N60191_001302
OCEANA_NAS
SSIC 5000-33a

FINAL ENGINEERING EVALUATION AND COST ANALYSIS FOR DRINKING WATER NALF FENTRESS FIELD NAS OCEANA VA

11/01/2018

CH2M HILL

Mid-Atlantic
Chesapeake, Virginia

Final

Engineering Evaluation and Cost Analysis for Drinking Water

Naval Auxiliary Landing Field Fentress
Chesapeake, Virginia

November 2018

Mid-Atlantic
Chesapeake, Virginia

Final

Engineering Evaluation and Cost Analysis for Drinking Water

Naval Auxiliary Landing Field Fentress
Chesapeake, Virginia

November 2018

Prepared for NAVFAC Mid-Atlantic
by CH2M HILL, Inc.
Virginia Beach, Virginia
Contract N62470-16-D-9000
CTO WE01

Executive Summary

This report presents an Engineering Evaluation and Cost Analysis (EE/CA) for a non-time-critical removal action (NTCRA) to address per- and polyfluoroalkyl substances (PFAS) in the on-base potable water system and off-base private drinking water within and near Naval Auxiliary Landing Field (NALF) Fentress, in Chesapeake, Virginia.

During the Basewide PFAS Site Inspection (SI), completed between 2015 and 2018, exceedances of the United States Environmental Protection Agency Lifetime Health Advisory of 70 nanograms per liter (ng/L) for total perfluorooctanoic acid (PFOA) and/or perfluorooctane sulfonate (PFOS) were identified in groundwater at NALF Fentress and in the on-base potable water system at the base. Base employees were supplied with bottled water to address the exceedances, and the on-base potable water system was later modified to include Granular Activated Carbon (GAC) to address PFOA and PFOS concentrations. 62 off-base private drinking water wells located within a 0.5-mile radius of identified exceedances of the Lifetime Health Advisory were also sampled for the presence of PFAS. Of the 62 off-base private drinking water wells sampled, 7 wells, located on 6 properties, had detections of total PFOA and/or PFOS at concentrations above the Lifetime Health Advisory and property owners were supplied with bottled water for drinking and cooking as an emergency response action. In conjunction with supplying bottled water, Point of Entry GAC Pilot Systems were also installed at the seven contaminated wells as part of a pilot study, for effectiveness evaluation.

This EE/CA evaluates alternatives to address only current exposure potential to drinking water on-base and at off-base properties contaminated with PFOA and/or PFOS at levels greater than the Lifetime Health Advisory. Alternatives presented are intended to provide base workers and property owners with a long-term drinking water solution.

The EE/CA identifies the objective of the NTCRA, identifies removal action alternatives to achieve that objective, and evaluates the effectiveness, implementability, and cost of those alternatives. The following is the removal action objective (RAO):

- Protect current human health receptors from ingestion of PFOA and/or PFOS at levels above the Lifetime Health Advisory in groundwater used as drinking water.

In order to meet the RAO, the preliminary remediation goal is to reduce receptor exposure to PFOA and/or PFOS to a cumulative concentration of less than the Lifetime Health Advisory of 70 ng/L through treatment or provision of an alternative water supply.

The following removal action alternatives were identified:

1. No Further Action: No further action would be conducted; the site would remain "as is." Thus, bottled water would continue to be provided to off-base drinking water receptors whose drinking water has tested above the Lifetime Health Advisory, and the pilot GAC systems currently installed at each off-base property would be taken off-line. The GAC system would continue to be operated at the on-base potable water treatment system.
2. Point of Entry Treatment: This action alternative would address PFOA and PFOS impacts at the on-base potable water treatment system before the finished potable water supply is stored for distribution to the base. This alternative would also address PFOA and/or PFOS at each individual private property with drinking water contaminant concentrations greater than the Lifetime Health Advisory before the potable water supply enters the distribution piping for the house. The following three treatment technologies are being considered under this alternative:
    a. <u>GAC Treatment</u> – This action would include the installation and/or continued maintenance of GAC vessels, implemented in series, for PFOA and/or PFOS removal. For the on-base system, this alternative would be the same as the No Further Action Alternative because the on-base GAC system is already fully functional. For the off-base systems, the GAC vessels would be implemented in coordination with the pilot study, where possible.

b. Ion Exchange (IX) Treatment – Installation of IX vessels for PFOA and/or PFOS removal. The on-base treatment system would include four IX vessels operated in series, while the off-base drinking water systems would include two IX vessels, operated in series.

c. Reverse Osmosis (RO) Treatment – Installation of RO membranes for PFOA and/or PFOS removal. The on-base treatment system would include four treatment trains, each with two RO membranes in series, implemented in parallel, while off-base drinking water systems would include two RO membranes implemented in series.

3. Connection to City Water: This action alternative would address PFOA and/or PFOS impacts by providing the base, and each private property with concentrations greater than the Lifetime Health Advisory, access to City water by extending the City water main to north of NALF Fentress base. Service lines from the water main would be installed to each of the privately owned buildings with drinking water concentrations greater than the Lifetime Health Advisory and to the on-base potable water distribution system.

Alternative 1 does not meet the objective of the removal action for the off-base homes because without continued operation of the pilot GAC systems, PFAS contaminated water used for non-potable purposes may be ingested and PFAS would continue to be re-released into groundwater through septic systems. The National Contingency Plan (NCP) indicates that to the extent practicable, removal actions should contribute to the effective performance of any future remedial action, assuming one is necessary. If a removal action is determined to be necessary for the off-base groundwater in the future, Alternative 1 would not contribute to its effective performance; and therefore, would not meet the requirement of the NCP. Alternative 3 is considered the most effective because it eliminates contaminated groundwater as the source of drinking water at the site. Alternatives 2a through 2c are comparable in effectiveness, but effectiveness is less permanent then under Alternative 3, since Alternatives 2a through 2c rely on continued media change out.

Alternatives 1 and 2a are easy to implement because the systems are already in place. Alternative 2b is moderate to implement because it requires some updates to the existing systems, and Alternative 2c is moderately difficult to implement because it requires large updates to the existing systems. Alternative 3 is moderately difficult to implement because it requires earth-moving equipment, access to rights-of-way, and coordination with the City of Chesapeake. However, Alternative 3 does not require any post-removal site controls (PRSCs), whereas Alternatives 1 and 2a through 2c have long-term implementation considerations.

Alternatives 1 and 2b are the least expensive alternatives, and Alternative 2c is the most expensive alternative. Alternative 3 has moderate costs that are higher than Alternatives 1 and 2b, comparable to Alternative 2a, and lower costs than Alternative 2c. Additionally, Alternative 3 does not have any costs associated with long term PRSCs, whereas Alternatives 1 and 2a through 2c have PRSC costs over 30 years.

Based on the evaluation of the trade-offs among the alternatives, the recommended removal action alternative is Alternative 3, Connection to City water.

In accordance with the National Oil and Hazardous Substance Pollution Contingency Plan, this EE/CA will be placed in the Administrative Record and the NALF local Administrative Record document repository, and a notice of its availability for public review, along with a summary of the EE/CA, will be published in the local newspaper. The EE/CA subsequently will be available for review during a 30-day public comment period. A public information session will be held if sufficient interest is expressed by the public, and will take place during or immediately following the public comment period.

Following the public comment period, if comments are received, a Responsiveness Summary documenting the Department of the Navy’s responses to significant comments will be prepared and included in an Action Memorandum, which also will be placed in the Administrative Record.

Contents

Appendixes

Tables

Figures

Acronyms and Abbreviations

APTIM	APTIM Government Solutions, LLC
ARARs	applicable or relevant and appropriate requirements
bgs	below ground surface
$CaCO_3$	calcium carbonate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
EE/CA	Engineering Evaluation/Cost Analysis
F600	Calgon FILTRASORB 600
ft/min	feet per minute
ft/yr	feet per year
GAC	granular activated carbon
GHG	greenhouse gas
gpd	gallons per day
gpm	gallons per minute
IX	ion exchange
mg/L	milligrams per liter
NALF	Naval Auxiliary Landing Field
Navy	Department of the Navy
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
ng/L	nanograms per liter
NTCRA	non-time-critical removal action
O&M	operations and maintenance
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutane sulfonic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PHA	provisional health advisory
PIL	project indicator limit
PM_{10}	particulate matter 10 micrometers or less in diameter
POE	point of entry
PRG	preliminary remediation goal
PRSC	post-removal site control
RAO	removal action objective
RO	reverse osmosis
RSL	regional screening level
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SI	site inspection

TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UCMR3	Third Unregulated Contaminant Monitoring Rule
UFC	Unified Facilities Criteria
USEPA	United States Environmental Protection Agency
UV	ultraviolet
VDEQ	Virginia Department of Environmental Quality
VDH	Virginia Department of Health
WTP	water treatment plant
yd^3	cubic yard(s)

SECTION 1

Introduction

This report presents an Engineering Evaluation and Cost Analysis (EE/CA) for a non-time-critical removal action (NTCRA) to address per- and polyfluoroalkyl substances (PFAS) in the on-base potable water system and off-base private drinking water within and near Naval Auxiliary Landing Field (NALF) Fentress, in Chesapeake, Virginia. This EE/CA has been prepared under the Naval Facilities Engineering Command Mid-Atlantic Comprehensive Long-Term Environmental Action Navy Contract Number N62470-16-D-9000, Contract Task Order WE01.

In 2015, the finished water from the NALF Fentress on-base water treatment system was sampled after the Department of the Navy (Navy) issued a policy in October 2014, requiring on-base drinking water sampling for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) for bases where groundwater was used as drinking water, and where PFAS could have been released near the drinking water wells. Finished water analysis from samples collected in December 2015 and May 2016 indicated the presence of PFOS and/or PFOA at concentrations above the United States Environmental Protection Agency (USEPA) Lifetime Health Advisory of 70 nanograms per liter (ng/L). Based on the exceedances, on-base personnel were provided bottled water until additional treatment could be provided to address the PFOS and/or PFOA in the finished water. In 2017 the on-base drinking water system was upgraded to include granular activated carbon (GAC) treatment as part of the treatment train to address PFOA and/or PFOS impacts. Since implementation of the GAC system, finished water from the on-base system has been below the Lifetime Health Advisory, and bottled water service is no longer required for on-base personnel.

The investigation activities for the off-base private drinking water wells were conducted following identification of the Lifetime Health Advisory exceedances on base as part of the Basewide Per- and Polyfluoroalkyl Substances Site Inspection (SI), which was completed between 2015 and 2018. As part of the SI, 62 off-base private drinking water wells located within a 0.5-mile radius of identified on-base exceedances of the Lifetime Health Advisory were sampled for total PFOA and/or PFOS. Of the 62 off-base private drinking water wells sampled between 2016 and 2018, 7 wells, located on 6 properties, had detections of total PFOA and/or PFOS at concentrations above the Lifetime Health Advisory. Residents and property owners with exceedances of the Lifetime Health Advisory were supplied with bottled water as part of an emergency response action in 2016. Pilot tests were initiated in 2017 to test GAC systems at the 7 impacted wells on 6 properties, but the bottled water provision has continued during testing of the pilot systems.

This EE/CA will evaluate alternatives to provide long-term options to protect current human health receptors from ingestion of groundwater used as drinking water at the on-base water treatment system and off-base properties contaminated with PFOA and/or PFOS at levels greater than the Lifetime Health Advisory only. Potential risks associated with future use of contaminated groundwater and potential exposure of ecological receptors to PFAS contaminants will be evaluated, as appropriate, as part of a separate installation-wide investigation currently in the expanded SI stage.

The following information is presented within this EE/CA:

- Site description
- Identification of removal action objective (RAO)
- Description of the removal action elements
- Identification of the removal action alternatives and technologies
- Recommendation of a preferred removal alternative
- Schedule for the selected removal alternative

1.1 Regulatory Background

This document is issued by the Navy, the lead agency responsible for environmental remediation at NALF Fentress, in partnership with USEPA Region 3 and the Virginia Department of Environmental Quality (VDEQ), under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) of 1986.

Section 104 of CERCLA and SARA allows an authorized agency to provide for removal action and to remove, or arrange for removal of, hazardous substances, pollutants, or contaminants at any time, or to take any other response measures consistent with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), as deemed necessary to protect public health or welfare and the environment.

The NCP, Title 40 of the *Code of Federal Regulations* (CFR), Section 300, provides regulations for implementing CERCLA and SARA and regulations specific to removal actions. The NCP defines a removal action as follows:

> [The] cleanup or removal of released hazardous substances from the environment, such actions as may be necessary to monitor, assess, and evaluate the threat of release of hazardous substances; the disposal of removed material; or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release.

A removal action is being considered for the on-base water treatment plant (WTP) and the off-base private drinking water wells, to protect current human health receptors from ingestion of groundwater used as drinking water at the on-base water treatment system and off-base properties contaminated with PFOA and/or PFOS at levels greater than the Lifetime Health Advisory. Under 40 CFR Section 300.415, the lead agency (Navy, in this case) is required to conduct an EE/CA when a removal action is planned for a site and a planning period of at least 6 months exists. The purpose of an EE/CA is to identify the objectives of the removal action, identify removal action alternatives to achieve those objectives, and evaluate the effectiveness, implementability, and cost of those alternatives. An EE/CA documents the removal action alternatives and selection process. Where the extent of the contamination is well defined and limited in extent, removal actions also allow for the expedited cleanup of sites in comparison to the remedial action process under CERCLA.

Community involvement requirements for removal actions include preparing an EE/CA and making it available for public review and comment for a period of 30-days. An announcement of the public review and comment period is required to be announced in a local newspaper. Written responses to significant comments are summarized in a Responsiveness Summary that is included in an Action Memorandum, which is placed in the Administrative Record file.

1.2 Purpose and Objectives

Submittal of this document fulfills the requirements for NTCRAs defined by CERCLA, SARA, and the NCP. This EE/CA has been prepared in accordance with USEPA's guidance document, *Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA* (USEPA, 1993). The following are purposes of this EE/CA:

- Satisfy environmental review and public information requirements for removal actions
- Satisfy Administrative Record requirements for documenting the removal action selection
- Provide a framework for evaluating and selecting removal action alternative technologies

The goals of the EE/CA are to identify the objectives of the removal action, identify removal action alternatives to achieve those objectives, and evaluate the effectiveness, implementability, and cost of those alternatives.

The objective of the removal action alternatives evaluated in this EE/CA is to identify and recommend measures to protect current human health receptors from ingestion of groundwater used as drinking water at the on-base water treatment system and off-base properties contaminated with PFOA and/or PFOS at levels greater than the Lifetime Health Advisory. Potential risks associated with future use of contaminated groundwater and potential exposure of ecological receptors to PFAS contaminants will be evaluated, as appropriate, as part of a separate installation-wide investigation currently in the expanded SI stage.

This EE/CA compares five removal action alternatives based on their effectiveness, implementability, and cost. The following alternatives were evaluated:

- **Alternative 1**—No Further Action; continued provision of bottled water for offsite drinking water receptors, discontinue current off-base GAC pilot systems, and operation of the on-base GAC system
- **Alternative 2a**—Point of Entry Treatment – Granular Activated Carbon Treatment
- **Alternative 2b**—Point of Entry Treatment – Ion Exchange Treatment
- **Alternative 2c**—Point of Entry Treatment – Reverse Osmosis Treatment
- **Alternative 3**—Connection to City Water

SECTION 2

Site Characterization

2.1 Site Background – NALF Fentress

NALF Fentress (**Figure 2-1**) is located in Chesapeake, Virginia, and is a noncontiguous property under the command of Naval Air Station Oceana. Established in 1943, the installation encompasses just over 2,500 acres and approximately 8,700 acres in restrictive easements. The facility primarily is used by squadrons stationed at Naval Air Station Oceana or Naval Station Norfolk Chambers Field for field carrier landing practice operations. Neither storage nor maintenance of aircraft is routinely performed at NALF Fentress.

2.2 Summary of Previous Investigations

2.2.1 PFAS Site Inspection

Environmental investigations completed in the 1990s indicated no further action was necessary at NALF Fentress. However, in May 2012, the USEPA issued the Third Unregulated Contaminant Monitoring Rule (UCMR3). The UCMR3 required monitoring, between 2013 and 2015, for 30 substances of all large public water systems serving more than 10,000 people, and 800 representative public water systems serving 10,000 or fewer people. Six PFAS compounds were included in the UCMR3 contaminant list. Of these six PFAS, USEPA issued provisional health advisory levels (PHAs) for only two, PFOA and PFOS. USEPA also published toxicity values for one other contaminant, perfluorobutane sulfonic acid (PFBS). Navy releases of PFAS that affected public water supplies were identified during UCMR3 monitoring. Consequently, the Navy issued a policy in October 2014, requiring on-base drinking water sampling for PFOA and PFOS for bases where groundwater was used as drinking water and where PFAS could have been released near the drinking water wells. Under this policy, all installations not previously tested under UCMR3 that produce drinking water from on-installation sources and have an identified or suspected PFAS release within approximately 1-mile upgradient from the drinking water source were required to sample their finished drinking water by December 2015.

NALF Fentress was identified as requiring sampling based on the October 2014 policy because of the use of potable production wells on-base and the installation's use of aqueous film-forming foam, which is a known source of PFAS. The initial round of SI sampling was completed in December 2015, and involved groundwater monitoring well installation; sampling of groundwater, drinking water, and wastewater at the facility; and completion of basewide water level surveys in the Surficial/Columbia aquifer and Yorktown aquifer. Exceedances of the PHAs were identified in samples collected from the on-base drinking water, groundwater, and wastewater. Consequently, sampling of off-base private drinking water wells was initiated. A total of 59 off-base private drinking water wells, located within 0.5 mile of the exceedances, were sampled during the first half of 2016 (February through May) with additional data collected at one well in 2017, and a subsequent sampling event completed in 2018, which included resampling of 30 wells sampled in 2016, and 3 additional residential wells for a total of 62 private wells sampled by 2018.

In May 2016, USEPA Office of Water also issued a drinking water Lifetime Health Advisory for PFOA and PFOS. Lifetime Health Advisories are not enforceable, regulatory levels. The Lifetime Health Advisory was set at a level that would provide Americans, including the most sensitive populations, with a margin of protection from a lifetime of exposure to PFOA and PFOS from drinking water. The Lifetime Health Advisory is 70 ng/L for PFOA and 70 ng/L for PFOS. When both PFOA and PFOS are found in drinking water, the combined concentrations of PFOA and PFOS are compared with the 70 ng/L health advisory level.

The SI identified total PFOA and/or PFOS concentrations at levels greater than the Lifetime Health Advisory (70 ng/L) in groundwater samples from the on-base sources shown on **Figure 2-2**, including the Fentress Landfill (Site 14), Former Firefighter Training Area (Site 17), the aqueous film-forming foam storage area near an existing petroleum site (Underground Storage Tank 20B), a crash truck test area, and at secondary sources areas associated with releases from untreated groundwater and wastewater (irrigation spray fields and areas where PFAS contaminated water was sprayed).

During the SI, the combined influent from the two on-base water supply wells and the finished water from the WTP were sampled in December 2015 and May 2016 for PFAS. The influent sample was collected from a storage tank containing influent that had not yet entered the treatment system, which is fed by the two on-base water supply wells, resulting in a combined influent sample from the two wells. The results, as shown on **Table 2-1**, indicated that combined influent stream, along with the finished water stream, had detections of total PFOA and/or PFOS at concentrations above the Lifetime Health Advisory (70 ng/L). The location of the groundwater supply wells and the WTP are shown on **Figure 2-2**. The on-base water treatment system is used to supply both potable water supply for personnel at the base and the fire protection system for the base. At the time of the SI, the fire protection system was sourced directly from the raw water groundwater supply wells, prior to treatment. The existing water system (without upgrades added to address PFOA and PFOS) has been online since 1995. Based on the results of the SI, which indicated that the effluent from the on-base potable water system had total PFOA and/or PFOS exceeding the Lifetime Health Advisory, the finished water was designated as non-potable by the Navy in January 2016. The Navy implemented bottled water service for on-base personnel, until a permanent solution could be implemented. A bottled water supply was initiated on the base in January 2016, following the receipt of results from the December 2015 sampling event.

Of the 59 off-base private drinking water wells sampled as part of the SI in 2016 in the vicinity of NALF Fentress 7 wells, located on 6 privately owned properties, had detections of total PFOA and/or PFOS at concentrations above the Lifetime Health Advisory (70 ng/L). In February 2018, a subsequent sampling event was performed, which included an additional round of sampling at 30 of the wells tested in 2016, and 3 additional private drinking water wells not previously sampled. The private drinking water wells sampled during the 2018 event were included based on positive verification from the property owner that they would like to have their well sampled. A total of 63 off-base private drinking water wells were sampled between 2016 and 2018. The results of the 2018 event confirmed the findings of the 2016 sampling event at the 30 properties sampled during both events, with the exception of OF-RW63. OF-RW63 had total PFOA and/or PFOS at concentrations greater than the Lifetime Health Advisory in 2016, and less than the Lifetime Health Advisory in 2018. For the purposes of this EE/CA, OF-RW63 is included as one of the seven contaminated private drinking water wells. The three additional wells sampled during the 2018 event only did not exceed the Lifetime Health Advisory for total PFOA and/or PFOS.

The contaminated off-base private drinking water wells are located on properties to the north of NALF Fentress and are mainly residential. The existing off-base property owners use private water supply wells to extract groundwater for potable and non-potable use. Within the six off-base properties, there are nine private drinking water wells, seven of which exceeded the Lifetime Health Advisory. One property has four wells onsite, two of which have PFOA and/or PFOS concentrations that exceed the Lifetime Health Advisory, and two of which have PFOA and/or PFOS concentrations that are less than the Lifetime Health Advisory. The remaining properties have one well each, with a total PFOA and/or PFOS concentration exceeding the Lifetime Health Advisory.

The results of the SI are summarized in the *Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report* (CH2M, 2018).

2.2.2 Emergency Response Action

Based on the findings of the March 2016 off-base potable water well sampling, an emergency response action was implemented from March through May 2016. Under the emergency response action, bottled water was provided to the users of drinking water at the six affected properties. Since that time, bottled water has been, and continues to be, provided to off-base users of drinking water until a long-term solution is implemented to provide drinking water with concentrations of total PFOA and/or PFOS below the Lifetime Health Advisory. The bottled water being provided is used mainly for drinking and cooking purposes.

In addition to providing bottled water to off-base drinking water receptors, public information meeting sessions were held in February, March, and June of 2016 to provide the public with the opportunity to discuss questions and concerns associated with the PFOA and PFOS. The meetings were attended by the Navy, USEPA, the City of Chesapeake, the VDEQ, the Virginia Department of Health (VDH), the City of Chesapeake Department of Health, and the Agency for Toxic Substances and Disease Registry.

The emergency response actions are detailed in the *Emergency Response Action Memorandum Site 17, Former Fire-Fighting Training Area* (Navy, 2017a).

2.2.3 Granular Activated Carbon Installation – On-base Water Treatment System

Based on exceedances of the Lifetime Health Advisory for total PFOA and/or PFOS in the effluent on the on-base potable water treatment system, action was taken to upgrade the system to treat total PFOA and/or PFOS at concentrations greater than the Lifetime Health Advisory. Based on the evaluation conducted in April 2016, GAC was considered to provide the best value for addressing PFAS at the on-base potable water treatment system because it is readily available, reasonably well demonstrated for PFOA and PFOS treatment, and relatively inexpensive to install (CH2M, 2016). Based on the selection to implement GAC treatment, a *Preliminary Engineering Report for Potable Water System Improvements* (CH2M, 2017c) was developed to document the design of the GAC treatment system prior to implementation and was approved by the VDH on February 2, 2017 (VDH, 2017).

The existing water treatment system (prior to modifications to treat total PFOA and/or PFOS) consisted of two groundwater wells, a fire protection system with a dedicated distribution, a WTP, and a potable water distribution system. The two groundwater wells are screened in the Yorktown aquifer and provide untreated source water for the Fire Protection System. The existing water system has been online since 1995. The existing major unit processes/equipment associated with the water system are shown on **Figure 2-3**, and include wells, fire protection storage and distribution, raw water storage, pumps (service, backwash, and fire protection), green sand filters, hydropneumatics tank, softeners, chemical feed, and potable water distribution.

Prior to installation of the GAC systems, NALF Fentress performed GAC bench tests for the on-base wastewater and WTP effluent to determine the most effective GAC medium to remove PFOA and PFOS. The results of the bench test concluded that the most effective GAC medium for removing PFOA and PFOS from the on-base drinking water effluent was Calgon FILTRASORB 600 (F600) (CH2M, 2017a).

As documented in the *Preliminary Engineering Report for Potable Water System improvements* (CH2M, 2017c), the existing WTP was upgraded to include two GAC vessels, operated in a lead-lag configuration, as shown on **Figure 2-3**. The WTP system was upgraded in 2017 and brought online in November 2017. The GAC vessels were installed at the effluent of the green sand filters and discharge into the hydropneumatic tank. In order to allow for sufficient footprint for the GAC vessels to be installed, the water softeners were removed from the treatment train. The GAC vessels were sized to handle 17 gallons per minute (gpm) and include 1,300 pounds of Calgon F600 in each vessel. The improvements also included modifications to the Fire Protection System, including the installation of a new water line from the hydropneumatic tank (treated water) to the fire protection tank. The upgrades to the system were sized to handle 7,875 gallons per day (gpd) (5.4 gpm), which includes a 2.25 peaking factor on the average demand for potable water at the site (3,500 gpd). The WPT system upgrades were approved by the City of Chesapeake in February 2018, at which time the base quit providing bottled water to on base personnel.

Since start-up in November 2017, the GAC has effectively treated PFOA and/or PFOS in the on-base potable water system to below the Lifetime Health Advisory, and has reduced concentrations of other PFAS, for which no Lifetime Health Advisories have been established by USEPA. Influent, intermediate, and effluent concentrations from the GAC system are included in **Table 2-1.** Since the WTP system was upgraded to include the GAC system in November 2017, total PFOA and/or PFAS has been reduced in the system effluent to below the Lifetime Health Advisory and was non-detect during the December 2017 and February 2018 sampling. During the February 2018 sampling event, influent concentrations also decreased significantly, as compared to previous sampling events. This fluctuation in influent concentration is believed to be a result of the cycled operation of the two raw water pumps, and influent concentrations may be influenced by which well is pumping at the time of sampling. Because of the limited time of operation, a change-out frequency has not been established for the WTP GAC units.

However, the GAC units will be changed out when the total PFOA and/or PFOS concentrations in the intermediate sample exceed the Lifetime Health Advisory (70 ng/L). The GAC units were designed for a minimum of 100 days before change-out would be required (CH2M, 2017c). Since the GAC system was installed, one additional PFAS compound, perfluorohexane sulfonic acid (PFHxS), has been detected in the effluent of the WTP GAC system; however, no Lifetime Health Advisory has been established for this compound.

2.2.4 Point of Entry Granular Activated Carbon Pilot Test – Off-base Properties

Following implementation of the emergency response action for off-base drinking water, a pilot test was implemented that consisted of the installation and operation of point of entry (POE) GAC systems at the seven contaminated wells located on six off-base properties.

Six off-base drinking water pilot systems were installed between May and June 2017, and the final off-base drinking water pilot system was installed in March 2018. Prior to installation, each off-base property was assessed, and the current system layout, along with existing groundwater quality, was documented. Each POE GAC system was installed downstream from the existing pressure tank, and water was routed through a 25-micrometer cartridge pre-filter, flowmeter, two GAC vessels, into existing water softening systems (if present), through an ultraviolet (UV) disinfection system, and back into existing plumbing (**Figure 2-4**). The GAC used for the pilot test was the Calgon F600, based on the results of the on-base bench test results (CH2M, 2017a). Details of the pilot test installation are included in the *Pilot Test Work Plan: Granular Activated Carbon System Installation on Residential Drinking Water Systems to Remove PFOA and PFOS* (CH2M, 2017b).

Influent, intermediate, and effluent concentrations from the pilot test are included in **Table 2-2.** To date, the pilot systems have effectively treated PFOA and/or PFOS in the off-base drinking water to below the Lifetime Health Advisory, and also have reduced concentrations of other PFAS, for which no Lifetime Health Advisories have been established by USEPA. No data are currently available for the pilot system installed in March 2018, and the discussion below includes only the six pilot systems installed in 2017.

A project indicator limit (PIL) of half the Lifetime Health Advisory (35 ng/L) at the intermediate sample was set to determine the GAC change-out schedule for the pilot systems. During the first 9 months of operation of the pilot study, complete breakthrough occurred in one system, OF-RW59, within 3 months of the system being brought online, with an effluent concentration of 69.1 ng/L in September 2017. The GAC was changed out in October 2017; however, the bypass valve was left open through December 2017, and during this time, effluent concentrations exceeded the Lifetime Health Advisory. During the February 2018 event, OF-RW59 had an effluent concentration less than the Lifetime Health Advisory (66.2 ng/L); however, the intermediate concentration was above the PIL (260.9 ng/L), and a GAC change-out was conducted on May 18, 2018. One additional system, OF-RW44, exceeded the PIL in the intermediate sample during December 2017 (38.8 ng/L), and remained elevated during the February 2018 event (21 ng/L); therefore, a change-out was conducted on May 18, 2018, which was within 7 months of the system being brought online.

Intermediate concentrations at three of the pilot systems have been non-detect since the pilot systems were installed. At OF-RW42B, the intermediate concentrations exceeded the PIL during the December 2017 event (51.6 ng/L); however, the February 2018 sample results were less than the detection limit; therefore, a GAC change-out was not conducted at that time. Effluent concentrations from May and June 2017 through February 2018 have been non-detect at five of the pilot systems, indicating that the pilot systems are effectively treating PFOA and/or PFOS.

Six other PFAS compounds, perfluoroheptanoic acid (PFHpA), perfluorohexane sulfonic acid (PFHxS), perfluorohexanoic acid (PFHxA), perfluorononanoic acid (PFNA), perfluorotridecanoic acid, and PFBS, have been detected in the intermediate samples of the pilot systems. Additionally, PFHpA, PFHxS, and PFHxA, have been detected in the effluent of the OF-RW59 and OF-RW42C (PFHxS only) pilot systems; however, no Lifetime Health Advisories have been established for these compounds.

After 9 months of system operations, four pilot systems have not shown exceedance of the PIL at the midpoint or breakthrough at the effluent. OF-RW44 required change-out 7 months after the system was brought online, based on exceedance of the PIL in the intermediate sample. OF-RW59 required GAC change-out within 3 months of the system being brought online, and required an additional change-out approximately 9 months after being brought online. OF-RW59 has seen more frequent change-out than the other six pilot studies, most likely because of poor water quality, which is characterized by elevated iron, elevated total dissolved solids (TDS) hardness, and potential presence of microbial growth. Based on the pilot systems operation and GAC change-out schedule, it is assumed for the purposes of this EE/CA that GAC change-outs will average once per year for all systems, except OF-RW59, which is assumed to have a quarterly change-out frequency.

2.3 Conceptual Site Model

A remedial investigation has not been completed for PFAS at NALF Fentress; therefore, the conceptual site model has not been fully developed. For the purposes of this EE/CA, the discussion of a conceptual site model will focus on information pertaining to the on-base potable water system and the off-base private drinking water wells with exceedances of the Lifetime Health Advisory.

2.3.1 Geology

The affected geology in the area consists of two main geological units, the Columbia Group and Chesapeake Group. The sediments of the Columbia Group comprise the surface materials and consist of interbedded gravels, sands, silts, and clays. In the vicinity of NALF Fentress, the thickness of these sediments is less than 30 feet, and typically the depth to groundwater is relatively shallow, less than 10 feet below ground surface (bgs). As a result, an unconfined aquifer, the Surficial/Columbia aquifer, with a saturated thickness of approximately 20 feet, is present in the sediments.

Underlying the Surficial/Columbia aquifer is the Yorktown aquifer, which makes up the uppermost portion of the Chesapeake Group. Regionally, a layer of silt and clay separates the Yorktown aquifer from the sediments of the Surficial/Columbia aquifer. This clay layer has been designated as the Yorktown confining unit. The Yorktown confining unit was identified as being a layer of olive-gray clay and silty clay, 8 to 15 feet thick, which was encountered at approximately 30 feet bgs. The Yorktown aquifer was encountered at approximately 45 feet bgs, directly beneath the Yorktown confining unit. The aquifer consists primarily of gray, very fine to medium sand, and in some cases, coarse sand and gravel. In the northern and eastern portions of the facility, the Yorktown confining unit contains higher percentages of silt and clay, which may allow for a hydraulic connection between the Surficial/Columbia and Yorktown aquifers.

2.3.2 Hydrogeology

Surficial/Columbia aquifer groundwater is generally within 3 to 10 feet of the land surface. Aquifer conditions are unconfined in the Surficial/Columbia aquifer and semi-confined to confined within the upper Yorktown aquifer. Preferential pathways from the Surficial aquifer to the Yorktown aquifer are present at NALF Fentress through conduits created during drilling of numerous production wells, which were not installed with double casing and possibly through the confining unit where high levels of sand and silt are mixed with the clay.

On NALF Fentress, groundwater flow in the Surficial/Columbia aquifer is to the north, northeast, east, and southeast from the approximate location of the original runway, with a higher component of flow to the northeast. Yorktown aquifer flow is toward the east. A downward vertical gradient exists between the Surficial/Columbia and Yorktown aquifers. No groundwater flow information is available for the properties with Lifetime Health Advisory exceedances; however, flow is presumed to be toward the Intercoastal Waterway, which lies to the north and east.

The measured hydraulic conductivity for the Surficial/Columbia aquifer on-base ranged from 1.45×10^{-3} to 1.14×10^{-2} feet per minute, and the calculated groundwater velocity is estimated to be 0.0468 foot per day, or approximately 17.07 feet per year.

The measured hydraulic conductivity for the Yorktown aquifer on base ranged from 4.99×10^{-3} to 3.70×10^{-2} feet per minute, and the calculated groundwater velocity is estimated to be 0.0778 foot per day, or approximately 28.38 feet per year.

Capacity testing was likely conducted during installation to confirm the ability of the wells to deliver water sufficient to meet demands and meet the requirements to obtain a Waterworks Operating Permit from VDH. CH2M could not locate the data or results from any testing; however, to date, the wells have met the Base's potable or training supply needs. To date, the Navy has not completed aquifer testing of the off-base private drinking water wells, and slug test and/or pump test data for these wells are not available. The two on-base potable water supply wells are screened within the Yorktown aquifer. Well depths are unknown at five of the six off-base properties with exceedances of PFOA and/or PFOS exceeding the Lifetime Health Advisory. The depth of one PFOA- and/or PFOS-contaminated potable well is 130 feet, and the well is screened within the Yorktown aquifer.

2.3.3 Affected Media – On-base

The two on-base potable water supply wells are screened within the Yorktown aquifer, which is encountered at approximately 45 feet bgs and may extend to a depth of approximately 300 feet bgs.

Based on the *Preliminary Engineering Report for Potable Water System Improvements* (CH2M, 2017c) the average day demand for the potable water at the on-base potable water system is 3,500 gpd, which includes supply for both the potable water system and the fire supply system. The design of new Navy water systems is subject to the guidance set by the Unified Facilities Criteria (UFC) developed by the Department of Defense (Water System Design, UFC 3-230-01, Section 2-1.1). According to the document, the new systems need to provide enough capacity defined as maximum day demand, which includes a peaking factor of 2.25 (Peaking factors [K Coefficients]), UFC 3-230-03 Table 3-2). The maximum daily demand for the on-base system is assumed to be 7,875 gpd, using a peaking factor of 2.25. More recently (January through March 2018), the average daily use of water is approximately 185 gpd. The maximum daily demand used for the design of the GAC system (7,875 gpd) will be assumed for purposes of this EE/CA.

Samples were collected at the combined influent and effluent of the on-base potable water system in May 2016, to assess potential geochemical impacts on the GAC system. The results are included in the *Preliminary Engineering Report for Potable Water System improvements* (CH2M, 2017c). Geochemical results of the sampling showed the influent stream had low total organic carbon (TOC) (2.1 milligrams per liter [mg/L]), elevated TDS (130 mg/L) and total suspended solids (TSS) (156 mg/L), and elevated hardness (87.8 mg/L as calcium carbonate [$CaCO_3$]) and alkalinity (80 mg/L as $CaCO_3$). The effluent stream also had low TOC (1.7 mg/L), elevated TDS (156 mg/L), reduced TSS as compared to the influent (67 mg/L), and elevated hardness (71.8 mg/L as $CaCO_3$) and alkalinity (94.7 mg/L as $CaCO_3$). Metals detected in the influent included calcium (19.4 mg/L), iron (69.2 mg/L), magnesium (3.69 mg/L), and manganese (0.495 mg/L). Concentrations of metals decrease in the effluent as compared to the influent, including calcium (16.1 mg/L), iron (31.4 mg/L), magnesium (2.95 mg/L), and manganese (0.138 mg/L).

2.3.4 Affected Media – Off-base

Although the construction details for six of the seven off-base private drinking water wells of interest in this EE/CA are unknown, other private drinking water wells in the area are recorded at total depths ranging from 60 to 130 feet bgs. One off-base private drinking water well exceeding the Lifetime Health Advisory is screened from 120 to 130 feet bgs. Based on these depths, the off-base private drinking water wells are most likely screened within the Yorktown aquifer, which is encountered at approximately 45 feet bgs and may extend to a depth of approximately 300 feet bgs. The daily usage rate for the GAC treatment systems varies from 25 to 349 (gpd), with an average usage of 135 gpd. The systems are operated with pressure storage tanks; hence, usage rates are not necessarily representative of groundwater pumping rates from the off-base private drinking water wells. Information is not available for the groundwater pumping rates.

Drinking water samples were collected by the GAC provider (Culligan) at the six private drinking water wells, located on five properties with signed access agreements, prior to installation of the GAC systems, in order to assess potential geochemical impacts on the GAC systems. The geochemical results are summarized in **Table 2-3.** Geochemical results of the sampling showed that pH in the drinking water ranged from 5 to 6.5. TDS ranged from 52 to 320 mg/L, with TDS from hardness ranging from 34 to 103 mg/L. Iron concentrations in the water ranged from 0 to 9 mg/L. An odor test at four of the six off-base properties indicated that hydrogen sulfide may be present.

Following installation of the pilot systems, geochemical parameters, including standard water chemistry field measurements (turbidity, pH, specific conductivity, temperature, and hardness), have been collected from the effluent of the pilot treatment systems (**Table 2-2**). Results of the samples show that pH ranges from 5.1 to 7.0, turbidity is below 5 nephelometric turbidity units, specific conductivity ranges from 0.1 to 1.5 millisiemens per centimeter, temperature ranges from 13.1 to 23.8 degrees Celsius, and hardness ranges from 3 to 86 mg/L.

2.3.5 Nature and Extent of Contamination

Concentrations of total PFOA and/or PFOS in the influent to the on-base potable water treatment system range from non-detect (February 2018) to 7,100 ng/L (May 2016). This fluctuation in influent concentration is believed to be a result of the cycled operation of the two raw water pumps, and influent concentrations may be influenced by which well is pumping at the time of sampling. The ratio of PFOS to PFOA ranges from 1.8 to 0.2, indicating that the combined concentrations of PFOA and PFOS are not dominated by one of the two contaminants. In addition to PFOA and/or PFOS detections, PFBS, PFHpA, PFHxS, PFNA, PFHxA, and nonadecafluorodecanoic acid have been detected in the influent. Of these, only PFHxS has been detected in the effluent to the WTP, both prior to and after the GAC system was installed. No USEPA health advisory limits are set for the six additional PFAS, and of these, PFHxS is the most prevalent at the site, with concentrations ranging from 1.8 to 1,000 ng/L in the influent.

Current concentrations of total PFOA and/or PFOS in the six contaminated off-base private drinking water wells for which access was granted in 2017 ranged from 60.7 to 870 ng/L in February 2018 (**Table 2-2**). The affected properties are located to the north of NALF Fentress, along Mt. Pleasant Road. Geographically, the affected properties are surrounded by undeveloped area, wells that have total PFOA and/or PFOS results below the Lifetime Health Advisory, and/or the NALF Fentress property boundary. The ratio of PFOS to PFOA ranges from 11 to 0.04, indicating that the combined concentrations of PFOA and PFOS are not dominated by one of the two contaminants. In addition to PFOA and/or PFOS detections, PFBS, PFHpA, PFHxS, PFNA, and PFHxA were detected. No USEPA health advisory limits are set for the five additional PFAS, and of these, PFHxS is the most prevalent at the site, with concentrations ranging from 8.5 to 672 ng/L in February 2018.

2.4 Risk Assessment Summary

To date, only a screening-level risk assessment has been performed, in accordance with current Navy policy on PFAS (NAVFAC, 2017). This screening-level risk assessment identified potential risks resulting from exceedances of the regional screening level (RSL) values (calculated using the RSL calculator for PFOA and PFOS). The results of the screening-level risk assessment identified PFOA and PFOS as contaminants of potential concern in drinking water for the on-base and off-base private drinking water wells (CH2M, 2018). Based on the screening-level risk assessment, current receptors include base workers and residents (child and adult) through ingestion of groundwater used as drinking water, contaminated with total PFOA and/or PFOS at concentrations greater than the RSLs. The screening-level risk assessment uses RSLs rather than the Lifetime Health Advisory, in accordance with risk screening guidance (Navy, 2000). However, the RSL is less conservative than the Lifetime Health Advisory; therefore, no additional off-base parcels would be identified as posing potential risk based on the screening-level risk assessment beyond those already identified during a comparison to the Lifetime Health Advisory.

Although future receptors were not considered for the scope of this EE/CA, future land use at the off-base properties is zoned for light residential and conservation, as stated in *Moving Forward -City of Chesapeake 2035 Comprehensive Plan* (Chesapeake, 2016b). Additionally, groundwater will continue to be used as a drinking water source for on-base workers and individuals at off-base private properties unless measures are taken to provide an alternate water supply.

Additionally, this EE/CA only addresses human exposure to PFOA and PFOS in off-base drinking water; other exposure pathways will be evaluated and addressed, as necessary, as part of other actions.

2.5 Development for Cleanup Goal

To meet the RAO, a preliminary remediation goal (PRG) for total PFOA and/or PFOS was established for the off-base private drinking water wells. The PRG is to reduce receptor exposure to PFOA and/or PFOS to a cumulative concentration of less than the Lifetime Health Advisory of 70 ng/L through treatment or provision of an alternative water supply. The PRG is based on the current exposure scenario and the Lifetime Health Advisory established by USEPA.

2.6 Determination of Removal Action Area

The on-base impacts discussed in this EE/CA include the potable water treatment system, with the two on-base supply wells and the treatment system, as shown on **Figure 2-2.** The contaminated off-base private drinking water wells are located on properties to the north of NALF Fentress, which are mainly residential and encompass 19.5 acres. The removal action area is the contaminated private drinking water well systems present at the six off-base private properties, and the on-base potable water treatment system. The average daily use for an individual private drinking water system is 135 gallons, and the calculated daily maximum use for an individual well is 350 gallons, based on monthly flow data. The average daily use for the on-base potable water treatment system, including a 2.25 peaking factor, is 7,875 gpd (5.4 gpm), as stated in the *Preliminary Engineering Report for Potable Water System Improvements* (CH2M, 2017c).

Table 2-1. On-base Potable Water Data

Engineering Evaluation and Cost Analysis for
Drinking Water
NALF Fentress, Chesapeake, Virginia

Sample Location	**USEPA Lifetime Health Advisory**	**Influent**					**Intermediate**			**Effluent**				
Sample ID		OF-INF01-1215[1]	OF-INF01-0516	OF-WT-INF01-113017	OF-INF01-WT-121517	OF-INF01-WT-021418	OF-WT-MID01-113017	OF-MID01-WT-121517	OF-MID01-WT-021418	OF-EFF01-1215[1]	OF-EFF01-0516	OF-WT-EFF01-113017[1]	OF-EFF01-WT-121517[1]	OF-EFF01-WT-021418[1]
Sample Date		12/30/15	5/10/16	11/30/17	12/15/17	2/14/18	11/30/17	12/15/17	2/14/18	12/30/15	5/10/16	11/30/17	12/15/17	2/14/18
Semivolatile Organic Compounds (NG/L)														
Perfluorobutanesulfonic acid (PFBS)	--	**12**	**35 J-**	**56.3**	**62.6**	5.3 U	9.01 U	8.38 U	5.21 U	**49**	**25 J-**	8.51 U	8.52 U	5.17 U
Perfluoroheptanoic acid (PFHpA)	--	**10**	**98**	**78.0**	**63.8**	5.3 U	9.01 U	8.38 U	5.21 U	**53**	**64**	8.51 U	8.52 U	5.17 U
Perfluorohexanesulfonic acid (PFHxS)	--	**260**	**1000 J-**	**915**	**954**	**1.8 JB**	9.01 U	8.38 U	**2 JB**	**630**	**850 J-**	8.51 U	8.52 U	**2.1 JB**
Perfluorononanoic acid (PFNA)	--	**1.8 J**	**38** U	**4.42 J**	**6.33 J**	5.3 U	9.01 U	8.38 U	5.21 U	**4.2**	38 U	8.51 U	8.44 U	5.17 U
Perfluorooctane Sulfonate (PFOS)	70	**540**	**1800**	**1250**	**1450**	5.3 U	9.01 U	**1.41 J**	5.21 U	**1000**	**1200 J-**	**1.73 J**	8.44 U	5.17 U
Perfluorooctanoic acid (PFOA)	70	**300**	**5300**	**3690**	**3000**	5.3 U	9.01 U	8.38 U	5.21 U	**1800**	**3700**	**0.923 J**	8.44 U	5.17 U
Total PFOS + PFOA*	70	**840**	**7100**	**4940**	**4450**	5.3 U	9.01 U	**1.41 J**	5.21 U	**2800**	**4900**	**1.73 J**	8.44 U	5.17 U
PFHxA	--	NS	NS	**309**	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
PFDA	--	NS	NS	**4.95** J	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
MeFOSAA	--	NS	NS	8.72 U	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
PFUnA	--	NS	NS	8.72 U	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
EtFOSAA	--	NS	NS	8.72 U	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
PFDoA	--	NS	NS	8.72 U	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
PFTrDA	--	NS	NS	8.72 U	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 U
PFTeDA	--	NS	NS	8.72 U	NS	5.3 U	9.01 U	NS	5.21 U	NS	NS	8.51 U	NS	5.17 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.

1 - The higher results of the parent and duplicate sample is reported.

Bolded text indicates analyte was positively detected.

Shaded text indicates exceedance of the USEPA Lifetime Health Advisory (May 2016).

J- - Analyte present. Value may be biased low. Value may be higher

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

J+ - Analyte present. Value may be biased high. Actual value may be lower

NG/L - Nanograms per liter

NS - Not sampled

U - The material was analyzed for, but not detected

Table 2-2. GAC Pilot Study Data
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Station ID	OF-RW63																							
Sample Date	5/17/2017			6/26/2017			8/3/2017			9/8/2017			10/12/2017			11/16/2017			12/15/2017			2/15/2018		
Sample Location	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**
Semivolatile Organic Compounds (ng/L)																								
Ethyl perfluorooctanesulfonamide acid (EtFOSAA)																						5.58 U	5.43 U	5.17 U
Methylperfuorooctanesulfonamido acid (MeFOSAA)																						5.58 U	5.43 U	5.17 U
Perfluorobutanesulfonic acid (PFBS)	**3.54 J**	4.10 U	4.13 U	**3.56 J**	5.08 U	5.08 U	**3.15 J**	5.17 U	5.63 U	**3.99 J**	5.25 U	5.58 U	**3.37 J**	5.39 U	5.48 U	**3.41 J**	5.68 U	5.34 U	**4.77 J**	5.43 U	5.48 U	**4.7 J**	5.43 U	5.17 U
Perfluoroheptanoic acid (PFHpA)	**2.53 J**	2.05 U	2.07 U	**2.75 J**	5.08 U	5.08 U	**2.93 J**	5.17 U	5.63 U	**2.75 J**	5.25 U	5.58 U	**1.64 J**	5.39 U	5.48 U	**2.55 J**	5.68 U	5.34 U	**2.60 J**	5.43 U	5.48 U	**3.28 J**	5.43 U	5.17 U
Perfluorohexanesulfonic acid (PFHxS)	**16.8**	2.05 U	2.07 U	**16.4**	**1.18 J**	5.08 U	**13.9**	5.17 U	5.63 U	**6.99**	5.25 U	5.58 U	**11.2**	5.39 U	5.48 U	**14.6**	5.68 U	5.34 U	**11.5**	5.43 U	5.48 U	**8.54 J**	5.43 U	5.17 U
Perfluorononanoic acid (PFNA)	2.08 U	2.05 U	2.07 U	5.21 U	5.08 U	5.08 U	5.53 U	5.17 U	5.63 U	5.25 U	5.25 U	5.58 U	5.39 U	5.39 U	5.48 U	5.00 U	5.68 U	5.34 U	5.25 U	5.43 U	5.48 U	5.58 U	5.43 U	5.17 U
Perfluorooctane Sulfonate (PFOS)	**41.6**	0.922 U	0.930 U	**44.1**	5.08 U	5.08 U	**34.5**	5.17 U	5.63 U	**32.4**	**2.01 J**	5.58 U	**34.8**	5.39 U	5.48 U	**40.4**	5.68 U	5.34 U	**53.9**	5.43 U	5.48 U	**38.6**	5.43 U	5.17 U
Perfluorooctanoic acid (PFOA)	**18.9**	2.05 U	2.07 U	**20.2**	8.08 U	5.08 U	**22.3**	5.17 U	5.63 U	**19.7**	5.25 U	5.58 U	**14.8**	5.39 U	5.48 U	**24.3**	5.68 U	5.34 U	**22.9**	5.43 U	5.48 U	**22.1**	5.43 U	5.17 U
Total PFOA/PFOA	**60.5**	2.972 U	3.000 U	**64.3**	13.16 U	10.16 U	**56.8**	10.34 U	11.26 U	**52.1**	**7.26 J**	11.16 U	**49.6**	10.78 U	10.96 U	**64.7**	11.36 U	10.68 U	**76.8**	10.86 U	10.96 U	**60.7**	10.9 U	10.3 U
Nonadecafluorodecanoic acid (PFDA)																						5.58 U	5.43 U	5.17 U
Perfluorododecanoic acid (PFDoA)																						5.58 U	5.43 U	5.17 U
Perfluorohexanoic acid (PFHxA)																						5.58 U	5.43 U	5.17 U
Perfluorotetradecanoic acid (PFTeDA)																						5.58 U	5.43 U	5.17 U
Perfluorotridecanoic Acid (PFTrDA)																						5.58 U	**1.09 J**	5.17 U
Perfluoroundecanoic acid (PFUnA)																						5.58 U	5.43 U	5.17 U
Field Parameters																								
Turbidity (NTU)			3.0			3.0			0.0			--			--			--			0.0			0.6
pH			6.39			6.39			5.05			5.24			4.99			--			5.07			4.69
Specific Conductivity (ms/cm)			0.164			0.164			0.166			0.164			0.162			--			0.168			0.158
Temperature (˚C)			19.19			19.19			20.41			20.29			21.6			--			18.7			18.0
Hardness (mg/L)			--			34.2			34.2			34.2			34.2			34.2			51.3			17.1
Flow																								
Flow Meter Reading (gal)			0.0			6,099.7			10,970.5			14,977.1			19,591.0			23,908.6			28,390.9			38,569.4
Incremental Volume (gal)			0.0			-			4,870.9			4,006.5			4,613.9			4,317.6			4,482.3			10,178.5
Calculated Daily Flow Rate (gal per day)			0.0			152.5			128.2			111.3			135.7			123.4			154.6			164.2

Table 2-2. GAC Pilot Study Data

Engineering Evaluation and Cost Analysis for Drinking Water

NALF Fentress, Chesapeake, Virginia

Station ID	OF-RW44																							
Sample Date	5/17/2017			6/26/2017			8/3/2017			9/8/2017			10/12/2017			11/16/2017			12/15/2017			2/15/2018[b]		
Sample Location	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**
Semivolatile Organic Compounds (ng/L)																								
Ethyl perfluorooctanesulfonamide acid (EtFOSAA)																						5.43 U	5.17 U	5.34 U
Methylperfuorooctanesulfonamido acid (MeFOSAA)																						5.43 U	5.17 U	5.34 U
Perfluorobutanesulfonic acid (PFBS)	**11.9**	4.13 U	4.27 U	**11.5**	5.17 U	5.34 U	**9.94**	5.21 U	5.21 U	**7.71 J**	5.34 U	5.30 U	**15.9**	5.48 U	5.58 U	**10.7**	5.17 U	6.01 U	**11.9**	5.39 U	5.17 U	**8.46 J**	5.17 U	5.34 U
Perfluoroheptanoic acid (PFHpA)	**12.2**	2.07 U	2.14 U	**10.5**	5.17 U	5.34 U	**9.83**	5.21 U	5.21 U	**10.4**	5.34 U	5.30 U	**14.5**	5.48 U	5.58 U	**10.2**	5.17 U	6.01 U	**11.5**	5.39 U	5.17 U	**8.85**	**0.771 J**	5.34 U
Perfluorohexanesulfonic acid (PFHxS)	**294**	2.07 U	2.14 U	**325**	5.17 U	**1.24 J**	**251**	5.21 U	5.21 U	**260**	5.34 U	5.30 U	**423**	5.48 U	5.58 U	**274**	5.17 U	6.01 U	**294**	**8.88**	5.17 U	**293**	**3.37 J**	5.34 U
Perfluorononanoic acid (PFNA)	**2.75**	2.07 U	2.14 U	5.25 U	5.17 U	5.34 U	**2.03 J**	5.21 U	5.21 U	**1.6 J**	5.34 U	5.30 U	**3.53 J**	5.48 U	5.58 U	**2.99 J**	5.17 U	6.01 U	**3.26 J**	5.39 U	5.17 U	**3.41 J**	5.17 U	5.34 U
Perfluorooctane Sulfonate (PFOS)	**818**	0.930 U	0.962 U	**528**	5.17 U	5.34 U	**826**	**0.921 J**	5.21 U	**816**	5.34 U	5.30 U	**993**	5.48 U	5.58 U	**983**	5.17 U	6.01 U	**963**	**23.7**	5.17 U	**640**	**11.1**	5.34 U
Perfluorooctanoic acid (PFOA)	**307**	2.07 U	2.14 U	**293**	5.17 U	5.34 U	**317**	5.21 U	5.21 U	**246**	5.34 U	5.30 U	**329**	5.48 U	5.58 U	**305**	5.17 U	6.01 U	**300**	**15.1**	5.17 U	**230**	**9.9**	5.34 U
Total PFOA/PFOA	**1125**	3.000 U	3.102 U	**821**	10.34 U	10.68 U	**1143**	**0.921 J**	10.42 U	**1062**	10.68 U	10.60 U	**1322**	10.96 U	11.16 U	**1288**	10.34 U	12.02 U	**1263**	**38.8**	10.34 U	**870**	**21**	10.68 U
Nonadecafluorodecanoic acid (PFDA)																						5.43 U	5.17 U	5.34 U
Perfluorododecanoic acid (PFDoA)																						5.43 U	5.17 U	5.34 U
Perfluorohexanoic acid (PFHxA)																						**23.5**	5.17 U	5.34 U
Perfluorotetradecanoic acid (PFTeDA)																						5.43 U	5.17 U	5.34 U
Perfluorotridecanoic Acid (PFTrDA)																						5.43 U	5.17 U	5.34 U
Perfluoroundecanoic acid (PFUnA)																						5.43 U	5.17 U	5.34 U
Field Parameters																								
Turbidity (NTU)			3.1			3.1			0.0			--			--			--			1.7			0.5
pH			6.35			6.35			5.48			5.71			5.60			--			5.60			5.61
Specific Conductivity (ms/cm)			0.264			0.264			0.271			0.258			0.273			--			0.269			0.253
Temperature (˚C)			19.7			19.7			23.8			23.0			23.9			--			14.9			13.4
Hardness (mg/L)			--			34.2			34.2			34.2			34.2			34.2			34.2			32.4
Flow																								
Flow Meter Reading (gal)			0.0			3,201.8			5,488.1			8,135.6			11,318.3			13,326.0			16,701.4			20,484.0
Incremental Volume (gal)			0.0			3,201.8			2,286.4			2,647.5			3,182.7			2,007.6			3,375.4			3,782.6
Calculated Daily Flow Rate (gal per day)			0.0			80.0			60.2			73.5			93.6			57.4			116.4			61.0

Table 2-2. GAC Pilot Study Data

Engineering Evaluation and Cost Analysis for Drinking Water

NALF Fentress, Chesapeake, Virginia

Station ID	**OF-RW42B**																							
Sample Date	5/25/2017			6/26/2017			8/3/2017			9/8/2017			10/12/2017			11/16/2017			12/15/2017			2/15/2018		
Sample Location	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**
Semivolatile Organic Compounds (ng/L)																								
Ethyl perfluorooctanesulfonamide acid (EtFOSAA)																						5.39 U	5.39 U	5.17 U
Methylperfuorooctanesulfonamido acid (MeFOSAA)																						5.39 U	5.39 U	5.17 U
Perfluorobutanesulfonic acid (PFBS)	**52.8**	4.13 U	3.97 U	**61.6**	5.04 U	5.21 U	**61.1**	5.48 U	5.63 U	**51.1**	5.48 U	5.39 U	**52.1**	5.68 U	6.26 U	**67.8**	5.43 U	4.84 U	**61.0**	**7.63 J**	5.30 U	**54.5**	5.39 U	5.17 U
Perfluoroheptanoic acid (PFHpA)	**15.8**	2.07 U	1.98 U	**15.2**	5.04 U	5.21 U	**14.2**	5.48 U	5.63 U	**17.6**	5.48 U	5.39 U	**16.6**	5.68 U	6.26 U	**17.0**	5.43 U	4.84 U	**19.1**	**2.88 J**	5.30 U	**16.2**	5.39 U	5.17 U
Perfluorohexanesulfonic acid (PFHxS)	**581**	2.07 U	1.98 U	**695**	5.04 U	**1.15 J**	**628**	**1.56 J**	5.63 U	**619**	**1.74 J**	5.39 U	**594**	5.68 U	6.26 U	**666**	**11.4**	4.84 U	**631**	**66.8**	5.30 U	**672**	**2.07 JB**	5.17 U
Perfluorononanoic acid (PFNA)	2.21 U	2.07 U	1.98 U	5.17 U	5.04 U	5.21 U	**5.68**	5.48 U	5.63 U	5.48 U	5.48 U	5.39 U	6.33 U	5.68 U	6.26 U	5.12 U	5.43 U	4.84 U	5.43 U	**5.25 J**	5.30 U	5.39 U	5.39 U	5.17 U
Perfluorooctane Sulfonate (PFOS)	**11.0**	0.930 U	0.893 U	**16.5**	5.04 U	5.21 U	**8.97 J**	5.48 U	5.63 U	**10.9**	5.48 U	5.39 U	**12.1**	5.68 U	6.26 U	**11.8**	5.43 U	4.84 U	**14.5**	**1.94 J**	5.30 U	**9.17**	5.39 U	5.17 U
Perfluorooctanoic acid (PFOA)	**253**	2.07 U	1.98 U	**247**	5.04 U	5.21 U	**244**	5.48 U	5.63 U	**208**	5.48 U	5.39 U	**220**	5.68 U	6.26 U	**270**	**4.66 J**	4.84 U	**301**	**49.7**	5.30 U	**228**	5.39 U	5.17 U
Total PFOA/PFOA	**264.0**	3.000 U	2.873 U	**263.5**	10.08 U	10.42 U	**252.97**	10.96 U	11.26 U	**218.9**	10.96 U	10.78 U	**232.1**	11.36 U	12.52 U	**281.8**	**4.66 J**	9.68 U	**315.5**	**51.64**	10.60 U	**237.17**	10.78 U	10.34 U
Nonadecafluorodecanoic acid (PFDA)											--											5.39 U	5.39 U	5.17 U
Perfluorododecanoic acid (PFDoA)																						5.39 U	5.39 U	5.17 U
Perfluorohexanoic acid (PFHxA)																						**122**	5.39 U	5.17 U
Perfluorotetradecanoic acid (PFTeDA)																						5.39 U	5.39 U	5.17 U
Perfluorotridecanoic Acid (PFTrDA)																						5.39 U	5.39 U	5.17 U
Perfluoroundecanoic acid (PFUnA)																						5.39 U	5.39 U	5.17 U
Field Parameters																								
Turbidity (NTU)			--			4.2			0.2			--			--			--			0.0			0.2
pH			--			6.54			6.12			6.37			6.30			--			6.39			16.70
Specific Conductivity (ms/cm)			--			1.546			0.835			0.734			0.775			--			0.647			0.720
Temperature (˚C)			--			19.0			20.8			20.2			21.2			--			13.1			16.7
Hardness (mg/L)			56			68.4			51.3			51.3			34.2			51.3			51.3			51.3
Flow																								
Flow Meter Reading (gal)			0.0			6,164.1			19,307.2			24,895.2			30,880.3			36,739.3			46,667.7			58,062.0
Incremental Volume (gal)			0.0			6,164.1			13,143.1			5,588.0			5,985.1			5,859.0			9,928.4			11,394.3
Calculated Daily Flow Rate (gal per day)			0.0			192.6			345.9			155.2			176.0			167.4			342.4			183.8

Table 2-2. GAC Pilot Study Data
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Station ID	**OF-RW42C**																							
Sample Date	5/25/2017			6/26/2017			8/3/2017			9/8/2017			10/12/2017			11/16/2017			12/15/2017			2/15/2018		
Sample Location	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**
Semivolatile Organic Compounds (ng/L)																								
Ethyl perfluorooctanesulfonamide acid (EtFOSAA)																						5.17 U	5.17 U	5.25 U
Methylperfuorooctanesulfonamido acid (MeFOSAA)																						5.17 U	5.17 U	5.25 U
Perfluorobutanesulfonic acid (PFBS)	**19.0**	4.03 U	3.91 U	**20.6**	5.12 U	5.00 U	**17.6**	5.25 U	5.43 U	**18.4 J**	5.30 U	5.48 U	**18.5**	5.53 U	5.34 U	**18.4**	5.25 U	5.21 U	**23.6**	5.43 U	5.25 U	**18.5**	5.17 U	5.25 U
Perfluoroheptanoic acid (PFHpA)	**6.13 J**	2.02 U	1.95 U	**5.62 J**	5.12 U	5.00 U	**5.88 J**	5.25 U	5.43 U	**3.60 J**	5.30 U	5.48 U	**6.21 J**	5.53 U	5.34 U	**5.97 J**	5.25 U	5.21 U	**6.61 J**	5.43 U	5.25 U	**5.98 J**	5.17 U	5.25 U
Perfluorohexanesulfonic acid (PFHxS)	**254**	2.02 U	1.95 U	**286**	5.12 U	5.00 U	**256**	5.25 U	5.43 U	**318**	5.30 U	5.48 U	**252**	**1.17 J**	**1.06 J**	**276**	5.25 U	5.21 U	**253**	5.43 U	5.25 U	**226 B**	5.17 U	**1.75 JB**
Perfluorononanoic acid (PFNA)	**1.24 J**	2.02 U	1.95 U	5.04 U	5.12 U	5.00 U	**5.25**	5.25 U	5.43 U	5.58 U	5.30 U	5.48 U	**1.11 J**	5.53 U	5.34 U	5.08 U	5.25 U	5.21 U	5.30 U	5.43 U	5.25 U	5.17 U	5.17 U	5.25 U
Perfluorooctane Sulfonate (PFOS)	**25.8**	0.907 U	0.879 U	**33.5**	5.12 U	5.00 U	**15.8**	5.25 U	5.43 U	**32.2**	5.30 U	5.48 U	**26.4**	5.53 U	5.34 U	**29.1**	5.25 U	5.21 U	**36.0**	5.43 U	5.25 U	**26.2**	5.17 U	5.25 U
Perfluorooctanoic acid (PFOA)	**98.6**	2.02 U	1.95 U	**86.5**	5.12 U	5.00 U	**88.4**	5.25 U	5.43 U	**88.6**	5.30 U	5.48 U	**93.0**	5.53 U	5.34 U	**91.7**	5.25 U	5.21 U	**103**	5.43 U	5.25 U	**81.8**	5.17 U	5.25 U
Total PFOA/PFOA	**124.4**	2.927 U	2.829 U	**120**	10.24 U	10.00 U	**104.2**	10.5 U	10.86 U	**120.8**	10.60 U	10.96 U	**119.4**	11.06 U	10.68 U	**120.8**	10.5 U	10.42 U	**139**	10.86 U	10.5 U	**108**	10.34 U	10.5 U
Nonadecafluorodecanoic acid (PFDA)																						5.17 U	5.17 U	5.25 U
Perfluorododecanoic acid (PFDoA)																						5.17 U	5.17 U	5.25 U
Perfluorohexanoic acid (PFHxA)																						**22**	5.17 U	5.25 U
Perfluorotetradecanoic acid (PFTeDA)																						5.17 U	5.17 U	5.25 U
Perfluorotridecanoic Acid (PFTrDA)																						5.17 U	5.17 U	5.25 U
Perfluoroundecanoic acid (PFUnA)																						5.17 U	5.17 U	5.25 U
Field Parameters																								
Turbidity (NTU)			--			2.1			0.2			--			--			--			0.1			0.2
pH			--			5.43			5.57			5.66			5.77			--			5.67			5.72
Specific Conductivity (ms/cm)			--			0.206			0.125			0.130			0.115			--			0.127			0.121
Temperature (˚C)			--			16.6			18.7			18.0			19.3			--			17.9			15.9
Hardness (mg/L)			24			51.3			34.2			34.2			51.3			34.2			34.2			32.4
Flow																								
Flow Meter Reading (gal)			0.0			2,392.9			4,009.0			5,799.3			7,634.6			8,519.6			13,100.5			18,323.6
Incremental Volume (gal)			0.0			2,392.9			1,616.1			1,790.2			1,835.3			885.0			4,580.9			5,223.1
Calculated Daily Flow Rate (gal per day)			0.0			74.8			42.5			49.7			54.0			25.3			158.0			84.2

Table 2-2. GAC Pilot Study Data
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Station ID	OF-RW59																				
Sample Date	6/26/2017			8/3/2017			9/8/2017[a]			10/12/2017[a]			11/16/2017[a]			12/15/2017			2/15/2018[b]		
Sample Location	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**
Semivolatile Organic Compounds (ng/L)																					
Ethyl perfluorooctanesulfonamide acid (EtFOSAA)																			5.43 U	5.21 U	5.12 U
Methylperfuorooctanesulfonamido acid (MeFOSAA)																			5.43 U	5.21 U	5.12 U
Perfluorobutanesulfonic acid (PFBS)	**11.6**	5.08 U	5.12 U	**9.79**	**9.34**	5.58 U	**9.06 J**	**4.39 J**	5.48 U	**8.64 J**	**7.86 J**	**9.35**	**9.24**	**10.2**	**11.7**	**6.92 J**	5.21 U	5.43 U	**9.84**	**5.6 J**	5.12 U
Perfluoroheptanoic acid (PFHpA)	**4.00 J**	5.08 U	5.12 U	**4.83 J**	**4.27 J**	5.58 U	**4.11 J**	**2.34 J**	5.48 U	**3.27 J**	**3.23 J**	**3.45 J**	**4.53 J**	**5.10 J**	**4.79 J**	**3.54 J**	5.21 U	5.43 U	**4.66 J**	**2.84 J**	**0.892 J**
Perfluorohexanesulfonic acid (PFHxS)	**293**	**1.84 J**	5.12 U	**277**	**264**	5.58 U	**260**	**154**	**32.3**	**220**	**237**	**254**	**284**	**239**	**285**	**227**	5.21 U	5.43 U	**272**	**167**	**29.5**
Perfluorononanoic acid (PFNA)	5.17 U	5.08 U	5.12 U	5.53 U	5.43 U	5.58 U	5.43 U	5.30 U	5.48 U	5.63 U	5.39 U	5.68 U	5.30 U	5.04 U	5.34 U	5.43 U	5.21 U	5.43 U	5.43 U	5.21 U	5.12 U
Perfluorooctane Sulfonate (PFOS)	**521**	**5.72 J**	5.12 U	**406**	**354**	5.58 U	**497**	**250**	**61.6**	**346**	**350**	**362**	**430**	**506**	**473**	**419**	5.21 U	5.43 U	**432**	**220**	**59.2**
Perfluorooctanoic acid (PFOA)	**67.0**	5.08 U	5.12 U	**80.4**	**69.2**	5.58 U	**72.9**	**34.4**	**7.51**	**59.5**	**64.0**	**62.9**	**74.4**	**65.2**	**79.1**	**60.7**	5.21 U	5.43 U	**59.9**	**40.9**	**7.01 J**
Total PFOA/PFOA	**588**	**5.72 J**	10.24 U	**486.4**	**423.2**	11.16 U	**569.9**	**284.4**	**69.11**	**405.5**	**414**	**424.9**	**504.4**	**571.2**	**552.1**	**479.7**	10.42 U	10.86 U	**491.9**	**260.9**	**66.21**
Nonadecafluorodecanoic acid (PFDA)																			5.43 U	5.21 U	5.12 U
Perfluorododecanoic acid (PFDoA)																			5.43 U	5.21 U	5.12 U
Perfluorohexanoic acid (PFHxA)																			**25.6**	**17.8**	**3.09 J**
Perfluorotetradecanoic acid (PFTeDA)																			5.43 U	5.21 U	5.12 U
Perfluorotridecanoic Acid (PFTrDA)																			5.43 U	5.21 U	5.12 U
Perfluoroundecanoic acid (PFUnA)																			5.43 U	5.21 U	5.12 U
Field Parameters																					
Turbidity (NTU)			5.1			0.7			--			--			--			0.0			0.5
pH			6.91			6.46			7.00			7.03			--			7.00			6.70
Specific Conductivity (ms/cm)			0.469			0.259			0.293			0.252			--			0.246			0.257
Temperature (˚C)			19.7			21.2			19.1			21.7			--			15.1			14.4
Hardness (mg/L)			3			NA*			NA*			NA*			NA*			NA*			0.5
Flow																					
Flow Meter Reading (gal)			0.0			8,572.8			15,222.4			20,428.9			24,833.4			31,636.6			43,554.7
Incremental Volume (gal)			0.0			8,572.8			6,649.6			5,206.5			4,404.5			6,803.1			11,918.1
Calculated Daily Flow Rate (gal per day)			0.0			225.6			184.7			153.1			125.8			234.6			192.2

Table 2-2. GAC Pilot Study Data

Engineering Evaluation and Cost Analysis for Drinking Water

NALF Fentress, Chesapeake, Virginia

Station ID	OF-RW08																				
Sample Date	6/26/2017			8/3/2017			9/8/2017			10/12/2017			11/16/2017			12/15/2017			2/15/2018		
Sample Location	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**	**Influent**	**Intermediate**	**Effluent**
Semivolatile Organic Compounds (ng/L)																					
Ethyl perfluorooctanesulfonamide acid (EtFOSAA)																			5.12 U	5.73 U	5.08 U
Methylperfuorooctanesulfonamido acid (MeFOSAA)																			5.12 U	5.73 U	5.08 U
Perfluorobutanesulfonic acid (PFBS)	**3.86 J**	5.34 U	5.17 U	**3.00 J**	5.34 U	5.39 U	**3.8 J**	5.48 U	5.53 U	**3.7 J**	5.34 U	5.25 U	**4.11 J**	5.25 U	5.58 U	**3.73 J**	5.34 U	5.25 U	**5.37 J**	5.73 U	5.08 U
Perfluoroheptanoic acid (PFHpA)	**1.43 J**	5.34 U	5.17 U	**1.87 J**	5.34 U	5.39 U	**1.28 J**	5.48 U	5.53 U	**1.47 J**	5.34 U	5.25 U	**1.80 J**	5.25 U	5.58 U	**1.88 J**	5.34 U	5.25 U	**2.36 J**	5.73 U	5.08 U
Perfluorohexanesulfonic acid (PFHxS)	**39.9**	5.34 U	5.17 U	**35.1**	5.34 U	5.39 U	**31.8**	5.48 U	5.53 U	**32.8**	5.34 U	5.25 U	**34.4**	5.25 U	5.58 U	**33.6**	5.34 U	5.25 U	**44.8**	5.73 U	5.08 U
Perfluorononanoic acid (PFNA)	5.3 U	5.34 U	5.17 U	5.17 U	5.34 U	5.39 U	5.43 U	5.48 U	5.53 U	5.68 U	5.34 U	5.25 U	5.39 U	5.25 U	5.58 U	5.43 U	5.34 U	5.25 U	5.12 U	5.73 U	5.08 U
Perfluorooctane Sulfonate (PFOS)	**148**	5.34 U	5.17 U	**125**	5.34 U	5.39 U	**160**	5.48 U	5.53 U	**118**	5.34 U	5.25 U	**168**	5.25 U	5.58 U	**164**	5.34 U	5.25 U	**149**	5.73 U	5.08 U
Perfluorooctanoic acid (PFOA)	**7.05 J**	5.34 U	5.17 U	**9.74**	5.34 U	5.39 U	**8.12 J**	5.48 U	5.53 U	**8.64 J**	5.34 U	5.25 U	**11.5**	5.25 U	5.58 U	**8.10 J**	5.34 U	5.25 U	**13.4**	5.73 U	5.08 U
Total PFOA/PFOA	**155.05**	10.68 U	10.34 U	**134.74**	10.68 U	10.78 U	**168.12**	10.96 U	11.06 U	**126.64**	10.68 U	10.5 U	**179.5**	10.5 U	11.16 U	**172.1**	10.68 U	10.5 U	**162.4**	11.46 U	10.16 U
Nonadecafluorodecanoic acid (PFDA)																			5.12 U	5.73 U	5.08 U
Perfluorododecanoic acid (PFDoA)																			5.12 U	5.73 U	5.08 U
Perfluorohexanoic acid (PFHxA)																			**6.95 J**	5.73 U	5.08 U
Perfluorotetradecanoic acid (PFTeDA)																			5.12 U	5.73 U	5.08 U
Perfluorotridecanoic Acid (PFTrDA)																			5.12 U	5.73 U	5.08 U
Perfluoroundecanoic acid (PFUnA)																			5.12 U	5.73 U	5.08 U
Field Parameters																					
Turbidity (NTU)			3.9			0.6			--			--			--			0.0			0.14
pH			6.05			5.26			5.46			5.63			--			5.09			5.20
Specific Conductivity (ms/cm)			0.356			0.217			0.308			0.213			--			0.111			0.239
Temperature (˚C)			19.4			19.1			19.4			20.9			--			16.9			17.4
Hardness (mg/L)			68.4			85.5			85.5			85.5			85.5			68.4			68.4
Flow																					
Flow Meter Reading (gal)			0.0			4,712.5			8,765.8			12,531.6			16,360.7			19,573.1			26,486.8
Incremental Volume (gal)			0.0			4,712.5			4,053.2			3,765.9			3,829.0			3,212.4			6,913.7
Calculated Daily Flow Rate (gal per day)			0.0			124.0			112.6			110.8			109.4			110.8			111.5

Notes:

Bolded text indicates analyte was positively detected.

Shaded text indicates exceedance of the USEPA Lifetime Health Advisory (May 2016).

NA* = Water too soft; could not titrate with field kit

a The GAC was changed out of OF-RW59 in October 2017, after which the bypass valve was not closed, thus influent was not being treated through the GAC vessels. The bypass valve was closed prior to the December 2017 sampling event.

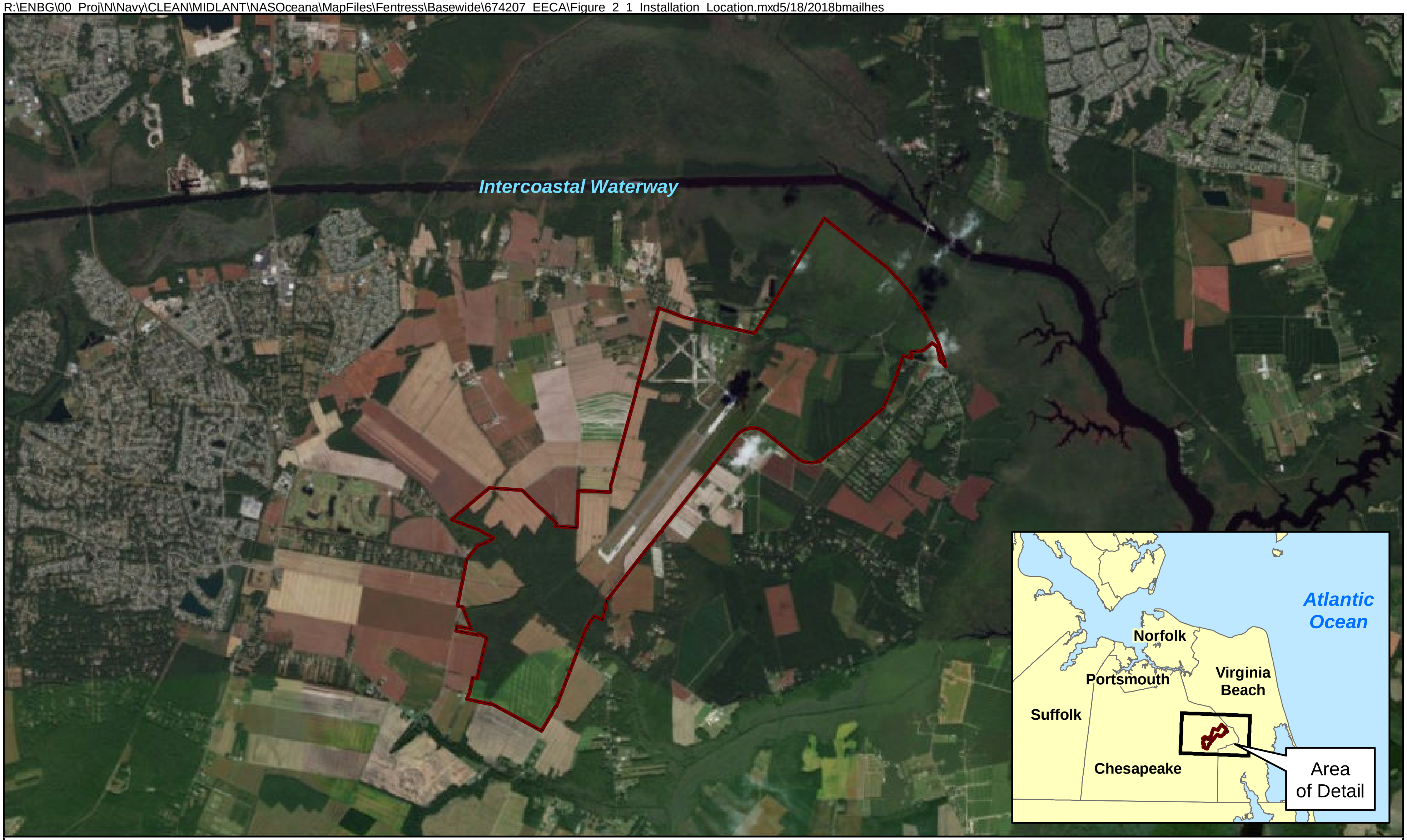
b GAC change out is scheduled for May 2018 at OF-RW44 and OF-RW59 based on results of the February 2018 sampling event.

Table 2-3. Pre-pilot Study Water Geochemistry Data
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Station ID	OF-RW08	OF-RW63	OF-RW59	OF-RW44	OF-RW42C	OF-RW42B
Sample Date	5/1/2017					
Water Chemistry						
Hardness (GPG)	4	2	6	2	2	5
Iron (ppm)	0	0	7.8	5.6	6.6	9
pH	5	6	6.5	6.5	6	6.5
TDS (ppm)	73	74	107	102	52	320
TDS from Hardness (ppm)	69	34	103	34	35	86
Unknown TDS (ppm)	4	40	4	68	17	234
Hydrogen Sulfide Smell Test	Negative	Negative	Positive	Positive	Positive	Positive
IRB, SRB, SFB	No visible evidence	No visible evidence	Visible Evidence	No visible evidence	No visible evidence	No visible evidence

GPG = grains per gram
ppm = parts per million
IRB = Iron Related Bacteria
SRB = Sulfate Related Bacteria
SFB = Slime Forming Bacteria
Note: Source of data: Culligan

R:\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\Fentress\Basewide\674207_EECA\Figure_2_1_Installation_Location.mxd5/18/2018bmailhes



Legend

Fentress Boundary

N
W E
S

0 0.5 1 Miles

1 inch = 1 mile

Imagery Source: ©2017 Esri

Figure 2-1
Installation Location Map
Engineering Evaluation and Cost Analysis for Drinking Water NALF
Fentress, Chesapeake, Virginia

ch2m

Legend
Water Supply Well
Fentress Boundary

N W E S

0 500 1,000 Feet

1 inch = 1,000 feet

Imagery Source: ©2017 Esri

Figure 2-2
Potential PFAS Source Areas and On-base Potable Water Treatment System
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

ch2m

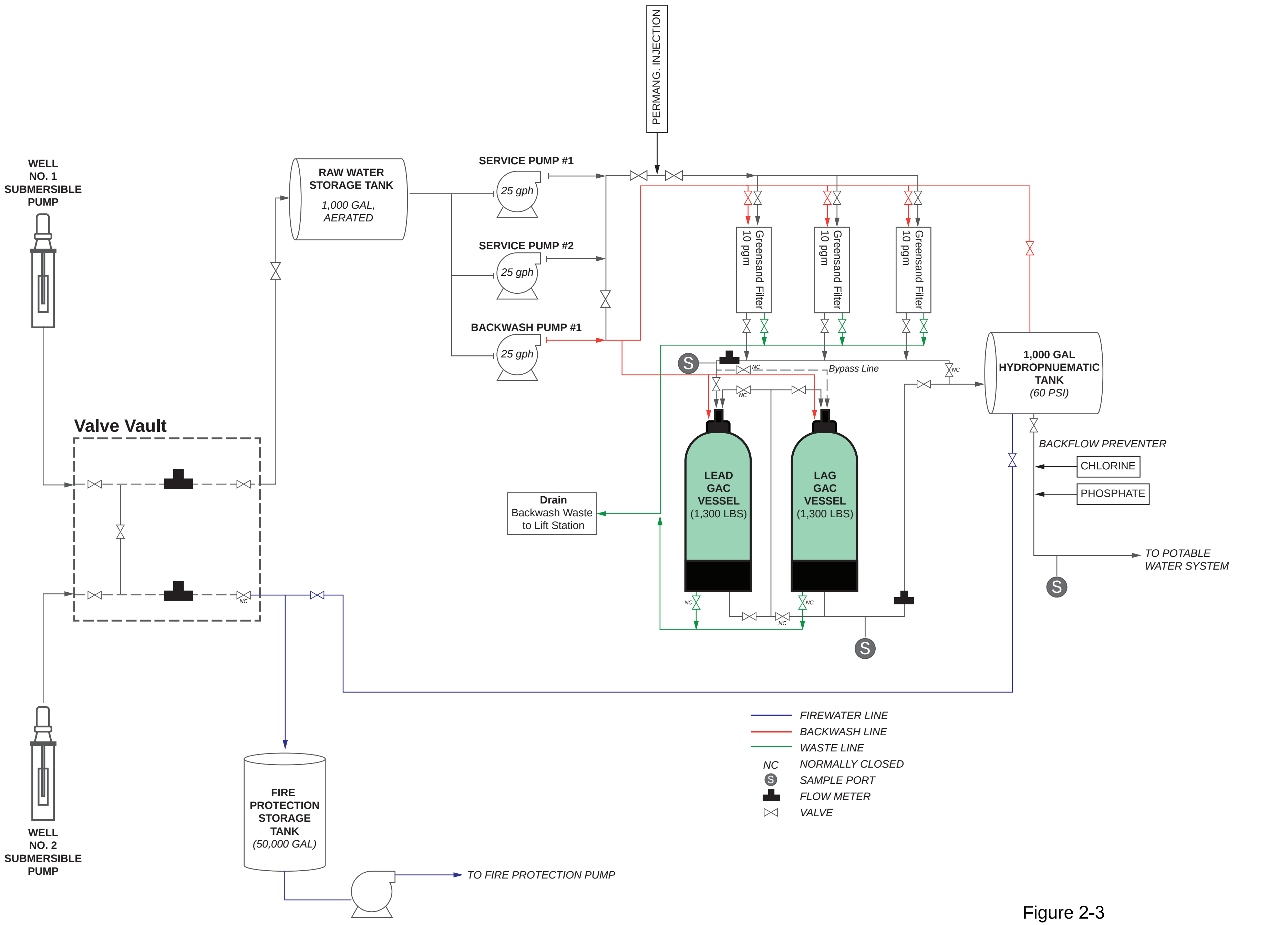


Figure 2-3
On-base Potable Water Treatment System Layout
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

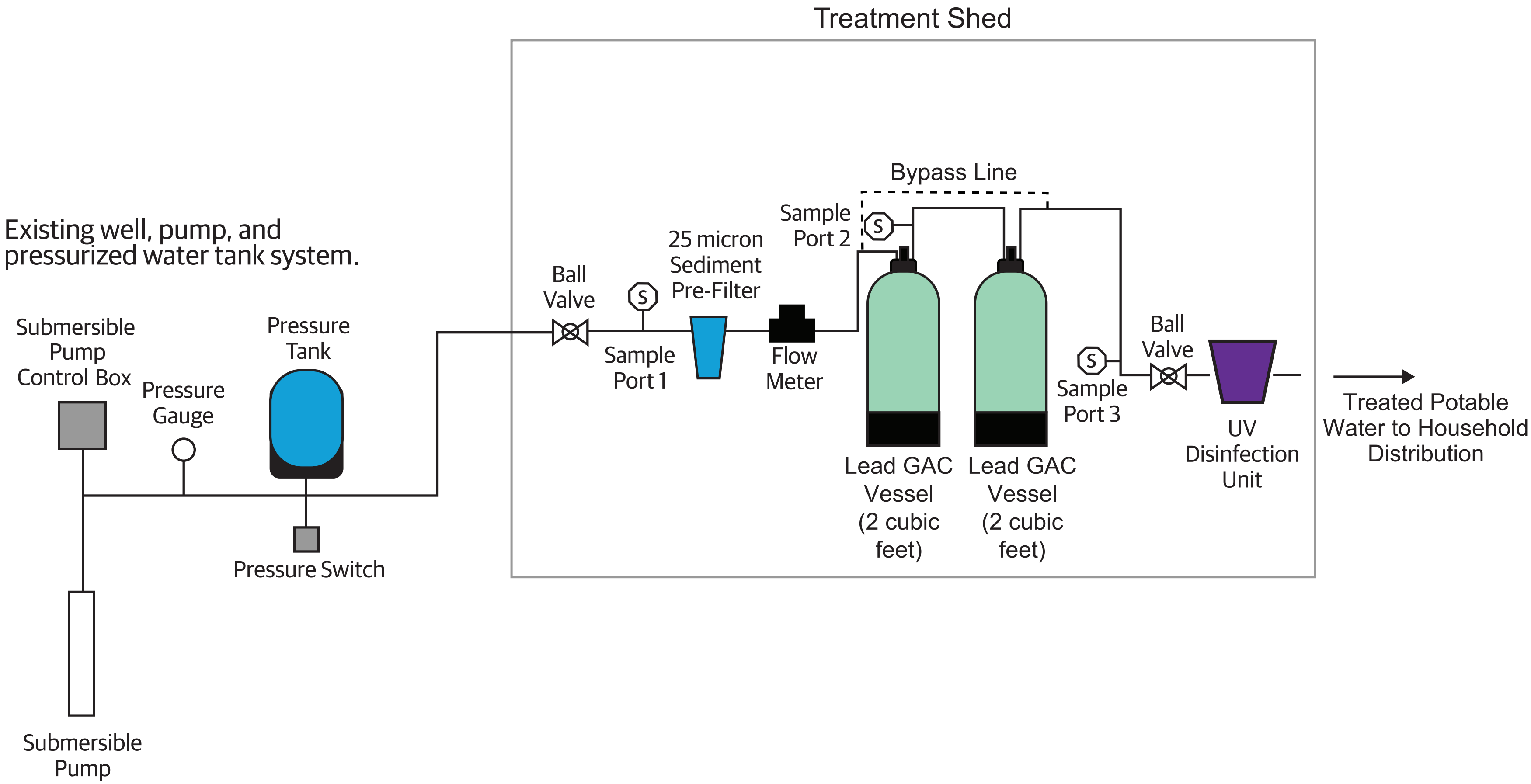


Figure 2-4
Privately Owned Point of Entry Granular Activated Carbon Treatment System
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Identification of Objectives

3.1 Statutory Limits on Removal Actions

The NCP, 40 CFR Part 300.415, dictates statutory limits of $2 million and a 12-month duration for USEPA fund-financed removal actions, with statutory exemptions for emergencies and actions consistent with the removal action to be taken. However, this removal action will not be USEPA fund-financed. The *Department of the Navy Environmental Restoration Program Manual* (Navy, 2018) does not limit the cost or duration of removal actions; cost-effectiveness is a recommended criterion for the evaluation of removal action alternatives and is discussed in Sections 4 and 5.

3.2 Removal Action Objective and Scope

3.2.1 Removal Action Objective

The RAO in this EE/CA will address only current human receptors ingesting contaminated groundwater used as drinking water at levels above the Lifetime Health Advisory. Therefore, the RAO only applies to the on-base drinking water system and the seven private drinking water wells located on the six privately owned properties.

The RAO is as follows:

- Protect current human health receptors from ingestion of PFOA and/or PFOS at levels above the Lifetime Health Advisory in groundwater used as drinking water.

In order to meet the RAO, the following PRG was established:

- Reduce receptor exposure to PFOA and/or PFOS to a cumulative concentration of less than the Lifetime Health Advisory of 70 ng/L through treatment or provision of an alternative water supply.

The PRG was established based on the Lifetime Health Advisory since there are currently there are no Safe Drinking Water Act (SDWA) federal regulations or Clean Water Act Ambient Water Quality Human Health Criteria for any PFAS. For contaminants not subject to any national primary drinking water regulation the SDWA authorizes USEPA to publish non-regulatory Lifetime Health Advisories or take other appropriate actions. These Lifetime Health Advisories are created to assist state and local officials in evaluating risks from these contaminants in drinking water. In May of 2016, the USEPA issued a Lifetime Health Advisory for two PFAS, specifically PFOA and PFOS. The USEPA Lifetime Health Advisory only applies to PFOA and PFOS; USEPA does not advocate applying these levels to any other PFAS. Additionally, no applicable or relevant and appropriate requirements (ARARs) currently exist from either the USEPA or the Commonwealth of Virginia for PFAS compounds.

3.2.2 Removal Action Scope

This EE/CA is intended to address current receptor exposure to PFOA and PFOS in drinking water for the on-base potable water system and off-base private drinking water wells near NALF Fentress. Additional action may be necessary to address PFAS contamination in groundwater, soil, surface water, and sediment within and around the installation; however, impacts on groundwater, soil, surface water, and sediment are not included in this removal action scope.

Removal action alternatives were scoped and developed to meet the RAO listed above. A preliminary screening of potential alternatives was performed, prior to selecting alternatives for the EE/CA. The preliminary screening of alternatives is included in **Table 3-1.** The scope of the engineering measures for each removal alternative is defined in this section.

1. No Further Action: No further action would be conducted; the site would remain “as is.” Thus, bottled water would continue to be provided to off-base drinking water receptors whose drinking water has tested above

the Lifetime Health Advisory, and the pilot GAC systems currently installed at each off-base property would be taken off-line. The GAC system would continue to be operated at the on-base potable water treatment system.

2. Point of Entry Treatment: This action alternative would address PFOA and PFOS impacts at the on-base potable water treatment system before the finished potable water supply is stored for distribution to the base. This alternative would also address PFOA and/or PFOS at each individual private property with drinking water contaminant concentrations greater than the Lifetime Health Advisory before the potable water supply enters the distribution piping for the house. The following three treatment technologies are being considered under this alternative:
    a. GAC Treatment – This action would include the installation or continued maintenance of GAC vessels, implemented in series, for PFOA and/or PFOS removal. For the on-base system, this alternative would be the same as the No Further Action Alternative because the on-base GAC system is already fully functional. For the off-base systems, the GAC vessels would be implemented in coordination with the pilot study, where possible.
    b. Ion Exchange (IX) Treatment – Installation of IX vessels for PFOA and/or PFOS removal. The on-base treatment system would include four IX vessels operated in series, while the off-base drinking water treatment systems would include two IX vessels, operated in series.
    c. Reverse Osmosis (RO) Treatment – Installation of RO membranes for PFOA and/or PFOS removal. The on-base treatment system would include four treatment trains, each with two RO membranes in series, implemented in parallel, while off-base drinking water treatment systems would include two RO membranes implemented in series.
3. Connection to City Water: This action alternative would address PFOA and/or PFOS impacts by providing the base, and each privately owned property with concentrations greater than the Lifetime Health Advisory, access to City water by extending the City water main to north of NALF Fentress base. Service lines from the water main would be installed to each of the privately-owned buildings with drinking water concentrations greater than the Lifetime Health Advisory and to the on-base potable water distribution system.

3.3 Determination of Removal Schedule

This EE/CA will be made available for a 30-day public comment period. Notice of its availability for public review, along with a summary of the EE/CA, will be published in the *Virginian Pilot* newspaper and in the *Virginian Pilot* insert specific to Chesapeake (*The Clipper*). The public comment period will be scheduled following approval of the EE/CA. A public information session will be held if sufficient interest is expressed by the public, and will take place during or immediately following the public comment period. If public comments are received during the public comment period, a Responsiveness Summary documenting the Navy's responses to significant comments will be prepared and included in the Action Memorandum, which will be placed in the Administrative Record for NALF Fentress.

Because this removal action has been designated as non-time-critical, the start date of the removal action will be determined by factors other than the immediate urgency of the threat. Possible factors include weather, availability of resources, and site constraints. The total project period is anticipated to last 16 months from the beginning of the public comment period to completion of the associated construction completion documentation. Critical milestone periods for the removal action are as follows:

- EE/CA public comment period—30 days
- Subcontracting, work plan, and mobilization—3 months
- Removal action—0 week (for Alternative 1 and 2a), 3 months (for Alternatives 2b and 2c), or 8 months (for Alternative 3)
- CERCLA documentation—4 months

3.4 Applicable or Relevant and Appropriate Requirements

The removal action will, to the extent practicable, comply with applicable or relevant and appropriate requirements (ARARs) under federal and state environmental laws, as described in 40 CFR 300.415. As outlined by 40 CFR 300.415(j), the lead agency may consider the urgency of the situation and the scope of the removal action to be conducted in determining whether compliance with ARARs is practicable.

Applicable requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limits promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, removal action, location, or other circumstance. Relevant and appropriate requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limits promulgated under federal or state law that, although not applicable to a hazardous substance, a pollutant, a contaminant, a removal action, or other circumstances at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the particular site. Other federal and state advisories, criteria, or guidance, such as risk assessment calculations, will be considered as needed in formulating the removal action; however, these are neither promulgated nor enforceable and, therefore, are not ARARs. The ARARs have been reviewed by the Navy, as the lead agent, and those that are approved are listed in **Appendix A**.

Three classifications of ARARs are defined by USEPA: chemical-specific, location-specific, and action-specific.

- ***Chemical-specific ARARs*** are promulgated and enforceable standards for specific chemicals that establish concentrations of contaminants for a given medium. These standards are established as ARARs when they have a direct effect on the implementation of a removal action. Promulgated and enforceable standards were reviewed, and no federal or Virginia chemical-specific ARARs have been identified for the removal alternatives proposed for the on-base drinking water system and off-base private properties (**Appendix A,** Tables A-1 and A-2).
- ***Location-specific ARARs*** are promulgated and enforceable standards that restrict removal activities and media concentrations based on the characteristics of the surrounding environment. Location-specific ARARs may include restrictions on removal actions within wetlands or coastal areas, near locations of known endangered species, or within protected waterways. Federal and Virginia location-specific ARARs have been identified for the on-base drinking water system and off-base private properties (**Appendix A,** Tables A-3 and A-4).
- ***Action-specific ARARs*** are promulgated and enforceable standards that govern activities that will be performed during the response actions, such as waste management, dust control, and erosion control. Federal and Virginia action-specific ARARs have been identified for on-base drinking water system and off-base private properties (**Appendix A,** Tables A-5 and A-6).

3.5 General Disposal Requirements

Waste disposal procedures implemented for the removal action will be in accordance with the state and federal laws and regulations that govern offsite disposal. For the purposes of this EE/CA, the cost estimates were based on the assumption that treatment media were used, and PFAS-contaminated groundwater will be characterized as nonhazardous, PFAS-containing. Soils excavated under Alternative 3, connection to city water, are assumed to be uncontaminated by PFAS, and for cost estimating purposes are assumed to be characterized as nonhazardous. Waste characterization testing will be conducted in accordance with the requirements of state and federal regulations. In accordance with Navy recommendations for NALF Fentress, PFAS-contaminated materials, including aqueous waste and treatment media, will be disposed of through incineration at a state-permitted disposal facility, or another appropriate method that is approved by the Navy. Used GAC material may be taken offsite for regeneration and reactivation, based on approval by the Navy. Nonhazardous waste, including PFAS-contaminated soils, will be disposed of in a state-permitted disposal facility that is approved by the Navy, and is permitted to accept CERCLA waste (Navy, 2017b).

3.6 City of Chesapeake Considerations

During development of the EE/CA, *Moving Forward -City of Chesapeake 2035 Comprehensive Plan* (Chesapeake, 2016b), was taken into consideration for the development of alternatives. The major components of the 2035 Comprehensive Plan that were taken into consideration were future zoning requirements near NALF Fentress and public works planning. The 2035 Comprehensive Plan lays out future zoning for the properties surrounding NALF Fentress as low-density residential and conservation. This zoning indicates that future use near NALF Fentress is anticipated to remain similar to current land use. For the purposes of this EE/CA, the land use considerations were taken into account when assessing effectiveness and implementation of each alternative over a 30-year timeframe, and to assess the flexibility of the alternatives to treat additional drinking water wells on other off-base properties, as needed, if plume migration occurs.

The 2035 Comprehensive Plan does not highlight extension of public utilities to the remedial action area; however, based on initial conversations with the City of Chesapeake, they have an interest in extending a water main down Mt. Pleasant Road. Based on the current public utilities planning documents, the water main, if extended, would need to be at a minimum 16-inches in diameter. The *Code of Ordinances, City of Chesapeake* (Chesapeake, 1994) specifies in Section 78-62, that all extensions for water lines must be constructed pursuant to the city master plan. Based on this evaluation, Alternative 3, connection to city water, must be compliant with the current public utilities planning documents; therefore, the water line would need to meet the minimum requirement of 16-inches in diameter.

Additionally, during development of Alternative 3, City of Chesapeake planning codes, specifically the *Chesapeake Public Facilities Manual Volume I* (Chesapeake, 2016a), were taken into consideration, including the implementation of service valves and fire hydrants. The *Chesapeake Public Facilities Manual* specifies that the spacing of fire hydrants be based on fire flow and defers to the public utilities department on the spacing of service valves.

The 2035 Comprehensive Plan was taken into consideration for the other alternatives as well, in that the treatment clean up timeframe is not determined by a plan to connect the off-base properties to the public water system.

Table 3-1 - Removal Alternatives Screening
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
No Further Action	Continued GAC for on-base water, continued bottled water supply for off-base water.	Wellhead or Point of Entry for on-base, bottled water for off-base	No further action to address contaminated drinking water. Bottled water would continue to be provided off-base and GAC treatment would continue on-base, as these interventions are already in progress.	X		Retained for baseline comparison in the EE/CA and also retained because these steps have already been implemented at the site to mitigate the exposure pathway to PFAS.
Institutional Controls	Administrative Restrictions or Engineering Controls	Land Use Controls (LUCs)	LUCs are implemented for property within potentially contaminated areas to restrict property use, well installation, and other intrusive activities.	X		Retained for use in conjunction with another alternative that would allow for supply of water to off-base drinking water receptors and the base from areas outside of their properties. This action is not feasible as a standalone action because off-base drinking water receptors and the base require access to water for potable use. Complications may exist because the Navy does not own off-base properties and would require property owner agreement to establish LUCs.
Water Treatment (Ex Situ)	Granular Activated Carbon (GAC) Filtration	Wellhead or Point of Entry	Water would be treated at the wellhead or point of entry using GAC. GAC is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. GAC is capable of adsorbing PFOA and PFOS. GAC can be regenerated through thermal desorption, resulting in ultimate destruction of the PFAS.	X		This technology has been tested on the benchscale for NALF Fentress water and on the field scale at the on-base potable water system and off-base private properties with exceedances of the lifetime health advisory (L-HA). The technology has been shown to be effective during treatability testing. Disposal or regeneration of used GAC is required as part of this technology. This technology is retained for further evaluation.
		Point of Use	Water would be treated at the point of use for potable purposes (under kitchen sink) using GAC, which is capable of sorbing PFOA and PFOS. Point of use GAC filters are readily available off-the-shelf.		X	Disposal or regeneration of used GAC filters is required as part of this technology. Additionally, while this treatment likely would be effective where implemented, if people consumed water from multiple points of use, multiple systems would be required per household/building. Additionally, this approach would not prevent re-release of contaminants in water used for toilets, baths, and showers, because systems would not be installed to address water used for those purposes, extending the time to achieve regulatory site closure because of the potential for untreated PFAS contaminated water to enter the septic tank and migrate to the groundwater. Off-the-shelf systems could be installed easily, but multiple GAC filters would be required to ensure protectiveness and off-the-shelf GAC systems do not allow for ease of monitoring for contaminant breakthrough. For these reasons, this alternative was not retained.
	Ion Exchange	Wellhead or Point of Entry	Water would be treated at the well head or point of entry using ion exchange. During ion exchange, resins loaded with non-toxic ions are "exchanged" for PFAS constituents, allowing the PFAS to remain in the resin, while non-toxic ions are added to the water exiting the treatment process. Ion exchange resins can be "regenerated" by flushing with a solvent/brine mixture thereby removing PFAS and replacing with more desirable ions. The solvent is recovered for reuse by distillation, leaving a highly concentrated brine solution that needs incineration or other destructive treatment.	X		Disposal or regeneration of ion exchange resins is a requirement for this option. However, field demonstrations of this technology have shown a 99.9998% reduction in contaminated liquid volume. This technology has been shown to be effective for removal of PFAS constituents; therefore, this treatment option has been retained for further evaluation.

Table 3-1 - Removal Alternatives Screening
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
Water Treatment (Ex Situ) (con't)	Ion Exchange	Point of Use	Water would be treated at the point of use for potable purposes (under kitchen sink) using ion exchange, as described above .		X	Disposal or regeneration of used ion exchange filters is required as part of this technology. Additionally, while this treatment would likely be effective where implemented, if people consumed water from multiple points of use, multiple systems would be required per household or building. Additionally, this approach would not prevent re-release of contaminants in water used for toilets, baths, and showers, because systems would not be installed to address water used for those purposes, extending the time to achieve regulatory site closure due to the potential for untreated PFAS contaminated water to enter the septic tank and migrate to the groundwater. Additionally, point of use ion exchange filters are not commercially available and would need to be designed specifically to support this project. For these reasons, this technology was not retained for further evaluation.
		Centralized Treatment Plant	Water would be supplied from a centralized treatment plant built and maintained by the Navy. The treatment plant would utilize ion exchange filtration, as described above.		X	Ion exchange is an effective technology for removing PFAS constituents. However, building a water treatment plant to support on-base and off-base drinking water receptors (a total of eight properties) has very high costs associated with it. The same effectivenss can be acheieved through individual POE systems, without incurring large capital costs. Supplying off-base drinking water receptors with water from on-base also is not typically advisable as water supply is not within the Navy's mission.
	Reverse Osmosis (RO) or Nanofiltration	Wellhead or Point of Entry	Water would be treated at the wellhead or point of entry using reverse osmosis or nanofiltration. For both of these technologies, a membrane acts as a sieve, allowing PFAS-free water to flow through the membrane, while contaminants do not flow through.	X		Wastes from RO and nanofiltration would contain more concentrated levels of PFAS and would require discharge through the septic leach field at each home/building, or containment and offsite disposal. However, this technology has been shown to be very effective for removal of PFAS constituents with very little potential for treatment failure; therefore, this treatment option has been retained for further evaluation.
		Point of Use	Water would be treated at the point of use for potable purposes (under kitchen sink) using RO or nanofiltration, as described above.		X	While this treatment would be effective where implemented, if people consumed water from multiple points of use, multiple systems would be required per household or building. Additionally, this approach would result in re-release of contaminants in water used for toilets, baths, and showers because systems would not be installed to address water used for those purposes. Maintaining sufficient pressure and flow rates through point of use RO systems also can be a challenge, requiring additional engineering and system features (such as water storage tanks), which may add to the size of these systems in under sink areas. For these reasons, this alternative was not retained.
Water Treatment (in Situ)	Injectable Carbon	Injection of carbon to facilitate sorption	An injectable carbon, such as PlumeStop, would be added to the subsurface to allow for sorption of PFAS onto the carbon, reducing mobility.		X	While commercially available products will reduce mobility, the PFAS plume at NALF Fentress is very large and treatment of all areas greater than the health advisory is not feasible or practicable.
Install Deeper Production Wells	Well Installation	Install wells in a Deeper, Unimpacted Aquifer	Wells would be installed in a deeper, unimpacted aquifer		X	The deepest potable aquifer (Yorktown) is contaminated. All deeper aquifers are brackish and not suitable for potable supply wells.

Table 3-1 - Removal Alternatives Screening

Engineering Evaluation and Cost Analysis for Drinking Water

NALF Fentress, Chesapeake, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
Centralized On-base Treatment Plant	GAC, RO, or ion exchange	Centralized Treatment Plant located On-base	Water would be supplied to both on- and off-base impacted properties from a centralized treatment plant built on-Base and maintained by the Navy. The treatment plant would utilize GAC, RO, or ion exchange, as described above.		X	As described above, GAC, RO, and ion echange are effective treatments. However, building a water treatment plant to support on-base and off-base drinking water receptors (a total of eight properties) has very high costs associated with it. The same effectivenss can be achieved through individual POE systems, without incurring large capital costs. The City statute also does not allow the Navy to be a water purveyor outside of Federal property.
Centralized Off-base Treatment Plant	GAC, RO, or ion exchange	Centralized Treatment Plant located Off-base	Water would be supplied to both on- and off-base impacted properties from a centralized treatment plant built off-Base and maintained by the Navy. The treatment plant would utilize GAC, RO, or ion exchange, as described above.		X	As described above, GAC, RO, and ion echange are effective treatments. However, building a water treatment plant to support on-base and off-base drinking water receptors (a total of eight properties) has very high costs associated with it. The same effectivenss can be achieved through individual POE systems, without incurring large capital costs. Additionally, the Navy does not own property off-base on which to construct such a system and would have to purchase the property and then return it to the city because the City statute also does not allow the Navy to be a water purveyor outside of Federal property.
Alternate Water Supply from Outside of Plume	Water Supply Lines	Extend water supply lines from City of Chesapeake	Water Supply lines from the City of Chesapeake would be run from along Mount Pleasant Road to NALF Fentress and the properties to the north of NALF Fentress.	X		While supplying an alternate water source would not result in reduction of toxicity, mobility, or volume of contaminants, it would prevent exposure without uncertainty.
	Bottled Water	Supply bottled water	Bottled water would be supplied and delivered for potable purposes at a single point of use (main sink) within the household/building. Bottled water is readily available for delivery to private drinking water receptors.	X		Supplying clean bottled water to private drinking water receptors likely would be effective where implemented; however, water can be consumed only from a single point of use in the building. this approach would not prevent re-release of contaminants in water used for toilets, baths, and showers, because bottled water would not be used for those purposes, extending the time to achieve regulatory site closure due to the potential for untreated PFAS contaminated water to enter the septic tank and migrate to the groundwater. However, this alternative is being retained as part of the no further action alternative, which takes into consideration current actions implemented at the site.

Description and Evaluation of Removal Action Alternatives

The alternatives for this NTCRA were developed and evaluated using professional judgment based on information from the SI, emergency removal actions, on-base potable water system upgrades, the POE GAC pilot study, and experience with current scientific knowledge of potential treatment for PFAS at similar sites. Alternatives were evaluated based on effectiveness, implementability, and cost.

4.1 Description of Removal Action Alternatives

4.1.1 Alternative 1: No Further Action

No further action would be conducted under this Alternative; the site would remain “as is.” Thus, bottled water would continue to be provided to off-base drinking water receptors whose drinking water has tested above the Lifetime Health Advisory, and the pilot GAC systems currently installed at each off-base property would be taken off-line. The GAC system would continue to be operated at the on-base potable water treatment system.

Pre-implementation Activities

Because the GAC unit has already been implemented at the on-base potable water treatment system, and bottled water does not require implementation activities, no pre-implementation activities are required under this alternative.

Site Layout

The layout of the on-base potable water treatment system with the GAC units installed is depicted on **Figure 2-3.** The GAC system consists of two 94-cubic-foot GAC vessels (1,300 pounds) plumbed in series with a lead and lag setup. The GAC systems are installed downstream from the green sand filters and upstream from the hydropneumatic tank and the fire protection storage tank.

For the purposes of this EE/CA, it is assumed that the treatment medium used in each GAC vessel is Calgon F-600 virgin coal-based activated carbon, which is currently used in the on-base potable water treatment system. Optimization to select another medium would not be implemented as part of this alternative because it is being implemented under No Further Action consideration. A sample port is installed on the piping between the two GAC vessels and at the effluent of the lagging GAC vessel for the system.

There is no site layout information required for supplying bottled water to the off-base private residences or buildings.

System Installation

Because the GAC treatment system has already been implemented, and there are no installation requirements for supplying bottled water, no system installation activities are required under this alternative.

Operations and Maintenance

Under this alternative, system operations for the on-base water treatment system would include periodic monitoring of the influent (prior to the lead vessel), intermediate (between the lead and lag vessels), and effluent (after the lag vessel) for PFAS (using LC/MS-MS Compliant with QSM 5.1 Table B-15 or an approved alternative method). Based on the recommendation in the *Preliminary Engineering Report for Potable Water System improvements* (CH2M, 2017c), the GAC vessels will be sampled every 70,000 gallons, or approximately once every 2 weeks.

System maintenance for the on-base water treatment system would include replacement of the GAC, as needed, to maintain effective treatment. The GAC would be changed when the cumulative PFOA and/or PFOS concentration in the intermediate sample (between the lead and lag vessels) exceeds 70 ng/L (the PRG), as determined by system operations monitoring. Based on recommendation in the *Preliminary Engineering Report for Potable Water System improvements* (CH2M, 2017c), the assumed timeframe for GAC change-out for the purposes of this EE/CA is every 100 days, or approximately every 4 months. The GAC change-out schedule could be more or less frequent than the assumptions used for costing in this EE/CA, based on the results of the system operations monitoring. For the purposes of the EE/CA, it is assumed that the used GAC will be taken offsite for regeneration. No other maintenance activities would be required for continued operation of the on-base GAC treatment system.

Other maintenance activities would require bottled water supply to the six off-base private properties on a monthly basis. Under this alternative the pilot GAC systems currently installed at the 7 off-base potable water wells would not be operated or maintained. For the purposes of this EE/CA, demand required at each off-base private property is assumed to remain consistent with what is currently being implemented.

The on-base GAC treatment system and off-base bottled water supply are anticipated to be run in perpetuity, pending additional source treatment of PFAS on-base at NALF Fentress. Therefore, the assumed operating timeframe for cost analysis purposes for this EE/CA is 30 years, to capture capital and long-term operations and maintenance (O&M) costs.

4.1.2 Alternative 2a: Point of Entry Treatment – Granular Activation Carbon

This alternative is a POE alternative and addresses PFOA and PFOS impacts at the on-base potable water treatment system before the finished potable water supply is stored for distribution to the base. This alternative would also address PFOA and/or PFOS at each individual private property with drinking water contaminant concentrations greater than the Lifetime Health Advisory before the potable water supply enters the distribution piping for the house. This alternative would include the installation and/or continued maintenance of GAC vessels, implemented in series, for PFOA and/or PFOS removal. For the on-base system, this alternative would be the same as the No Further Action Alternative because the on-base GAC system is already fully functional. For the off-base systems, the GAC vessels would be implemented in coordination with the pilot study, where possible.

GAC is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption. Given sufficient GAC media and surface area contact time for effective adsorption to occur, organic contaminants are attracted into and retained within the GAC media. GAC is widely used in water treatment to remove or adsorb organic molecules like PFOS and PFOA. GAC adsorption capacity depends on influent water quality, and GAC's treatment effectiveness may be influenced by water temperature and pH, flow rates, contact time, the type and concentrations of organic and inorganic substances present, and residual chlorine concentrations present.

GAC media have a finite lifespan and contaminant adsorption capacity. Adsorption sites within the GAC media progressively approach saturation as compounds are adsorbed, and the capacity for further adsorption declines. The media bed is considered exhausted and consumed when contaminants targeted for removal "break through" and are detected at or greater than a predetermined concentration in the effluent. Once this occurs, the exhausted media must be removed and replaced. The exhausted media can be appropriately disposed of or thermally regenerated offsite to remove adsorbed contaminants and restore adsorption capacity such that the media can be reused.

GAC treatment is currently being piloted at the six off-base properties (seven wells) that are known to be contaminated with PFOA and/or PFOS. GAC treatment has also been added to the existing on-base water treatment system with approval from VDH. Under this alternative, the GAC treatment systems (on-base system [currently operational] and off-base systems [currently being implemented as pilot tests]) would continue to operate as implemented. Details are provided below regarding the general system layout and O&M; however, for cost estimating purposes, it is assumed that all installation costs have already been accounted for under previous actions at the site.

Pre-implementation Activities

Because the GAC treatment systems have already been implemented full scale at the on-base potable water treatment system and as part of the off-base pilot study, no pre-implementation activities are required under this alternative.

Site Layout

The layout of the on-base potable water treatment system with the GAC units installed is depicted on **Figure 2-3.** The GAC system consists of two 94-cubic-foot GAC vessels (1,300 pounds) plumbed in series with a lead and lag setup. The GAC systems are installed downstream from the green sand filters and upstream from the hydropneumatic tank and the fire protection storage tank.

The general layout of a pilot POE GAC treatment system for an off-base property is depicted on **Figure 2-4**; however, the system configurations varied during installation to meet conditions present at each property. As shown on **Figure 2-4**, each POE GAC system was either housed in its own treatment shed or installed within an existing treatment shed, when possible. The POE GAC system was connected to the existing well, pump, and pressurized water tank. Upstream from the GAC vessels, on the inlet piping, a ball valve, sample port, 25-micrometer sediment pre-filter, and a flow meter were installed. The GAC system consists of two 2-cubic-foot GAC vessels plumbed in series, with a lead and lag setup. Downstream from the GAC vessels, the system includes a ball valve and a UV disinfection unit, prior to connection with the main distribution piping to the house.

For the purposes of this EE/CA, it is assumed that the treatment medium used in each GAC vessel is Calgon F-600 virgin coal-based activated carbon, which is currently implemented under the pilot study and in the on-base potable water treatment system. If selected as the preferred removal action, another medium may be selected as part of optimization efforts, if additional data become available indicating that a change in medium is warranted. A sample port is installed on the piping between the two GAC vessels and at the effluent of the lagging GAC vessel at each system.

System Installation

Because the GAC systems have been installed full scale at the on-base potable water treatment system and as part of the off-base pilot study, no system installation activities are required under this alternative.

Operations and Maintenance

Under this alternative, system operations would include periodic monitoring of the influent (prior to the lead vessel), intermediate (between the lead and lag vessels), and effluent (after the lag vessel) for PFAS (using LC/MS-MS Compliant with QSM 5.1 Table B-15 or an approved alternative method). For the purposes of this EE/CA, it is assumed that off-base GAC sampling would occur on a quarterly basis for six of the seven GAC systems. Based on the pilot study data, OF-RW59 requires more frequent GAC change-outs; therefore, it requires more frequent sampling, which is assumed to be monthly for the purposes of this EE/CA. Based on the recommendation in the *Preliminary Engineering Report for Potable Water System Improvements* (CH2M, 2017c), the on-base potable water treatment system GAC vessels will be sampled every 70,000 gallons, or approximately once every 2 weeks.

System maintenance would include replacement of the GAC, as needed, to maintain effective treatment. The GAC in the on-base potable water treatment system would be changed when the cumulative PFOA and/or PFOS concentration in the intermediate sample (between the lead and lag vessels) exceeds 70 ng/L (the PRG), as determined by system operations monitoring. Based on recommendation in the *Preliminary Engineering Report for Potable Water System Improvements* (CH2M, 2017c). The assumed timeframe for GAC change-out for the purposes of this EE/CA is every 100 days, or approximately every 4 months. The GAC would be changed at the off-base systems when the cumulative PFOA and/or PFOS concentration in the intermediate sample (between the lead and lag vessels) exceeds a PIL of 35 ng/L (half of the PRG), as determined by system operations monitoring.

Based on the results of the pilot study, the assumed timeframe for GAC change-out for the purposes of this EE/CA is annually for six of the seven wells. Based on the pilot study data, the seventh GAC system, at OF-RW59, will require more frequent GAC change-out, which is assumed to be quarterly for the purposes of this EE/CA.

The GAC change-out schedule would me more or less frequent than the assumptions used for costing in this EE/CA, based on the results of the system operations monitoring. For the purposes of this EE/CA, it is assumed that the used GAC will be taken offsite for regeneration. Other maintenance activities include semiannual change-out of the pre-filter and annual maintenance on the UV units at the off-base property systems.

The POE GAC systems are anticipated to be run in perpetuity, pending additional source treatment of PFAS on-base at NALF Fentress. Therefore, the assumed operating timeframe for cost analysis purposes for this EE/CA is 30 years to capture capital and long-term O&M costs.

4.1.3 Alternative 2b: Point of Entry Treatment – Ion Exchange

This alternative is a POE alternative and addresses PFOA and PFOS impacts at the on-base potable water treatment system before the finished potable water supply is stored for distribution to the base. This alternative would also address PFOA and/or PFOS at each individual private property with drinking water contaminant concentrations greater than the Lifetime Health Advisory before the potable water supply enters the distribution piping for the house. The alternative includes the installation of IX vessels for PFOA and/or PFOS removal. The on-base treatment system would include four IX vessels operated in series, while the off-base drinking water systems would include two IX vessels, operated in series.

IX is a treatment process that uses specialized resin media that exchange undesirable ions in water with benign ions on the resin surface as a means to remove dissolved contaminants to produce a clean water product. The resins used in IX processes include small plastic, porous beads with a fixed ionic charge that facilitates the exchange of ions and associated contaminant removal. IX can involve cation exchange of positively charged ions, and anion exchange of ions that are negatively charged. Treatment and removal of PFOS and PFOA via IX primarily involves anion exchange. IX resins are somewhat selective, but their treatment effectiveness may be influenced by water temperature and pH, flow rates, contact time, types and concentrations of organic and inorganic substances present, and residual chlorine present. Specifically, for PFOS and PFOA removal using IX, water with high concentrations of TDS, iron, other dissolved organics, sulfates, chlorides, and competing anions, as well as potential foulants and scalants, can potentially hinder the treatment and IX performance of resins.

As ions are exchanged and contaminants are captured within IX resin media, the IX capacity of the resin declines, eventually reaching a point at which the target compound for removal is detected at or greater than a predetermined concentration in the effluent. Once the resin is spent, it must be removed, disposed of and replaced, or chemically regenerated to restore its IX capacity such that it can be reused. Currently, resins available for POE treatment of PFOS and PFOA are considered single use and must be removed and disposed of; they are not viable for regeneration.

Details are provided below regarding the pre-implementation activities, general system layout, system installation, and O&M.

Site Preparation

Prior to finalizing the design for the IX systems, a site visit would be required to evaluate the on-base potable water system and the existing system layout for each off-base property. The site visits will include a drawing of each existing system layout and potential installation space, and documentation of conversations with the on-base potable water system operators, and owners of properties with private drinking water wells.

During the site visit, samples would be collected from the existing systems, upstream from any current treatment for water quality parameters, assumed to include TDS, sulfate, nitrate, bicarbonate, chloride, TOC, free chlorine TSS, and general water quality parameters (to be measured in the field), including temperature, pH, conductivity, oxidation-reduction potential, and turbidity.

The results of the water quality samples will be used to finalize system sizing and resin selection.

Site Layout

The general layouts of POE IX treatment systems are shown on **Figure 4-1** (for the on-base potable water treatment system) and **Figure 4-2** (for the off-base properties); however, the system configurations will vary during installation to meet conditions present at each property.

As shown on **Figure 4-1**, the on-base IX system will be housed within the existing treatment building. The IX system will be connected to the existing treatment system, downstream from the green sand filters, and upstream from the hydropneumatic tank and fire protection storage tank. The IX system would be implemented in the same location as the existing GAC vessels, and the GAC vessels would be removed. All other parts of the existing, upgraded water treatment system would be retained for use. The IX system will include four 1.5-cubic-foot IX vessels plumbed in series, with a lead and lag setup, assuming a flow rate of 5 gpm, and an empty bed contact time of 3 minutes.

As shown on **Figure 4-2**, each off-base POE IX system will be housed in its own treatment shed or installed within an existing treatment shed, when possible. The POE IX system will be connected to the existing well, pump, and pressurized water tank. Upstream from the IX vessels on the inlet piping, the existing ball valve, sample port, 25-micrometer sediment pre-filter, and a flow meter will be retained for use. The IX system will include two 1.5-cubic-foot IX vessels plumbed in series, with a lead and lag setup. Downstream from the IX vessels, the system will retain the existing ball valve and a UV disinfection unit, prior to connection with the main distribution piping to the house.

For the purposes of this EE/CA, it is assumed that the treatment medium used in each IX vessel is Purolite PFA694E single-use resin, which has been implemented successfully for removal of PFOA or PFAS at other sites. If selected as the preferred removal action, the final full-scale treatment medium would be selected as part of the design, and selection would take into consideration continuing developments of IX resins for PFAS treatment, including multi-use resins for regeneration. A sample port will be installed on the piping between the two IX vessels and at the effluent of the lagging IX vessel.

System Installation

System installation of the POE IX treatment systems would include upgrading the current on-base GAC system and pilot POE GAC systems by replacing the GAC vessels with IX vessels. The IX vessels are smaller in size than the GAC vessels, and therefore will fit into the existing treatment system layouts. The IX vessels will be installed in series, with a lead and lag vessel, similar to the existing GAC vessels. Other components of the existing water treatment system (on-base) and pilot POE GAC systems (off-base), including piping, ball valves, flow meters, sample ports, and UV treatment system (off-base only), will be left in place and used in conjunction with the IX vessels. Additional piping and replacement of the intermediate sampling port would be required to fit the IX vessels into the existing system.

Once the IX vessels are installed, the system would be backwashed prior to making the final service connection to the existing system. Once connected to the existing system, the IX vessels and associated piping would be pressure tested to ensure there are no leaks in the system.

For this EE/CA, system installation costs are assumed to included installation of the IX vessels, including resin, piping, and a sample port to fit the IX vessels into the existing system; removal of the existing pilot GAC vessels; and back flushing and pressure testing of the system once installed prior to startup. For the purposes of this EE/CA, it is assumed that the removed GAC vessels would be returned to APTIM Government Solutions, LLC (APTIM) (on-base WTP) and Culligan (off-base), who currently operates the on-base system and pilot systems, at no additional cost.

Operations and Maintenance

Under this alternative, system operations would include periodic monitoring of the influent (prior to the lead vessel), intermediate (between the vessels), and effluent (after the lagging vessel) for PFAS (using LC/MS-MS

Compliant with QSM 5.1 Table B-15 or an approved alternative method). For the purposes of this EE/CA, it is assumed that IX sampling would occur on a monthly basis for the on-base water treatment system and on a quarterly basis for the off-base systems.

System maintenance would include replacement of the IX resin, as needed, to maintain effective treatment. The IX resin would be changed when the cumulative PFOA and/or PFOS concentration in the intermediate sample (between the lead and lagging vessel) exceeds a PIL of 35 ng/L (half of the PRG), as determined by system operations monitoring. Based on laboratory studies with the Purolite PFA694E, the anticipated minimum service life for one 1.5-cubic-foot vessel is 120,000 gallons, and the service life for two 1.5-cubic-foot vessels operated in series is 180,000 gallons. Sizing up from the service life for two 1.5-cubic-foot vessels (180,000 gallons), the service life for the on-base system, including four 1.5-cubic-foot vessels, is 360,000 gallons using Purolite PFA694E. Based on the service life, the IX resin in the on-base potable water system is assumed to last approximately 50 days under average usage (7,875 gpd); therefore, the assumed timeframe for IX resin change-out for the purposes of this EE/CA is quarterly. Based on the service life for two 1.5-cubic-foot vessels (180,000 gallons), the IX resin in the off-base systems is assumed to last 18 months under maximum usage (10,000 gallons per month) and 30 months under average usage (4,600 gallons per month). Therefore, the assumed timeframe for IX resin change-out for the off-base systems for the purposes of this EE/CA is biannually, based on average usage.

The IX change-out schedule would be more or less frequent than the assumptions used for costing in this EE/CA, based on the results of the system operations monitoring. Based on the assumed single-use IX resin chosen for this EE/CA, used IX resin will be taken offsite for incineration or another appropriate method that is approved by the Navy. Other maintenance activities include semiannual change-out of the pre-filter and annual maintenance on the UV units at the off-base systems.

The POE IX systems are anticipated to be run in perpetuity, pending additional source treatment of PFAS on-base at NALF Fentress. Therefore, the assumed operating timeframe for cost analysis purposes for this EE/CA is 30 years to capture capital and long-term O&M costs.

4.1.4 Alternative 2c: Point of Entry Treatment – Reverse Osmosis

This alternative is a POE alternative and addresses PFOA and PFOS impacts at the on-base potable water treatment system before the finished potable water supply is stored for distribution to the base. This alternative would also address PFOA and/or PFOS at each individual private property with drinking water contaminant concentrations greater than the Lifetime Health Advisory before the potable water supply enters the distribution piping for the house. This alternative includes the installation of RO membranes for PFOA and/or PFOS removal. The on-base treatment system would include four treatment trains, each with two RO membranes in series, implemented in parallel, while off-base drinking water systems would include two RO membranes implemented in series.

This alternative consists of RO treatment of water at the POE at the on-base potable water treatment system and at each privately owned structure with drinking water concentrations greater than the Lifetime Health Advisory.

RO is a membrane treatment process in which water is forced through semi-permeable membranes with effective pore sizes small enough to exclude targeted contaminants. Targeted contaminants are concentrated on the “dirty”/reject side of the membrane, and purified water passes through to the “clean”/permeate side of the membrane. Membranes typically are classified depending on their range of effective molecular weight cutoff, with RO having the smallest molecular weight cutoff. Given their ability to remove dissolved contaminants at a molecular size level, RO processes can be used to remove PFOS and PFOA from drinking water.

Because some leakage occurs across the membrane, 100 percent contaminant removal is not achievable; however, more than 95 percent removal of PFOA or PFOS is achievable. Because of particle deposition, mineral precipitation, leakage across the product water o-ring seal, or exposure to free chlorine that can occur over time, RO membranes need to be replaced periodically to maintain high removal rates. Replacement timeframes for RO membranes are much greater than those associated with GAC and IX processes (typically more than 3 to 5 years).

The RO membranes must be operated in a cross flow pattern, in which a portion of the influent (feed) water must be continuously flushed to the waste stream (as reject) in order to remove the salts in the well water and prevent scaling. As such, overall water supply rates are much lower than those achieved by GAC and IX processes. Typically, around 70 to 90 percent of the water supplied into a membrane RO process is recoverable as treated water depending on the amount of salts present in the well water. The remaining 10 to 30 percent remains as the reject waste stream. The reject waste stream water, containing the concentrated salts and other chemicals, including PFAS, must be properly disposed of. Additionally, the pressure required to drive flow through the RO membrane is considerably higher than that needed for GAC and IX processes. The pressure needed for the RO membrane to function results in higher pumping and electrical operating costs.

Details are provided below regarding the RO membrane pre-implementation activities, general system layout, system installation, and O&M.

Site Preparation

Prior to finalizing the design for the RO systems, a site visit would be required so that the team could evaluate the existing system layout for the on-base potable water system and for each off-base property. The site visit submittals will include drawings of each existing system layout and potential installation space, and documentation of conversations with the on-base potable water system operator and the owners of properties with private drinking water wells.

During the site visit, samples would be collected from the existing systems, upstream from any current treatment for the following water quality parameters: calcium, magnesium, sodium, potassium, barium, strontium, iron, manganese, bicarbonate (alkalinity), chloride, sulfate, nitrate, TDS, TOC, and TSS, and general water quality parameters (to be measured in the field), including temperature, pH, conductivity, oxidation-reduction potential, free chlorine, and turbidity.

The results of the water quality samples will be used to finalize system sizing and membrane selection.

Site Layout

The general layout of a POE RO treatment system for the on-base potable water treatment system is depicted on **Figure 4-3,** and for the off-base property, the system is depicted on **Figure 4-4;** however, the system configurations will vary during installation to meet conditions present at each property.

As shown on **Figure 4-3**, for the on-base potable water RO treatment system will be housed in the existing treatment shed. The RO treatment system will be installed as a series of four prefabricated units, operated in parallel that are designed for up to 2,500 gpd. Upstream from each of the four RO treatment system units, the treatment train would include two sediment filters (25-micrometer and 5-micrometer) and a water softener to remove hardness and dissolved iron prior to RO treatment. The RO units would include a total fluids pump to provide pressures required to operate the RO unit, two RO treatment membrane units, flow meters for both product water (clean) and the reject waste stream (contaminated), conductivity meters for both the feed water and product water, associated piping, pressure gauges, and valves. Downstream from the RO treatment units, on each of the four treatment trains, a calcite filter would be installed to neutralize the pH, and to increase the levels of calcium and alkalinity to stabilize the product water and minimize corrosion of piping. The RO treatment trains will be connected to the existing treatment system, downstream from the green sand filters, and upstream from the hydropneumatic tank and fire protection storage tank.

In addition, a separate unpressurized 40,000-gallon storage tank for the reject waste stream (contaminated) waste stream will be installed outside the on-base treatment shed. It is estimated that the reject waste stream storage tank will be sized to store up to 1 month of reject waste stream water, assuming a maximum daily flow rate of 7,875 gallons and a 15 percent rejection rate, or approximately 35,000 gallons. The tank will be plumbed directly from the reject waste stream discharge for the RO unit and will provide an outlet valve for periodic emptying.

As shown on **Figure 4-4** for the off-base property systems, each POE RO system will be housed in its own treatment shed or installed within an existing treatment shed, when possible. The RO treatment system would be installed as a preassembled unit that can be operated up to 1,000 gpd. Upstream from the RO unit, on the inlet piping, the existing ball valve, sample port, and flow meter will be retained for use. Upstream from the RO treatment system, the treatment train would include two sediment filters (25-micrometer and 5-micrometer) and a water softener to remove hardness and dissolved iron prior to RO treatment. For the purposes of this EE/CA, it is assumed that three off-base properties will need water softener systems installed, while the remaining four will use water softeners that are currently in place. The preassembled RO unit would include a total fluids pump to provide pressures required to operate the RO unit, two RO treatment membrane units, flow meters for both product water (clean) and the reject waste stream (contaminated), conductivity meters for both the feed water and product water, associated piping, pressure gauges, and valves.

Product water (clean) from the RO treatment system would pass through a calcite filter to neutralize the pH, and to increase the levels of calcium and alkalinity to stabilize the product water and minimize corrosion of in-house piping. The product water would then be collected into a 500-gallon pressurized storage tank prior to distribution into the house. The collection tank allows for the RO to treat larger batches of water, while still allowing for demand to be met. Downstream from the storage tank, the system will retain the existing UV disinfection unit, prior to connection with the main distribution piping to the residence/building. The product water storage tank would be placed in an additional, heated treatment shed, to keep it from freezing in the winter, that is separate from the treatment sheds currently installed at each property.

In addition to the treated water storage tank, a separate unpressurized 3,000-gallon storage tank for the reject waste stream (contaminated) will be installed at each residence/building. The tank will be housed in the additional treatment shed installed at each property, which will also be used to house the product water (clean) storage tank. It is estimated that the reject waste stream storage tank will be sized to store up to 1 month of reject waste stream water, assuming a maximum daily flow rate of 500 gallons and a 15 percent rejection rate, or approximately 2,250 gallons. The tank will be plumbed directly from the reject waste stream discharge for the RO unit and will provide an outlet valve for periodic emptying.

For the purposes of this EE/CA, it is assumed that the treatment membranes to be used are the Dow FilmTec BW30-2540 membranes for the off-base property, and the Dow FilmTech BW30-404 for the on-base potable water treatment system, which have shown more than 99 percent removal for PFOA and PFOS in a laboratory setting. If selected as the preferred removal action, the final full-scale treatment medium would be selected as part of the design, and the selection team would take into consideration continuing developments of RO membranes for PFAS treatment. A sample port will be installed on the piping prior to (influent) and after (effluent) the RO membrane systems.

System Installation

System installation of the POE RO treatment systems would include upgrading the current on-base GAC system and off-base pilot POE GAC systems by replacing the GAC vessels with the prefabricated RO units, sediment filters, calcite filters, and water softeners (as needed). The RO units, filters, and water softeners are anticipated to fit into the existing treatment buildings and be plumbed into the existing layout. Other components of the GAC systems, including piping, ball valves, flow meters, sample ports, and UV treatment system (off-base only), will be left in place and used in conjunction with the RO unit. Additional piping and replacement of sampling ports or valves may be required to fit the RO unit into the existing system.

Other system installation components include a 40,000-gallon water tank for the on-base potable water system, which will need to be installed outside the current water treatment shed and supplied with piping to connect the tank to the RO unit. For the off-base properties, other system installation components will include the installation and electrical hook-up of additional treatment buildings to store the two additional water tanks. The treatment buildings will be hooked up to electricity to provide for heat and lighting. Once the buildings are in place, the two tanks will be installed within each building, and piping will be installed to connect the tanks to the RO unit and residence/building distribution system (upgradient from the UV system). Once all components are connected, the systems would be pressure tested to ensure there are no leaks in the system.

For this EE/CA, system installation costs are assumed to included installation of the 5-micrometer sediment filters, water softeners (at the on-base system and three houses only), prefabricated RO units, including membranes, the calcite filters, the 40,000-gallon storage tank (on-base system), an additional treatment building at each off-base property, the 500- and 3,000-gallon storage tanks (off-base property), piping, and associated valves needed to connect the storage tanks to the RO unit; removal of the existing GAC vessels; and pressure testing of the system once installed prior to startup. For the purposes of this EE/CA, it is assumed that the removed GAC vessels would be returned to APTIM (on-base WTP) and Culligan (off-base), who currently operates the on-base system and pilot systems, at no additional cost.

Operations and Maintenance

Under this alternative, system operations would include periodic monitoring of the feed water (prior to the RO system) and final product water (RO system permeate) for PFAS (using LC/MS-MS Compliant with QSM 5.1 Table B-15 or an approved alternative method). For the purposes of this EE/CA, it is assumed that RO sampling would occur on a semiannual basis for each of the four RO treatment trains for the on-base water treatment system, and for the off-base systems. Operations also would include monthly emptying of the reject waste stream storage tank. The reject waste stream water would be taken offsite for incineration or another appropriate method that is approved by the Navy.

System maintenance would include replacement of the RO membranes, as needed, to maintain effective treatment. The removal efficiency would be determined by the real-time conductivity readings between the feed and product water, and the results of the systems operation semiannual monitoring. The assumed timeframe for RO membrane change-out for the purposes of this EE/CA is every five 5 years. The RO membrane change-out schedule would be more or less frequent than the assumptions used for costing in this EE/CA, based on the results of the system operations monitoring. The used RO membranes will be taken offsite for incineration or another appropriate method that is approved by the Navy. Other maintenance activities include semiannual change-out of the sediment filters, and annual maintenance on the UV units (off-base only), water softeners, and calcite filters.

The POE RO systems are anticipated to be run in perpetuity, pending additional source treatment of PFAS on-base at NALF Fentress. Therefore, the assumed operating timeframe for cost analysis purposes for this EE/CA is 30 years to capture capital and long-term O&M costs.

4.1.5 Alternative 3: Connection to City Water

This alternative would address PFOA and/or PFOS impacts by providing the base, and each private property with concentrations greater than the Lifetime Health Advisory, access to City water by extending the City water main to north of NALF Fentress base. Service lines from the water main would be installed to each of the privately-owned buildings with drinking water concentrations greater than the Lifetime Health Advisory and to the on-base potable water distribution system.

Service lines would be run from the main line to the seven off-base potable water systems and service connections would be made as part of this alternative. A service line would also be run to the on-base drinking water system; however, no service connection would not be made under this alternative and would be left up to the discretion of the base. Under this alternative, it is assumed that the off-base private drinking water wells and water treatment systems would remain in place but would no longer be used as the water supply for the off-base properties. Additionally, the on-base potable water treatment system would be taken offline; however, decommissioning costs are not included as part of this EE/CA. Used GAC vessels would be removed and returned to APTIM (on-base WTP) and Culligan (off-base), who currently operates the on-base system and pilot systems, at no additional cost.

Details are provided below regarding the pre-implementation activities, general system layout, system installation, and O&M.

Site Preparation

Prior to installation of the water main, demand calculations and hydraulic modeling would be performed to determine final system details. Additionally, a site visit would be required to evaluate the service line connections for the facility and each off-base property, and to confirm construction, routing, and preparation (tree removal, laydown areas, etc.). The site visit submittals will include drawings of the proposed service line connection and existing system details (pipe sizing, location of hook-up to the residence/building, etc.), and documentation of conversations with on-base potable water system operators and owners of properties with private drinking water wells. As part of the design process, City utility drawings and a utility survey would be performed to determine the most appropriate route for the water main.

Once the final system is designed, the results of the hydraulic modeling and the system layout details would be provided to the City of Chesapeake for review and approval prior to installation.

Assumptions have been made to determine the system layout for the purposes of this EE/CA, as detailed in the site layout section.

Site Layout

The general layout of the water main and associated service lines to the off-base properties is depicted on **Figure 4-5**. As shown on **Figure 4-5**, the water main will be extended approximately 14,000 feet (2.65 miles) from its existing location near the intersection of Mt. Pleasant Road and Centerville Turnpike, due east along Mount Pleasant Road to the affected houses. The water main would be 16 inches in diameter, as required by the City of Chesapeake(Section 3.6).

At a 16-inch diameter, the water main would provide for sufficient flow to meet the VDH hydraulic requirement (Virginia Waterworks Regulations, Sections 12VAC5-590-690 and 1120), which requires a pressure of 20 pounds per square inch to be maintained in the system during the maximum daily demand plus fire flow conditions. The maximum daily demand for the seven off-base private drinking water wells is 4,725 gpd or 3.3 gpm, based on 100 gpd per person, 2.7 people per household/privately owned structure, and a maximum daily multiplier of 2.5. The fire flow, as determined by the City of Chesapeake Fire Marshal, is 2,000 gpm. The on-base demand is 7,875 gpd or 5.5 gpm, based on the average daily demand (3,500 gpd) plus a 2.25 peaking factor, and includes both potable water use and demand associated with fire training efforts at the base (i.e., filling the storage tank). Therefore, the total demand required for the system is 2,010 gpm, which is well under the volume supplied by a 16-inch pipe at 20 pounds per square inch.

Based on the length of the water main, 18 service valves will be installed (one every 800 feet), to allow for adequate isolation of the water main for future repairs. Service valve spacing was determined based on conversations with the City of Chesapeake public utility department, in compliance with the *Chesapeake Public Facilities Manual Volume I* (Chesapeake, 2016a). A total of 28 fire hydrants would be installed along the length of the water main, spaced every 500 feet, in compliance with the *Chesapeake Public Facilities Manual Volume I* (Chesapeake, 2016a). Each off-base service line will be 1-inch and vary in length from 75 to 600 feet, and the on-base service line will be a 1,500-foot 2-inch line, for a total length of approximately 3,700 feet. The service lines will include a meter box, valves, flow meter (provided by the City of Chesapeake), and back flow prevention, and will be connected to the existing structure plumbing and facility distribution piping.

System Installation

System installation of the water main and service lines will include trenching, pipe installation, backfill, and site restoration. System installation would be carried out in accordance with the City of Chesapeake Considerations, as detailed in Section 3.6.

For installation of the water main, it is assumed that the main will be placed in a trench that is 3 feet wide by 5 feet deep (below the frost line). A total of 8,000 cubic yards (yd^3) of soil will be removed to accommodate installation of the water main. The excavated soil will be used as backfill in the trench, in accordance with City of Chesapeake requirements. Objects greater than 6 inches in size would be removed from the backfill material, and it would be placed to 95 percent maximum density compaction, as confirmed by Virginia Department of Transportation standard TM-1. The water main will be installed as a 16-inch, class 350 ductile iron pipe, and will include the installation of 18 service valves. The remaining native material not placed back in the trench (750 yd^3 total) will be taken offsite for disposal as nonhazardous waste, as appropriate. The disturbed area will be restored to its original condition, either through placement of asphalt or topsoil and seed. For the purposes of this EE/CA, it is assumed that the water main will be installed along the side of Mt. Pleasant Road, and 1.5 acres of land will be disturbed during the water main installation. Of the total disturbed land, approximately 10 percent will require replacement of asphalt to account for side roads and driveways that are crossed during installation. An assumed total of 1.35 acres will be restored with 6 inches of topsoil, seed, and erosion matting, and 0.15 acre will be restored with asphalt.

For installation of the service lines, it is assumed that the lines will be placed in trenches 2 feet wide by 3 feet deep. A total of 820 yd^3 of soil will be removed to accommodate installation of the eight service lines. The pipes will be installed as 1-inch-diameter ASTM International A88 Type K copper pipe for the off-base connections, and a 2-inch-diameter ASTM International A88 Type K copper pipe for the on-base connection. In addition to the piping, a meter box, valves, flow meter, and backflow preventer will be installed at each service line, in compliance with the *Chesapeake Public Facilities Manual Volume I* (Chesapeake, 2016a). The trench will be backfilled with the excavated native material (820 yd^3 total). The disturbed area will be restored to its original condition either through placement of asphalt or topsoil and seed. For the purposes of this EE/CA, it is assumed that 14,800 square feet of land will be disturbed during the service line installations. Of the total disturbed land, approximately 10 percent will require replacement of asphalt to account for lines that are installed on the southern side of Mt. Pleasant Road. An assumed total of 13,320 square feet will be restored with 6 inches of topsoil, seed, and erosion matting, and 1,480 square feet will be restored with asphalt.

Following installation of the water main and service lines, the newly installed system will be pressure tested and disinfected prior to connection to the houses. Installation also will include the costs of connection fees paid to the City of Chesapeake for connection to City water.

Operations and Maintenance

Under this alternative, there are no O&M requirements. Once service connections are made, property owners will be responsible for costs associated with water use and repairs over time to lines on their property from the meter to the privately owned structure (and associated plumbing). The City of Chesapeake will be responsible for repairs to lines from the meter to the main. The current on-base drinking water system would no longer be used, operated or maintained; however, the system may be reused, at the discretion of the base, for future needs such as groundwater treatment. The aspect of reuse of the on-base system was not taken into consideration during comparison of the alternatives.

The off-base properties will stay connected to City water in perpetuity. However, because there are no O&M requirements associated with this alternative, the operating timeframe is 1 year to allow for installation of the water main and service lines.

4.2 Evaluation of Alternatives

4.2.1 Evaluation Criteria

The criteria used to evaluate the removal action alternatives are based on *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993).

4.2.2 Effectiveness

The ***effectiveness*** criterion addresses the expected results of the removal action alternatives. It includes two major subcategories: protectiveness and ability to achieve the removal objectives.

- Protectiveness

  - Protective of public health and community
  - Protective of workers during implementation
  - Protective of the environment
  - Complies with ARARs

- Ability to Achieve Removal Objectives
  - Ability to meet the expected level of treatment or containment
  - Has no residual effect concerns
  - Maintains long-term control

4.2.3 Implementability

The ***implementability*** criterion encompasses the technical and administrative feasibility of the removal action. It includes three subcategories: technical feasibility, availability of resources, and administrative feasibility.

- Technical feasibility
  - Construction and operational consideration
  - Demonstrated performance and useful life
  - Adaptability to environmental conditions
  - Contribution to performance of long-term removal actions
  - Implementation within the allotted time
- Availability of resources
  - Availability of equipment
  - Availability of personnel and services
  - Laboratory testing capacity
  - Offsite treatment and disposal capacity
  - Post-removal action site control
- Administrative feasibility
  - Required permits or easement or rights-of-way
  - Impacts on adjoining property
  - Ability to impose institutional controls
  - Likelihood of obtaining exemptions from statutory limits (if needed)

4.2.4 Costs

The ***cost*** criterion encompasses the life-cycle costs of a project, including the projected implementation costs and the long-term O&M costs of each alternative. For the detailed cost analysis, the expenditures required to complete each alternative were estimated in terms of capital costs, including direct and indirect costs, to complete initial construction activities. Direct costs include the cost of construction, equipment, land and site development, treatment, transportation, and disposal. Indirect costs include engineering expenses and contingency allowances.

Future O&M costs would be required to ensure the continued effectiveness of Alternatives 1, 2a, 2b, and 2c. The future costs were calculated using an assumed annual inflation rate of 2.6 percent for a 30-year timeframe. After inflating the future costs, they were analyzed using present worth, which discounts all future costs to a common base year (2018). Present-worth analysis allows the cost of the removal action to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the removal action. The present-worth calculations included an assumed discount rate of 2.6 percent (White House OMB, 2018).

The estimated costs are provided to an expected accuracy of +50 percent and -30 percent. The cost estimates are in 2018 dollars, and the unit pricing is based on costs from similar projects, vendor quotes, or engineering estimates. The enclosed Engineer's Estimate (**Appendix C**) is only an estimate of possible costs for budgeting purposes.

4.2.5 Sustainability Considerations

In addition to the protectiveness and ability to achieve the RAO, sustainability should be considered, in accordance with the *Department of the Navy Environmental Restoration Program Manual* (Navy, 2018). Therefore, a sustainability assessment was conducted using SiteWise Version 3.0 (SiteWise), a standalone tool that assesses the environmental footprint of a removal alternative to compare the overall life-cycle environmental impacts of each remedy (Battelle, 2013). The sustainability assessment provides an additional comparison criterion with respect to effectiveness, implementability, and costs that may allow options with smaller environmental impacts to be selected when all other criteria are met. The sustainability assessment is included in **Appendix B**. In addition, the environmental footprint of the selected alternative may be further evaluated in the design phase of the project to explore opportunities to optimize the environmental footprint of the project and integrate sustainable remediation best practices in the design, construction, and operation of the removal action.

4.2.6 Evaluation of Alternatives

Table 4-1 summarizes the results of the alternatives evaluation with respect to effectiveness, ease of implementation, and cost.

Table 4-1. Evaluation of Removal Action Alternatives
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Alternative	Description	Effectiveness	Ease of Implementation	Cost
Alternative 1 - No Further Action	Removal action would include continued implementation of actions already being implemented on site. This includes supply of bottle water to the off-base privately-owned properties and continued operation of the granular activated carbon (GAC) system at the on-base potable water treatment plant. The pilot GAC systems currently installed at each off-base property would be taken off-line and no longer operated.	**Minimally Effective.** Is protective of human health, but allows for redistribution of contaminants in septic systems and allows potential for incidental ingestion. For current off-base drinking water receptors, although PFOA and/or PFOS impacted groundwater would not be use for drinking and cooking, it may be ingested during showering or other household/recreational activities. For on-base workers, GAC treatment is protective of human health. There are no potential short-term risks to site workers since the systems are already implemented. There are no potential short-term risks to the community under this alternative. Although there are no chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs), the contaminant concentrations pose potential unacceptable risk, which Alternative 1 only removes at the on-base system. Does not achieve removal objective for current off-base drinking water receptors. Long-term protectiveness is not achieved as impacted groundwater may incidentally be used as drinking water. Additionally, impacted groundwater remains untreated and is recirculated back into the ground via the septic system. On-base, long-term protectiveness is achieved provided that treatment media is changed out in a timely manner once project indicator levels (PILs) are reached, and impacted treatment media is transported safely offsite for disposal. Environmental impacts are primarily associated with material production and transportation of bottled water and GAC, incineration (or other approved disposal method) of used GAC and energy usage associated with the treatment systems. The SiteWise evaluation indicates greenhouse gas, energy use and accident risk are comparatively moderate and priority pollutant emissions are comparatively low. Water usage is similar across all alternatives as the majority of water use is attributed to consumption on- and off-base. If additional off-base drinking water wells are identified as requiring action, this alternative would not be effective because no further action beyond the actions already taken would be conducted.	**Moderately easy.** Implementation is technically feasible. System installation has already occurred with components that are well-established, available and can be replaced easily. Systems are already installed, so there is no installation timeframe. The on-base system has already been installed and off-base drinking water is already being provided. Post-removal site controls (PRSCs) are required and include sampling and anticipated relatively frequent change out of the GAC (every 4 months) for the on-base treatment system.	Capital Cost $42,000 Future Cost $2,156,000 Total Cost $2,198,000
Alternative 2a - Point of Entry - Granular Activated Carbon	Removal action includes treatment of water at the point of entry to each private property and at the on-base water treatment system using GAC. GAC is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions. GAC is capable of adsorbing PFOA and PFOS. GAC can be regenerated through thermal desorption, of disposed of via incineration, resulting in ultimate destruction of the PFAS.	**Effective.** Is protective of human health to current off-base drinking water receptors because PFOA and/or PFOS would be removed from groundwater used as drinking water through treatment via GAC. There are no potential short-term risks to site workers since the systems are already implemented. There are no potential short-term risks to the community under this alternative. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk, which Alternative 2a would remove. Achieves removal objective for current drinking water receptors and on-base workers. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once PILs are reached, and impacted treatment media is transported safely offsite for disposal. Environmental impacts are primarily associated with material production, transportation and incineration (or other approved dipsosal methods) of GAC, and energy usage associated with the treatment systems. The SiteWise evaluation indicates greenhouse gas, energy use and accident risk are comparatively moderate and priority pollutant emissions are comparatively low. Water usage is similar across all alternatives as the majority of water use is attributed to consumption on- and off-base. If expansion was required, the alternative would be protective of human health, provided that the GAC systems are implemented in a timely manner, and continue to be monitored with time.	**Moderately easy.** Implementation is technically feasible. System installation has already occurred with components that are well-established, available and can be replaced easily. Systems are already installed, so there is no installation timeframe. The systems have already been installed. However, PRSCs are required and include different sampling and changeout frequencies associated with each system and anticipated relatively frequent change out of the GAC (every 4 months) for the on-base treatment system. Expansion of the system would require implementing GAC systems at additional off-base properties. The GAC systems are readily available and can be fit into most existing treatment trains.	Capital Cost $92,000 Future Cost $4,221,000 Total Cost $4,313,000

Table 4-1. Evaluation of Removal Action Alternatives
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Alternative	Description	Effectiveness	Ease of Implementation	Cost
Alternative 2b - Point of Entry - Ion Exchange	Removal action includes treatment of water at the point of entry to each private property and at the on-base water treatment system using ion exchange. During ion exchange, resins loaded with non-toxic ions are "exchanged" for PFAS constituents, allowing the PFAS to remain in the resin, while non-toxic ions are added to the water exiting the treatment process. Used ion exchange resins would be taken offsite for incineration or other destructive treatment, resulting in ultimate destruction of the PFAS.	**Effective:** Protective of human health to current off-base drinking water receptors because PFOA and/or PFOS would be removed from groundwater used as drinking water through treatment via IX. Potential short-term risks to site workers would be managed through provisions of proper personal protective equipment (PPE) and bottled water. There are no potential short-term risks to the community under this alternative. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk, which Alternative 2b would remove. Achieves removal objective for current off-base drinking water receptors and on-base workers. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once PILs are reached, and impacted treatment media is transported safely offsite for disposal. Environmental impacts are primarily associated with transportation and disposal through incineration (or other approved disposal method) of used IX and energy usage associated with the treatment system. The SiteWise evaluation indicates greenhouse gas, energy use, and priority pollutant emissions are comparatively low, and accident risk is comparatively moderate. Water usage is similar across all alternatives as the majority of water use is attributed to consumption on- and off-base. If expansion was required, the alternative would be protective of human health, provided that the IX systems are implemented in a timely manner, and continue to be monitored with time.	**Moderately Easy.** Implementaion is technically feasible - components are well established, available, and can be completed with conventional equipment and equipment already available onsite (i.e. piping, pre-sediment filter, UV treatment). System installation timeframe is relatively short (less than 3 months). The existing systems would be retrofitted to incorporate IX, and IX equipment installation does not require specialized equipment. PRSCs are required and include realitvely infrequent sampling and changeout associated with each off-base system and anticipated relatively frequent change out of the GAC (every 3 months) for the on-base treatment system. Expansion of the system would require implementing IX systems at the additional off-base properties. The IX systems are readily available and can be fit into most existing treatment trains.	Capital Cost $325,000 Future Cost $2,390,000 Total Cost $2,715,000
Alternative 2c - Point of Entry - Reverse Osmosis	Removal action includes treatment of water at the point of entry to each private property and at the on-base water treatment system using RO. During RO, a membrane acts as a sieve, allowing PFAS-free water to flow through the membrane while contaminants are retained. Reject waste stream water from the membrane, and used membranes, would be containerized and taken offsite for incineration or other destructive treatment, resulting in the ultimate destruction of the PFAS.	**Effective.** Protective of human health to current off-base drinking water receptors because PFOA and/or PFOS would be removed from groundwater used as drinking water through treatment via RO. Potential short-term risks to site workers would be managed through provisions of proper PPE and bottled water. There is no potential short-term risks to the community under this alternative. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk, which Alternative 2c would remove. Achieves removal objective for current off-base drinking water receptors and on-base workers. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once PILs are reached, and impacted treatment media and RO reject wastes stream water is transported safely offsite for disposal. Long-term effectiveness would account for potential exposure to stored reject waste stream water from the RO system, by providing a secure structure to secure the reject waste stream storage tank. Environmental impacts are primarily associated with transportation and disposal through incineration (or other approved disposal method) of RO reject waste stream water and used RO membranes and energy usage associated with the treatment system. The SiteWise evaluation indicates greenhouse gas and energy use are comparatively high, accident risk and priority pollutant emissions are comparatively moderate to high. Water usage is similar across all alternatives as the majority of water use is attributed to consumption on- and off-base. If expansion was required, the alternative would be protective of human health, provided that the RO systems are implemented in a timely manner, and continue to be monitored with time.	**Moderately Hard.** Implmentation is technically feasible - components are well established, available, and can be completed with conventional equipment and equipment already available onsite (i.e. piping, pre-sediment filter, UV treatment). System installation timeframe is moderate (approximately 6 months). The existing systems would be retrofitted to incorporate RO, and RO equipment installation does not require specialized equipment. However, installation of the RO system requires an additional treatment equipment as compared to GAC and IX. PRSCs are required and include management of the RO reject waste stream water on a monthly basis, as well as infrequent sampling and RO membrane changeout. Expansion of the system would require implementing RO systems at the additional off-base properties. The RO systems are readily available, however upgrades to most existing treatment trains would be required.	Capital Cost $663,000 Future Cost $47,480,000 Total Cost $48,142,000

Table 4-1. Evaluation of Removal Action Alternatives
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Alternative	Description	Effectiveness	Ease of Implementation	Cost
Alternative 3 - City Water Connection	Water Supply lines from the City of Chesapeake would be run along Mt. Pleasant Road to NALF Fentress and impacted off-base properties with drinking water concentrations greater than the Lifetime Health Advisory (L-HA).	**Very Effective.** Protective of human health to current off-base drinking water receptors because PFOA and/or PFOS would be removed from groundwater used as drinking water through alternative supply of drinking water from the City of Chesapeake. Potential short-term risks to site workers would be managed through provisions of proper PPE and bottled water. Potential short-term risks to the community as a result of transporting fill material would be managed by ensuring trucks are not overloaded and are covered as they transport fill material to the site. There would also be added traffic and noise impacts to the community. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk. Alternative 3 would eliminate potential exposure. Achieves removal objective for current off-base drinking water receptors and on-base workers. No residual effect concerns, because impacted groundwater would no longer be used for drinking water purposes. Provides a permanent, long-term solution. Environmental impacts are primarily associated with production of materials and operation of mechanical earthwork equipment. The SiteWise evaluation indicates the greenhouse gas emissions and energy use as moderate and the priority pollutant emissions as comparatively high due to material production of the water main. The accident risk is comparatively low. Water usage is similar across all alternatives as the majority of water use is attributed to consumption on- and off-base. If expansion was required, the alternative would be protective of human health, provided that the connection to the city water system could be implemented in a timely manner.	**Moderately Easy.** Implementation is technically feasible. Components are well established and available, and can be completed with conventional equipment. Water line installation timeframe is a moderate timeframe (around 6 to 8 months). This alternative requires earth moving equipment, access to rights of way, potential disruption of traffic, and large amount of earth moving. Additionally, implementation requires coordination with the City of Chesapeake. There are no PRSCs required. Expansion of the system would require installation of additional service lines from the City water main to additional homes, as needed.	Capital Cost $5,240,000 Future Cost $0 Total Cost $5,240,000

Notes:
ARAR = Applicable or Relevant and Appropriate Requirements
GAC = granular activated carbon
L-HA = Lifetime Health Advisory
NALF = Naval Auxiliary Landing Field
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonic acid
PIL = project indicator level
PRSC = Post-Removal Site Controls
PPE = personal protective equipment

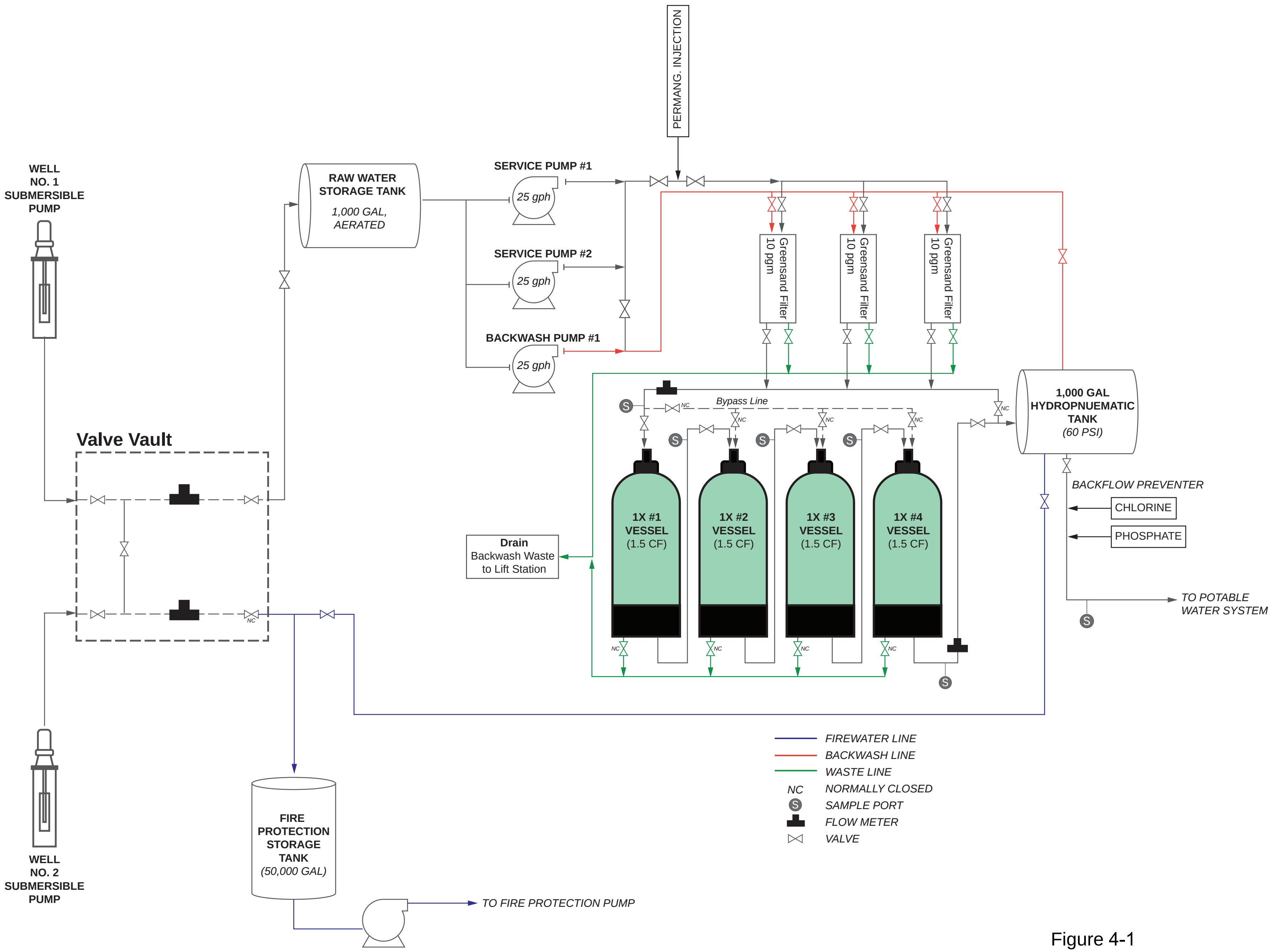


Figure 4-1
On-base Potable Water Treatment Ion Exchange Treatment System
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

ch2m

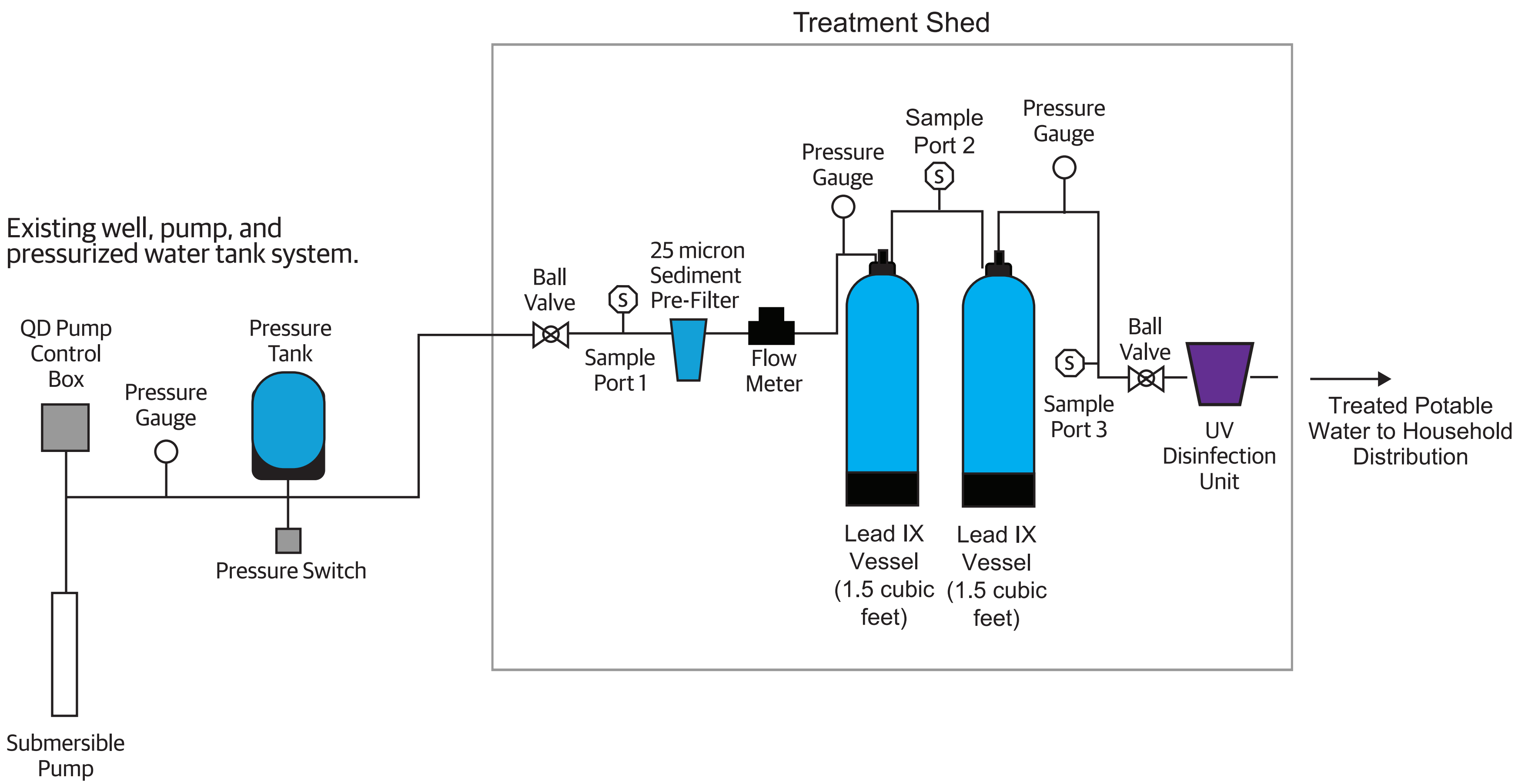


FIGURE 4-2
Privately Owned Drinking Water Ion Exchange Treatment System
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

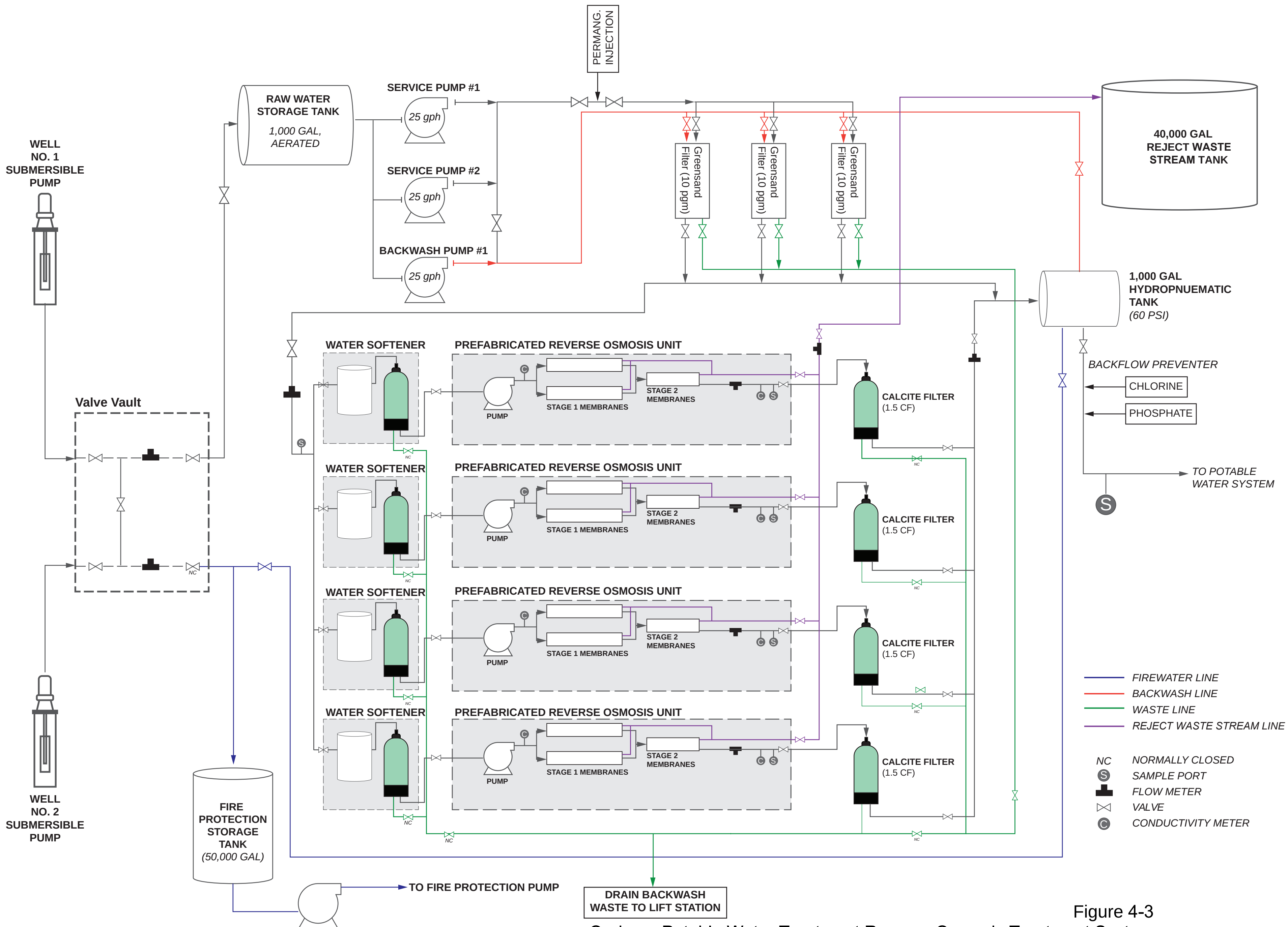


Figure 4-3
On-base Potable Water Treatment Reverse Osmosis Treatment System
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

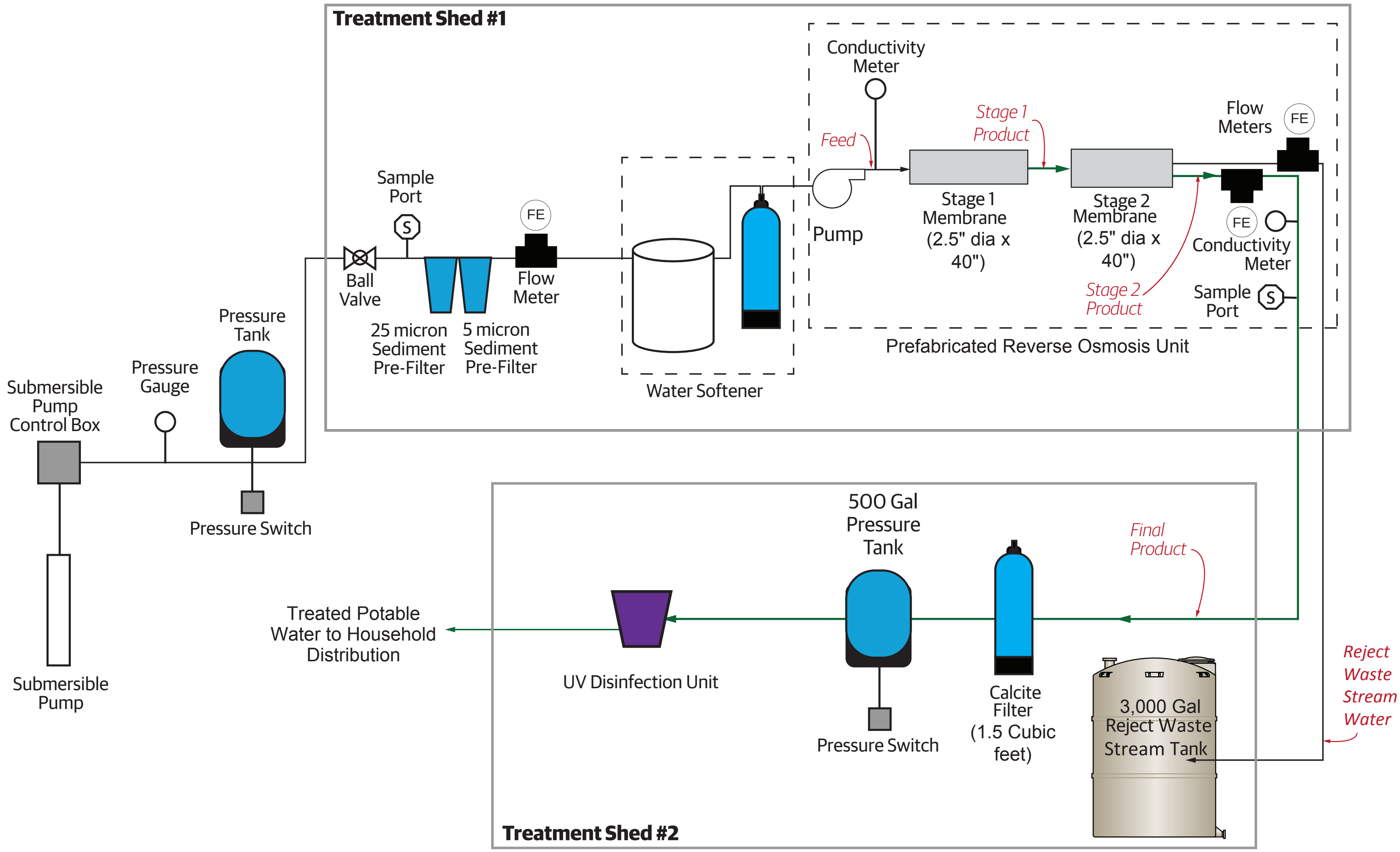


FIGURE 4-4
Privately Owned Drinking Water Reverse Osmosis Treatment
System Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

ch2m

\\brooksidefiles\GIS_SHARE\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\Fentress\Basewide\674207_EECA\Figure_4_5_City_Water_System_Layout.mxd10/25/2018AM038876

Legend
- Fire Hydrant
- Water Meters
- Water Line

N

0 500 1,000 Feet

1 inch = 1,000 feet

Figure 4-5
City Water System Layout
Engineering Evaluation and Cost Analysis For Residential Drinking Water
NALF Fentress, Chesapeake, Virginia

Imagery Source: ©2017 Esri

ch2m

Comparative Analysis of Removal Action Alternatives

Section 5 expands on the evaluation of the alternatives by providing a comparative analysis to assist the decision-making process by which a removal action will be selected. In Section 4, these alternatives were described according to their effectiveness, ease of implementation, and cost. In this section, the alternatives are compared to one another for each of the three criteria.

Table 5-1 summarizes the results of the alternatives comparison. Comparative terms used in **Table 5-1** are defined relative to other alternatives.

5.1 Effectiveness

Overall, Alternative 3 is the most effective, Alternative 1 is the least effective, and Alternatives 2a through 2c are comparable in effectiveness.

Alternative 1 is minimally effective, as it isonly moderately protective of human health off-base, whereas Alternatives 2a, 2b, 2c, and 3 are effective to very effective and are protective of human health. Although Alternative 1 provides for bottled water for drinking and cooking for the off-base parcels, it does not address ingestion that may occur for inadvertently using contaminated water from the tap for household and recreational activities since the pilot GAC systems currently in place will no longer be maintained. It also provides less long-term control and does not contribute to the effective performance of a future groundwater remedy, if any, because contaminants in water used for non-potable purposes at off-base homes would be re-released to the environment in septic leach fields with no controls. Alternatives 2a through 2c are considered effective and are protective of human health because PFOA or PFOS is removed from the groundwater used for private and Navy use through media treatment. Alternative 3 is considered very effective and is protective of human health because contaminated groundwater is no longer used to provide water to the private properties or the base, thus eliminating receptor exposure. Additionally, because water used for household purposes under Alternatives 2a through 2c and 3 does not contain PFOA or PFOS, contaminants would not be released back into the environment through disposal of wastewater (i.e septic system).

Under Alternatives 1 and 2a, there are no short-term risks to workers at NALF Fentress because the GAC systems have already been implemented. Alternatives 2b, 2c, and 3 pose short-term risks to workers during implementation of the alternatives, although risk can be managed through the use of personal protective equipment and providing workers with bottled water. There are no risks to the community under Alternatives 1, 2a, and 2b. Under Alternatives 2c and 3, there is risk to the community through transportation of contaminated reject waste stream water monthly (Alternative 2c) and transportation of fill materials (Alternative 3). The impacts on the community can be managed by covering trucks and implementing traffic controls, as needed.

Although there are no chemical-specific ARARs, Alternative 1 is only minimally effective in addressing exposure to PFAS contamination. The risk of ingestion from the presence of PFAS in groundwater is not completely addressed for the off-base properties under Alternative 1. Similarly, while there are no chemical specific ARARs, Alternatives 2a through 2c are effective at addressing drinking water exposure to below the Lifetime Health Advisory by removing PFOA and PFOS from groundwater used as drinking water. Alternative 3 is very effective at addressing exposure through provision of an alternative drinking water source.

The RAO and long-term protectiveness is achieved under Alternative 3. The RAO is also achieved under Alternatives 2a through 2c, but the alternatives have associated maintenance requirements that could reduce effectiveness in that treatment media must be replaced in a timely manner and contaminated media must be transported offsite safely for disposal. Under Alternative 1, the RAO is achieved on-base similar to Alternatives 2a through 2c; however, at off-base properties, the RAO is not achieved because the contaminated groundwater may incidentally be used as drinking water, as the pilot GAC systems, currently in place, will no longer be maintained. Additionally, under Alternative 1, contaminated groundwater continues to be disposed of through existing septic systems and, therefore, does not maintain long-term control of contaminants or contribute to the effective performance of any necessary long term remedy because the contaminants may be redistributed in the waste streams.

If expansion of the alternatives was required in the future, Alternative 3 would be the most effective because installation of water service lines could be done in a timely manner. Alternative 1 is not effective because No Further Action indicates that no changes will be made to the existing bottled water supply and on-base treatment, including addition of properties not yet affected. Alternatives 2a through 2c would be protective once the systems were installed. Over the long-term, Alternative 3 would be the most protective because Alternatives 1 and 2a through 2c rely on ongoing maintenance to ensure protectiveness.

5.2 Implementability

Alternatives 1, 2a, 2b, and 3 are overall moderately easy to implement, while Alternatives 2c is moderately hard to implement.

The five alternatives are all technically feasible to implement and can be implemented with components that are well established, available, and easily replaced.

Alternatives 1 and 2a require no implementation because the systems are already in place and are functional; therefore, Alternatives 1 and 2a are the easiest to implement. Alternative 2b is moderately easy to implement because it uses much of the infrastructure from the existing pilot system, which is already in place. Alternative 2c requires the most implementation efforts of the POE systems because it requires additional installation of equipment such as storage tanks, water softeners, and pre- and post- filtration, as compared to Alternatives 2a and 2b. Alternative 3 is considered moderate to implement because it requires earth-moving equipment, access to rights-of-way, and coordination with the City of Chesapeake. Alternative 3 also has the greatest impact on the surrounding community during implementation because of the transport of materials during construction; however, impacts could be mitigated through best management practices.

Once implemented, Alternative 3 has no long-term implementation requirements. Alternatives 1 and 2a through 2c have post-removal site control (PRSC) requirements. Alternatives 2b has the lowest PRSC requirements, including infrequent media change-out and sampling, and minimal waste management. Alternatives 2a has the slightly higher PRSC requirements, due to variable and frequent, media changeout and sampling. Alternative 1 requires monthly delivery of bottled water to homes, and Alternative 2c requires monthly collection and disposal of PFAS-contaminated waste stream water, thus increasing PRSC requirements.

As part of assessing adaptability to environmental conditions, the flexibility of each alternative to be adapted should contaminant plume migration occur in the future was considered. If additional properties were identified as requiring treatment based on future groundwater monitoring and expansion of the alternatives were required, Alternative 3 would be the easiest to implement because additional water service lines from the proposed main could be installed in a timely manner. Alternative 1 implies that no additional properties would be addressed because this alternative would involve No Further Action beyond what has already been taken. Alternatives 2a through 2c would be moderately easy to implement because they require design and implementation of the treatment systems, with Alternative 2c requiring the most alterations to existing systems.

5.3 Cost

Alternatives 1 and 2b are the least expensive alternatives, and Alternative 2c is the most expensive alternative. Of the three POE Alternatives (2a through 2c), Alternative 2a has the lowest capital costs because the systems are already in place, but Alternative 2a has higher PRSC costs over 30 years than Alternative 2b. Alternative 2b has the lowest overall costs of the three POE alternatives over 30 years. Alternative 3 has moderate costs that are higher than Alternatives 1 and 2b, comparable to Alternative 2a, and lower than Alternative 2c. Additionally, Alternative 3 does not have any costs associated with long term PRSCs, whereas Alternatives 1 and 2a through 2c have PRSC costs over 30 years. The detailed cost estimates for the alternatives are provided in **Appendix C** and summarized in **Table 4-1.**

5.4 Sustainability

Based on the results of the SiteWise Evaluation (**Appendix B**), Alternatives 2a and 2b have similar environmental footprints, which are comparatively low compared to the footprints of Alternatives 2c and 3. Alternatives 2a and 2b have similarly low greenhouse gas (GHG) emissions, energy footprints, priority pollutant emissions, and accident risk, with the greatest environmental impacts coming from energy used to run the system and transport treatment media. Alternative 2c has the highest GHG emissions, energy use, water use, and criteria air pollutant footprint of the POE alternatives because of its increased electricity needs to operate the RO system, and for management of the reject waste stream water from the RO system, including transport and disposal. Additionally, Alternative 2c has the highest amount of particulate matter of 10 micrometers or less in diameter (PM_{10}) and the highest accident risk footprint of all alternatives, primarily from transporting reject waste stream water to a disposal facility and disposal of the water. Alternative 3 has the highest GHG emissions, energy, and priority pollutant (with the exception of PM_{10}) footprints by several orders of magnitude compared to the POE alternatives, mainly because of material production of the water main pipe, and installation of the alternative using heavy equipment. The accident risk for Alternative 3 is moderate and is primarily from onsite labor for installing the main and transportation of personnel and equipment during installation.

Table 5-1. Removal Action Alternative Comparison
Engineering Evaluation and Cost Analysis for Drinking Water
NALF Fentress, Chesapeake, Virginia

Alternative	Effectiveness	Ease of Implementation	Cost	Total Score
Alternative 1 - No Further Action	1	3	4	8
Alternative 2a - Point of Entry - Granular Activated Carbon	3	3	3	9
Alternative 2b - Point of Entry - Ion Exchange	3	3	4	10
Alternative 2c - Point of Entry - Reverse Osmosis	3	2	1	6
Alternative 3 - City Water Connection	5	3	3	11

Effectiveness
Minimally effective - 1
Effective - 3
Very Effective -5

Ease of Implementation
Easiest - 5
Easy - 4
Moderately Easy - 3
Moderately Hard - 2
Hard - 1

Cost
Low- 5
Moderately Low - 4
Moderate - 3
Moderately High - 2
High - 1

SECTION 6

Recommended Removal Action Alternative

Overall, Alternative 3 is the most effective, Alternative 1 is the least effective, and Alternatives 2a through 2c are comparable in effectiveness. Alternative 3 is considered very effective because it eliminates contaminated groundwater used as the source of drinking water at the site, eliminates the potential for migration of PFAS contamination through wastewater to septic leach fields and has no maintenance requirements. Alternatives 2a through 2c are effective but have additional maintenance requirements post implementation and in perpetuity. Alternative 1 is minimally effective because contaminated groundwater can still inadvertently be consumed as drinking water, and wastewater will still contain PFAS, resulting in additional contaminant migration. Thus, Alternative 1 would not contribute to the effectiveness of any further groundwater response, if determined necessary.

The five alternatives are all technically feasible to implement and can be implemented with components that are well established, available, and easily replaced. Alternatives 1 and 2a are considerate moderately easy to implement because the systems are already in place on-base and off-base as pilot systems; however, each alternative has elevated PRSCs requirements as compared to Alternatives 2b and 3. Alternative 2b is moderately easy to implement because it requires some updates to the existing on-base and off-base pilot systems, along with PRSCs requirements. Alternative 2c is moderately difficult to implement because it requires large updates to the existing on-base and off-base pilot systems, and has elevated PRSCs requirements associated with monthly disposal of reject water from the systems. Alternative 3 is moderately easy to implement even though it requires earth-moving equipment, access to rights-of-way, and coordination with the City of Chesapeake, it does not require any PRSCs. Additionally, Alternative 3 has the highest potential for adaptability to changing environmental conditions if additional private drinking water wells are identified with exceedances of the Lifetime Health Advisory.

Alternatives 1 and 2b are the least expensive alternatives, and Alternative 2c is the most expensive alternative. Alternative 3 has moderate costs that are higher than Alternatives 1 and 2b, comparable to Alternative 2a, and lower than Alternative 2c. Additionally, Alternative 3 does not have any costs associated with long term PRSCs, whereas Alternatives 1 and 2a through 2c have PRSC costs over 30 years.

Based on evaluation of the alternatives, the recommended removal action alternative is Alternative 3, Connection to City Water. Alternative 3 would address PFOA and/or PFOS impacts by providing the base and each private property with concentrations greater than the Lifetime Health Advisory, access to City water by extending the City water main to north of NALF Fentress base. Service lines from the water main would be installed to each of the privately owned buildings with drinking water concentrations greater than the Lifetime Health Advisory and to the on-base potable water distribution system. The seven off-base potable water systems, would be connected to the main line via individual service lines, and service would be connected as part of this alternative. A service line would also be run to the on-base drinking water system; however, the service connection would not be made under this alternative and would be left up to the discretion of the base. System installation would be carried out in accordance with the City of Chesapeake Considerations, as detailed in Section 3.6. Under this alternative, it is assumed that the off-base private drinking water wells and water treatment systems would remain in place but would no longer be used as the water supply for the off-base properties. The end result of Alternative 3 is a solution that provides for unlimited use of drinking water at the off-base properties and for on-base workers, with no PRSCs or periodic O&M.

Navy, USEPA, and VDEQ representatives were involved with developing the recommended removal action alternative through the Tier I Partnering Team process and will have the opportunity to comment on the recommendation during the regulatory review period for this EE/CA. Following the regulatory review period, a 30-day public comment period will be held to assess public acceptance of the recommended alternative. If comments are received, a Responsive Summary addressing significant comments will be prepared as part of the Action Memorandum and included in the Administrative Record, along with the final EE/CA.

References

Battelle. 2013. *SiteWise Version 3*. NAVFAC Engineering Service Center. August.

CH2M HILL, Inc. (CH2M). 2016. *Water Treatment Upgrade Recommendation for Naval Auxiliary Landing Field Fentress*, *Virginia Beach, Virginia*. April.

CH2M. 2017a. *Bench-Scale Treatability Study Results: Granular Activated Carbon Testing to Remove PFOA and PFOS in Drinking Water, Naval Auxiliary Landing Field Fentress, Chesapeake, Virginia*. February.

CH2M. 2017b. *Pilot Test Work Plan: Granular Activated Carbon System Installation on Residential Duking Water Systems to Remove PFOA and PFOS, Naval Auxiliary Landing Field Fentress, Chesapeake, Virginia*. August.

CH2M. 2017c. *Preliminary Engineering Report for Potable Water System Improvements, Naval Auxiliary Landing Field Fentress, Chesapeake, Virginia.* February.

CH2M. 2018. *Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report, Naval Auxiliary Landing Field Fentress, Chesapeake, Virginia.* October.

City of Chesapeake (Chesapeake). 1994. *Code of Ordinances, City of Chesapeake, Virginia.* March.

Chesapeake. 2016a. *City of Chesapeake Public Facilities Manual Volume I – Design Criteria & Policy.* January.

Chesapeake. 2016b. *City of Chesapeake 2035 Comprehensive Plan*. November.

Department of the Navy (Navy). 2000. *Overview of Screening, Risk Ratio, and Toxicological Evaluation. Procedures for Northern Division Human Health Risk Assessments*. May.

Department of the Navy (Navy). 2017a. *Emergency Response Action Memorandum site 17, Former Fire-fighting Training Area, Naval Auxiliary Landing Field Fentress, Chesapeake, Virginia.* March.

Navy. 2017b. *Interim Per- and Polyfluoralkyl Substances (PFAS) Site Guidance for NAVFAC Remedial Project Mangers (RPMS).* September 2017 Update*.* September.

Navy. 2018. *Department of the Navy Environmental Restoration Program Manual*.

United States Environmental Protection Agency (USEPA). 1993. *Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA, PB93-963402.* August.

Virginia Department of Health (VDH). 2017. *City of Chesapeake Water – NALF Fentress Field PWSID No. 3550615*. February.

White House Office of Management and Budget (White House OMB). 2014. *Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses – Real Discount Rates: Real Interest Rates on Treasury Notes and Bonds of Specified Maturities.* Circular No. A-94, Appendix C. Revised December 2014. Accessed May 2018. http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html.

Appendix A
ARARs

Acronyms and Abbreviations

ARAR	Applicable or relevant and appropriate requirement
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
DCR	Virginia Department of Conservation and Recreation
DNH	Division of Natural Heritage
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NAAQS	National Ambient Air Quality Standards
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NSDWRs	National Secondary Drinking Water Regulations
NSPS	New Source Performance Standards
PCB	Polychlorinated biphenyls
PMCL	Primary Maximum Contaminant Level
POTW	Publicly Owned Treatment Works
ppm	Parts per Million
RBC	Risk-Based Concentrations
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SMCL	Secondary Maximum Contaminant Level
TBC	To Be considered
TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substance Control Act
USACE	US Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
VA	Virginia
VAC	Virginia Administrative Code
VMRC	Virginia Marine Resource Commission
VPA	Virginia Pollutant Abatement
VPDES	Virginia Pollutant Discharge Elimination System

References

Commonwealth of Virginia, 2004. Preliminary Identification, Applicable or Relevant and Appropriate Requirements.

USEPA, 1998. *CERCLA Compliance with Other Laws Manual: Interim Final* . Office of Emergency and Remedial Response. EPA/540/G-89/006.

USEPA, 1998. *CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes.* Office of Emergency and Remedial Response. EPA/540/G-89/009.

USEPA, 1998. RCRA, Superfund & EPCRA Hotline Training Manual. Introduction to Applicable or Relevant and Appropriate Requirements. EPA540-R-98-020.

Table A1-1
Federal Chemical-Specific ARARs
NALF Fentress - Off-base Residential Drinking Water
Naval Auxiliary Landing Field Fentress, Virginia

Media	Requirement	Prerequisite	Citation	Alternative	ARAR/TBC Determination	Comment

No Federal Chemical-Specific ARARs apply.

Table A1-2
Virginia Chemical-Specific ARARs
NALF Fentress - Off-base Residential Drinking Water
Naval Auxiliary Landing Field Fentress, Virginia

Media	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment

No Virginia Chemical-Specific ARARs apply.

Table A1-3
Federal Location-Specific ARARs
NALF Fentress - Off-base Residential Drinking Water
Naval Auxiliary Landing Field Fentress, Virginia

Location	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment
Migratory Flyway						
Migratory bird habitat	Protects almost all species of native birds in the United States from unregulated taking.	Presence of migratory birds.	16 USC 703	2a, 2b, 2c, and 3	Applicable	NALF Fentress is located in the Atlantic Migratory Flyway. If migratory birds listed in the Act, or their nests or eggs, are identified at NALF Fentress, operations will not destroy the birds, nests, or eggs.

Table A1-4
Virginia Location-Specific ARARs
NALF Fentress - Off-base Residential Drinking Water
Naval Auxiliary Landing Field Fentress, Virginia

Location	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment

No Virginia Location-Specific ARARs apply.

Table A1-5
Federal Action-Specific ARARs
NALF Fentress - Off-base Residential Drinking Water
Naval Auxiliary Landing Field Fentress, Virginia

Action	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment

No Federal Action-Specific ARARs apply.

Table A1-6
Virginia Action-Specific ARARs
NALF Fentress - Off-base Residential Drinking Water
Naval Auxiliary Landing Field Fentress, Virginia

Action	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment
Erosion and Sediment Control						
Erosion and deposits of soil/sediment caused by land disturbing activities	Regulations for the effective control of soil erosion, sediment deposition and nonagricultural runoff that must be met in any control program to prevent the unreasonable degradation of properties, stream channels, waters, and other natural resources.	Construction activities that will disturb more than 10,000 square feet of land.	9 VAC 25-840-40A(1); (2); (3); (4); (17); (18); (19)(h), (i)	3	Applicable	Erosion control measures will be implemented for the installation of water lines.
Waste Management						
Management of non-hazardous waste in containers	Establishes standards and procedures pertaining to the management of nonhazardous solid wastes in containers. Nonputrescible wastes must be stored in appropriate containers and not staged for more than 90 days.	Generation of nonhazardous solid waste that is managed onsite in containers.	9 VAC 20-81-95(D)(10)(b)	2a, 2b, 2c, and 3	Applicable	It is anticipated that some wastes may be generated and managed onsite in containers. Based on the analytical results from previous investigations, it is expected that these wastes will be nonhazardous solid waste. Wastes will be characterized prior to offsite disposal.
Dust Control						
Generation of fugitive dust	Regulations regarding reasonable precautions to prevent particulate matter from becoming airborne.	Conducting any activity which may cause particulate matter to become airborne.	9 VAC 5-50-90	3	Applicable	Dust control measures will be implemented during activities at the site.

Appendix B
SiteWise Evaluation

Sustainability Analysis for Drinking Water, NALF Fentress

1.1 Introduction

This appendix presents the approach taken and results obtained from a sustainability analysis performed for on-base and off-baseDrinking Water at Naval Auxiliary Landing Field (NALF) Fentress, Chesapeake, Virginia. Details of the project are provided in the Engineering Evaluation/Cost Analysis (EE/CA). The following alternatives were developed to address current exposure potential= to drinking water on-base and at off-base properties contaminated with perfluorooctanonic acid (PFOA) and/or perfluorooctane sulfonate (PFOS) at levels greater than the United States Environmental Protection Agency (USEPA) lifetime health advisory (L-HA) of 70 nanograms per liter (ng/L). A detailed summary of the alternatives is provided in the EE/CA.

- Alternative 1 – No Further Action
  - Continue on-base granular activated carbon (GAC) treatment
  - Continue supplying bottled water to off-base properties
- Alternative 2 – Point of Entry and On-Base Water Treatment
  - 2a – Granular Activated Carbon (GAC) Treatment
  - 2b – Ion Exchange (IX) Treatment
  - 2c – Reverse Osmosis (RO) Treatment
- Alternative 3 – Connection to City Water

The purpose of this analysis is to provide a quantitative assessment of the potential environmental and social impact of each alternative. The sustainability analysis was performed using SiteWise Version 3.1 (Battelle, 2015) for Alternatives 1, 2a, 2b, 2c, and 3.

1.2 Method and Assumptions

The SiteWise tool consists of a series of Excel-based spreadsheets used to conduct a baseline assessment of sustainability metrics. The assessment is carried out using a spreadsheet-based building block approach, where every removal alternative can be broken down into components for discrete phases of work (such as construction, operation, long-term monitoring), or different systems for more complex removal actions.

SiteWise uses various emission factors from governmental or non-governmental research sources to determine the environmental impact of each activity. The quantitative metrics calculated by the tool include:

1) Greenhouse gases (GHGs) reported as metric tons of carbon dioxide equivalents (CO_2e), consisting of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)
2) Energy usage (expressed as millions of British Thermal Units [MMBTU])
3) Water usage (gallons of water)
4) Air emissions of criteria pollutants consisting of metric tons of nitrogen (NO_x), sulfur oxides (SO_x), and particulate matter 10 micrometers or less in diameter (PM_{10})
5) Accident risk (risk of injury and risk of fatality)

For the purpose of this discussion, the term "footprint" will be used to describe the quantified emissions or quantities for each metric. To estimate the sustainability footprint for each alternative, only those elements possessing important sustainability impacts were included in the assessment. A lower footprint indicates lower deleterious impacts to environmental and social metrics, which collectively make up the SiteWise sustainability metrics. Conversely, a higher footprint indicates higher deleterious impacts associated with the SiteWise metrics. The major conclusions of this sustainability analysis are incorporated into the effectiveness criteria evaluation of the EE/CA.

1.2.1 Assumptions

The following is a description of the major activities for each alternative. A total of seven off-base systems, and the on-base potable water system are considered as part of each alternative, and the assumed operation timeframe is 30 years for the purpose of this evaluation. Activities such as sampling or vessel delivery are assumed to be completed for both on-base and the seven off-base systems in one event, rather than separate events. The data entered into the SiteWise tool represent the total 30-year timeframe for this evaluation.

- Alternative 1 – No Further Action
  - Materials: Production of GAC (virgin) two 94 cubic foot vessels changed out approximately 3 times per year (564 cubic feet per year x 30 years = 16,920 cubic feet). Assume plastic bottles are reusable.
  - Transportation of personnel: Biweekly sampling, 30 miles round-trip, one light duty truck (780 trips total)
  - Transportation of Equipment: Vessel shipment via on-road truck – 300 miles one-way, approximately 2 tons per trip x 3 trips per year x 30 years (54,000 miles total roundtrip with 2 tons each way). Monthly bottled water deliveries – 50 gallons per house per month x 7 houses x 8.34 lb/gal 30 miles roundtrip (1.5 tons per trip, 10,800 miles total).
  - Disposal: Incineration/thermal treatment of 6 tons GAC per year (360 tons total for 30 years – proxy "regenerated GAC" for impacts)
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 7 off-base wells × 12 months × 30 years = 17.64 million gallons, 7,875 gallons per day for on-base x 365 days x 30 years = 86.23 million gallons.
- Alternative 2a – GAC and UV Treatment (off-base properties only)
  - Materials: Production of GAC (virgin) 4 cubic feet per system per year x 7 systems x 30 years (840 cubic feet total), 16,920 cubic feet for on-base treatment.
  - Transportation of personnel: Biweekly sampling, 30 miles round-trip, 1 light duty truck, on-base sampling to occur biweekly, six off-base systems sampled quarterly, one off-base system sampled monthly as needed during scheduled on-base sampling event (780 trips total)
  - Transportation of Equipment: Vessel shipment via on-road truck – On-base changeouts 300 miles one-way, approximately 2 tons per trip x 2 trips per year x 30 years (36,000 miles each way, 2 tons both direction). On-base and off-base change-outs 1 per year 300 miles one-way, approximately 3.75 tons of material for all systems per year, spent GAC to return to source for incineration/ regeneration (18,000 miles total, 3.75-ton load both directions).
  - Electricity use: Power for UV system (off-base only), approximately 450 kilowatt hours (kwh) per system per year (94,500 kwh total)
  - Disposal: Incineration/thermal treatment of 7.75 tons GAC per year for all systems (420 tons total for 30 years – proxy "regenerated GAC" for impacts)
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 7 off-base wells × 12 months × 30 years = 17.64 million gallons, 7,875 gallons per day for on-base x 365 days x 30 years = 86.23 million gallons.
- Alternative 2b – IX and UV Treatment (off-base properties only)

- Materials: Production of resin – Off-base: biennial change-outs of 3 cubic feet of single-use resin per system x 7 systems x 30 years (315 cubic feet total). On-base: quarterly change-outs of four 1.5 cubic foot vessels of single-use resin (720 cubic feet total)
- Transportation of personnel: Monthly sampling, 30 miles round-trip, 1 light duty truck, on-base sampling to occur monthly, seven off-base systems sampled quarterly during scheduled on-base sampling event (360 trips total)
- Transportation of Equipment: Vessel shipment via on-road truck – Off-base: 500 miles one-way, 0.7 ton material each load, spent resin to travel similar distance for incineration, 15 trips . On-base: 500 miles one-way, 1.5 tons each load, quarterly change-outs (120 trips), spent resin to travel similar distance for incineration. Assume off-base change outs occur during on-base change outs – 105,000 miles with 1.5-ton load, 15,000 miles with 2.3-ton load.
- Electricity use: Power for UV system (off-base only), approximately 450 kwh system per year (94,500 kwh total)
- Disposal: Disposal of IX resin via incineration (approximately 190.5 tons total – proxy "regenerated GAC" for impacts)
- Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 7 off-base well × 12 months × 30 years = 17.64 million gallons, 7,875 gallons per day for on-base x 365 days x 30 years = 86.23 million gallons.

• Alternative 2c – RO and UV Treatment (off-base only)
  - Materials: RO filter and components have negligible material impacts compared with waste treatment.
  - Transportation of personnel: Monthly sampling, 30 miles round-trip, 1 light duty truck, on-base sampling to occur monthly, seven off-base systems sampled quarterly during scheduled on-base sampling event (360 trips total)
  - Transportation of Equipment:
    - Initial tank/component shipment:
      - Off-base: 500 gallon and 3,000 gallon tanks plus associated piping and equipment, 3 tons total, 7 loads (one load per off-base system), 250 miles one way
      - On-base: 40,000 gallon tank, 10 tons total, 1 load, 250 miles one way
    - RO system: initial installation and component change outs (500 miles one way, 1 ton total every 5 years, 30 year timeframe: 3,500 miles full, same empty)
  - Electricity use: Power for UV (off-base only) and RO system, approximately 900 kwh per system per year (189,000 kwh total)
  - Residual management: Disposal of reject water from RO membranes: Off-base- approximately 1,800 gallons (7.5 tons) per system per month via incineration to treatment plant 50 miles away (6,300,000 gallons total or 26,208 tons disposed, transport 7.5 tons × 7 loads × 12 months × 30 years = 2,520 trips). On-base – approximately 35,000 gallons per month (146 tons, 7 trips per month x 12 x 30 = 2,520 total trips, 21 tons each).
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 7 off-base well × 12 months × 30 years = 17.64 million gallons, 7,875 gallons per day for on-base x 365 days x 30 years = 86.23 million gallons.

• Alternative 3 – Connection to City Water
  - Installation:

  - Material Production: 14,000 feet of 16-inch ductile iron water main (75 pounds of "medium impact material" per foot × 14,000 feet = 1,050,000 pounds "medium impact material" or 525 tons)
  - Service lines – 3,700 feet of 1- to 2-inch copper pipe, approximately 1.5 tons of "medium impact material".
  - Transportation of personnel: 28 days to install, crew of 6 people driving 30 miles roundtrip per day, 500 feet production per day, 168 trips total
  - Transportation of equipment and materials: Heavy equipment – 25 tons × 50 miles, pipe 27 trips × 100 miles × 20 tons each trip, empty load back (2,700 miles full with 20 tons and 2,700 miles empty)
  - Equipment use: trenching using an excavator to an average of 3 feet deep, 2 feet wide (3,111 cubic yards moved twice)
  - Onsite labor hours: 6 people × 28 days × 10 hour days = 1,680 hours, construction laborers
- Operations: Estimate 7,000 gallons per off-base well per month × 7 off-base well × 12 months × 30 years = 17.64 million gallons, 7,875 gallons per day for on-base x 365 days x 30 years = 86.23 million gallons.

The following general assumptions are used for the SiteWise tool evaluation:

- The complete environmental footprint for production of equipment used, or production of the vehicles used for transportation, is not considered in this analysis.

1.3 Results and Conclusions

Table B-1 presents the quantitative environmental footprint metrics evaluated for each of the alternatives. A relative impact summary is also provided in **Table B-1** and results are graphically presented on **Figure B-1**. The relative impact is a qualitative assessment of the relative footprint of each alternative. A rating of high or low is assigned to each alternative based on its performance against the other alternatives. The tool assigns a rating of high to the highest footprint in each category and assigns the ratings of other alternatives based on the difference in the data between alternatives. The rating is based on a 30 percent difference; for example, if the footprints of two alternatives are within 30 percent of each other, they will be assigned the same rating. This allows for some uncertainty inherent in the assumptions used in the model.

It should be noted that while this analysis compares the environmental footprints of each of the alternatives, the alternatives may differ with respect to other evaluation criteria. Therefore, a comparison of the results of the alternatives needs to be made in the context of the benefits (e.g., applicable or relevant and appropriate requirement (ARAR) compliance, contaminant reduction, site reuse, cost effectiveness) of each of the alternatives.

The following is a comparison of the alternatives for each metric. Details are provided in **Table B-2** and **Figure B-1**.

GHG and Energy Use. Alternative 2c (RO) had the highest GHG and Energy use footprints of all of the alternatives by several orders of magnitude, primarily from disposal of the concentrate (reject) water from the RO membranes. Alternatives1 and 2a had the second highest GHG footprints followed by Alternative 3. The primary driver for GHG footprints for the three alternatives is material production, with approximately 50 to 65 percent of the total GHG footprints coming from GAC(Alternative 1 and 2a), and iron for the sewer main piping (Alteranative 3) . Waste disposal and transportation of materials also contributes to the Alternative 1 and 2a GHG footprints. Equipment use was the second largest contributor of the GHG footprint for Alternative 3. The GHG footprint for Alternative 2b was significantly lower than the other alternatives, primarily because the volume of IX resin needed for on-base treatment was comparatively lower than the GAC alternatives (Alternatives 1 and 2a). Alternatives 1 and 2a have lower energy footprints than Alternative 3. The majority of the energy use footprint for Alternative 3 was from the pipe material production.

Water Use. All alternatives had similar water use, with the majority of water use attributed to consumption of water on-base and at the off-site properties, with a minor contribution from electricity use (cooling water at power plant).

Criteria Air Pollutants (NO_X, SO_X, PM_{10}). Alternative 3 had the highest NO_X and SO_X footprints, , compared with the other alternatives, almost exclusively from material production (between 75 and 90 percent of the total footprint). Alternatives 1, 2a, and 2b had similar criteria air pollutant footprints although the source of the contributions for each alternative varied. The majority of the impacts are from electricity to power the UV systems. Alternative 2c had higher NO_X and SO_X footprints compared with Alternatives 1, 2a and 2b because of the handling of the concentrate (reject) water from the RO membranes. Alternative 2c had the highest PM_{10} footprint of all the alternatives from disposal as a hazardous waste.

Accident Risks. Alternative 3 had the lowest accident risk footprint because after installation there is no transportation of personnel, materials, or waste to and from the sites. The remaining alternatives had similarly high accident risk footprints, primarily from transporting replacement IX resin, GAC, or concentrate (reject) water from the RO membranes..

1.4 Uncertainty

The SiteWise tool calculates environmental and risk footprints based on industry averages, published emissions factors, and generalized data sources. The footprint results are not representative of actual emissions and should be used for comparative purposes only.

Proxies or assumptions were made that contribute to uncertainty including:

- Using regenerated GAC as a proxy for thermal treatment of GAC and IX resin.
- Ductile iron pipe and copper pipe is not included in SiteWise, however the impact was expected to be slightly lower than steel, therefore a “moderate impact material” was used as a proxy.
- The impact from treating concentrate (reject) water from the RO system was assumed to be the same as treatment as a hazardous waste using the default value in SiteWise, however treatment of PFAS-contaminated water requires incineration.
- Distance traveled for the waste treatment and replacement materials was assumed based on professional knowledge but may vary based on actual design and implementation.

1.5 Recommendations

The inventory from the SiteWise tool were used to estimate the environmental footprint of the alternatives. Once the alternative is selected, it is recommended that the footprint of the selected alternative be further evaluated in the design phase of the projects to explore opportunities to optimize the environmental footprint of the project and integrate sustainable remediation best practices in the design, construction, and operation of the alternative.

A best practice for the point of entry treatment alternatives would be using alternative energy sources to power the UV light, such as solar to supplement grid power, or purchase of green power where it is available.

1.6 References

Battelle. 2015. *SiteWise Version 3.1*. NAVFAC Engineering Service Center. September.

Tables

Table B-1. Relative Impact of Alternatives

Sustainability Analysis for Residential Drinking Water

Naval Auxiliary Landing Field Fentress

Chesapeake, Virginia

Remedial Alternatives	GHG Emissions	Total Energy Used	Water Used	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1 - No Further Action	855	6,557	1.04E+08	4.97E-01	6.16E-01	8.10E-02	8.70E-04	7.01E-02
Alternative 2A - Granular Activated Carbon (GAC) Treatment	978	8,139	1.04E+08	5.84E-01	7.79E-01	1.58E-01	1.07E-03	8.59E-02
Alternative 2B - Ion Exchange (IX) Treatment	268	3,898	1.04E+08	1.91E-01	2.51E-01	9.13E-02	1.10E-03	8.89E-02
Alternative 2C - Reverse Osmosis (RO) Treatment	1,797	30,063	1.04E+08	5.26E+00	2.89E+00	1.42E+01	4.14E-03	3.33E-01
Alternative 3 – Connection to City Water	729	14741	1.04E+08	1.93E+00	2.67E+00	1.23E+00	2.17E-04	4.42E-02

Relative Impact

Remedial Alternatives	GHG Emissions	Total Energy Used	Water Used	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
Alternative 1 - No Further Action	Medium	Low	High	Low	Low	Low	Low	Low
Alternative 2A - Granular Activated Carbon (GAC) Treatment	Medium	Low	High	Low	Low	Low	Low	Low
Alternative 2B - Ion Exchange (IX) Treatment	Low	Low	High	Low	Low	Low	Low	Low
Alternative 2C - Reverse Osmosis (RO) Treatment	High	High	High	High	High	High	High	High
Alternative 3 – Connection to City Water	Medium	Medium	High	Medium	High	Low	Low	Low

Notes:

The relative impact is a qualitative assessment of the relative footprint of each alternative, a rating of High for an alternative is assigned if it is at least 70 percent of the maximum footprint, a rating of Medium is assigned if it is between 30 and 70 percent of the maximum footprint, and a rating of Low is assigned if it is less than 30 percent of the maximum footprint.

MMBTU - million British Thermal Unit

NOx - Nitrogen Oxides

SOx - Sulfur Oxides

PM10 - Particulate Matter

GHG - Greenhouse Gases

NA - Not applicable

Table B-2. Sustainability Analysis Results by Activity

Sustainability Analysis for Residential Drinking Water

Naval Auxiliary Landing Field Fentress

Chesapeake, Virginia

Alternative	Activities	GHG Emissions		Total Energy Used		Water Used		NO_x Emissions		SO_x Emissions		PM_{10} Emissions		Accident Risk Fatality		Accident Risk Injury	
		metric ton	Percent of total	MMBTU	Percent of total	gallons	Percent of total	metric ton	Percent of total	metric ton	Percent of total	metric ton	Percent of total		Percent of total		Percent of total
1 - NFA	Material Production	518	61%	2739	42%	NA		4.6E-01	93%	6.1E-01	100%	7.7E-02	95%	NA		NA	
	Transportation-Personnel	13	2%	163	2%	NA		5.4E-03	1%	1.7E-04	0%	7.7E-04	1%	3.7E-04	42%	2.9E-02	42%
	Transportation-Equipment and Materials	94	11%	1222	19%	NA		2.9E-02	6%	5.2E-04	0%	2.6E-03	3%	5.1E-04	58%	4.1E-02	58%
	Equipment Use and Miscellaneous	0	0%	1	0%	1.04E+08	100%	5.5E-04	0%	3.4E-04	0%	9.1E-04	1%	0.0E+00	0%	0.0E+00	0%
	Residual Transport and Disposal	230	27%	2432	37%	NA		0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%
	Total	**855**		**6,557**		**1.04E+08**		**5.0E-01**		**6.2E-01**		**8.1E-02**		**8.7E-04**		**7.0E-02**	
2a - GAC	Material Production	543	56%	2875	35%	NA		1.1E-03	0%	1.1E-03	0%	5.4E-05	0%	NA		NA	
	Transportation-Personnel	13	1%	163	2%	NA		5.4E-03	1%	1.7E-04	0%	7.7E-04	0%	3.7E-04	34%	2.9E-02	34%
	Transportation-Equipment and Materials	131	13%	1708	21%	NA		4.1E-02	7%	7.3E-04	0%	3.7E-03	2%	7.0E-04	66%	5.7E-02	66%
	Equipment Use and Miscellaneous	49	5%	840	10%	1.04E+08	100%	5.3E-02	9%	1.3E-01	17%	7.3E-02	46%	0.0E+00	0%	0.0E+00	0%
	Residual Transport and Disposal	242	25%	2553	31%	NA		4.8E-01	83%	6.4E-01	83%	8.1E-02	51%	0.0E+00	0%	0.0E+00	0%
	Total	**978**		**8,139**		**1.04E+08**		**5.8E-01**		**7.8E-01**		**1.6E-01**		**1.1E-03**		**8.6E-02**	
2b - IX	Material Production	26.3	10%	581	15%	NA		5.3E-02	28%	7.9E-02	32%	8.8E-03	10%	NA		NA	
	Transportation-Personnel	5.9	2%	75	2%	NA		2.5E-03	1%	7.8E-05	0%	3.5E-04	0%	1.7E-04	15%	1.4E-02	15%
	Transportation-Equipment and Materials	172.6	64%	2253	58%	NA		5.4E-02	28%	9.6E-04	0%	4.8E-03	5%	9.4E-04	85%	7.5E-02	85%
	Equipment Use and Miscellaneous	49.3	18%	840	22%	1.04E+08	100%	5.3E-02	28%	1.3E-01	53%	7.3E-02	80%	0.0E+00	0%	0.0E+00	0%
	Residual Transport and Disposal	14.1	5%	149	4%	NA		2.8E-02	15%	3.8E-02	15%	4.7E-03	5%	0.0E+00	0%	0.0E+00	0%
	Total	**268.1**		**3,898**		**1.04E+08**		**1.9E-01**		**2.5E-01**		**9.1E-02**		**1.1E-03**		**8.9E-02**	
2c - RO	Material Production	0	0%	0	0%	NA		0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	NA		NA	
	Transportation-Personnel	6	0%	75	0%	NA		2.5E-03	0%	7.8E-05	0%	3.5E-04	0%	1.7E-04	4%	1.4E-02	4%
	Transportation-Equipment and Materials	16	1%	205	1%	NA		4.9E-03	0%	8.7E-05	0%	4.4E-04	0%	4.3E-05	1%	3.5E-03	1%
	Equipment Use and Miscellaneous	99	5%	1680	6%	1.04E+08	100%	1.1E-01	2%	2.7E-01	9%	1.5E-01	1%	0.0E+00	0%	0.0E+00	0%
	Residual Transport and Disposal	1,677	93%	28102	93%	NA		5.1E+00	98%	2.6E+00	91%	1.4E+01	99%	3.9E-03	95%	3.2E-01	95%
	Total	**1,797**		**30,063**		**1.04E+08**		**5.3E+00**		**2.9E+00**		**1.4E+01**		**4.1E-03**		**3.3E-01**	
3 - City Water	Material Production	476	65%	13,543	92%	NA		1.4E+00	74%	2.4E+00	89%	4.8E-01	39%	NA		NA	
	Transportation-Personnel	3	0%	35	0%	NA		1.2E-03	0%	3.6E-05	0%	1.6E-04	0%	3.9E-05	18%	3.2E-03	7%
	Transportation-Equipment and Materials	9	1%	120	1%	NA		2.9E-03	0%	5.1E-05	0%	2.6E-04	0%	2.1E-05	10%	1.7E-03	4%
	Equipment Use and Miscellaneous	241	33%	1,043	7%	1.04E+08	100%	4.9E-01	26%	2.9E-01	11%	7.6E-01	61%	1.6E-04	72%	3.9E-02	89%
	Residual Transport and Disposal	0	0%	0	0%	NA		0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%
	Total	**729**		**14,741**		**1.04E+08**		**1.9E+00**		**2.7E+00**		**1.2E+00**		**2.2E-04**		**4.4E-02**	

Notes:

MMBTU - million British Thermal Unit

NOx - Nitrogen Oxides

SOx - Sulfur Oxides

PM_{10} - Particulate Matter 10 micrometers or less in diameter

NA - Not Applicable

GHG - Greenhouse Gases

Figure

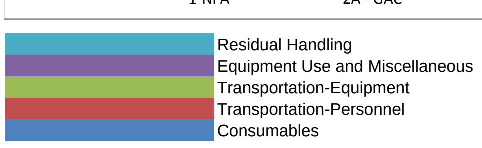


FIGURE B-1
Sustainability Analysis Results
Sustainability Analysis for Residential Drinking Water
Naval Auxiliary Landing Field Fentress
Chesapeake, Virginia

Appendix C
Cost Estimate

Table C-1. Engineer's Cost Estimate for Alternative 1: No Further Action

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Construction Work Plan	Lump Sum	1	$ 5,000.00	$ 5,000.00	Includes draft and final submission.
UFP-SAP	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes scoping plus draft and final submission.
Health and Safety Plan	Lump Sum	1	$ 5,000.00	$ 5,000.00	Includes draft and final submission and AHAs.
Construction Completion Report	Lump Sum	1	$ 5,000.00	$ 5,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 25,000.00**	
Subtotal				***$ 25,000.00***	
Contingency (15%)		15%		$ 3,750.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 2,500.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 31,250.00***	
Performance Bond (2%)		2%		$ 625.00	Industry Average
Subtotal				***$ 31,875.00***	
Project Management (10%)		*10%*		$ 3,187.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 1,912.50	Navy Estimating Guidance.
Construction Oversight (15%)		15%		$ 4,781.25	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 41,756.25**	
Operations and Maintenance (O&M) Years 1-30					
On-base GAC PFAS Sampling (every 2 weeks)	Each	30	$ 28,800.00	$ 864,000.00	24 times per year at 1 location, 3 samples per well plus 1 QC sample per location. Total samples/ year = 72. $275 per sample based on costing of WE7G under CLEAN 8012. 0.5 day per sampling event, 24 sampling events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
On-base GAC Change Out Activities	Each	30	$ 19,200.00	$ 576,000.00	$3200/day - includes 2 man crew and vacuum truck (Calgon verbal, 2018). Assume 2 days per change out, 3 change outs per year.
On-base GAC Materials	Each	30	$ 21,450.00	$ 643,500.00	$2.75/lbs GAC including freight to and from the site (Calgon verbal, 2018). 2600 lbs per changeout, 3 changeouts per year.
Bottled Water Supply	Each	30	$ 4,200.00	$ 126,000.00	$350/month based (APTIM, 2018). 12 change outs per year.
Subtotal				***$ 2,209,500.00***	
Contingency (15%)		15%		$ 331,425.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 220,950.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 331,425.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 37,957.50	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 3,131,257.50**	
Total O&M Cost Per Year				$ 104,375.25	
Total Years of O&M				30	
Discount Rate				2.6%	Office of Management and Budget, Circular A-94 2018.
Total Present Value of O&M Costs				**$ 2,155,758.12**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 2,197,514.37**	
			+50%	$ 3,296,271.56	
			-30%	$ 1,538,260.06	

This is not an offer for construction and/or project execution. Please note, these order of magnitude cost estimates are assumed to represent the actual installed cost within the range of - 30 percent to + 50 percent of the costs indicated. The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor, material costs, and competitive variable factors. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific decisions to help ensure proper project evaluation and adequate funding.

Table C-2. Engineer's Cost Estimate for Alternative 2a: Point of Entry Granular Activated Carbon

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Construction Work Plan	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes draft and final submission.
UFP-SAP	Lump Sum	1	$ 25,000.00	$ 25,000.00	Includes scoping plus draft and final submission.
Health and Safety Plan	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes draft and final submission and AHAs.
Construction Completion Report	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 55,000.00**	
Subtotal				***$ 55,000.00***	
Contingency (15%)		15%		$ 8,250.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 5,500.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 68,750.00***	
Performance Bond (2%)		2%		$ 1,375.00	Industry Average
Subtotal				***$ 70,125.00***	
Project Management (10%)		*10%*		$ 7,012.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 4,207.50	Navy Estimating Guidance.
Construction Oversight (15%)		15%		$ 10,518.75	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 91,863.75**	
Operations and Maintenance (O&M) Years 1-30					
Off-base GAC PFAS Sampling (Monthly -1 well) Quarterly - 6 wells)	Each	30	$ 51,600.00	$ 1,548,000.00	4 times per year at 6 wells, 3 samples per well plus 1 QC sample per well. 12 times per year at 1 well, 3 samples per well plus 1 QC sample per well. Total samples/ year = 144. $275 per sample based on costing of WE7G under CLEAN 8012. 2 days per sampling event, 4 sampling events per year. 1 day for monthly sampling, 8 events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
Off-base GAC Change Out	Each	30	$ 15,500.00	$ 465,000.00	$1,550 per household based on current costs of pilot system GAC changeout (Culligan, 2018). 6 households once a year, 1 household 4 times per year. Includes disposal via regeneration. Includes semiannual replacement of sediment filters.
Off-base Miscellaneous Items Allowance	Each	30	$ 1,250.00	$ 37,500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of miscellaneous items for pilot system installation (Culligan, 2018).
Off-base On call service	Each	30	$ 1,435.00	$ 43,050.00	On call rate for Culligan for pilot tests is $205. Assume 1 service call per household per year.
Off-base UV unit and sediment filter maintenance	Each	30	$ 5,880.00	$ 176,400.00	$840/household for annual maintenance of UV and sediment filter, based on current pilot test (Culligan, 2018). 7 households Includes disposal of used filters.
On-base GAC PFAS Sampling (every 2 weeks)	Each	30	$ 28,800.00	$ 864,000.00	24 times per year at 1 location, 3 samples per well plus 1 QC sample per location. Total samples/ year = 72. $275 per sample based on costing of WE7G under CLEAN 8012. 0.5 day per sampling event, 24 sampling events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
On-base GAC Change Out Activities	Each	30	$ 19,200.00	$ 576,000.00	$3200/day - includes 2 man crew and vacuum truck (Calgon verbal, 2018). Assume 2 days per change out, 3 change outs per year.
On-base GAC Materials	Each	30	$ 21,450.00	$ 643,500.00	$2.75/lbs GAC including freight to and from the site (Calgon verbal, 2018). 2600 lbs per changeout, 3 changeouts per year.
Subtotal				***$ 4,353,450.00***	
Contingency (15%)		15%		$ 653,017.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 435,345.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 653,017.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 36,206.25	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 6,131,036.25**	
Total O&M Cost Per Year				$ 204,367.88	
Total Years of O&M				30	
Discount Rate				2.6%	Office of Management and Budget, Circular A-94 2018.
Total Present Value of O&M Costs				**$ 4,220,997.85**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 4,312,861.60**	
			+50%	$ 6,469,292.40	
			-30%	$ 3,019,003.12	

This is not an offer for construction and/or project execution. Please note, these order of magnitude cost estimates are assumed to represent the actual installed cost within the range of - 30 percent to + 50 percent of the costs indicated. The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor, material costs, and competitive variable factors. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific decisions to help ensure proper project evaluation and adequate funding.

Table C-3. Engineer's Cost Estimate for Alternative 2b: Point of Entry Ion Exchange

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Construction Work Plan	Lump Sum	1	$ 40,000.00	$ 40,000.00	Includes draft and final submission.
UFP-SAP	Lump Sum	1	$ 35,000.00	$ 35,000.00	Includes scoping plus draft and final submission.
Health and Safety Plan	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes draft and final submission and AHAs.
Construction Completion Report	Lump Sum	1	$ 20,000.00	$ 20,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 105,000.00**	
Site Preparation					
Mobilization/Demobilization	Each	8	$ 1,000.00	$ 8,000.00	Engineer Estimate
Site Visit and Document of Existing System	Each	8	$ 1,500.00	$ 12,000.00	Engineer Estimate
Water Quality Sampling	Each	8	$ 143.00	$ 1,144.00	Based on costs from Navy Laboratory BOA for TDS ($12), sulfate ($15), nitrate ($15), bicarbonate ($15), chloride ($14), TOC ($40), TSS ($12), and water quality parameters. Free chlorine and water quality parameters tested with field test kits ($20). Total is $143/sample locations. Costs for labor to perform sampling are included in the site visit.
Site Preparation Total				**$ 21,144.00**	
System Installation					
Off-Base Ion Exchange System with IX resins included	Each	7	$ 6,000.00	$ 42,000.00	2 vessels per system, 10" dia by 54" FRP Tanks, preloaded with IX resin. Includes backwash at set up. Estimate from Barry Zvibleman, OEC (2018).
Off-Base Installation of IX systems by certified plumber	Each	7	$ 1,582.00	$ 11,074.00	Based on costs for installation of the pilot systems (Culligan, 2018). Assumes 30% of the total installation costs, since majority of equipment will stay in place from the pilot systems. Includes installation of equipment, and sterilization of lines.
Off-base Miscellaneous Items Allowance	Each	7	$ 1,250.00	$ 8,750.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of miscellaneous items for pilot system installation (Culligan, 2018).
On-Base Ion Exchange System with IX resins included	Each	1	$ 12,000.00	$ 12,000.00	4 vessels per system, 10" die by 54" FRP Tanks, preloaded with IX resin. Includes backwash at set up. Estimate from Barry Zvibleman, OEC (2018).
On-Base Installation of IX systems by certified plumber	Each	1	$ 3,200.00	$ 3,200.00	Based on costs for installation of the pilot systems (Culligan, 2018). Assumes 30% of the total installation costs, since majority of equipment will stay in place from the on-base treatment system. Includes installation of equipment, and sterilization of lines.
On-base Miscellaneous Items Allowance	Each	1	$ 2,500.00	$ 2,500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of miscellaneous items for pilot system installation (Culligan, 2018).
System Installation Total				**$ 79,524.00**	
Subtotal				***$ 205,668.00***	
Contingency (15%)		15%		$ 30,850.20	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 20,566.80	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 257,085.00***	
Performance Bond (2%)		2%		$ 5,141.70	Industry Average
Subtotal				***$ 262,226.70***	
Project Management (8%)		*8%*		$ 20,978.14	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 15,733.60	Navy Estimating Guidance.
Construction Oversight (10%)		10%		$ 26,222.67	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 325,161.11**	
Operations and Maintenance (O&M) Years 1-30					
Off-base Quarterly Sampling for PFAS	Each	30	$ 36,800.00	$ 1,104,000.00	4 times per year, 3 samples per household plus 1 QC sample per household, 7 households. Total samples/ year = 112. $275 per sample based on costing of WE7G under CLEAN 8012. 2 days per sampling event, 4 sampling events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
Off-base Resin Change Out	Each	15	$ 7,875.00	$ 118,125.00	$375/CF of resin (estimate from Purolite, including transportation costs). Total CF required is 3 CF per house, 7 house holds = 21 CF of resin.
Off-base Used Resin Disposal	Each	15	$ 2,454.00	$ 36,810.00	21 CF of used resin per changeout event. $200 for mobilization/demobilization per event. $175 per event per household for profiling. $7/gallon for incineration based on CERCLA rates, $49/CF of material disposed.
Off-base Miscellaneous Items Allowance	Each	30	$ 1,250.00	$ 37,500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of miscellaneous items for pilot system installation (Culligan, 2018).
Off-base On call service	Each	30	$ 1,435.00	$ 43,050.00	On call rate for Culligan for pilot tests is $205. Assume 1 service call per household per year.
Off-base UV unit and sediment filter maintenance	Each	30	$ 8,050.00	$ 241,500.00	$840/household for annual maintenance of UV and sediment filter, based on current pilot test (Culligan, 2018). Assume an additional $310 per year for semiannual maintenance and disposal of sediment filter. 7 households. Includes disposal of used filters.

Table C-3. Engineer's Cost Estimate for Alternative 2b: Point of Entry Ion Exchange

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
On-base Monthly Sampling for PFAS	Each	30	$ 24,300.00	$ 729,000.00	12 times per year, 5 samples plus 1 QC sample. Total samples/year = 72. $275 per sample based on costing of WE7G under CLEAN 8012. 0.5 days per sampling event, 12 sampling events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
On-base Resin Change Out	Each	30	$ 3,000.00	$ 90,000.00	$750/CF of resin (estimate from Purolite, including transportation costs). Total CF required is 6 CF. Change out resin quarterly.
On-base Used Resin Disposal	Each	30	$ 2,151.00	$ 64,530.00	6 CF of used resin per changeout event. Quarterly change out events $200 for mobilization/demobilization per event. $175 per year for profiling. $7/gallon for incineration based on CERCLA rates, $49/CF of material disposed.
Subtotal				***$ 2,464,515.00***	
Contingency (15%)		15%		$ 369,677.25	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 246,451.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 369,677.25	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 21,862.28	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 3,472,183.28**	
Total O&M Cost Per Year				$ 115,739.44	
Total Years of O&M				30	
Discount Rate				2.6%	Office of Management and Budget, Circular A-94 2018.
Total Present Value of O&M Costs				***$ 2,390,473.25***	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 2,715,634.36**	
			+50%	$ 4,073,451.54	
			-30%	$ 1,900,944.05	

This is not an offer for construction and/or project execution. Please note, these order of magnitude cost estimates are assumed to represent the actual installed cost within the range of - 30 percent to + 50 percent of the costs indicated. The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor, material costs, and competitive variable factors. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific decisions to help ensure proper project evaluation and adequate funding.

Table C-4. Engineer's Cost Estimate for Alternative 2c: Point of Entry Reverse Osmosis

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Construction Work Plan	Lump Sum	1	$ 50,000.00	$ 50,000.00	Includes draft and final submission.
UFP-SAP	Lump Sum	1	$ 35,000.00	$ 35,000.00	Includes scoping plus draft and final submission.
Health and Safety Plan	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes draft and final submission and AHAs.
Construction Completion Report	Lump Sum	1	$ 30,000.00	$ 30,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 125,000.00**	
Site Preparation					
Mobilization/Demobilization	Each	8	$ 2,000.00	$ 16,000.00	Engineer Estimate
Site Visit and Document of Existing System	Each	8	$ 1,500.00	$ 12,000.00	Engineer Estimate
Water Quality Sampling	Each	8	$ 279.00	$ 1,500.00	Based on costs from Navy Laboratory BOA for metals ($95) (barium, strontium, iron, manganese, magnesium, calcium), ions ($55) (sodium, potassium, chloride) bicarbonate (alkalinity) ($15), sulfate ($15), nitrate ($15), TDS ($12), TOC ($40), TSS ($12). Free chlorine and water quality parameters tested with field test kits ($20). Costs for labor to perform sampling are included in the site visit.
Site Preparation Total				**$ 29,500.00**	
System Installation					
Treatment Shed to House Tanks (14' x 24')	Each	7	$ 6,220.00	$ 43,540.00	https://www.woodtex.com/sheds/original-storage-shed/. Includes 7 for off-base systems only.
Concrete Pad Installation for Treatment Shed	CY	31	$ 500.00	$ 15,500.00	Costs for concrete pad installation to place treatment shed on. 2' x 16' x 26' installation. Includes 7 for Off-base properties only.
Electrical Hook Up for Treatment Shed	Each	7	$ 900.00	$ 6,300.00	Based on electrical modification costs during installation of the pilot studies (Culligan, 2018). Includes 7 for Off-base properties only.
5-micron inline sediment filter	Each	11	$ 150.00	$ 1,650.00	http://www.purewaterproducts.com/products/wh101 Includes 7 for off-base systems and 4 for the on-base system.
Water Softener (40,000 grain)	Each	7	$ 600.00	$ 4,200.00	http://www.purewaterproducts.com/products/bw403 Includes 3 for off-base systems and 4 for the on-base system.
Prefabricated RO system (600 GPD)	Each	7	$ 2,268.00	$ 15,876.00	http://www.purewaterproducts.com/watts-r12-whole-house-ro. Includes 7 for off-base systems.
Prefabricated RO system (2500 GPD)	Each	4	$ 3,315.00	$ 13,260.00	http://www.filterwater.com/pc-382-19-commercial-reverse-osmosis-system-2500-gpd.aspx Includes the 4 on-base treatment trains
RO System Installation	Each	11	$ 5,275.00	$ 58,025.00	Based on costs for installation of the pilot systems (Culligan, 2018). Includes installation of equipment, and sterilization of lines. Includes 7 off-base systems and 4 for the on-base system.
Initial RO Membranes (DowFilmtech TW30-2540) Off-base	Each	7	$ 600.00	$ 4,200.00	$200/membrane, 3 membranes per household. Includes delivery. http://www.filterwater.com/
Initial RO Membranes (DowFilmtech TW30-4040) On-Base	Each	4	$ 1,120.00	$ 4,480.00	$280/membrane, 3 membranes per treatment train. Includes delivery. http://www.filterwater.com/
Calcite pH adjustment Filter	Each	11	$ 700.00	$ 7,700.00	http://www.purewaterproducts.com/products/bw002 Includes 7 for off-base systems and 4 for the on-base system.
500-gallon pressured tank	Each	7	$ 2,595.00	$ 18,165.00	http://www.purewaterproducts.com/products/ro914 Includes 7 for off-base systems only
3,000 gallon unpressurized storage tank	Each	7	$ 1,175.95	$ 8,231.65	https://www.rainharvest.com/norwesco-3000-gallon-above-ground-water-tank-102-inch.asp. Includes 7 for off-base systems only
40,000 gallon unpressurized storage tank	Each	1	$ 36,000.00	$ 36,000.00	http://www.plastic-mart.com/category/109/plastic-storage-tanks. Cost based on 2 x 20,000 gallon storage tanks.
Miscellaneous Items Allowance	Each	11	$ 2,500.00	$ 27,500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 50% of costs of miscellaneous items for pilot system installation (Culligan, 2018).
System Installation Total				**$ 264,627.65**	
Subtotal				***$ 419,127.65***	
Contingency (15%)		15%		$ 62,869.15	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 41,912.77	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 523,909.56***	
Performance Bond (2%)		2%		$ 10,478.19	Industry Average
Subtotal				***$ 534,387.75***	
Project Management (8%)		*8%*		$ 42,751.02	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 32,063.27	Navy Estimating Guidance.
Construction Oversight (10%)		10%		$ 53,438.78	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 662,640.81**	
Operations and Maintenance (O&M) Years 1-30					
Semiannual Sampling for PFAS (off-base and on-base)	Each	30	$ 22,650.00	$ 679,500.00	2 times per year, 2 samples per household plus 1 QC sample per household, 7 households. 2 samples per treatment train plus 1 QC sample, 4 treatment trains. Total samples/ year = 66. $275 per sample based on costing of WE7G under CLEAN 8012. 3 days per sampling event, 2 sampling events per year. Average rate of field staff is $75/hr.
RO Change Out - Off-base	Each	6	$ 4,200.00	$ 25,200.00	$200/membrane, 3 membranes per household, 7 households. Includes delivery. http://www.filterwater.com/
RO Change Out - On-base	Each	6	$ 3,360.00	$ 20,160.00	$280/membrane, 3 membranes per treatment train, 4 treatment trains. Includes delivery. http://www.filterwater.com/

Table C-4. Engineer's Cost Estimate for Alternative 2c: Point of Entry Reverse Osmosis
Engineered Evaluation and Cost Estimate for Residential Drinking Water
NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Used Resin Disposal	Each	6	$ 1,894.00	$ 11,364.00	6 CF of used membranes per changeout event. $200 for mobilization/demobilization per event. $175 per event per household and on-base for profiling. $7/gallon for incineration based on CERCLA rates, $49/CF of material disposed.
Disposal of Reject	Each	30	$ 1,576,600.00	$ 47,298,000.00	2,250 gallons per month per household. 7 households. 35,000 gallons per month for on-base system. 224,000 gallons per year to be disposed of. $600 for mobilization/demobilization per event, 12 events per year. $175 per year per household plus on-base for profiling. $7/gallon for incineration based on CERCLA rates.
Calcite filter and Water softener annual maintenance	Each	30	$ 1,650.00	$ 49,500.00	1.5 CF per container, 7 containers off-base, 4 containers on-base. $50/0.5 CF including shipping "https://www.freshwatersystems.com/p-764-calcite-ph-neutralizer-12-cu-ft-ups-box.aspx"
Off-base Miscellaneous Items Allowance	Each	30	$ 1,250.00	$ 37,500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of miscellaneous items for pilot system installation (Culligan, 2018).
Off-base On call Service	Each	30	$ 1,435.00	$ 43,050.00	On call rate for Culligan for pilot tests is $205. Assume 1 service call per household per year.
Off-base UV unit and sediment filter maintenance	Each	30	$ 8,050.00	$ 241,500.00	$840/household for annual maintenance of UV and sediment filter, based on current pilot test (Culligan, 2018). Assume an additional $310 per year for semiannual maintenance and disposal of sediment filter. 7 households. Includes disposal of used filters.
Subtotal				***$ 48,405,774.00***	
Contingency (15%)		15%		$ 7,260,866.10	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 4,840,577.40	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 7,260,866.10	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 1,196,554.35	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 68,964,637.95**	
Total O&M Cost Per Year				$ 2,298,821.27	
Total Years of O&M				30	
Discount Rate				2.6%	Office of Management and Budget, Circular A-94 2018.
Total Present Value of O&M Costs				***$ 47,479,671.76***	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 48,142,312.57**	
			+50%	$ 72,213,468.86	
			-30%	$ 33,699,618.80	

This is not an offer for construction and/or project execution. Please note, these order of magnitude cost estimates are assumed to represent the actual installed cost within the range of - 30 percent to + 50 percent of the costs indicated. The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor, material costs, and competitive variable factors. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific decisions to help ensure proper project evaluation and adequate funding.

Table C-5. Engineer's Cost Estimate for Alternative 3: City Water Connection

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Construction Work Plan	Lump Sum	1	$ 50,000.00	$ 50,000.00	Includes draft and final submission.
UFP-SAP	Lump Sum	1	$ 35,000.00	$ 35,000.00	Includes scoping plus draft and final submission.
Health and Safety Plan	Lump Sum	1	$ 20,000.00	$ 20,000.00	Includes draft and final submission and AHAs.
Construction Completion Report	Lump Sum	1	$ 30,000.00	$ 30,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 135,000.00**	
Site Preparation					
Mobilization/Demobilization	Lump Sum	1	$ 5,000.00	$ 5,000.00	Engineer Estimate
Demand Calculations and Hydraulic Modeling	Lump Sum	1	$ 20,000.00	$ 20,000.00	Engineer Estimate
Site Visit and Document of Existing System	Each	8	$ 1,500.00	$ 12,000.00	Engineer Estimate
Utility Locates	Each	8	$ 1,500.00	$ 12,000.00	Engineer Estimate
Erosion and Sediment Controls	Lump Sum	1	$ 15,000.00	$ 15,000.00	Engineer Estimate
Dust Control	Lump Sum	1	$ 10,000.00	$ 10,000.00	Engineer Estimate
Vegetative Clearing	Lump Sum	1	$ 15,000.00	$ 15,000.00	Engineer Estimate
City of Chesapeake Coordination	Lump Sum	1	$ 10,000.00	$ 10,000.00	Engineer Estimate
Site Preparation Total				**$ 99,000.00**	
System Installation					
Water Main Piping	LF	14000	$ 123.14	$ 1,723,960.00	16-inch diameter class 50 ductile iron pipe, mechanical joint. RS Means (2018) - 33 14 13.15 2140 (material).
Water Main Piping, Mechanical Joints (@ 18')	Each	780	$ 380.00	$ 296,400.00	16-inch diameter class 50 ductile iron pipe, mechanical joint. RS Means (2018) - 33 14 13.15 8770
Water Main Service Valves, Butterfly, Mech. Joint	Each	18	$ 5,500.00	$ 99,000.00	Service valves for the 16-inch water main. RS Means (2018) - 33 12 16.10 3440
Fire Hydrants, 4.5" valve, 5' deep	Each	28	$ 2,725.00	$ 76,300.00	Fire Hydrants along the main water line. RS Means (2018) - 33 12 19.10 1220
Water Main Excavation	CY	8000	$ 12.19	$ 97,520.00	Installed via trenching 3 feet wide, 5 feet deep. RS Means (2018) -G 1030 805 1420 75%.
Installation of Water Main	LF	14000	$ 38.86	$ 544,040.00	RS Means (2018) - 33 14 13.15 2140 (labor & equipment)
Backfill of Water Main Excavation	CY	7250	$ 4.06	$ 29,435.00	Use existing material from excavation, Placed to 95 % maximum density. RS Means (2018) - G 1030 805 1420 25%
Disposal of unused excavated soils	CY	750	$ 112.00	$ 84,000.00	Non-hazardous waste. RS Means (2018) - 1 CY @ 1.6 tons/cy x $70/ton
Top Soil	CY	1089	$ 45.00	$ 49,005.00	6 inch placement on all disturbed areas. Allowance
Hydro Seed, with mulch & fertilizer	Acres	1.35	$ 3,027.42	$ 4,087.02	Utility mix, 7#/MSF RS Means (2018) - 32 92 19.14 5400 ($69.50/msf)
Revegetation Matting	Acres	0.675	$ 4,017.20	$ 2,711.61	Paper, biodegradable mesh. RS Means (2018) - 31 25 14.16 0070 (0.83/sy)
Asphalt (6" stone base, 2" binder course, 2" topping)	SF	6534	$ 3.15	$ 20,582.10	Driveways and Side roads. RS Means (2018) - 32 12 16.14 0025
Service Lines	LF	3700	$ 15.59	$ 57,683.00	1-inch of 2-inch type k copper. RS Means (2018) - 22 11 13.23 1200 (material)
Service Line Meters (1" bronze, threaded)	Each	8	$ 104.00	$ 832.00	5/8 inch. RS Means (2018) - 22 11 19.38 2060
Service Lines meter boxes, valves, flow meter and back flow prevention	Each	8	$ 2,000.00	$ 16,000.00	Allowance
Header Excavation	CY	820	$ 0.69	$ 565.80	Installed via trenching 2 feet wide, 3 feet deep. RS Means (2018) - G 1030 805 1320 (75%)
Installation of Headers	LF	3700	$ 8.02	$ 29,674.00	RS Means (2018) - 22 11 13.23 1200 (labor & equipment)
Backfill of Header Excavation	CY	820	$ 0.23	$ 188.60	Use existing material from excavation, Placed to 95 % maximum density. RS Means (2018) - G 1030 805 1320 (25%)
Top Soil	CY	275	$ 45.00	$ 12,375.00	6 inch placement on all disturbed areas. Allowance
Hydro Seed, with mulch & fertilizer	SF	13320	$ 0.07	$ 925.74	Utility mix, 7#/MSF. RS Means (2018) - 32 92 19.14 5400 ($69.50/msf)
Revegetation Matting	SF	13320	$ 0.09	$ 1,228.10	Paper, biodegradable mesh. RS Means (2018) - 31 25 14.16 0070 (0.83/sy)
Asphalt (replacement over trench, 6" thick)	SF	1480	$ 9.72	$ 14,385.60	Service lines that cross Mt. Pleasant Road. RS Means (2018) - 32 12 16.13 1080 ($87.50/sy)
Pressure Testing and Chlorination of lines	Lump Sum	1	$ 30,000.00	$ 30,000.00	Engineer Estimate
System Installation Total				**$ 3,190,898.57**	
Subtotal				***$ 3,424,898.57***	

Table C-5. Engineer's Cost Estimate for Alternative 3: City Water Connection

Engineered Evaluation and Cost Estimate for Residential Drinking Water

NALF Fentress, Chesapeake, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Contingency (15%)		15%		$ 513,734.79	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 342,489.86	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 4,281,123.21***	
Performance Bond (2%)		2%		$ 85,622.46	Industry Average
Subtotal				***$ 4,366,745.68***	
Project Management (6%)		*6%*		$ 262,004.74	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 262,004.74	Navy Estimating Guidance.
Construction Oversight (8%)		8%		$ 349,339.65	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 5,240,094.81**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 5,240,094.81**	
			+50%	$ 7,860,142.22	
			-30%	$ 3,668,066.37	

This is not an offer for construction and/or project execution. Please note, these order of magnitude cost estimates are assumed to represent the actual installed cost within the range of - 30 percent to + 50 percent of the costs indicated. The cost estimate has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor, material costs, and competitive variable factors. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific decisions to help ensure proper project evaluation and adequate funding.