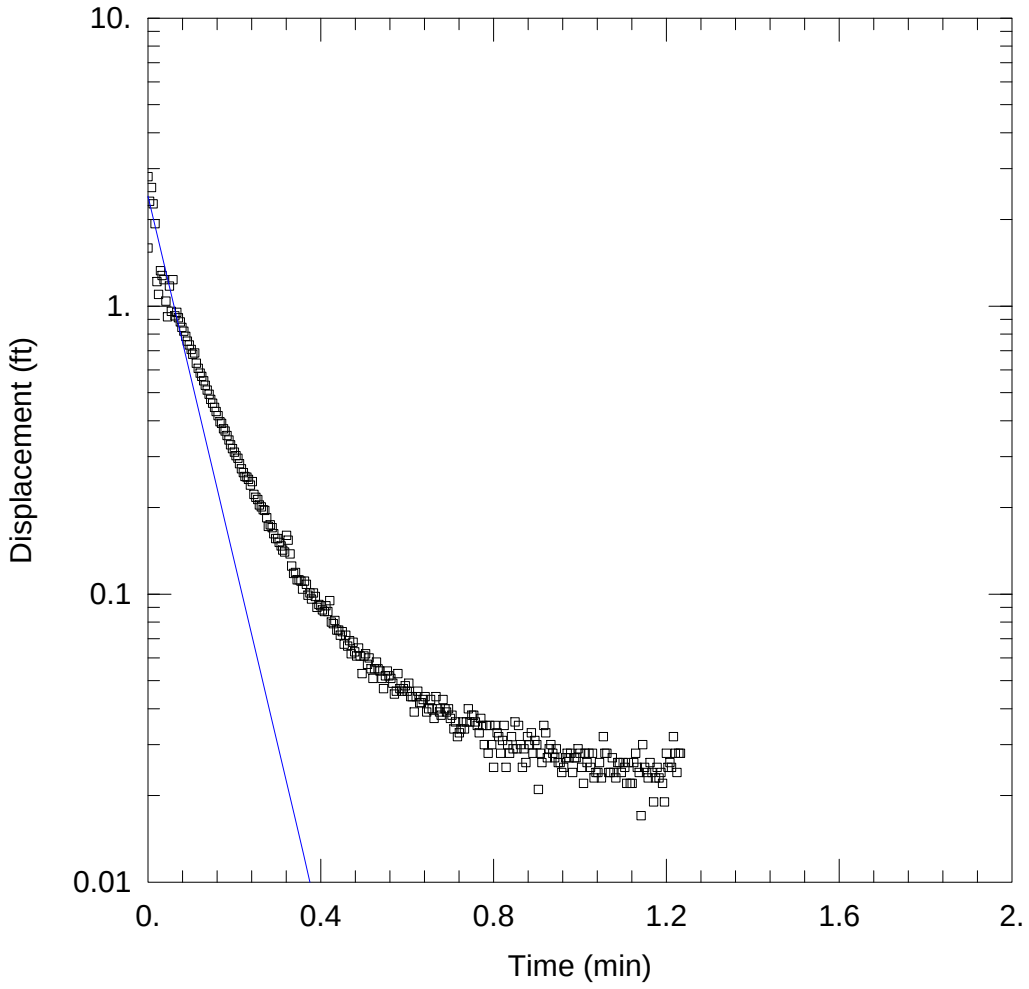
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 16.48 ft
Casing Radius: 0.083 ft
Static Water Column Height: 16.48 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.009235 ft/min y0 = 2.099 ft



WELL TEST ANALYSIS

Data Set: \...\OW2C-MW19-Slug in 1.aqt
Date: 06/02/17 Time: 14:00:09

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

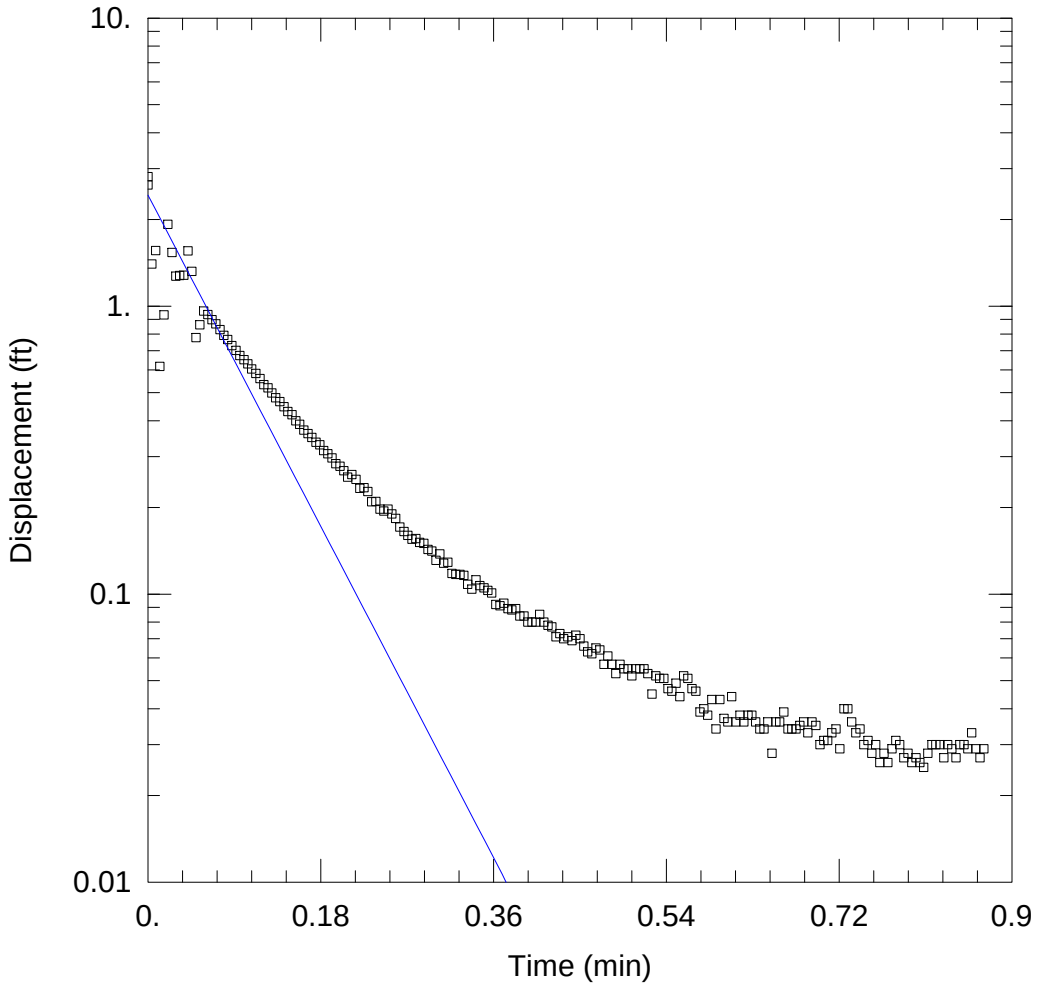
Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 10.89 ft
Casing Radius: 0.083 ft
Static Water Column Height: 10.89 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.007445 ft/min
y0 = 2.41 ft



WELL TEST ANALYSIS

Data Set: \...\OW2C-MW19-Slug in 2.aqt
Date: 06/02/17 Time: 14:00:28

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

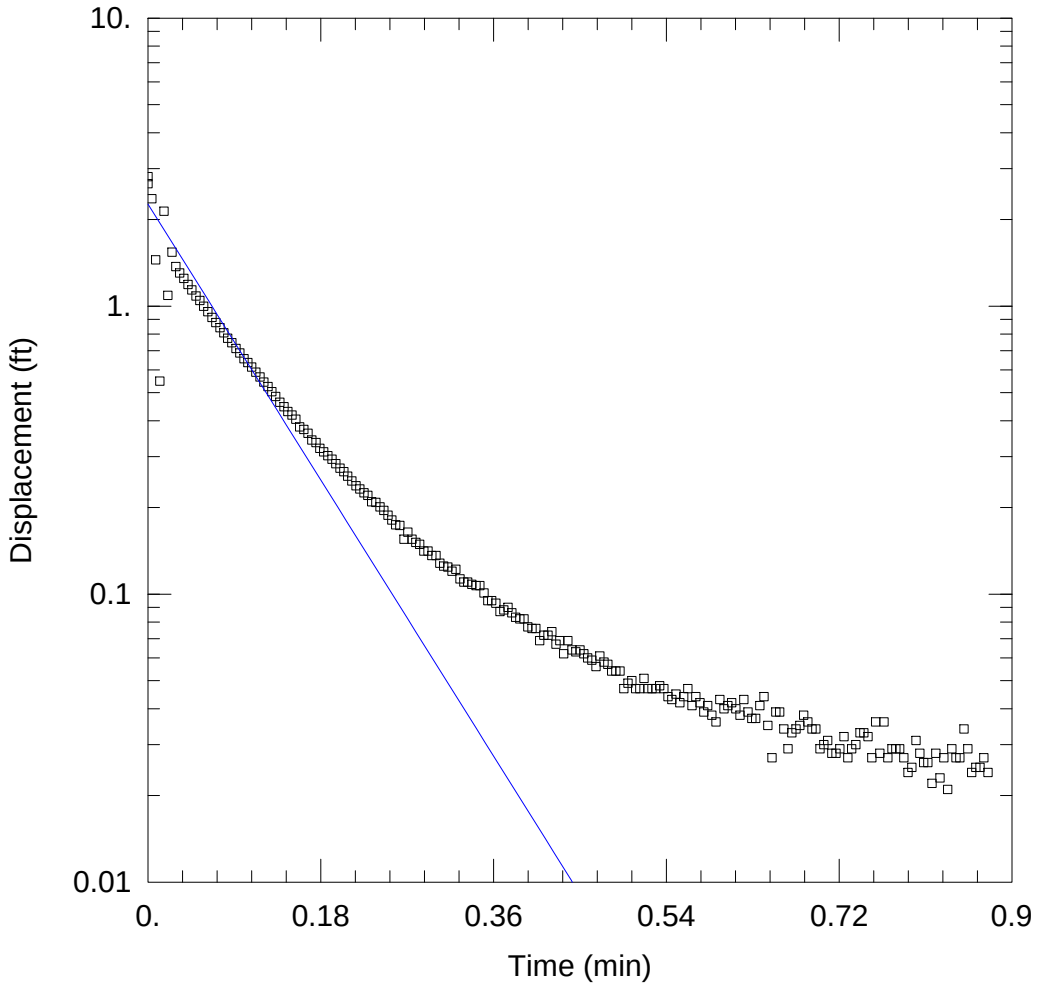
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 10.89 ft
Casing Radius: 0.083 ft
Static Water Column Height: 10.89 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.007498 ft/min y0 = 2.428 ft



WELL TEST ANALYSIS

Data Set: \...\OW2C-MW19-Slug in 3.aqt
Date: 06/02/17 Time: 14:00:50

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

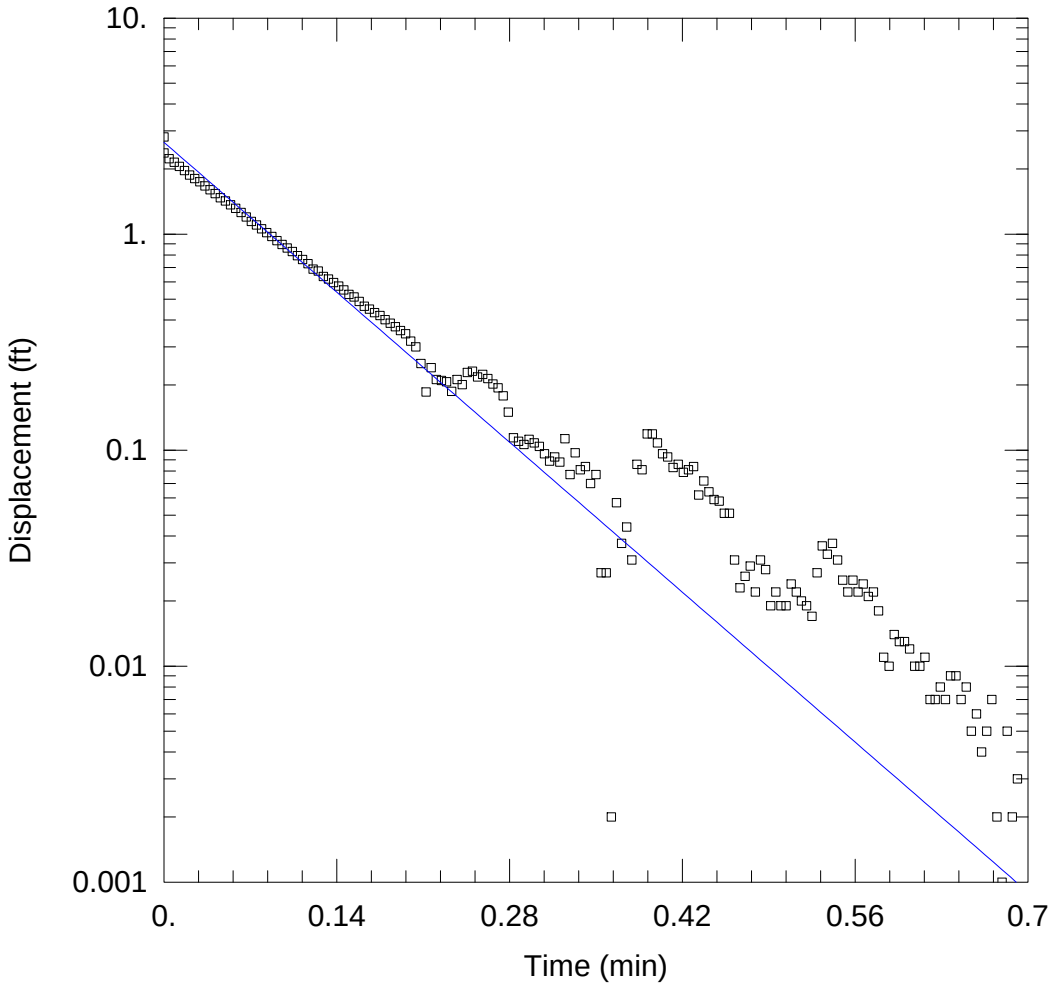
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 10.89 ft
Casing Radius: 0.083 ft
Static Water Column Height: 10.89 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.006248 ft/min y0 = 2.261 ft



WELL TEST ANALYSIS

Data Set: \...\OW2C-MW19-Slug out 1.aqt
Date: 06/02/17 Time: 14:01:39

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

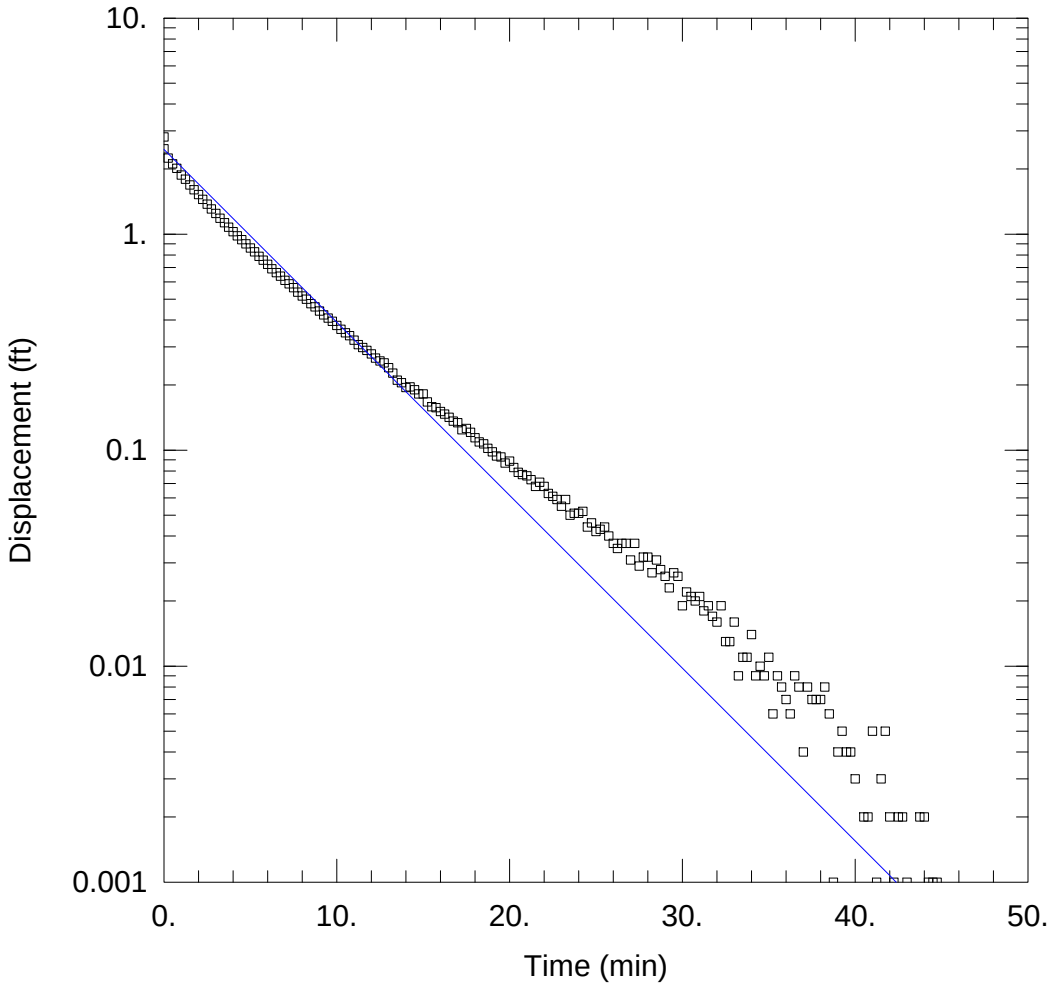
Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 10.89 ft
Casing Radius: 0.083 ft
Static Water Column Height: 10.89 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.005819 ft/min
y0 = 2.66 ft



WELL TEST ANALYSIS

Data Set: \...\OW2C-MW19-Slug out 2.aqt
Date: 06/02/17 Time: 14:01:55

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

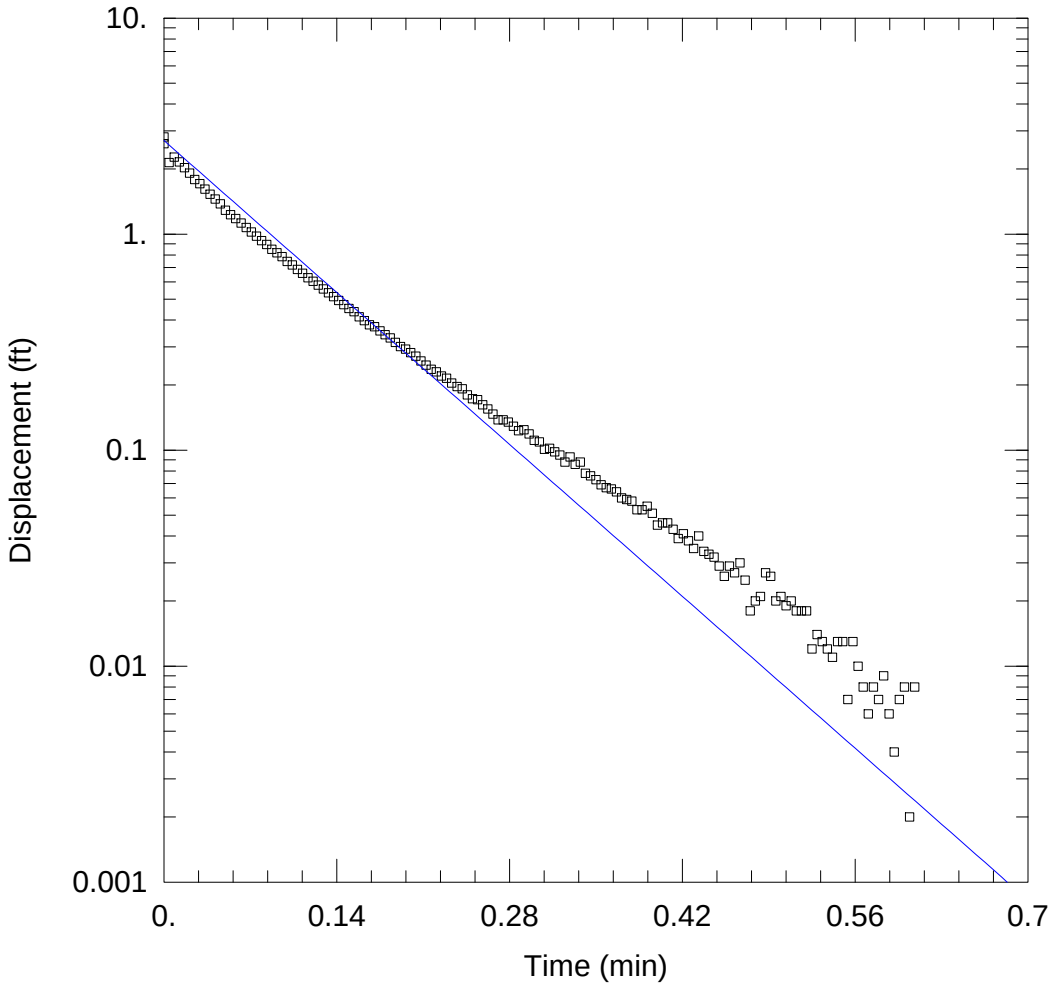
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 10.89 ft
Casing Radius: 0.083 ft
Static Water Column Height: 10.89 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 9.389E-5 ft/min y0 = 2.462 ft



WELL TEST ANALYSIS

Data Set: \...\OW2C-MW19-Slug out 3.aqt
Date: 06/02/17 Time: 14:02:13

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

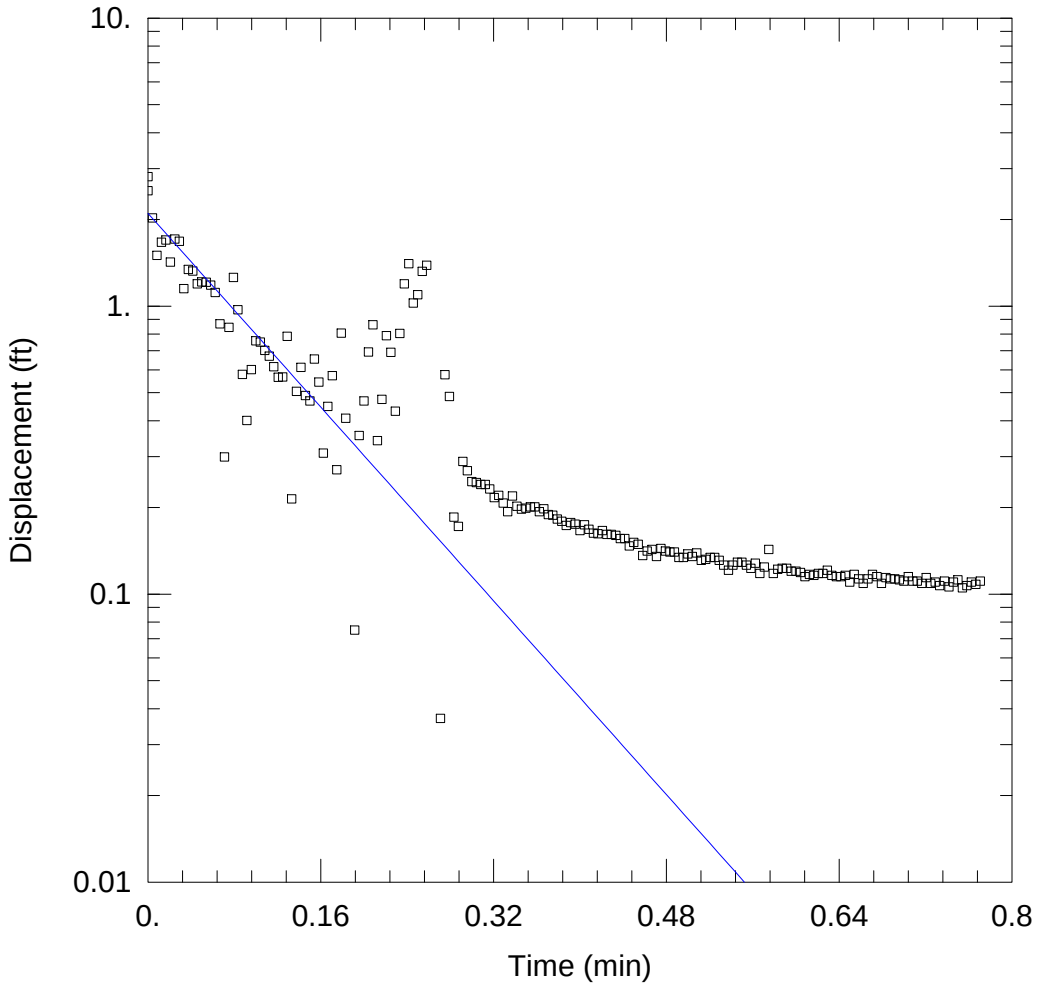
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 10.89 ft
Casing Radius: 0.083 ft
Static Water Column Height: 10.89 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.005895 ft/min y0 = 2.708 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW04-Slug In 1.aqt
Date: 06/02/17 Time: 14:02:29

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.82 ft Anisotropy Ratio (Kz/Kr): 1.

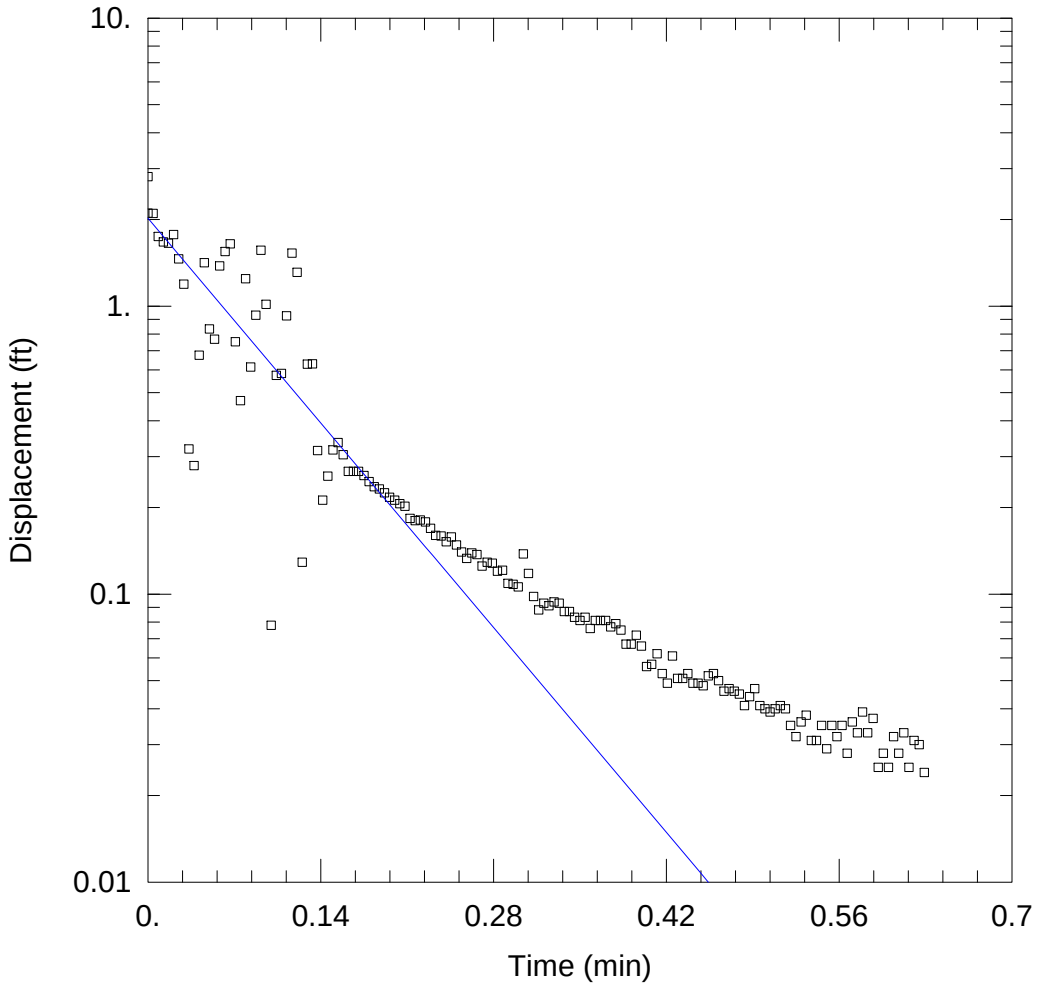
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.82 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.82 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.005761 ft/min y0 = 2.098 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW04-Slug in 2.aqt
Date: 06/02/17 Time: 14:03:11

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

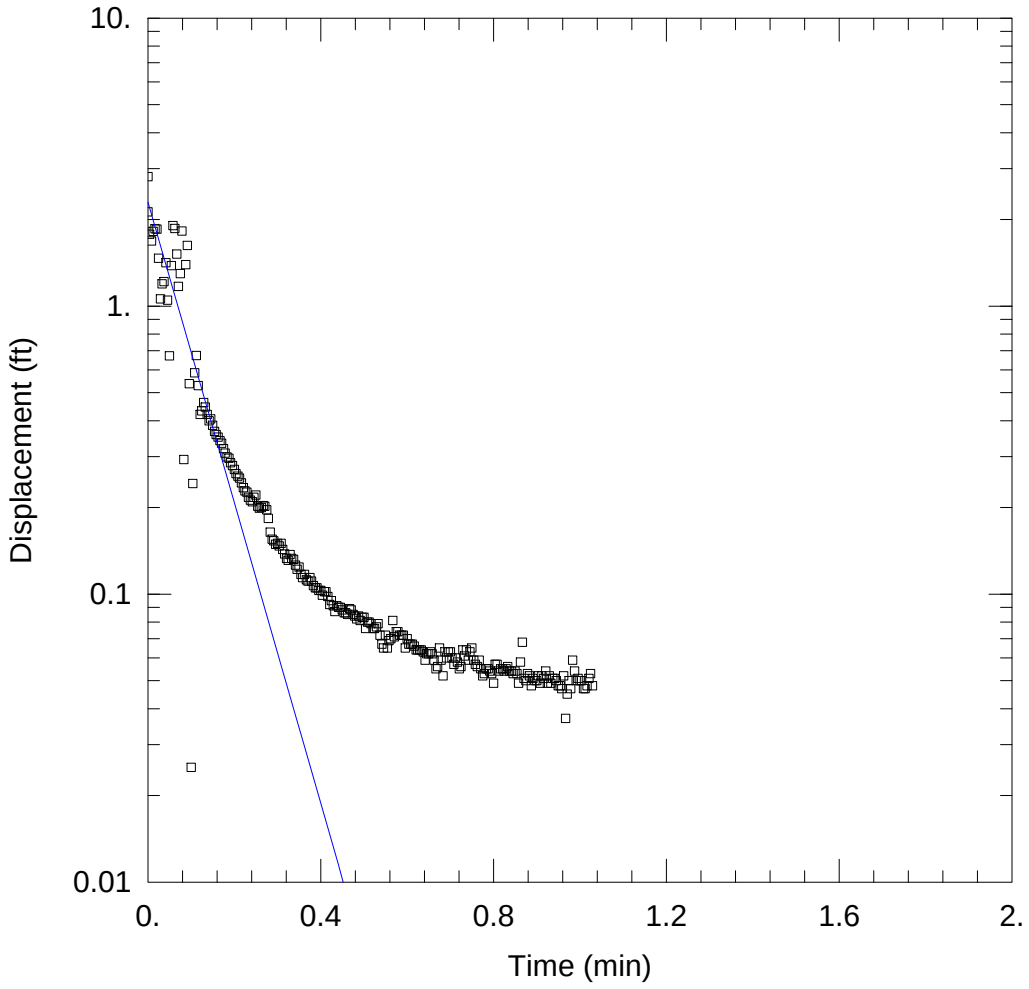
Saturated Thickness: 15.82 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.82 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.82 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.006955 ft/min
y0 = 2.016 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW04-Slug in 3.aqt
Date: 06/02/17 Time: 14:03:22

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

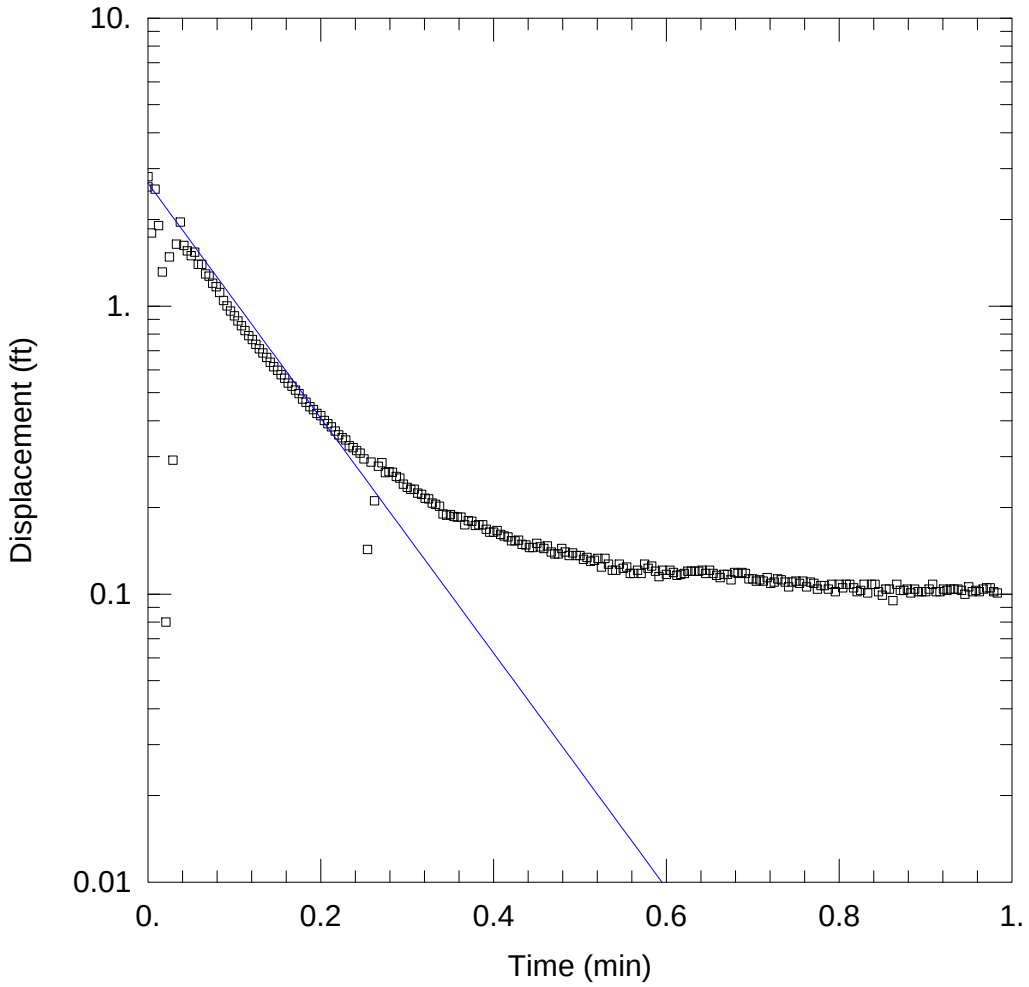
Saturated Thickness: 15.82 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.82 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.82 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.007151 ft/min
y0 = 2.295 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW04-Slug out 1.aqt
Date: 06/02/17 Time: 14:03:33

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

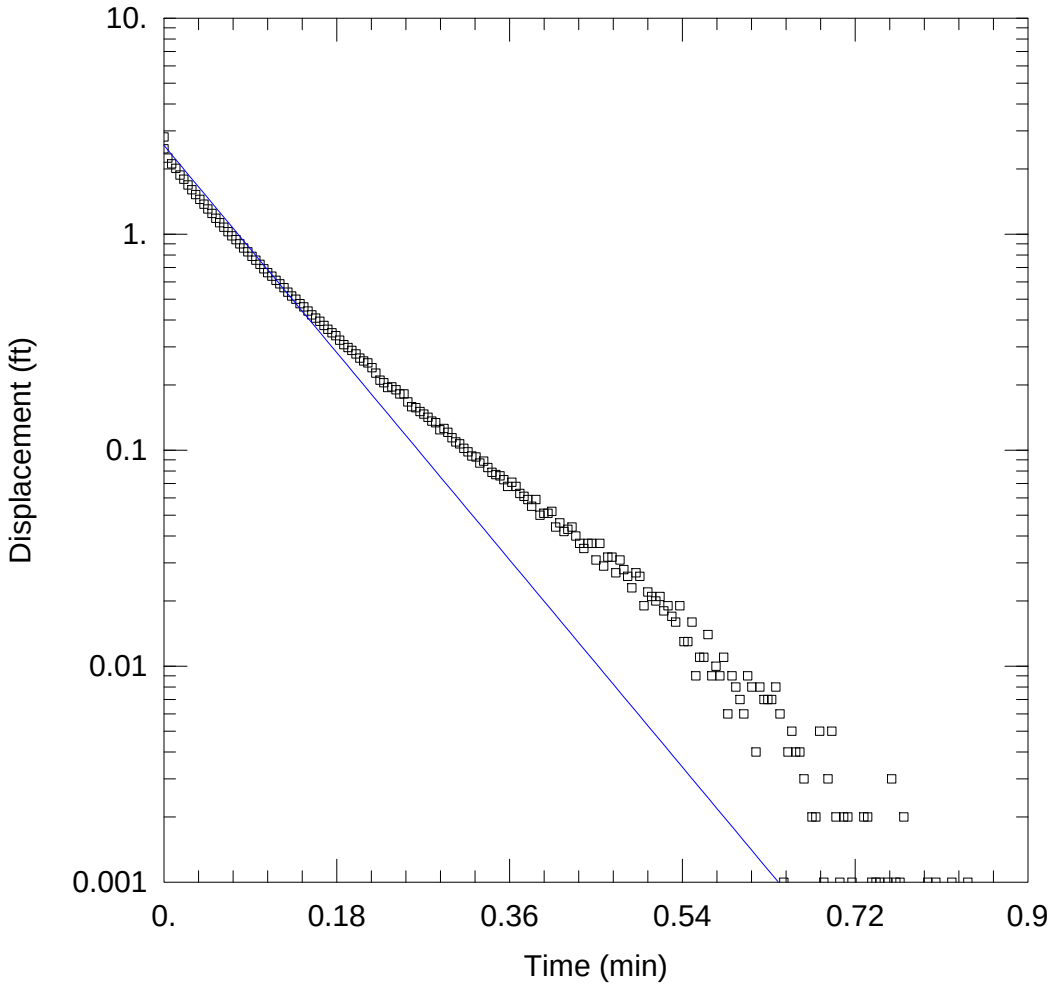
Saturated Thickness: 15.82 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.82 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.82 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.00559 ft/min
y0 = 2.671 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW04-Slug out 2.aqt
Date: 06/02/17 Time: 14:03:48

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.82 ft Anisotropy Ratio (Kz/Kr): 1.

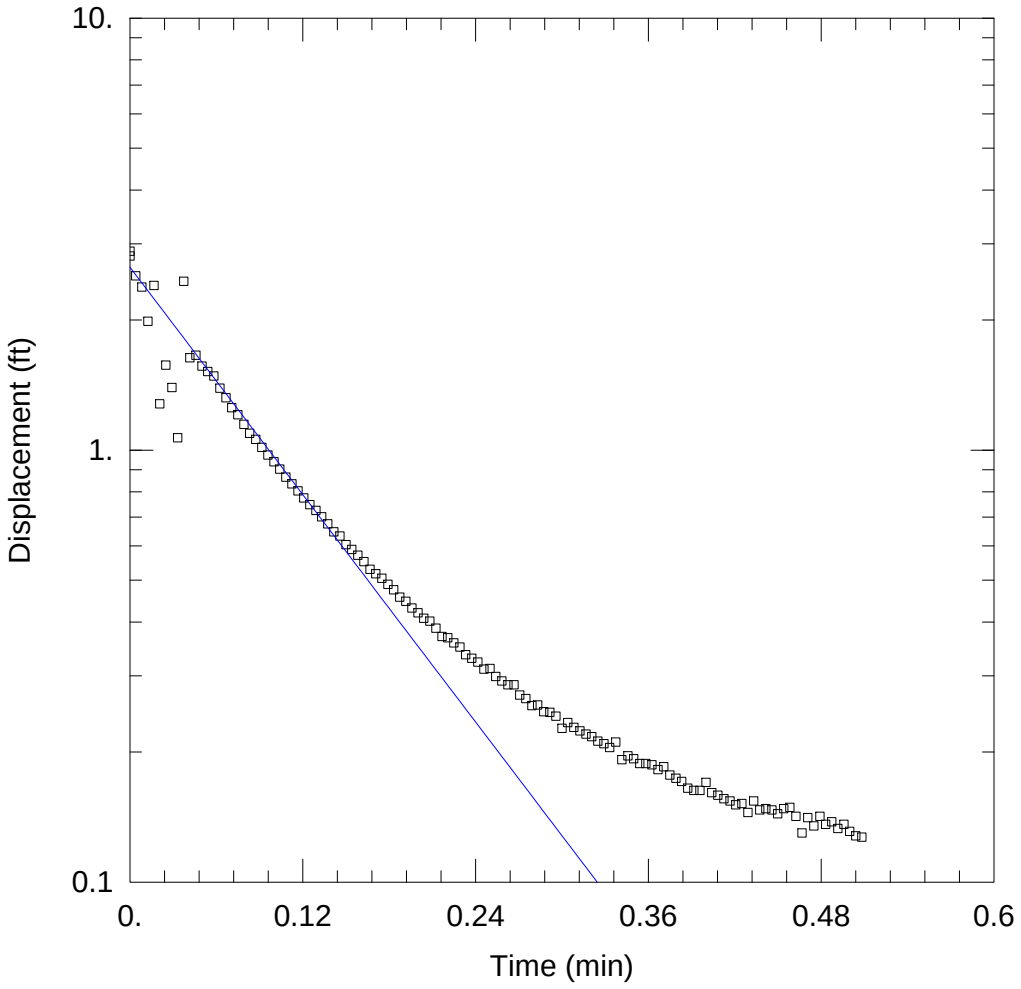
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.82 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.82 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.007304 ft/min y0 = 2.573 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW04-Slug out 3.aqt
Date: 06/02/17 Time: 14:04:12

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

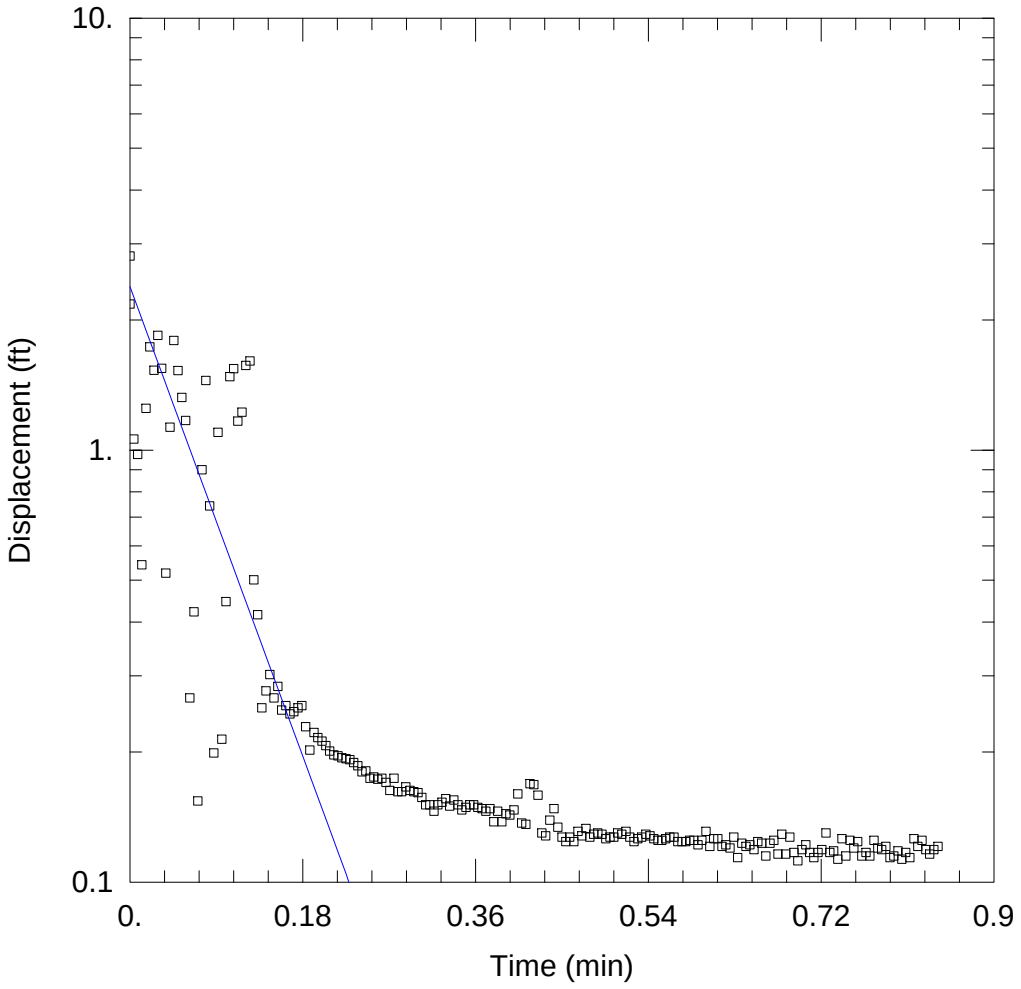
Saturated Thickness: 15.82 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.82 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.82 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.00601 ft/min
y0 = 2.649 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW07-Slug in 1.aqt
Date: 06/02/17 Time: 14:05:02

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

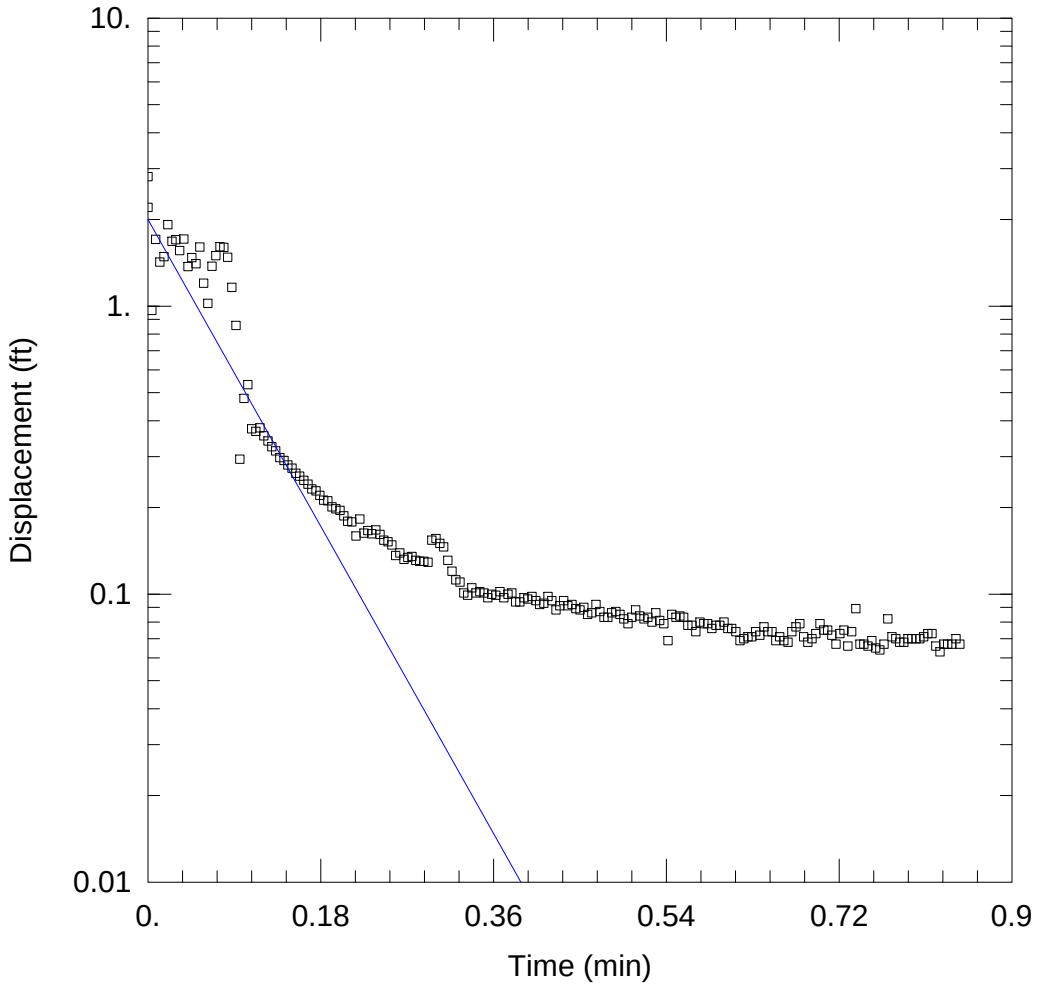
Saturated Thickness: 14.2 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 14.2 ft
Casing Radius: 0.083 ft
Static Water Column Height: 14.2 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.008133 ft/min
y0 = 2.389 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW07-Slug in 2.aqt
Date: 06/02/17 Time: 14:05:23

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

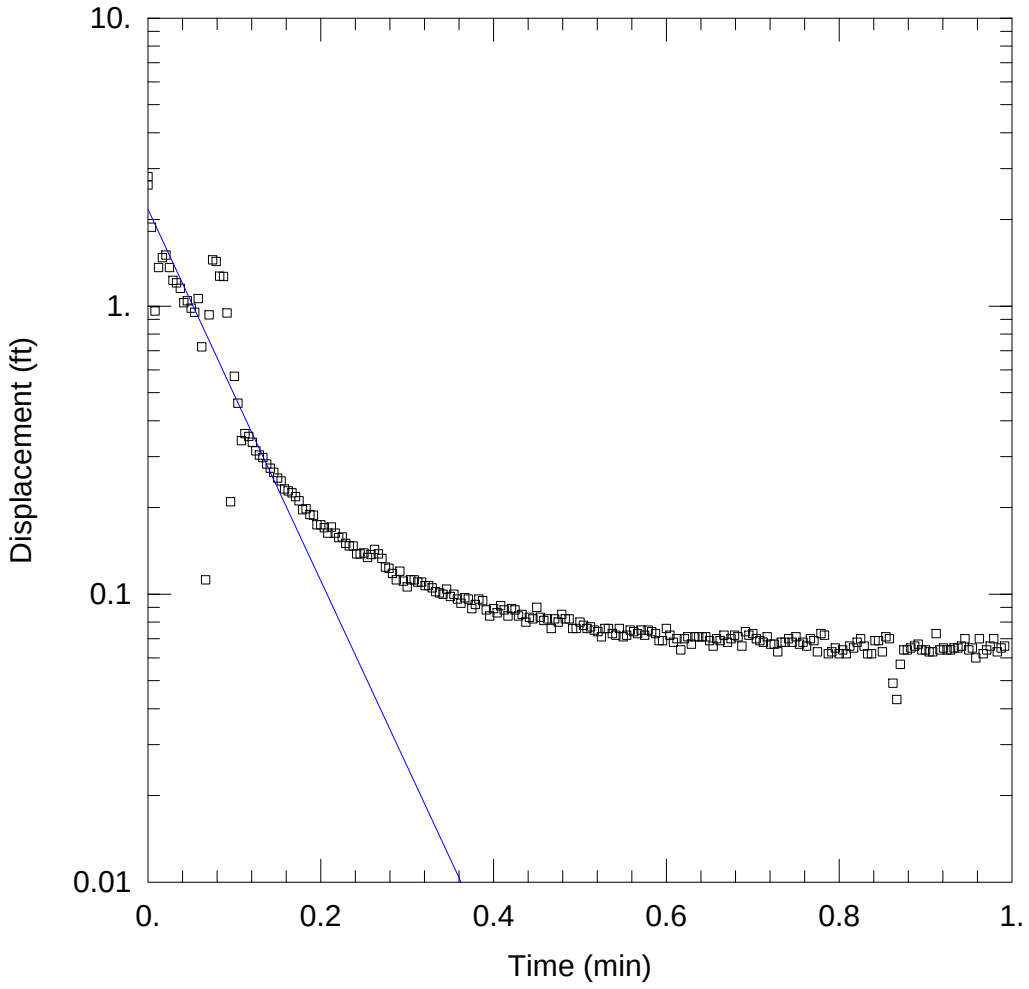
Saturated Thickness: 14.2 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 14.2 ft
Casing Radius: 0.083 ft
Static Water Column Height: 14.2 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.007977 ft/min
y0 = 1.999 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW07-Slug in 3.aqt
Date: 06/02/17 Time: 14:05:32

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 14.2 ft Anisotropy Ratio (Kz/Kr): 1.

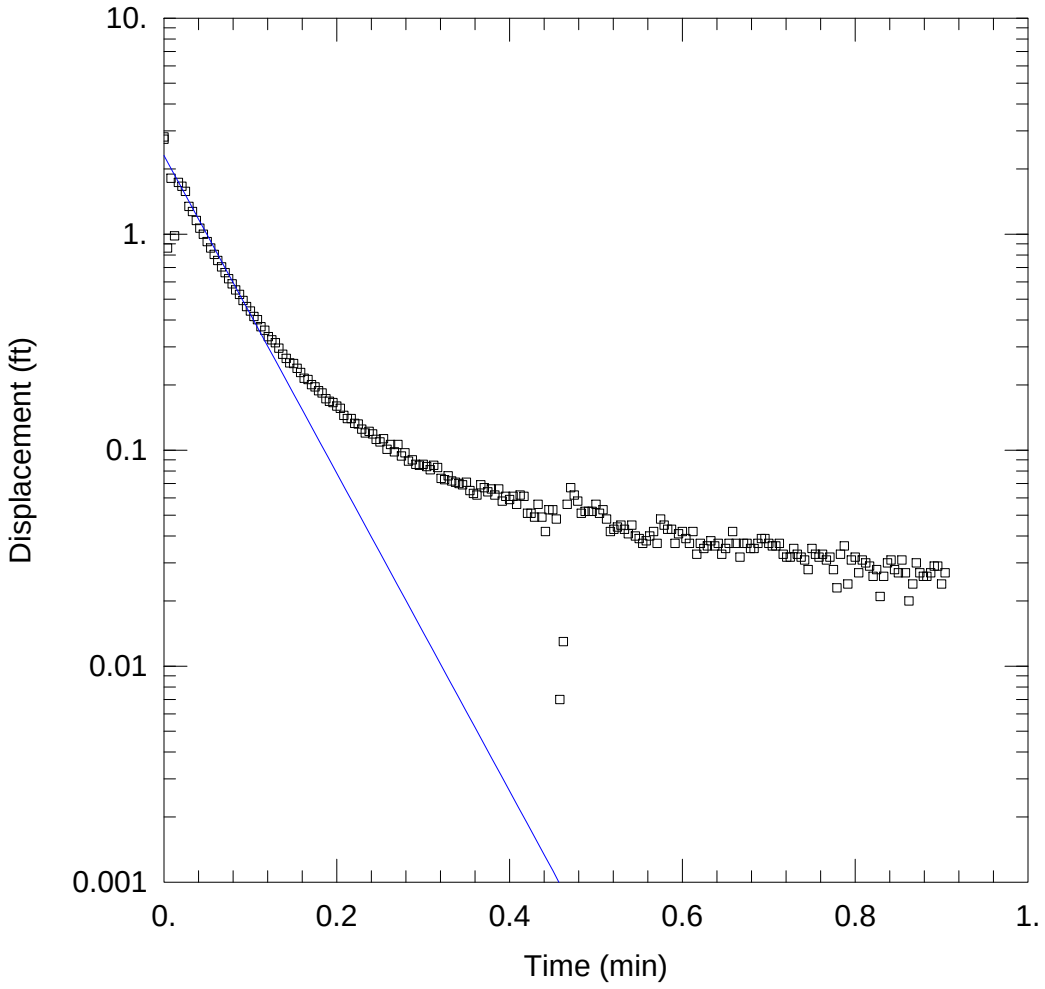
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 14.2 ft
Casing Radius: 0.083 ft
Static Water Column Height: 14.2 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.008682 ft/min y0 = 2.166 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW07-Slug out 1.aqt
Date: 06/02/17 Time: 14:05:43

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 14.2 ft Anisotropy Ratio (Kz/Kr): 1.

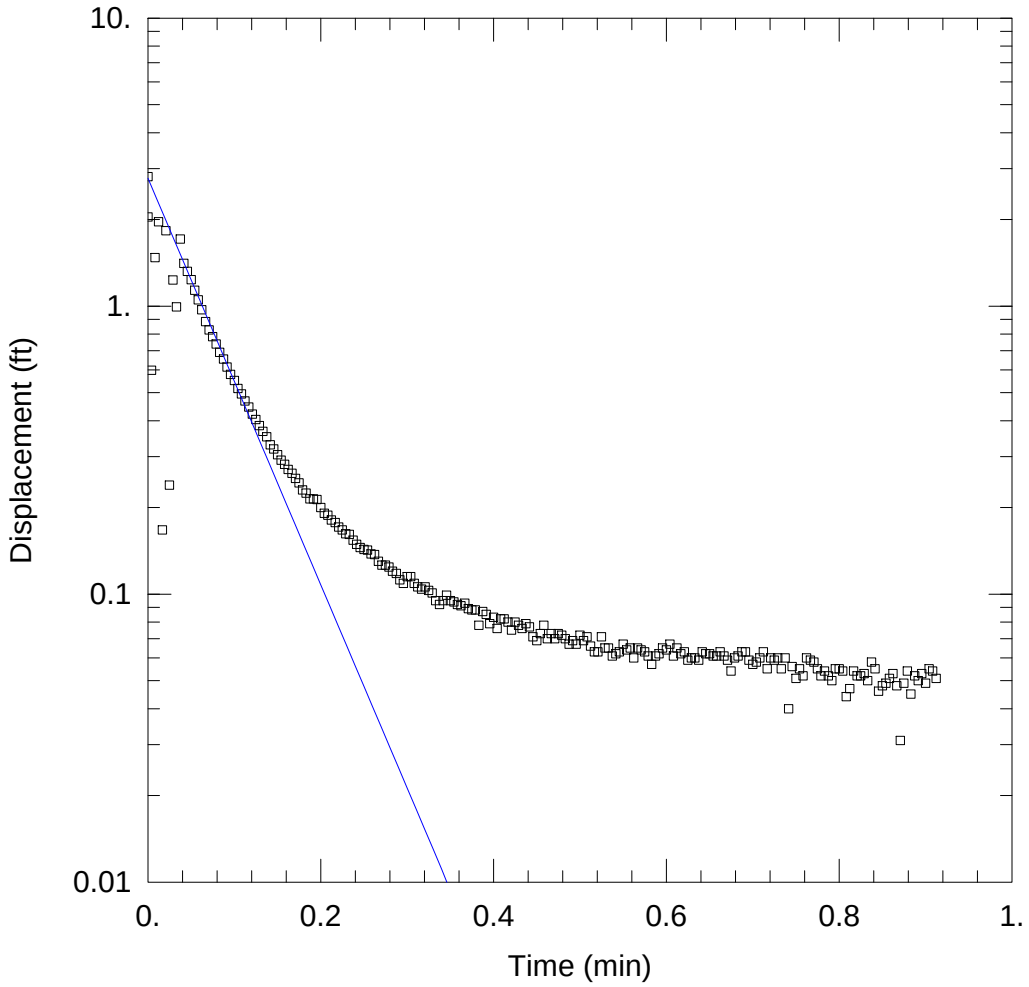
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 14.2 ft
Casing Radius: 0.083 ft
Static Water Column Height: 14.2 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.009907 ft/min y0 = 2.311 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW07-Slug out 2.aqt
Date: 06/02/17 Time: 14:05:52

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

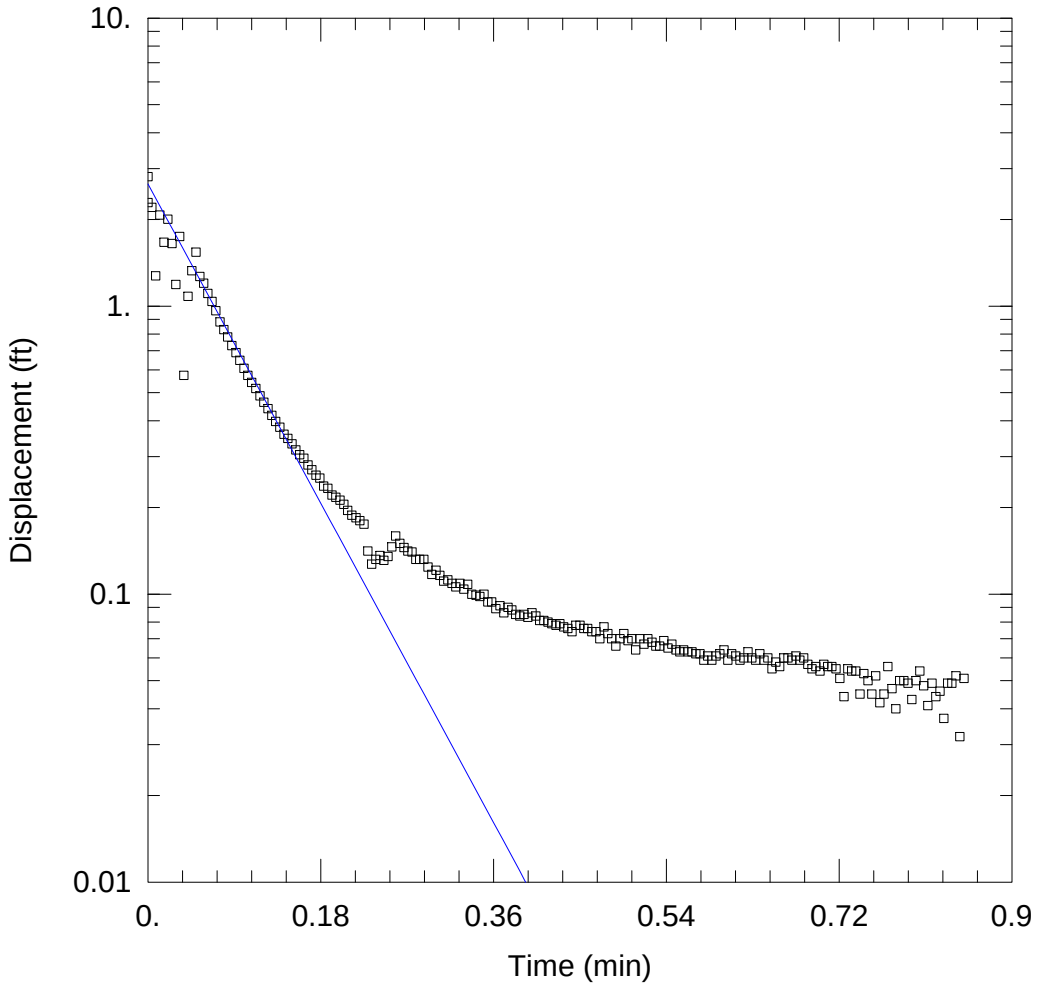
Saturated Thickness: 14.2 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 14.2 ft
Casing Radius: 0.083 ft
Static Water Column Height: 14.2 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.009506 ft/min
y0 = 2.778 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW07-Slug out 3.aqt
Date: 06/02/17 Time: 14:06:06

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

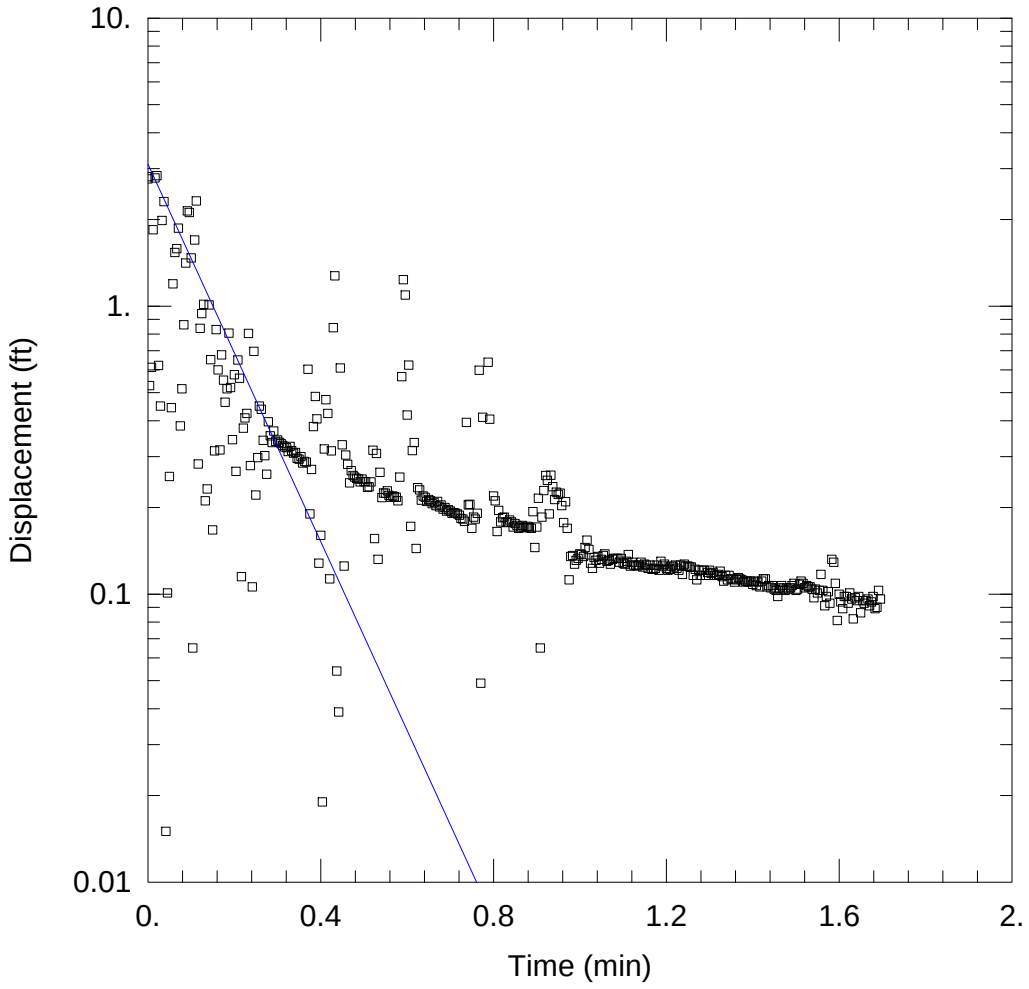
Saturated Thickness: 14.2 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 14.2 ft
Casing Radius: 0.083 ft
Static Water Column Height: 14.2 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.008296 ft/min
y0 = 2.655 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW09-Slug in 1.aqt
Date: 06/02/17 Time: 14:06:21

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

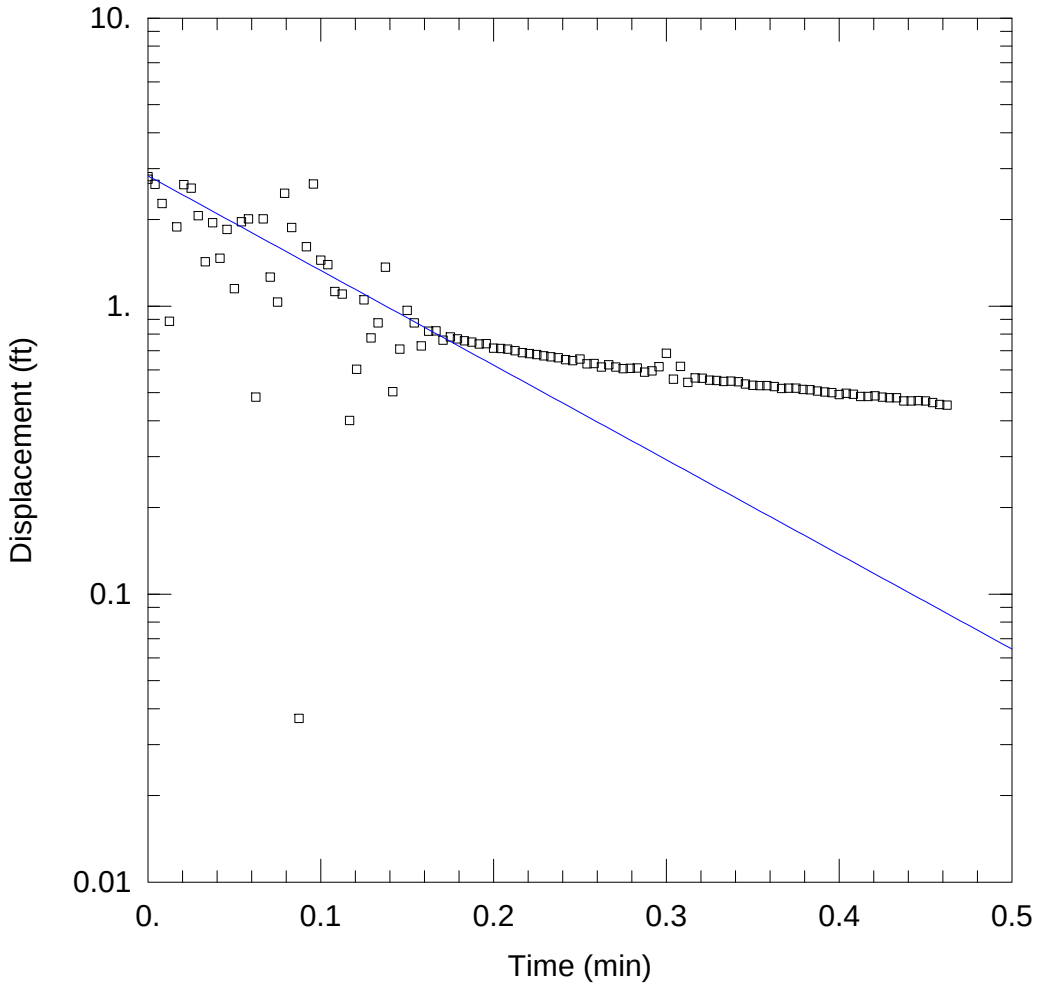
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.32 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.32 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.004468 ft/min y0 = 3.108 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW09-Slug in 2.aqt
Date: 06/02/17 Time: 14:06:49

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

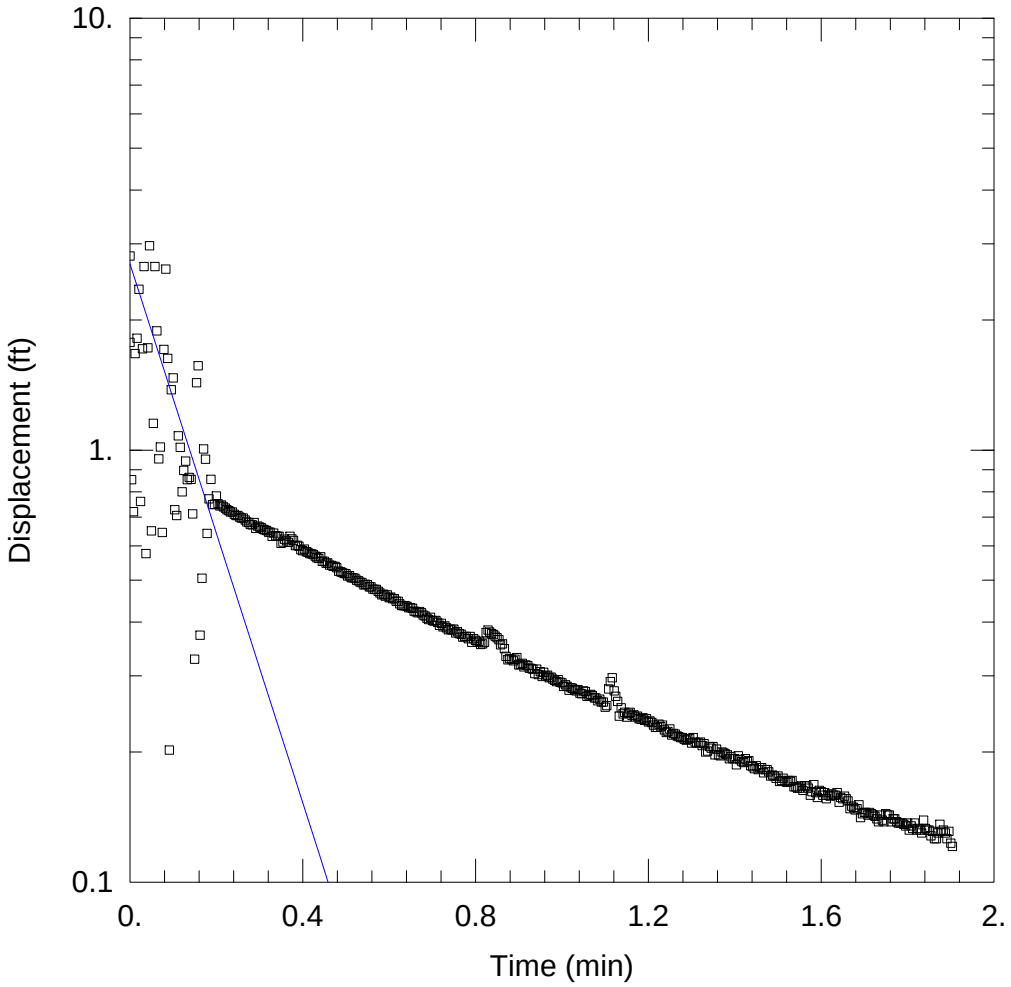
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.32 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.32 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.004481 ft/min y0 = 2.833 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW09-Slug in 3.aqt
Date: 06/02/17 Time: 14:07:02

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

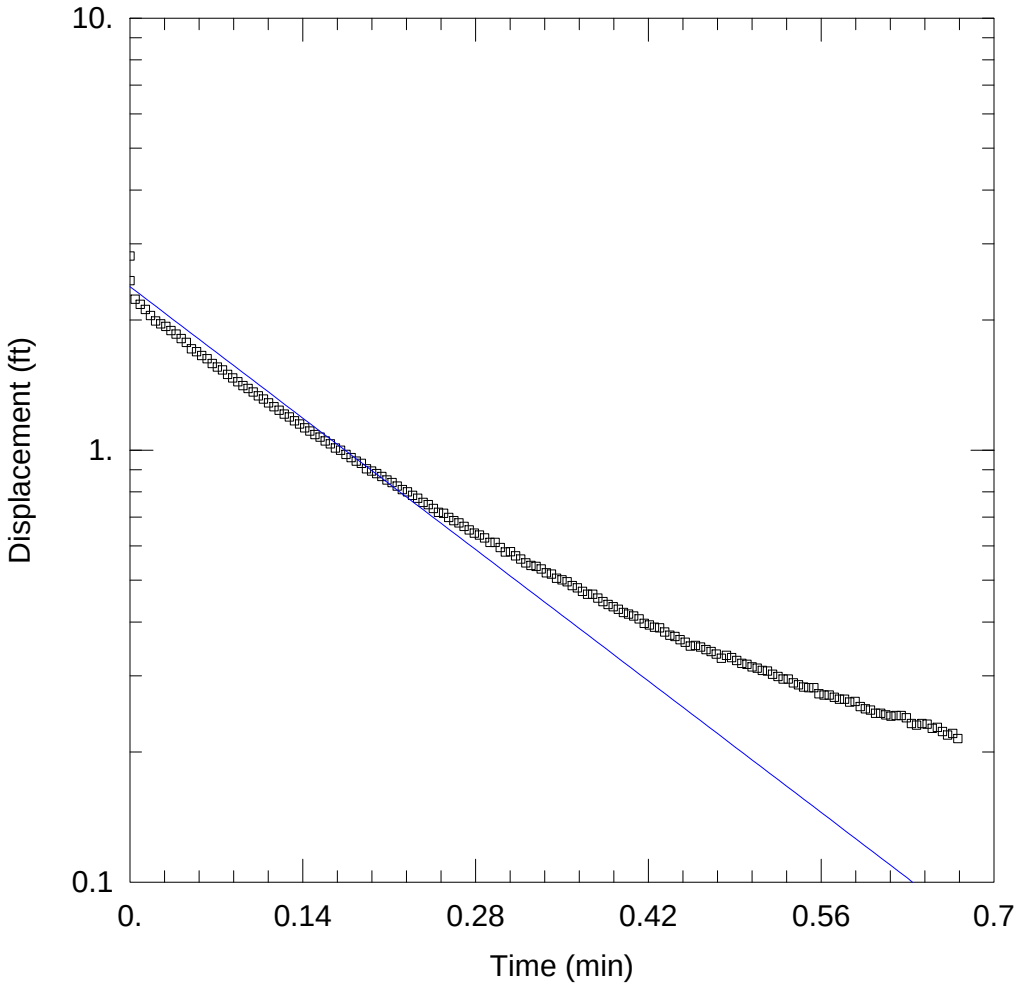
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.32 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.32 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.004251 ft/min y0 = 2.697 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW09-Slug out 1.aqt
Date: 06/02/17 Time: 14:07:18

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

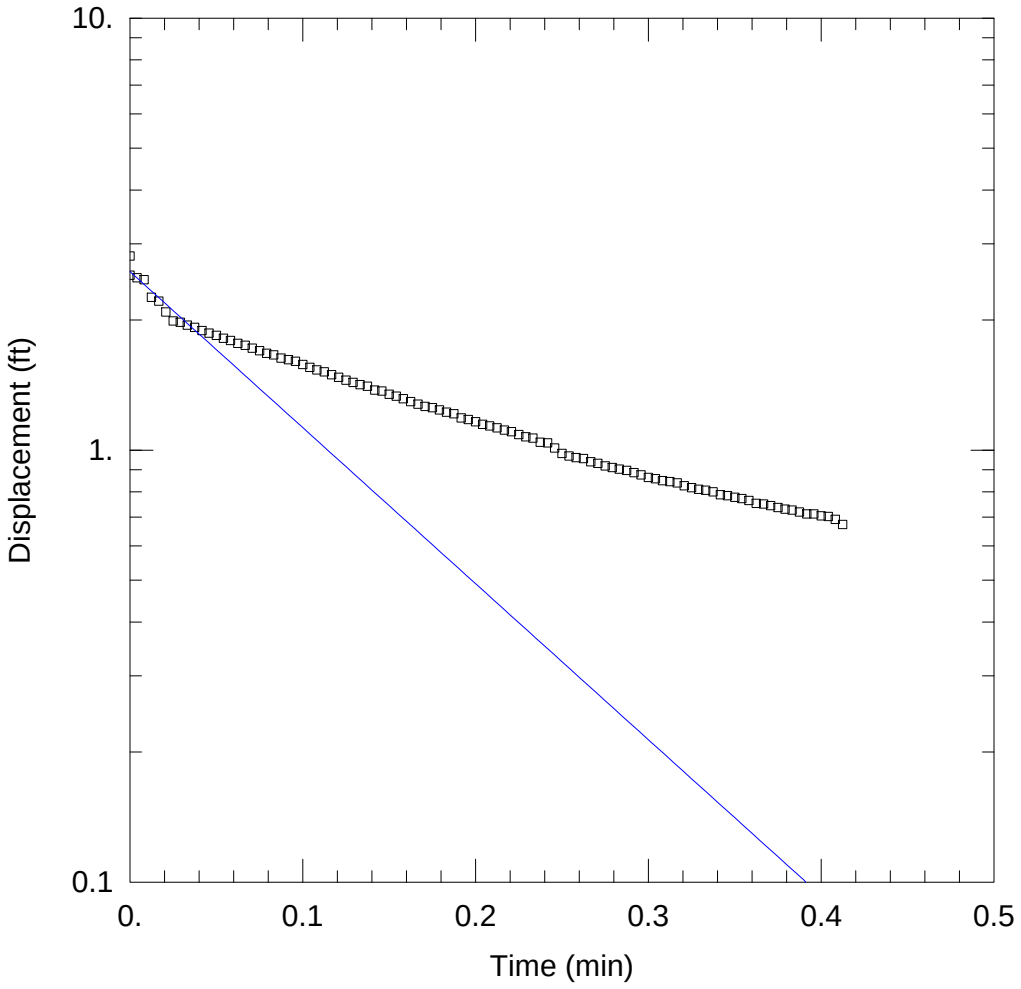
Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.32 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.32 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.002963 ft/min
y0 = 2.389 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW09-Slug out 2.aqt
Date: 06/02/17 Time: 14:07:30

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

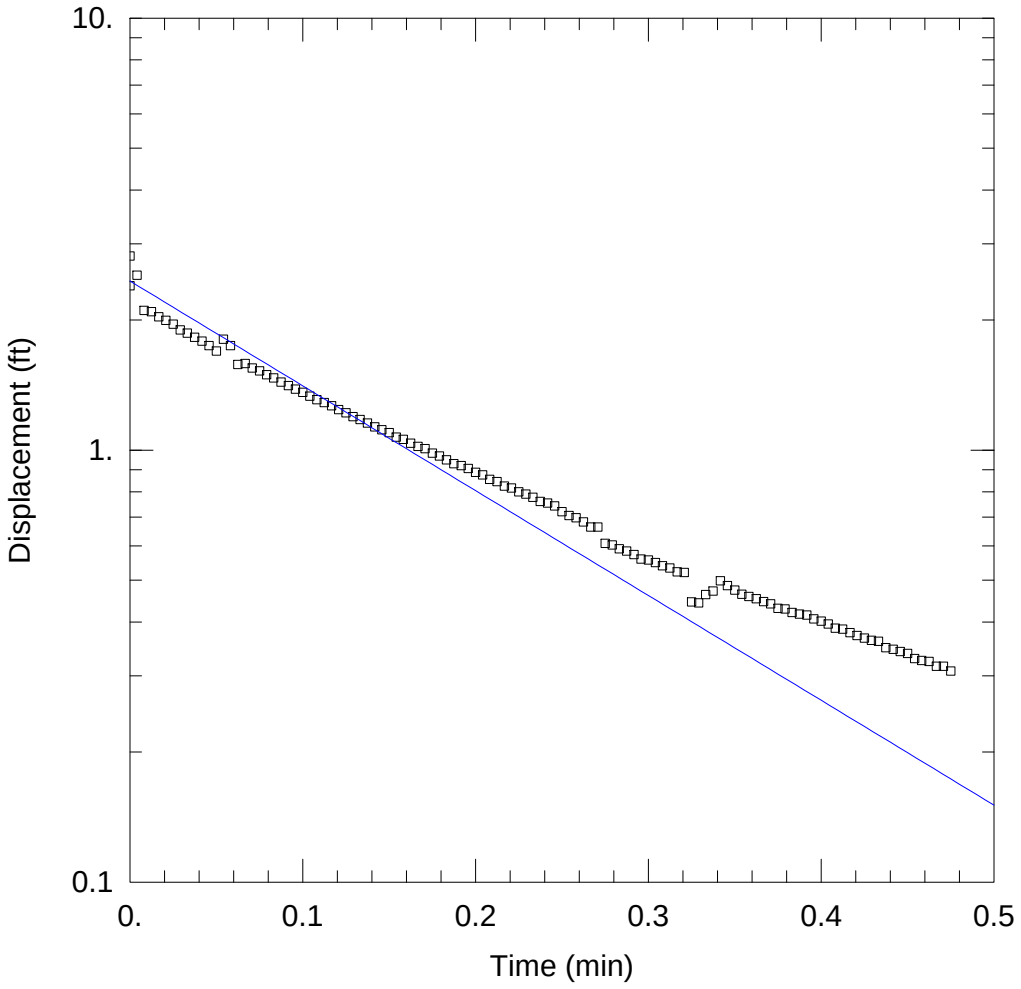
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.32 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.32 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.004924 ft/min y0 = 2.588 ft



WELL TEST ANALYSIS

Data Set: \...\OW11-MW09-Slug out 3.aqt
Date: 06/02/17 Time: 14:08:40

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 15.32 ft Anisotropy Ratio (Kz/Kr): 1.

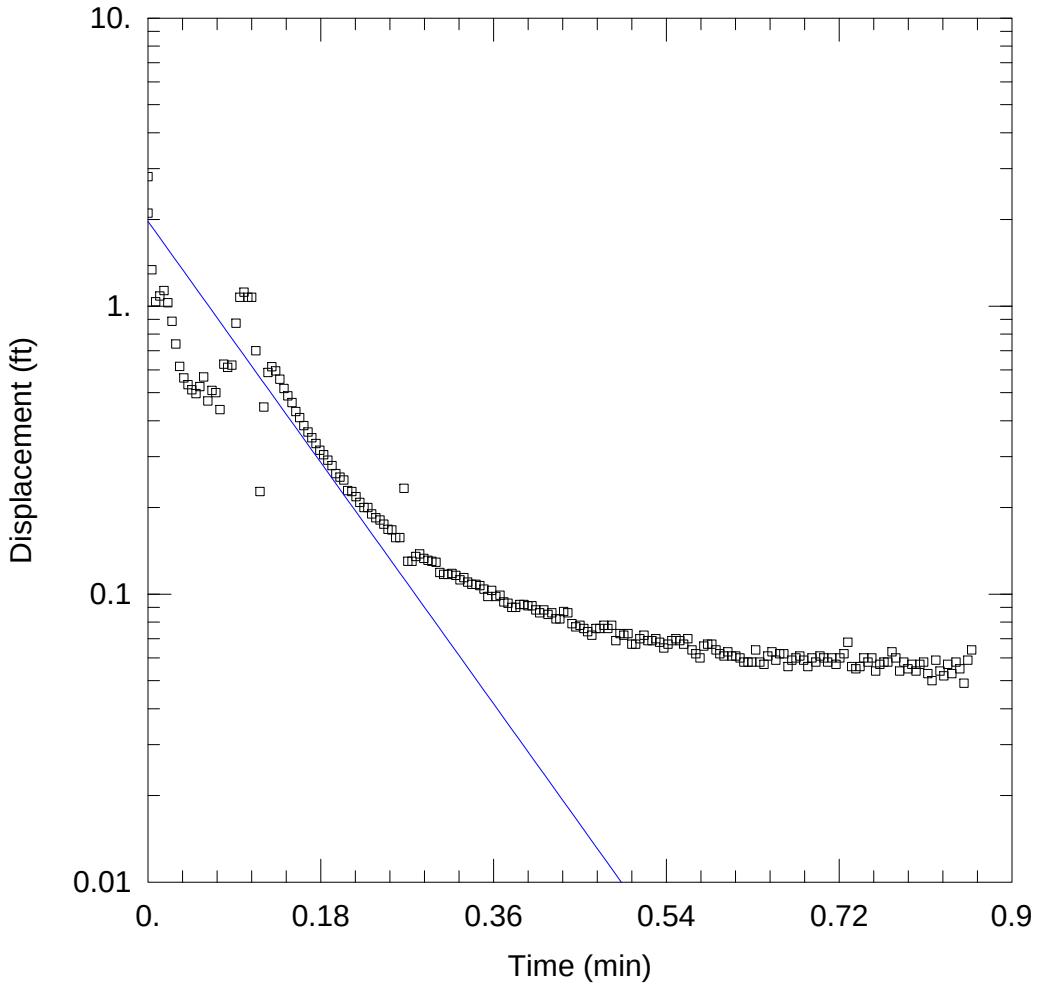
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 15.32 ft
Casing Radius: 0.083 ft
Static Water Column Height: 15.32 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.003308 ft/min y0 = 2.462 ft



WELL TEST ANALYSIS

Data Set: \...\OW26-MW01-Slug in 1.aqt
Date: 06/02/17 Time: 14:08:55

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

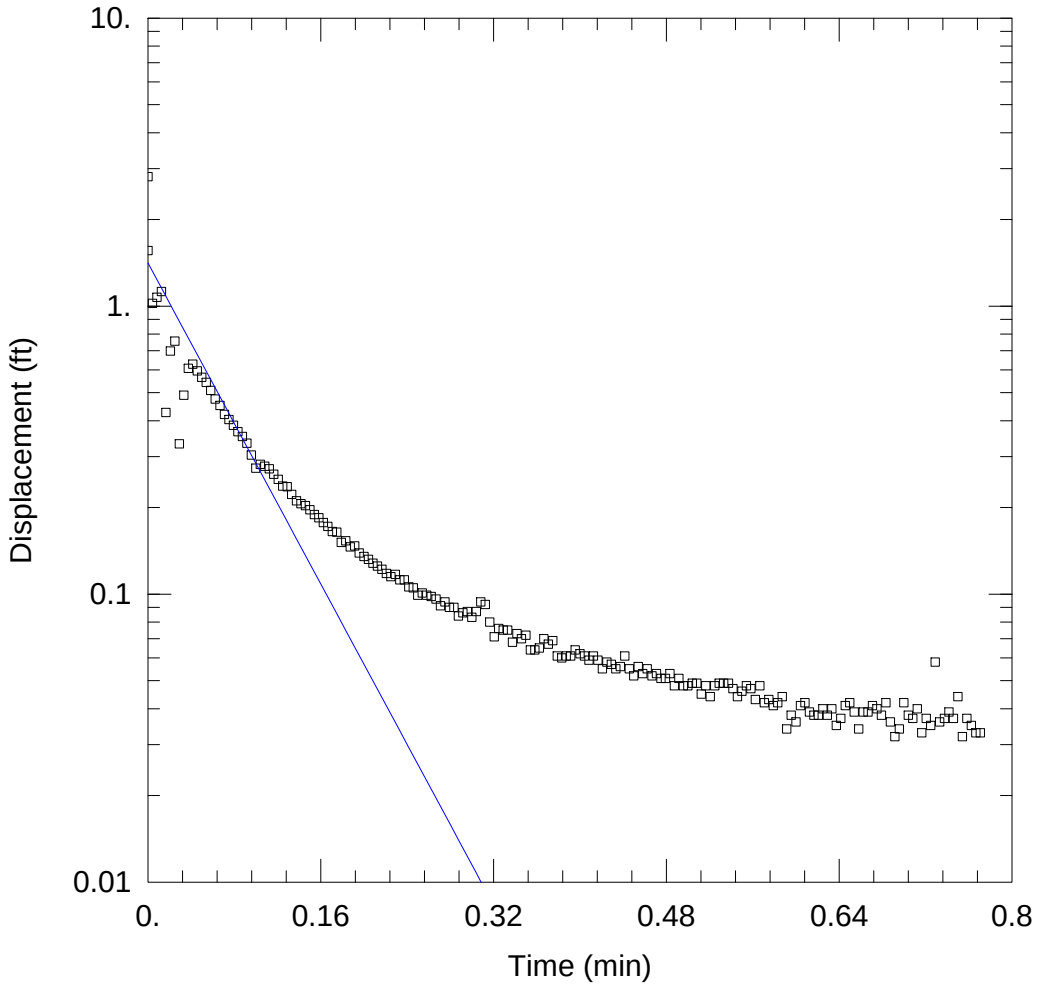
Saturated Thickness: 13.97 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 13.97 ft
Casing Radius: 0.083 ft
Static Water Column Height: 13.97 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.00625 ft/min
y0 = 1.969 ft



WELL TEST ANALYSIS

Data Set: \...\OW26-MW01-Slug in 2.aqt
Date: 06/02/17 Time: 14:09:10

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 13.97 ft Anisotropy Ratio (Kz/Kr): 1.

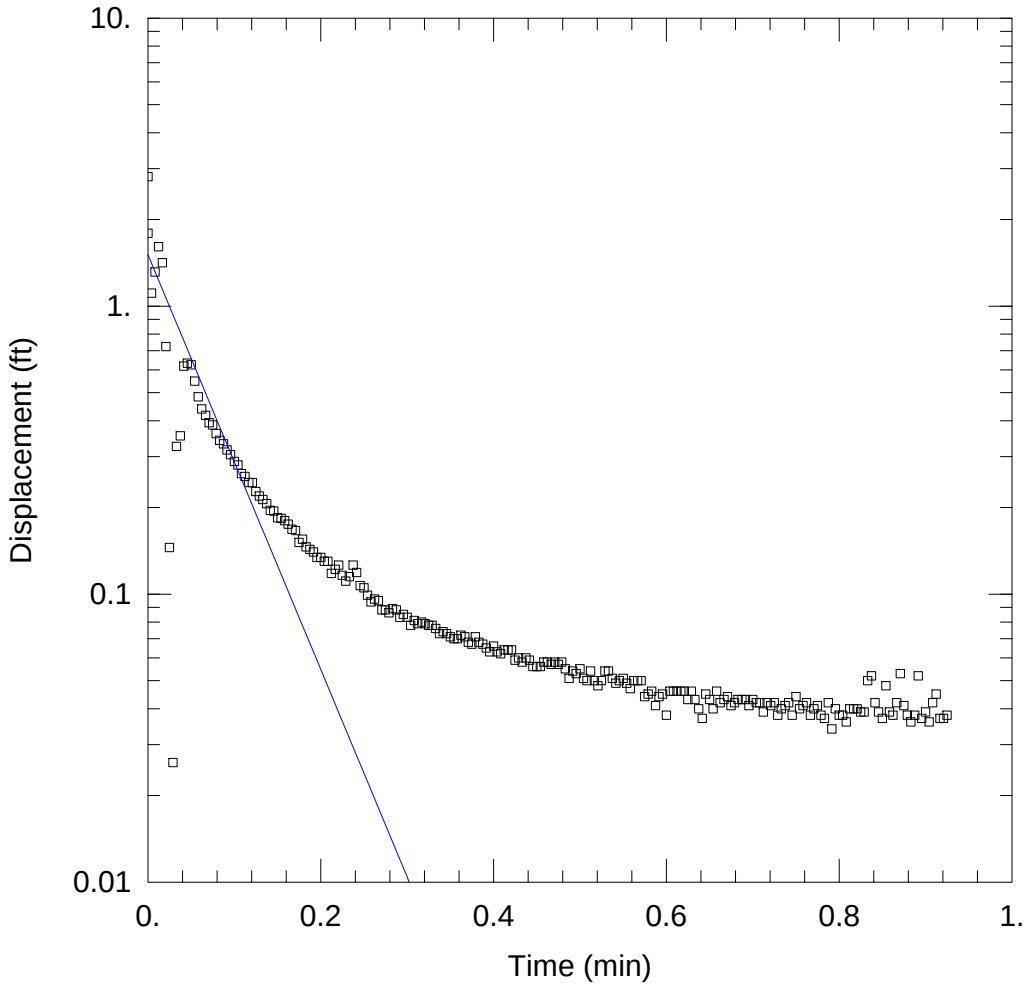
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 13.97 ft
Casing Radius: 0.083 ft
Static Water Column Height: 13.97 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.009356 ft/min y0 = 1.411 ft



WELL TEST ANALYSIS

Data Set: \...\OW26-MW01-Slug in 3.aqt
Date: 06/02/17 Time: 14:09:26

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

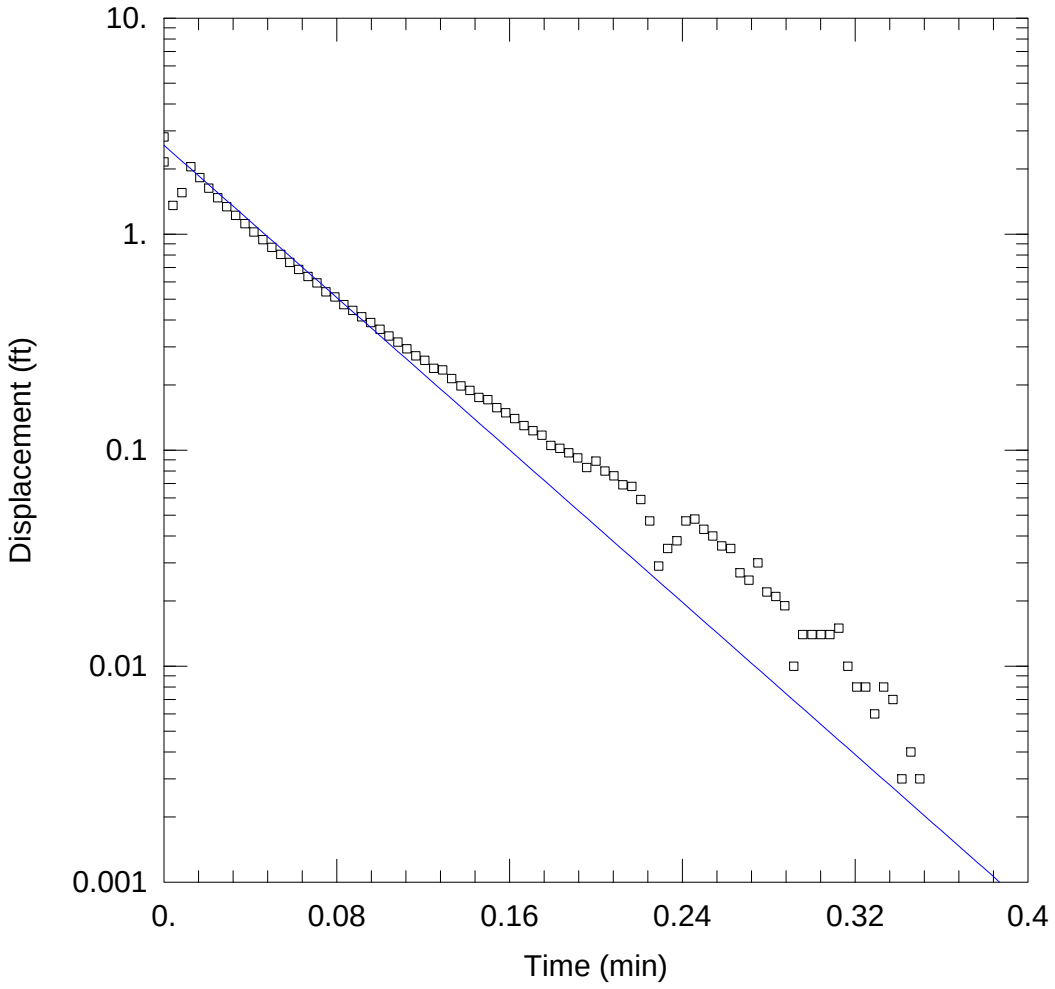
Saturated Thickness: 13.97 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 13.97 ft
Casing Radius: 0.083 ft
Static Water Column Height: 13.97 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.009673 ft/min
y0 = 1.508 ft



WELL TEST ANALYSIS

Data Set: \...\OW26-MW01-Slug out 1.aqt
Date: 06/02/17 Time: 14:09:38

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 13.97 ft Anisotropy Ratio (Kz/Kr): 1.

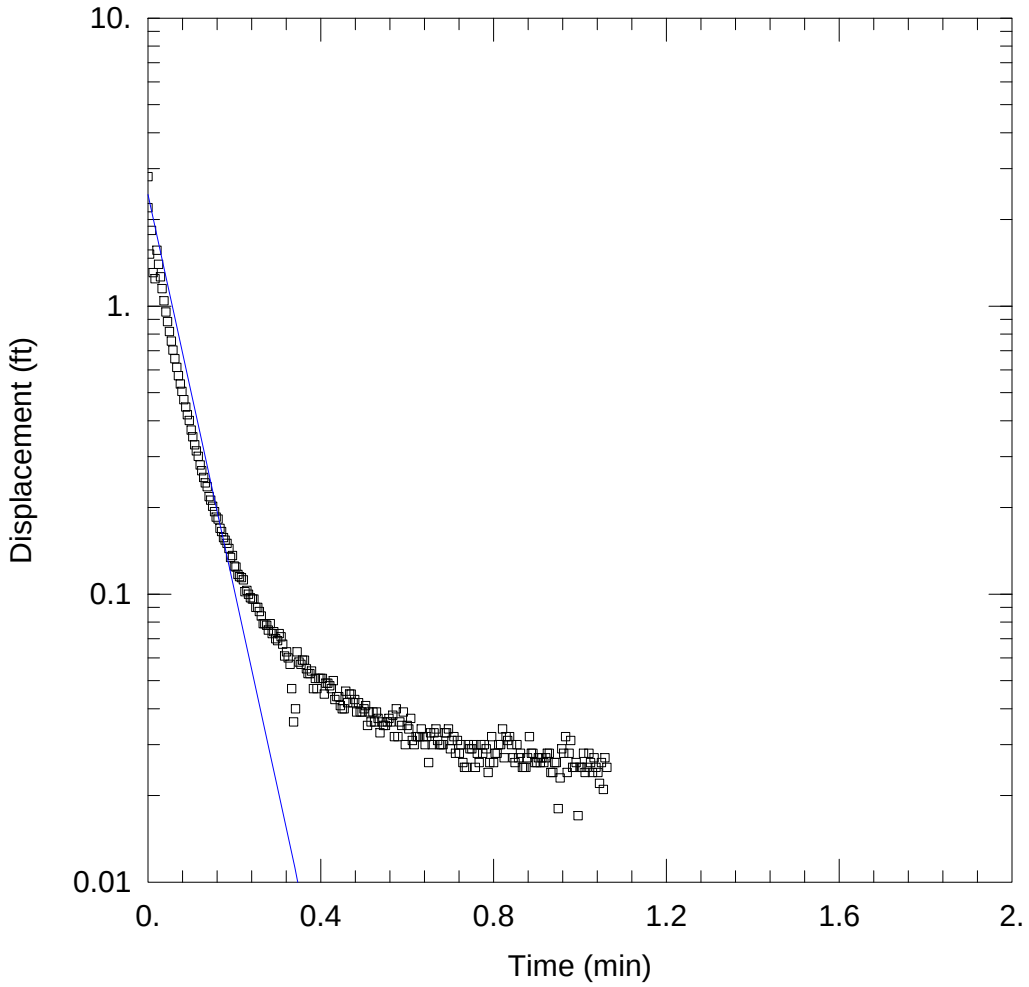
WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 13.97 ft
Casing Radius: 0.083 ft
Static Water Column Height: 13.97 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.01184 ft/min y0 = 2.578 ft



WELL TEST ANALYSIS

Data Set: \...\OW26-MW01-Slug out 2.aqt
Date: 06/02/17 Time: 14:09:50

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

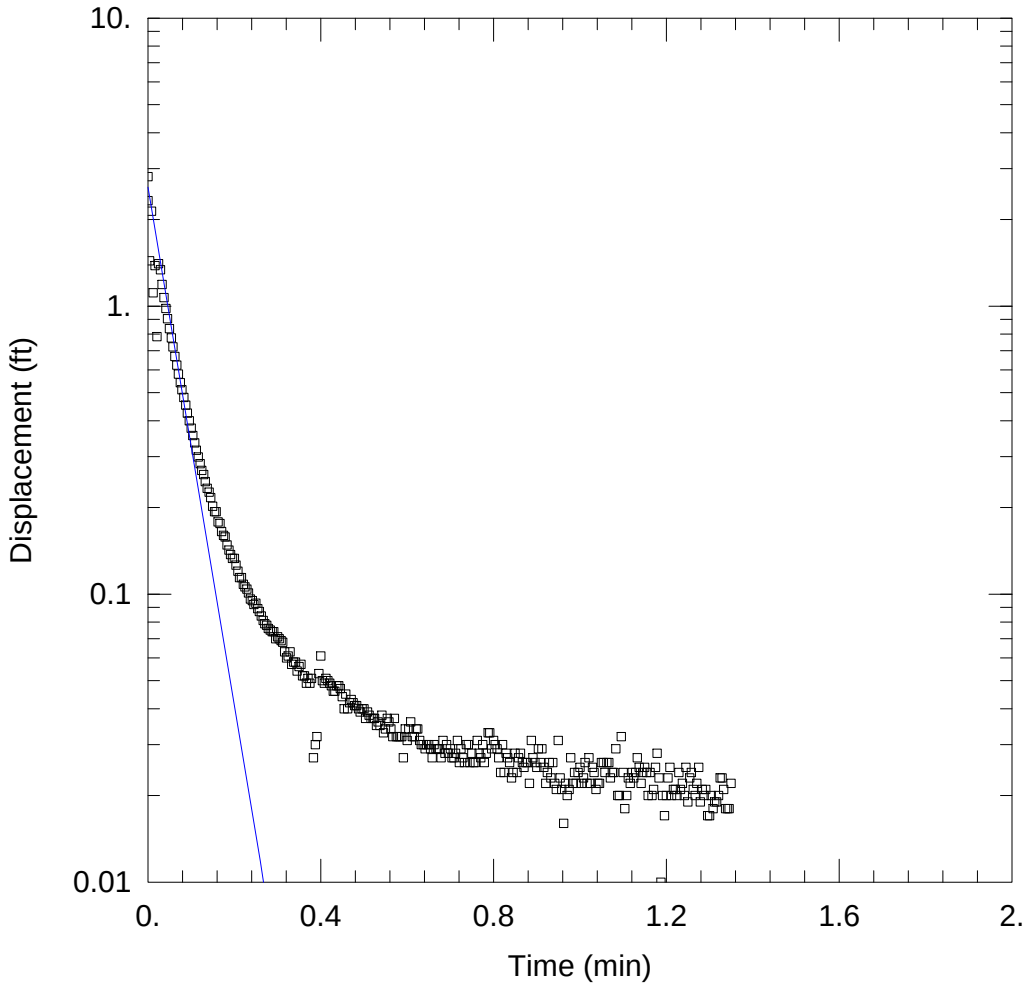
Saturated Thickness: 13.97 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 13.97 ft
Casing Radius: 0.083 ft
Static Water Column Height: 13.97 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.009229 ft/min
y0 = 2.438 ft



WELL TEST ANALYSIS

Data Set: \...\OW26-MW01-Slug out 3.aqt
Date: 06/02/17 Time: 14:10:06

PROJECT INFORMATION

Company: CH2M
Client: NAVY CLEAN
Location: OCEANA
Test Well: OW11-MW04
Test Date: 11-10-2016

AQUIFER DATA

Saturated Thickness: 13.97 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

Initial Displacement: 2.813 ft
Total Well Penetration Depth: 13.97 ft
Casing Radius: 0.083 ft
Static Water Column Height: 13.97 ft
Screen Length: 10. ft
Well Radius: 0.083 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 0.01209 ft/min
y0 = 2.588 ft

Appendix E
Survey Reports

CLEAN 8012 CTO WE14

Site 11, Oceana Crash Site Areas, SWMU 26

Virginia Beach, Virginia

MSA Project #16127B

Survey Report

MSA, P.C. provided surveying support for activities associated with the base wide perfluorinated compound investigation being performed at Site 11, SWMU 26, and locations around a 1986 crash near Oceana Boulevard located a Naval Air Station (NAS) Oceana in Virginia Beach, Virginia.

HORIZONTAL CONTROL

In order to establish on-site horizontal control, MSA, P.C. verified City of Virginia Beach Stations 711903, and C306 using GPS. After verification, on-site points #50, #51, #74 and #75 were set using GPS and multiple observations were made to ensure their accuracy. Horizontal control work complies with Third Order (1:10,000). The relative precision of the on-site traverse was as follows

Site 11 (1,857.51'/0.0065' = 1:285,771) Closed Traverse point #'s 50, 51, 53 and 54

SWMU 26 (11,243.59'/.004 = 1:2,810,898) Closed Traverse point #'s 74, 75, 76, 77, 78, 80, 81 and 82

VERTICAL CONTROL

Vertical control was established through GPS by verifying the known published elevations of City of Virginia Beach Control Stations PS540 andC306. Elevations were then applied to on-site control points #50, #51, #74 and #75 and a level loop was run through the traverse points, control points, and PVC casings of the monitoring wells. Vertical control work complies with Third Order (0.05 √m) and the maximum vertical error for the City of Virginia Beach Stations C306 and PS540 was 0.030'.

FIELD OPERATION DATES

The surveying took place beginning on October 17, 2016, and following the scope of work, the field crew field located twenty-one (21) monitoring wells throughout the Oceana NAS. Weather conditions on the first date of the field work was temperatures in the low 70's and clear.

CONTROL POINTS SET

MSA, P.C. set points #50, #51, #74 and #75 using GPS. Once these were in place, a traverse was run around the sites and permanent control points were put in place. Points #50, #51, #74 and #75 are 5/8" rebar set at ground level. Horizontal control points are referenced to the Virginia State Plane Coordinate System, South Zone, NAD 83/94 HARN. Vertical datum is based upon NAVD 88 and the US Survey Foot.

GPS OBSERVATIONS

A Leica 1200GPS was used with the ATX1230 SmartAntenna. All antenna heights were 6.562' to the bottom of the antenna mount. The RTK system utilizes the Leica SpiderNet CORS system with the base station being located in Virginia Beach, Virginia and named LS03.

CERTIFICATION

This survey was completed under the direct and responsible charge of Gregory M. Zoby, LS #2991, from an actual ground survey made under my supervision. The imagery and/or original data was obtained on October 17, 2016; and that this plat, map, or digital geospatial data including metadata complies with the accuracy requirements and with federal, state codes, ordinances, rules and regulations.


MW05D
MW02D
MW10D
MWF4
MW1D
MW07
MW07D
Naval Air Station Oceana
Southern Blvd
Potters Rd
London Bridge Rd
S Oceana Blvd
Oceana Blvd
S First Colonial Rd
Tomcat Blvd
Harpers Rd
Aeropines Golf Course
Dewey Rd
Railroad Dr

MONITORING WELLS	COORDINATES		ELEVATIONS			
	NORTHING	EASTING	GROUND	RIM	PVC	CONCRETE
OC-MW05D	3474053.93	12205440.12	16.6	16.53	16.28	
OC-MW02D	3470248.68	12211475.87	22.9	22.95	22.79	
OW26-MW1D	3465586.92	12206848.06	18.6	18.65	18.35	
OC-MW07D	3459527.53	12198113.53	9.6	13.64	13.59	9.87
OC-MW07	3459532.08	12198118.00	9.7	13.93	13.96	10.28
OC-MW-F4	3467331.72	12201491.29	15.2	17.68	17.64	15.35
OW11-MW10D	3469397.72	12204008.22	17.4	17.38	17.11	

Appendix F
Investigation-derived Waste Profiles and Disposal Manifests

TABLE F-1

Aqueous Investigation-Derived Waste Analytical Data (October 2016)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID	TCLP Regulatory Level	AQ-IDW01-1116	AQ-IDW02-1116
Sample Date		11/2/16	11/2/16
Chemical Name			
TCLP Volatile Organic Compounds (UG/L)			
No Detections			
TCLP Semivolatile Organic Compounds (UG/L)			
No Detections			
TCLP Pesticides/Polychlorinated Biphenyls (UG/L)			
No Detections			
TCLP Herbicides (UG/L)			
No Detections			
TCLP Metals (UG/L)			
Barium	100,000	133	240
Mercury	200	0.1 U	0.735
Wet Chemistry			
pH	2 - 12.5	7.4	7.2

Notes:

PH = pH units

TCLP = Toxicity Characteristic Leaching Procedure

U - The material was analyzed for, but not detected

UG/L = microgram per liter

Shading indicates detection

TABLE F-2

Soil Investigation-Derived Waste Analytical Data (October 2016)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID	TCLP Regulatory Level	IDW-SO-01-1016	IDW-SO-02-1016	IDW-SO-03-1016	IDW-SO-04-1016	IDW-SO-05-1016	IDW-SO-06-1016	IDW-SO-07-1016
Sample Date		10/14/16	10/14/16	10/14/16	10/14/16	10/14/16	10/14/16	10/14/16
Chemical Name								
TCLP Volatile Organic Compounds (UG/L)								
Tetrachloroethene	700	10 U	10 U	12 J	11 J	10 U	10 U	10 U
TCLP Semivolatile Organic Compounds (UG/L)								
No Detections								
TCLP Pesticides/Polychlorinated Biphenyls (UG/L)								
No Detections								
TCLP Herbicides (UG/L)								
No Detections								
TCLP Metals (UG/L)								
Barium	100,000	364	579	544	592	794	674	470
Cadmium	1,000	0.76 J	15 U	15 U	0.7 J	0.52 J	0.3 J	15 U
Chromium	5,000	3 J	2 J	3.7 J	3.1 J	20 U	3.4 J	20 U
Lead	5,000	180	11 J	14 J	30	19 J	16 J	11 J
Mercury	200	0.1 U	0.1 U	0.1 U	0.022 J	0.022 J	0.1 U	0.1 U
Selenium	1,000	35 U	35 U	14 J	35 U	35 U	12 J	35 U
Silver	5,000	20 U	20 U	20 U	20 U	20 U	20 U	2.5 J
Wet Chemistry								
pH	2 - 12.5	7	6.3	5	5.6	5.4	5.7	6.2

Notes:

J = Analyte present. Value may or may not be accurate or precise.

TCLP = Toxicity Characteristic Leaching Procedure

U = The material was analyzed for, but not detected.

UG/L = micrograms per liter

Shading indicates detection

TABLE F-3

Aqueous Investigation-Derived Waste Analytical Data (May 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID	**TCLP Regulatory Level**	IDW-AQ-01-0417
Sample Date		4/4/17
Chemical Name		
TCLP Volatile Organic Compounds (UG/L)		
No Detections		
Semivolatile Organic Compounds (NG/L)		
Perfluoroheptanoic acid (PFHpA)		4.22 J
Perfluorohexanesulfonic acid (PFHxS)		21.4
Perfluorooctane Sulfonate (PFOS)		56.5
Perfluorooctanoic acid (PFOA)		11.5
Total PFOS + PFOA		68.0
TCLP Semivolatile Organic Compounds (UG/L)		
No Detections		
TCLP Pesticides/Polychlorinated Biphenyls (UG/L)		
No Detections		
TCLP Herbicides (UG/L)		
No Detections		
TCLP Metals (UG/L)		
Barium	100,000	213
Mercury	200	0.014 J
Wet Chemistry		
pH	2 - 12.5	7.5

Notes:

J - Analyte present. Value may or may not be accurate or precise

NG/L - Nanograms per liter

NS - Not sampled

PH - pH units

TCLP = Toxicity Characteristic Leaching Procedure

UG/L - Micrograms per liter

Shading indicates detection

TABLE F-4

Soil Investigation-Derived Waste Analytical Data (May 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID	**TCLP Regulatory Level**	IDW-SO-01-0417
Sample Date		4/4/17
Chemical Name		
TCLP Volatile Organic Compounds (UG/L)		
No Detections		
TCLP Semivolatile Organic Compounds (UG/L)		
No Detections		
TCLP Pesticides/Polychlorinated Biphenyls (UG/L)		
No Detections		
TCLP Herbicides (UG/L)		
No Detections		
TCLP Metals (UG/L)		
Barium	100,000	277
Cadmium	1,000	0.47 J
Wet Chemistry		
pH	2 - 12.5	8

Notes:

J - Analyte present. Value may or may not be accurate or precise

PH - pH units

TCLP = Toxicity Characteristic Leaching Procedure

UG/L - Micrograms per liter

Shading indicates detection

Appendix G
Data Validation Reports

ENVIRONMENTAL
Data Services, Inc.

DATA VALIDATION SUMMARY REPORT
NAS OCEANA, VIRGINIA BEACH, VIRGINIA

Client: CH2M HILL, Inc., Virginia Beach, Virginia
SDG: 1700417
Laboratory: Vista Analytical Laboratory, El Dorado Hills, California
Site: NAS Oceania, Virginia Beach, Virginia, CTO-WE14
Date: May 22, 2017

PFCs			
EDS ID	Client Sample ID	Laboratory Sample ID	Matrix
1	OC-MW05D-0417	1700417-01	Water
2	OC-MW05DP-0417	1700417-02	Water
3	OC-MW02D-0417	1700417-03	Water
4	OW26-MW01D-0417	1700417-04	Water
5	OW11-MW10D-0417	1700417-05	Water
6	OC-F8F9-MW-F4-0417	1700417-06	Water
7	OC-MW07D-0417	1700417-07	Water
8	OC-MW07-0417	1700417-08	Water
8MS	OC-MW07-0417MS	1700417-08MS	Water
8MSD	OC-MW07-0417MSD	1700417-08MSD	Water
9	OC-EB040417	1700417-09	Water
10	OC-FB040417	1700417-10	Water

A full data validation was performed on the analytical data for eight water samples, one aqueous equipment blank sample, and one aqueous field blank sample collected on April 3-4, 2017 by CH2M HILL at the NAS Oceana site in Virginia Beach, Virginia. The samples were analyzed under the EPA Method "Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)".

Specific method references are as follows:

Analysis	*Method References*
PFCs	USEPA Method 537 Modified

The data have been validated according to the protocols and quality control (QC) requirements of the analytical method, and the U.S. Department of Defense (DoD) Quality Systems Manual (QSM), Version 5.0 (July 2013) and the USEPA National Functional Guidelines for Organic Data Review as follows:

- The USEPA "Contract Laboratories Program National Functional Guidelines for Superfund Organic Methods Data Review," August 2014;
- and the reviewer's professional judgment.

The following data quality indicators were reviewed for this report:

Organics

- Date Completeness, Case Narrative & Custody Documentation
- Holding times
- Initial and continuing calibration summaries
- Method blank and field QC blank contamination
- Surrogate recoveries (%R)
- Matrix Spike/Matrix Spike Duplicate (MS/MSD) recoveries
- Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD) recoveries
- Target Compound Identification
- Compound Quantitation
- Field Duplicate sample precision

A full (Level IV) data validation was performed with this review including a recalculation of 10% of the detected results in the samples.

Data Usability Assessment

There were no rejections of data.

Overall the data is acceptable for the intended purposes. There were no qualifications.

Perfluorinated Compounds (PFCs)

Data Completeness, Case Narrative & Custody Documentation

- The case narrative and chain-of-custody documentation were included in the data package as required. All criteria were met.

Holding Times

- All samples were extracted within 14 days for water samples and analyzed within 28 days.

Initial Calibration

- All percent difference (%D) and/or correlation coefficients criteria were met.

Continuing Calibration

- All percent recovery (%R) criteria were met.

Method Blank

- The method blanks were free of contamination.

Field QC Blank

- The field blank samples were free of contamination.

Blank ID	Compound	Conc. ng/L	Qualifier	Affected Samples
OC-EB040417	None - ND	-	-	-
OC-FB040417	None - ND	-	-	-

Surrogate Spike Recoveries

- All samples exhibited acceptable surrogate %R values.

Matrix Spike/Matrix Spike Duplicate (MS/MSD) Recoveries

- The MS/MSD sample exhibited acceptable percent recoveries (%R) and RPD values.

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

- The LCS/LCSD samples exhibited acceptable percent recoveries (%R) and RPD values.

Target Compound Identification

- All mass spectra and quantitation criteria were met.

Compound Quantitation

- All criteria were met.

Field Duplicate Sample Precision

- Field duplicate results are summarized below. The precision was acceptable.

Compound	OC-MW05D-0417 ng/L	OC-MW05DP-0417 ng/L	RPD	Qualifier
PFOS	1.01	2.42	82%	None - <5X LOQ

Please contact the undersigned at (757) 564-0090 if you have any questions or need further information.

Signed: Nancy Weaver Dated: 5/23/17

Nancy Weaver
Senior Chemist

Data Qualifier	Definition
U	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.
J	The analyte is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
NJ	The analysis has been "tentatively identified" or "presumptively" as present and the associated numerical value is the estimated concentration in the samples.
UJ	The analyte was analyzed for but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the samples.

1

Sample ID: OC-MW05D-0417

Modified EPA Method 537

Client Data
Name: CH2M Hill
Project: 678440.51.51.01
Date Collected: 03-Apr-2017 9:45
Location:

Sample Data
Matrix: Aqueous
Sample Size: 0.118 L

Laboratory Data
Lab Sample: 1700417-01 Date Received: 05-Apr-2017 9:50
QC Batch: B7D0026 Date Extracted: 06-Apr-2017 10:58
Date Analyzed: 15-Apr-17 13:03 Column: BEH C18

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.89	4.24	8.45	
PFHpA	ND	0.624	2.12	8.45	
PFHxS	ND	1.00	2.12	8.45	
PFOA	ND	0.687	2.12	8.45	
PFOS	1.01	0.852	0.953	8.45	J
PFNA	ND	0.855	2.12	8.45	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	98.5	60 - 150	
IS	13C4-PFHpA	97.0	60 - 150	
IS	18O2-PFHxS	90.0	60 - 150	
IS	13C2-PFOA	87.0	60 - 150	
IS	13C8-PFOS	97.5	60 - 150	
IS	13C5-PFNA	91.9	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

NW 5/22/17

2

Sample ID: OC-MW05DP-0417 — **Modified EPA Method 537**

Client Data		Sample Data		Laboratory Data			
Name:	CH2M Hill	Matrix:	Aqueous	Lab Sample:	1700417-02	Date Received:	05-Apr-2017 9:50
Project:	678440.51.51.01	Sample Size:	0.122 L	QC Batch:	B7D0026	Date Extracted:	06-Apr-2017 10:58
Date Collected:	03-Apr-2017 9:50			Date Analyzed:	15-Apr-17 13:16	Column:	BEH C18
Location:							

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.83	4.10	8.18	
PFHpA	ND	0.604	2.05	8.18	
PFHxS	ND	0.968	2.05	8.18	
PFOA	ND	0.666	2.05	8.18	
PFOS	2.42	0.825	0.922	8.18	J
PFNA	ND	0.828	2.05	8.18	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	94.4	60 - 150	
IS	13C4-PFHpA	94.3	60 - 150	
IS	18O2-PFHxS	97.9	60 - 150	
IS	13C2-PFOA	86.5	60 - 150	
IS	13C8-PFOS	99.6	60 - 150	
IS	13C5-PFNA	95.8	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

MW 5/22/17

3

Sample ID: OC-MW02D-0417 — **Modified EPA Method 537**

Client Data		Sample Data		Laboratory Data			
Name:	CH2M Hill	Matrix:	Aqueous	Lab Sample:	1700417-03	Date Received:	05-Apr-2017 9:50
Project:	678440.51.51.01	Sample Size:	0.122 L	QC Batch:	B7D0026	Date Extracted:	06-Apr-2017 10:58
Date Collected:	03-Apr-2017 11:40			Date Analyzed:	15-Apr-17 13:29	Column:	BEH C18
Location:							

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.84	4.10	8.22	
PFHpA	3.41	0.608	2.05	8.22	J
PFHxS	10.0	0.973	2.05	8.22	
PFOA	8.98	0.669	2.05	8.22	
PFOS	ND	0.830	0.922	8.22	
PFNA	ND	0.833	2.05	8.22	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	103	60 - 150	
IS	13C4-PFHpA	99.7	60 - 150	
IS	18O2-PFHxS	94.3	60 - 150	
IS	13C2-PFOA	85.1	60 - 150	
IS	13C8-PFOS	89.3	60 - 150	
IS	13C5-PFNA	96.0	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

NW 5/22/17

1D NW 4

Sample ID: OW26-MW2-0417 **Modified EPA Method 537**

Client Data		Sample Data		Laboratory Data			
Name:	CH2M Hill	Matrix:	Aqueous	Lab Sample:	1700417-04	Date Received:	05-Apr-2017 9:50
Project:	678440.51.51.01	Sample Size:	0.119 L	QC Batch:	B7D0026	Date Extracted:	06-Apr-2017 10:58
Date Collected:	03-Apr-2017 13:05			Date Analyzed:	15-Apr-17 13:41	Column:	BEH C18
Location:							

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.87	4.20	8.38	
PFHpA	ND	0.619	2.10	8.38	
PFHxS	2.37	0.991	2.10	8.38	J
PFOA	ND	0.682	2.10	8.38	
PFOS	10.1	0.845	0.945	8.38	
PFNA	ND	0.848	2.10	8.38	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	92.3	60 - 150	
IS	13C4-PFHpA	89.5	60 - 150	
IS	18O2-PFHxS	91.9	60 - 150	
IS	13C2-PFOA	80.9	60 - 150	
IS	13C8-PFOS	86.5	60 - 150	
IS	13C5-PFNA	87.6	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

NW 5/22/17

5

Sample ID: OW11-MW10D-0417 — **Modified EPA Method 537**

Client Data		Sample Data		Laboratory Data			
Name:	CH2M Hill	Matrix:	Aqueous	Lab Sample:	1700417-05	Date Received:	05-Apr-2017 9:50
Project:	678440.51.51.01	Sample Size:	0.122 L	QC Batch:	B7D0026	Date Extracted:	06-Apr-2017 10:58
Date Collected:	04-Apr-2017 8:45			Date Analyzed:	15-Apr-17 13:54	Column:	BEH C18
Location:							

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	8.13	1.84	4.10	8.20	J
PFHpA	22.4	0.606	2.05	8.20	
PFHxS	124	0.971	2.05	8.20	
PFOA	61.3	0.668	2.05	8.20	
PFOS	578	0.828	0.922	8.20	
PFNA	5.19	0.831	2.05	8.20	J

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	101	60 - 150	
IS	13C4-PFHpA	101	60 - 150	
IS	18O2-PFHxS	96.4	60 - 150	
IS	13C2-PFOA	83.7	60 - 150	
IS	13C8-PFOS	99.5	60 - 150	
IS	13C5-PFNA	96.1	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

MW 5/22/17

6

Sample ID: OC-F8F9-MW-F4-0417

Modified EPA Method 537

Client Data
Name: CH2M Hill
Project: 678440.51.51.01
Date Collected: 04-Apr-2017 9:55
Location:

Sample Data
Matrix: Aqueous
Sample Size: 0.00110 L

Laboratory Data
Lab Sample: 1700417-06 Date Received: 05-Apr-2017 9:50
QC Batch: B7D0026 Date Extracted: 06-Apr-2017 10:58
Date Analyzed: 15-Apr-17 14:06 Column: BEH C18

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	203	455	909	
PFHpA	ND	67.2	227	909	
PFHxS	ND	108	227	909	
PFOA	ND	74.0	227	909	
PFOS	ND	91.7	102	909	
PFNA	ND	92.0	227	909	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	108	60 - 150	
IS	13C4-PFHpA	104	60 - 150	
IS	18O2-PFHxS	89.0	60 - 150	
IS	13C2-PFOA	81.3	60 - 150	
IS	13C8-PFOS	93.2	60 - 150	
IS	13C5-PFNA	98.1	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

MW 5/22/17

7

Sample ID: OC-MW07D-0417

Modified EPA Method 537

Client Data		Sample Data		Laboratory Data			
Name:	CH2M Hill	Matrix:	Aqueous	Lab Sample:	1700417-07	Date Received:	05-Apr-2017 9:50
Project:	678440.51.51.01	Sample Size:	0.118 L	QC Batch:	B7D0026	Date Extracted:	06-Apr-2017 10:58
Date Collected:	04-Apr-2017 11:05			Date Analyzed:	15-Apr-17 14:19	Column:	BEH C18
Location:							

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.90	4.24	8.50	
PFHpA	ND	0.628	2.12	8.50	
PFHxS	ND	1.01	2.12	8.50	
PFOA	ND	0.691	2.12	8.50	
PFOS	ND	0.857	0.953	8.50	
PFNA	ND	0.860	2.12	8.50	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	99.5	60 - 150	
IS	13C4-PFHpA	91.0	60 - 150	
IS	18O2-PFHxS	90.2	60 - 150	
IS	13C2-PFOA	85.7	60 - 150	
IS	13C8-PFOS	83.2	60 - 150	
IS	13C5-PFNA	86.6	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers.
Only the linear isomer is reported for all other analytes

MW 5/22/17

8

Sample ID: OC-MW07-0417 — **Modified EPA Method 537**

Client Data		Sample Data		Laboratory Data			
Name:	CH2M Hill	Matrix:	Aqueous	Lab Sample:	1700417-08	Date Received:	05-Apr-2017 9:50
Project:	678440.51.51.01	Sample Size:	0.124 L	QC Batch:	B7D0026	Date Extracted:	06-Apr-2017 10:58
Date Collected:	04-Apr-2017 11:45			Date Analyzed:	15-Apr-17 14:31	Column:	BEH C18
Location:							

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.81	4.03	8.08	
PFHpA	ND	0.597	2.02	8.08	
PFHxS	ND	0.957	2.02	8.08	
PFOA	0.685	0.658	2.02	8.08	J
PFOS	3.63	0.815	0.907	8.08	J
PFNA	ND	0.818	2.02	8.08	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	91.4	60 - 150	
IS	13C4-PFHpA	87.5	60 - 150	
IS	18O2-PFHxS	95.5	60 - 150	
IS	13C2-PFOA	86.8	60 - 150	
IS	13C8-PFOS	91.7	60 - 150	
IS	13C5-PFNA	93.2	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

MW 5/22/17

9

Sample ID: OC-EB040417

Modified EPA Method 537

Client Data
Name: CH2M Hill
Project: 678440.51.51.01
Date Collected: 04-Apr-2017 11:50
Location:

Sample Data
Matrix: Aqueous
Sample Size: 0.117 L

Laboratory Data
Lab Sample: 1700417-09 Date Received: 05-Apr-2017 9:50
QC Batch: B7D0026 Date Extracted: 06-Apr-2017 10:58
Date Analyzed: 15-Apr-17 14:44 Column: BEH C18

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.92	4.27	8.56	
PFHpA	ND	0.632	2.14	8.56	
PFHxS	ND	1.01	2.14	8.56	
PFOA	ND	0.696	2.14	8.56	
PFOS	ND	0.863	0.962	8.56	
PFNA	ND	0.867	2.14	8.56	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	96.5	60 - 150	
IS	13C4-PFHpA	93.9	60 - 150	
IS	18O2-PFHxS	93.6	60 - 150	
IS	13C2-PFOA	83.7	60 - 150	
IS	13C8-PFOS	95.5	60 - 150	
IS	13C5-PFNA	91.5	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

MW 5/22/17

10

Sample ID: OC-FB040417

Modified EPA Method 537

Client Data
Name: CH2M Hill
Project: 678440.51.51.01
Date Collected: 04-Apr-2017 11:55
Location:

Sample Data
Matrix: Aqueous
Sample Size: 0.122 L

Laboratory Data
Lab Sample: 1700417-10 Date Received: 05-Apr-2017 9:50
QC Batch: B7D0026 Date Extracted: 06-Apr-2017 10:58
Date Analyzed: 15-Apr-17 14:57 Column: BEH C18

Analyte	Conc. (ng/L)	DL	LOD	LOQ	Qualifiers
PFBS	ND	1.84	4.10	8.22	
PFHpA	ND	0.607	2.05	8.22	
PFHxS	ND	0.973	2.05	8.22	
PFOA	ND	0.669	2.05	8.22	
PFOS	ND	0.829	0.922	8.22	
PFNA	ND	0.833	2.05	8.22	

	Labeled Standard	%R	LCL-UCL	Qualifiers
IS	13C3-PFBS	105	60 - 150	
IS	13C4-PFHpA	93.5	60 - 150	
IS	18O2-PFHxS	84.1	60 - 150	
IS	13C2-PFOA	84.7	60 - 150	
IS	13C8-PFOS	89.2	60 - 150	
IS	13C5-PFNA	93.3	50 - 150	

LCL-UCL - Lower control limit - upper control limit
Results reported to DL
When reported, PFBS, PFHxS, PFOA and PFOS include both linear and branched isomers
Only the linear isomer is reported for all other analytes

MW 5/22/17

Oceana CTO-WE14 Oceana PFC
Attachment 1 Change Qual. Table

SDG	Sample ID	Compound	Q Flag	Qual Code
1601420	FTWG-MW-02-1116	Perfluorononanoic acid (PFNA)	U	FBL
1601388	MW-BG01-1016	Perfluorononanoic acid (PFNA)	U	MBL
1601388	MW-BG04-1016	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601388	MW-BG05-1016	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601388	MW-BG05P-1016	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601388	MW-BG07-1016	Perfluorononanoic acid (PFNA)	U	MBL
1601388	MW-BG09-1016	Perfluorononanoic acid (PFNA)	U	MBL
1601388	MW-BG09-1016	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601401	MW-BG10-1116	Perfluorooctanoic acid (PFOA)	U	EBL
1601388	MW-BG11-1016	Perfluorononanoic acid (PFNA)	U	MBL
1601370	MW-BG13-1016	Perfluorohexanesulfonic acid (PFHxS)	J	FD
1601370	MW-BG13-1016	Perfluorooctanoic acid (PFOA)	U	MBL
1601370	MW-BG13-1016	Perfluorooctane Sulfonate (PFOS)	J	FD
1601370	MW-BG13P-1016	Perfluorobutanesulfonic acid (PFBS)	UJ	ISL
1601370	MW-BG13P-1016	Perfluoroheptanoic acid (PFHpA)	UJ	ISL
1601370	MW-BG13P-1016	Perfluorohexanesulfonic acid (PFHxS)	UJ	ISL
1601370	MW-BG13P-1016	Perfluorooctanoic acid (PFOA)	UJ	ISL
1601370	MW-BG13P-1016	Perfluorooctane Sulfonate (PFOS)	J	FD
1601420	OC-EB110816	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601420	OC-EB110816	Perfluoroheptanoic acid (PFHpA)	U	MBL
1601388	OC-FB-102816	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601420	OC-FB110816	Perfluorooctane Sulfonate (PFOS)	U	MBL
1601420	OC-FB110816	Perfluoroheptanoic acid (PFHpA)	U	MBL
1601401	OC-MW02-1116	Perfluorooctanoic acid (PFOA)	U	EBL
1601388	OC-MW04-1016	Perfluorononanoic acid (PFNA)	U	MBL
1601437	OW11-MW1-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601437	OW11-MW4-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601437	OW11-MW5-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601437	OW11-MW6-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601437	OW11-MW7-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601437	OW11-MW9-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601437	OW11-MW9P-1016	Perfluorooctane Sulfonate (PFOS)	J	HT
1601401	OW26-MW1-1116	Perfluorohexanesulfonic acid (PFHxS)	J	ISH
1601401	OW26-MW1P 1116	Perfluorohexanesulfonic acid (PFHxS)	J	ISH
1601401	OW26-MW1P 1116	Perfluorooctanoic acid (PFOA)	J	ISH

Data Validation Summary

Oceana CTO-WE14, NAS Oceana

TO: Tiffany Hill/CVO
Anita Dodson/VBO

FROM: Tiffany McGlynn/GNV

CC: Herb Kelly/GNV

DATE: December 9, 2016

Introduction

The following data validation report discusses the data validation process and findings for Vista Analytical in the Sample Delivery Groups (SDGs) listed in the table below.

Samples were analyzed using the following analytical methods:

- 537 MOD Perfluorinated Hydrocarbons

The samples included in these SDGs are listed in the table below.

SDG	Sample Name	Matrix
1601370	OW11-MW9-1016	Water
1601370	OW11-MW9P-1016	Water
1601370	OW11-MW8-1016	Water
1601370	OW11-MW1-1016	Water
1601370	OW11-MW7-1016	Water
1601370	OW11-MW5-1016	Water
1601370	OW11-MW6-1016	Water
1601370	OW11-MW4-1016	Water
1601370	MW-BG13-1016	Water
1601370	MW-BG13P-1016	Water
1601370	MW-BG12-1016	Water
1601388	MW-BG07-1016	Water

SDG	Sample Name	Matrix
1601388	MW-BG06-1016	Water
1601388	MW-BG05-1016	Water
1601388	MW-BG05P-1016	Water
1601388	MW-BG04-1016	Water
1601388	OC-FB-102816	Water
1601388	MW-BG01-1016	Water
1601388	MW-BG09-1016	Water
1601388	OC-MW04-1016	Water
1601388	MW-BG11-1016	Water
1601401	203MW-19-1116	Water
1601401	JTC-MW-B-1116	Water
1601401	MW-BG10-1116	Water
1601401	OW2C-MW19-1116	Water
1601401	OW2E-MW19-1116	Water
1601401	OW2B-MW41-1116	Water
1601401	OC-EB-110216	Water
1601401	OC-MW03-1116	Water
1601401	OC-MW01-1116	Water
1601401	OC-FB-110216	Water
1601401	OC-MW02-1116	Water
1601401	OW26-MW1-1116	Water
1601401	OW26-MW1P 1116	Water
1601420	FTWG-MW-02-1116	Water
1601420	OC-EB110816	Water
1601420	OC-FB110816	Water
1601437	OW11-MW1-1016	Water
1601437	OW11-MW4-1016	Water
1601437	OW11-MW5-1016	Water
1601437	OW11-MW6-1016	Water
1601437	OW11-MW7-1016	Water
1601437	OW11-MW9-1016	Water
1601437	OW11-MW9P-1016	Water

Data Evaluation

Data was evaluated in accordance with the analytical methods and with the criteria found in the following guidance documents: Sampling and Analysis Plan Basewide Site Inspection for Perfluorinated Compounds Naval Air Station Oceana Virginia Beach, Virginia CTO-WE14 (October 2016) and National Functional Guidelines for Superfund Organic Methods Data Review (September 2016), as applicable. The samples were evaluated based on the following criteria:

- Data Completeness
- Technical Holding Times
- Tuning Instrument
- Initial/Continuing Calibrations
- Blanks
- Internal Standards
- Laboratory Control Samples
- Isotope Dilution Analyte
- Field Duplicates
- Identification/Quantitation
- Reporting Limits

Overall Evaluation of Data/Potential Usability Issues

Specific details regarding qualification of the data are addressed in the sections below. If an issue is not addressed there were no actions required based on unmet quality criteria. When more than one qualifier is associated with a compound/analyte, the validator has chosen the qualifier that best indicates possible bias in the results and qualified these data accordingly.

Data Completeness

The SDG was received complete and intact.

Technical Holding Times

According to the chain of custody records, sampling was performed on 10/25/16 through 11/8/16. Samples were received at the laboratory 10/27/16 through 11/9/16. All sample preparation and analyses were originally performed within holding time requirements with the exception of selected samples in SDG 1601437, which were re-extracted 15 days out of holding time. These samples were reanalyzed for Perfluorooctane Sulfonate (PFOS) only due to the high concentration detected in the original sample analysis. Affected data are summarized in **Attachment 1**.

Blanks

Target compounds were detected in the method blanks, equipment blanks, and field blanks as listed in the table below. Affected data are summarized in **Attachment 1**.

Blank ID	Compound	Conc.	Units
B6K0053-BLK1	Perfluorooctane Sulfonate (PFOS)	1.48	NG_L
B6K0124-BLK1	Perfluorooctane Sulfonate (PFOS)	1.71	NG_L
B6K0001-BLK1	Perfluorooctanoic acid (PFOA)	0.818	NG_L
B6K0053-BLK1	Perfluorononanoic acid (PFNA)	0.933	NG_L
OC-FB-110216	Perfluorooctanoic acid (PFOA)	0.691	NG_L
OC-EB-110216	Perfluorooctanoic acid (PFOA)	0.731	NG_L
OC-FB110816	Perfluorononanoic acid (PFNA)	0.866	NG_L
B6K0124-BLK1	Perfluoroheptanoic acid (PFHpA)	0.802	NG_L

Field Duplicate Precision

Native sample MW-BG13-1016 and field duplicate MW-BG13P-1016 did not meet precision criteria for perfluorohexanesulfonic acid (PFHxS) and PFOS. Affected data are summarized in **Attachment 1**.

Internal Standards

Sample MW-BG13P-1016 exhibited low recoveries in the internal standards. Samples OW26-MW1-1116 and OW26-MW1P 1116 exhibited high recoveries in the internal standards. Affected data are summarized in **Attachment 1**.

Conclusion

These data can be used in the project decision-making process as qualified by the data quality evaluation process.

Please do not hesitate to contact us about this validation report.

Sincerely,

Tiffany McGlynn

Qualification Flags

Exclude	More appropriate data exist for this analyte.
R	Data were rejected for use.
UL	Analyte not detected, quantitation limit is potentially biased low.
UJ	Analyte not detected, estimated quantitation limit.
U	Analyte not detected.
B	Not detected substantially above the level reported in laboratory or field blanks.
L	Analyte present, estimated value potentially biased low.
K	Analyte present, estimated value potentially biased high.
N	Analyte identification presumptive; no second column analysis performed or GC/MS tentative identification.
J	Analyte present, estimated value.
NJ	Analysis indicates the presence of an analyte that was "tentatively identified" and the associated value represents its approximate concentration.
None	Placeholder for calculating quality control issues that do not require flagging.
=	Analyte was detected at a concentration greater than the quantitation limit.

Qualifier Code Reference

Value	Description
%SOL	High Moisture content
2C	Second Column – Poor Dual Column Reproducibility
2S	Second Source – Bad reproducibility between tandem detectors
BD	Blank Spike/Blank Spike Duplicate(LCS/LCSD) Precision
BRL	Below Reporting Limit
BSH	Blank Spike/LCS – High Recovery
BSL	Blank Spike/LCS – Low Recovery
CC	Continuing Calibration
CCBL	Continuing Calibration Blank Contamination
CCH	Continuing Calibration Verification – High Recovery
CCL	Continuing Calibration Verification – Low Recovery
DL	Redundant Result – due to Dilution
EBL	Equipment Blank Contamination
EMPC	Estimated Possible Maximum Concentration
ESH	Extraction Standard - High Recovery
ESL	Extraction Standard - Low Recovery
FBL	Field Blank Contamination
FD	Field Duplicate
HT	Holding Time
ICB	Initial Calibration – Bad Linearity or Curve Function
ICH	Initial Calibration – High Relative Response Factors
ICL	Initial Calibration – Low Relative Response Factors
IR15	Ion ratio exceeds +/- 15% difference
ISH	Internal Standard – High Recovery
ISL	Internal Standard – Low Recovery
LD	Lab Duplicate Reproducibility
LR	Concentration Exceeds Linear Range
MBL	Method Blank Contamination
MDP	Matrix Spike/Matrix Spike Duplicate Precision
MI	Matrix interference obscuring the raw data

Value	Description
MSH	Matrix Spike and/or Matrix Spike Duplicate – High Recovery
MSL	Matrix Spike and/or Matrix Spike Duplicate – Low Recovery
OT	Other
PD	Pesticide Degradation
RE	Redundant Result - due to Reanalysis or Re-extraction
SD	Serial Dilution Reproducibility
SSH	Spiked Surrogate – High Recovery
SSL	Spiked Surrogate – Low Recovery
TBL	Trip Blank Contamination
TN	Tune

Appendix H
Analytical data (PFHpA, PFHxS, and PFNA) for the Columbia and Yorktown aquifers, and Potable and Non-Potable Water

TABLE H-1

Columbia Aquifer Groundwater Analytical Data (October 2016, February and April 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID			203MW-19-1116	FTWG-MW-02-1116	JTC-MW-B-1116	MW-BG01-1016	MW-BG04-1016	MW-BG05-1016	MW-BG05P-1016	MW-BG06-1016	MW-BG07-1016
Sample Date	**RSLs Tapwater HQ = 1.0 (June 2016)**	**USEPA Lifetime Health Advisory (May 2016)**	11/1/16	11/8/16	11/1/16	10/31/16	10/28/16	10/28/16	10/28/16	10/28/16	10/28/16
Chemical Name											
Semivolatile Organic Compounds (ng/L)											
Perfluoroheptanoic acid (PFHpA)	--	--	1.85 J	8.36 J	6.29 J	2.03 U	1.91 U	0.665 J	0.598 J	2.02 U	1.98 U
Perfluorohexanesulfonic acid (PFHxS)	--	--	16.9	11	212	3.81 J	1.1 J	3.02 J	2.78 J	2.02 U	5.48 J
Perfluorononanoic acid (PFNA)	--	--	2.02 U	3.59 U	6.08 J	2.03 U	1.91 U	1.97 U	2.02 U	2.02 U	1.98 U

Notes:

* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise.

ng/L = nanogram per liter

RSL = Regional Screening Level

U = The material was analyzed for, but not detected

UJ = Analyte not detected, quantitation limit may be inaccurate

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)

TABLE H-1

Columbia Aquifer Groundwater Analytical Data (October 2016, February and April 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID		**USEPA Lifetime**	MW-BG09-1016	MW-BG10-1116	MW-BG11-1016	MW-BG12-1016	MW-BG13-1016	MW-BG13P-1016	OC-F8F9-MW-F4-0417	OC-MW01-1116	OC-MW02-1116
Sample Date	**RSLs Tapwater HQ = 1.0 (June 2016)**	**Health Advisory (May 2016)**	10/31/16	11/2/16	10/31/16	10/26/16	10/26/16	10/26/16	4/4/17	11/1/16	11/1/16
Chemical Name											
Semivolatile Organic Compounds (ng/L)											
Perfluoroheptanoic acid (PFHpA)	--	--	2 U	2.1 U	2.05 U	2.7 J	0.997 J	1.97 UJ	0.611 UJ	2.7 J	2.02 U
Perfluorohexanesulfonic acid (PFHxS)	--	--	10.1	2.9 J	19.3	79.7	12.3 J	1.97 UJ	2.71 J	19.4	2.02 U
Perfluorononanoic acid (PFNA)	--	--	2 U	2.1 U	2.05 U	1.37 J	2.05 U	1.97 U	1.81 J	1.76 J	2.02 U

Notes:

* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise.

ng/L = nanogram per liter

RSL = Regional Screening Level

U = The material was analyzed for, but not detected

UJ = Analyte not detected, quantitation limit may be inaccurate

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)

TABLE H-1

Columbia Aquifer Groundwater Analytical Data (October 2016, February and April 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID		**USEPA Lifetime**	OC-MW03-1116	OC-MW04-1016	OC-MW07-0417	OC-MW07D-0417	OW11-MW1-1016	OW11-MW4-1016	OW11-MW5-1016	OW11-MW6-1016	OW11-MW7-1016
Sample Date	**RSLs Tapwater HQ = 1.0 (June 2016)**	**Health Advisory (May 2016)**	11/1/16	10/31/16	4/4/17	4/4/17	10/25/16	10/26/16	10/25/16	10/26/16	10/25/16
Chemical Name											
Semivolatile Organic Compounds (ng/L)											
Perfluoroheptanoic acid (PFHpA)	--	--	9.62	6.37 J	2.02 U	2.12 U	9,820	2,630	2,480	4,360	10,100
Perfluorohexanesulfonic acid (PFHxS)	--	--	46.7	42.8	2.02 U	2.12 U	30,500	33,100	25,500	38,900	37,100
Perfluorononanoic acid (PFNA)	--	--	1.98 U	1.98 U	2.02 U	2.12 U	1,970	99.5	596	1,080	2,660

Notes:

* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise.

ng/L = nanogram per liter

RSL = Regional Screening Level

U = The material was analyzed for, but not detected

UJ = Analyte not detected, quantitation limit may be inaccurate

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)

TABLE H-1

Columbia Aquifer Groundwater Analytical Data (October 2016, February and April 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID		**USEPA Lifetime**	OW11-MW8-1016	OW11-MW9-1016	OW11-MW9P-1016	OW26-MW1-1116	OW26-MW1P 1116	OW2B-MW41-1116	OW2C-MW05-0217	OW2C-MW19-1116
Sample Date	**RSLs Tapwater HQ = 1.0 (June 2016)**	**Health Advisory (May 2016)**	10/25/16	10/25/16	10/25/16	11/1/16	11/1/16	11/1/16	2/23/17	11/1/16
Chemical Name										
Semivolatile Organic Compounds (ng/L)										
Perfluoroheptanoic acid (PFHpA)	--	--	2,630	4,570	3,940	13,900	12,900	275	26.3	113
Perfluorohexanesulfonic acid (PFHxS)	--	--	16,900	22,200	24,200	52,400 J	51,300 J	473	78.8	881
Perfluorononanoic acid (PFNA)	--	--	151	956	978	1,530	1,650	6.59 J	108	23.1

Notes:

* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise.

ng/L = nanogram per liter

RSL = Regional Screening Level

U = The material was analyzed for, but not detected

UJ = Analyte not detected, quantitation limit may be inaccurate

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)

TABLE H-1

Columbia Aquifer Groundwater Analytical Data (October 2016, February and April 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID		**USEPA Lifetime**	OW2C-MW19-0217	OW2C-MW24-0217	OW2C-MW25-0217	OW2E-MW09R-0217	OW2E-MW09RP-0217	OW2E-MW19-1116
Sample Date	**RSLs Tapwater HQ = 1.0 (June 2016)**	**Health Advisory (May 2016)**	2/23/17	2/23/17	2/23/17	2/23/17	2/23/17	11/1/16
Chemical Name								
Semivolatile Organic Compounds (ng/L)								
Perfluoroheptanoic acid (PFHpA)	--	--	52.8	40.3	531	41.5	39.1	493
Perfluorohexanesulfonic acid (PFHxS)	--	--	489	87.1	3,580	406	389	290
Perfluorononanoic acid (PFNA)	--	--	29.2	9.82	248	4.66 U	3.16 U	93.6

Notes:

* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise.

ng/L = nanogram per liter

RSL = Regional Screening Level

U = The material was analyzed for, but not detected

UJ = Analyte not detected, quantitation limit may be inaccurate

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)

TABLE H-2
Yorktown Aquifer Groundwater Analytical Data April 2017)
Basewide PFAS Site Inspection
NAS Oceana, Virginia Beach, Virginia

Sample ID **Sample Date**	**RSLs Tapwater HQ = 1.0 (June 2016)**	**USEPA Lifetime Health Advisory (May 2016)**	OC-MW02D-0417 4/3/17	OC-MW05D-0417 4/3/17	OC-MW05DP-0417 4/3/17	OC-MW07D-0417 4/4/17	OW11-MW10D-0417 4/4/17	OW26-MW01D-0417 4/3/17
Chemical Name								
Semivolatile Organic Compounds (ng/L)								
Perfluoroheptanoic acid (PFHpA)	--	--	3.41 J	2.12 U	2.05 U	2.12 U	22.4	2.1 U
Perfluorohexanesulfonic acid (PFHxS)	--	--	10	2.12 U	2.05 U	2.12 U	124	2.37 J
Perfluorononanoic acid (PFNA)	--	--	2.05 U	2.12 U	2.05 U	2.12 U	5.19 J	2.1 U

Notes:
* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.
B - Analyte not detected above the level reported in blanks
HQ = hazard quotient
J = Analyte present. Value may or may not be accurate or precise
ng/L = nanogram per liter
U = The material was analyzed for, but not detected
UJ - Analyte not detected, quantitation limit may be inaccurate
Shading indicates detection
Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)
Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)

TABLE H-3

Potable and Non-Potable Water Analytical Data (December 2016 and January 2017)

Basewide PFAS Site Inspection

NAS Oceana, Virginia Beach, Virginia

Sample ID	**RSLs Tapwater HQ = 1.0 (June 2016)**	**USEPA Lifetime Health Advisory (May 2016)**	OC-RW01-1216	OC-RW03-1216	OC-RW03P-1216	OC-RW04-1216	OC-RW10-0117	OC-RW12-1216	OC-RW13-1216	OCSTR-WL01-1216
Sample Date			12/16/16	12/16/16	12/16/16	12/19/16	1/3/17	12/16/16	12/21/16	12/22/16
Chemical Name										
Semivolatile Organic Compounds (NG/L)										
Perfluoroheptanoic acid (PFHpA)	--	--	8.52	1.94 U	1.98 U	1.97 U	1.97 U	1.95 U	2 U	1.95 U
Perfluorohexanesulfonic acid (PFHxS)	--	--	32.5	1.94 U	1.98 U	1.97 U	1.97 U	1.95 U	2 U	1.95 U
Perfluorononanoic acid (PFNA)	--	--	1.16 J	1.94 U	1.98 U	1.97 U	1.97 U	1.95 U	2 U	1.95 U

Notes:

* In cases when both PFOS and PFOA are non-detect, non-detect values are added together to equal Total PFOS + PFOA. In cases when a detect and non-detect of PFOS and PFOA exist, only the detect value is used to determine Total PFOS + PFOA.

B = Analyte not detected above the level reported in blanks

HQ = hazard quotient

J = Analyte present. Value may or may not be accurate or precise

NG/L = nanogram per liter

U = The material was analyzed for, but not detected

UJ = Analyte not detected, quantitation limit may be inaccurate

Shading indicates detection

Bolded text indicates exceedance of USEPA Lifetime Health Advisory (May 2016)

Italicized text indicates exceedance of RSLs Tapwater HQ = 1.0 (June 2016)