Mid-Atlantic
Norfolk, Virginia

Final

Engineering Evaluation and Cost Analysis for Private Drinking Water

Naval Air Station Oceana
Virginia Beach, Virginia

April 2020

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Virginia Beach, Virginia
Contract N62470-16-D-9000
CTO WE14

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 off-Base private drinking water near Naval Air Station (NAS) Oceana, in Virginia Beach, Virginia.

The PFAS Basewide Site Inspection (SI) fieldwork was completed at NAS Oceana in late 2016 to spring 2017 and involved the following:

- Sampling monitoring wells in likely source areas to determine the presence of perfluorooctanoic acid/ perfluorooctane sulfonic acid (PFOA/PFOS) at levels above the United States Environmental Protection Agency (USEPA) Lifetime Health Advisory
- Confirming suspected source areas
- Determining whether PFOA/PFOS have migrated offsite and are present at levels exceeding the USEPA Lifetime Health Advisory in offsite private drinking water.

The SI included collection of groundwater samples from monitoring wells at Solid Waste Management Unit (SWMU) 11, SWMU 26, the Aircraft Hangars and Maintenance Buildings, the 1996 Crash Site, and Jet Test Cell area. Samples of perfluorobutane sulfonic acid (PFBS) were also taken and levels were found to be below the regional screening level at all monitoring wells sampled. As a result of on-Base exceedances of the United States Environmental Protection Agency USEPA Lifetime Health Advisory of 70 parts per trillion (ppt)[1] for PFOA/PFOS, off-Base parcels that use groundwater as drinking water were identified within a 1-mile radius of exceedances. In total, nine samples have been collected from eight parcels.

- Drinking water at one parcel had detections of PFOA and PFOS (combined) above the USEPA Lifetime Health Advisory
- Drinking water at two parcels had detections of PFOA and PFOS below the USEPA Lifetime Health Advisory
- Drinking water at one parcel had one well with detections of PFOA and PFOS below the USEPA Lifetime Health Advisory and one well with no detections of PFOA or PFOS
- Drinking water at four parcels did not have detections of PFOA or PFOS.

The well that had an exceedance of the USEPA Lifetime Health Advisory for PFOA/PFOS is suspected to be shallow and in the Surficial/Columbia aquifer. In accordance with the SWMU 11 Action Memorandum (Navy, 2019), bottled water has been, and continues to be, provided to the off-Base parcel that uses non-City-provided groundwater as drinking water with exceedances of the USEPA Lifetime Health Advisory for PFOA/PFOS.

This EE/CA evaluates alternatives to address potential current and future exposure to drinking water at the off-Base property with PFOA/PFOS at levels greater than the USEPA Lifetime Health Advisory. Alternatives presented are intended to provide the property with a long-term drinking water solution.

The EE/CA identifies the objective of the NTCRA, identifies response 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 and future human health receptors from ingestion of PFOA and PFOS at levels above the USEPA Lifetime Health Advisory in groundwater used as drinking water.

[1] Parts per trillion (ppt) is equivalent to nanograms per liter (ng/L).

In order to meet the RAO, the preliminary remediation goal is to reduce receptor exposure to PFOA and PFOS to a cumulative concentration of less than the USEPA Lifetime Health Advisory of 70 ppt 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 USEPA Lifetime Health Advisory.
2. Point of Entry Treatment: This alternative would address PFOA and PFOS at the private property with drinking water concentrations greater than the USEPA Lifetime Health Advisory before the potable water supply enters the distribution piping for the building. The following three treatment technologies are being considered under this alternative:
    a. Granular Activated Carbon (GAC) Treatment – This action would include the installation of GAC vessels, implemented in series, for PFOA and PFOS removal.
    b. Ion Exchange (IX) Treatment – Installation of IX vessels for PFOA and PFOS removal. 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 PFOS removal. The 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 PFOS impacts by installing a service line from the City water main to the privately-owned building with drinking water concentrations greater than the USEPA Lifetime Health Advisory.

Alternative 1 does not meet the objective of the removal action for the off-Base homes because PFAS-containing 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 remedial action is determined to be necessary for the off-Base groundwater in the future, Alternative 1 would not contribute to its effective performance; therefore, it would not meet the requirement of the NCP. Alternative 3 is considered the most effective because it eliminates groundwater with PFOA/PFOS concentrations exceeding the USEPA Lifetime Health Advisory as the source of drinking water at the site. Alternatives 2a through 2c are comparable in effectiveness, but effectiveness is less permanent than under Alternative 3, since Alternatives 2a through 2c rely on continued media or membrane change-out.

Alternative 1 is considered the easiest to implement because the system is already in place; however, the alternative has similar post-removal site controls (PRSCs) requirements to Alternative 2a and elevated PRSCs requirements as compared to Alternatives 2b and 3. Alternatives 2a and 2b are moderately easy to implement. Alternative 2c is moderately difficult to implement because it is a more extensive system compared to Alternatives 2a and 2b and has elevated PRSCs requirements associated with monthly disposal of reject water from the systems. Alternative 3 is easier to implement than Alternatives 2a through 2c. Even though it requires earth-moving equipment, access to rights-of-way, and coordination with the City of Virginia Beach, it does not require any PRSCs.

Alternatives 1 and 3 are the least expensive alternatives, and Alternative 2c is the most expensive alternative. 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 NAS Oceana 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.

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Acronyms and Abbreviations

AFFF	aqueous film-forming foam
ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
EE/CA	Engineering Evaluation/Cost Analysis
GAC	granular activated carbon
GHG	greenhouse gas
IX	ion exchange
NAS	Naval Air Station
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
ORP	oxidation-reduction potential
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutane sulfonic acid
PFHpA	perfluoroheptanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
PIL	project indicator limit
PM_{10}	particulate matter 10 micrometers or less in diameter
POE	point of entry
ppt	parts per trillion
PRG	preliminary remediation goal
PRSC	post-removal site control
QSM	Quality Systems Manual
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
SWMU	solid waste management unit
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UCMR3	Third Unregulated Contaminant Monitoring Rule
USEPA	United States Environmental Protection Agency

UV	ultraviolet
VDEQ	Virginia Department of Environmental Quality

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 off-Base private drinking water near Naval Air Station (NAS) Oceana, in Virginia Beach, 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 WE14.

This EE/CA will evaluate alternatives to provide a long-term solution to protect current and future human health receptors from ingestion of groundwater used as drinking water at the off-Base property containing levels of PFOA and PFOS (combined) at levels greater than the United States Environmental Protection Agency (USEPA) Lifetime Health Advisory. Potential risks associated with future use of groundwater and other media will be evaluated, as appropriate, as separate investigations and actions.

1.1 Regulatory Background

This document is issued by the Department of the Navy (Navy), the lead agency responsible for environmental remediation at NAS Oceana, 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 of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA).

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, 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 off-Base private drinking water well, to protect current and future human health receptors from ingestion of groundwater used as drinking water at the off-Base property with PFOA and PFOS (combined) at levels greater than the USEPA 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 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. The public review and comment period are 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 and future human health receptors from ingestion of groundwater used as drinking water at the off-Base property containing PFOA and PFOS (combined) at levels greater than the USEPA Lifetime Health Advisory. Potential risks associated with future use of groundwater and other media will be evaluated, as appropriate, as separate investigations and actions.

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
- **Alternative 2a**—Point of Entry Treatment – Granular Activated Carbon (GAC) Treatment
- **Alternative 2b**—Point of Entry Treatment – Ion Exchange (IX) Treatment
- **Alternative 2c**—Point of Entry Treatment – Reverse Osmosis (RO) Treatment
- **Alternative 3**—Connection to City Water

Site Characterization

2.1 Site Background – NAS Oceana

NAS Oceana (**Figure 2-1**) is in Virginia Beach, Virginia, and was established in 1943 as a small auxiliary airfield. Since 1943, NAS Oceana has grown to more than 16 times its original size and is now a 6,000-acre master jet base supporting more than 9,100 Navy personnel and 11,000 dependents. The mission of NAS Oceana is to provide the personnel, operations, maintenance, and training facilities to ensure that fighter and attack squadrons on aircraft carriers of the U.S. Atlantic Fleet are ready for deployment.

2.2 Summary of Previous Investigations

In May 2012, USEPA issued the Third Unregulated Contaminant Monitoring Rule (UCMR3). 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, at the time of UCMR 3 sampling, the USEPA had issued provisional health advisory levels for only two, PFOA and PFOS. USEPA also published toxicity values for one other contaminant, 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 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 of the drinking water source were required to sample their finished drinking water by December 2015. Additionally, installations with known releases of PFAS-containing substances, such as aqueous film-forming foam (AFFF), used for firefighting, were to evaluate PFAS releases, including potential migration offsite. In May 2016, USEPA Office of Water issued updated drinking water Lifetime Health Advisory levels for PFOA and PFOS. The USEPA Lifetime Health Advisory level is 70 parts per trillion (ppt)[2] for PFOA and 70 ppt for PFOS. When both constituents are detected, the combined concentration is compared to 70 ppt. NAS Oceana was identified as a site requiring PFAS sampling of groundwater based on the June 20, 2016 policy because of the use of AFFF in several portions of the facility and the presence of off-Base private drinking water wells located within one-mile of the facility.

The PFAS Basewide SI fieldwork was completed in late 2016 to spring 2017 and involved sampling monitoring wells in likely source areas to determine the presence of PFOA/PFOS at levels posing potentially unacceptable risks, confirming suspected source areas, and determining whether PFOA/PFOS have migrated offsite and are present at levels exceeding the USEPA Lifetime Health Advisory in offsite private drinking water. The SI included collection of groundwater samples from monitoring wells at SWMU 11, SWMU 26, the Aircraft Hangars and Maintenance Buildings, the 1996 Crash Site, and Jet Test Cell area. PFBS levels were found to be below the regional screening level (RSL), 400,000 ppt based on a hazard quotient of 1, at all monitoring wells sampled. As a result of on-Base exceedances of the USEPA Lifetime Health Advisory of 70 (ppt) for PFOA/PFOS, off-Base parcels that use groundwater as drinking water were identified within a 1-mile radius of exceedances and parcel owners were offered voluntary drinking water sampling. In total, nine wells have been sampled from eight parcels. Drinking water at one parcel had detections of PFOA and PFOS (combined) above the USEPA Lifetime Health Advisory, two parcels had detections of PFOA and PFOS below the USEPA Lifetime Health Advisory, one parcel had one well with detections of PFOA and PFOS below the USEPA Lifetime Health Advisory and one well with no detections of PFOA or PFOS, and four parcels did not have detections of PFOA or PFOS. The well that provides water to the parcel with detections of PFOA and PFOS (combined) above the USEPA Lifetime Health Advisory is

[2] Parts per trillion (ppt) is equivalent to nanograms per liter (ng/L).

suspected to be shallow and in the Surficial/Columbia aquifer. In accordance with the SWMU 11 Action Memorandum (Navy, 2019), bottled water has been, and continues to be, provided to the off-Base parcel that uses non-City-provided groundwater as drinking water with exceedances of the USEPA Lifetime Health Advisory for PFOA/PFOS. The results of the SI are summarized in the *Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report* (CH2M, 2018).

2.3 Conceptual Site Model

A remedial investigation has not been completed for PFAS at NAS Oceana; 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 off-Base private drinking water well with an exceedance of the USEPA Lifetime Health Advisory.

2.3.1 Geology

The subsurface geology relevant to environmental investigations at NAS Oceana consists of three stratigraphic units. The uppermost unit is a 4- to 8-foot-thick unit of fine sediments, mainly silty clays and silty sands, which is underlain by a 15- to 20-foot layer of poorly graded fine to medium sand with some silty lenses. The two units correspond to the Columbia Group Sediments.

Underlying the Columbia Group is the Yorktown Formation, which makes up the uppermost portion of the Chesapeake Group. Shells and shell hash indicative of the top of the Yorktown Formation have been typically encountered at approximately 25 feet below ground surface.

2.3.2 Hydrogeology

Groundwater at NAS Oceana is generally within 4 to 10 feet of the ground surface. The surficial hydrogeologic unit consists of the Surficial/Columbia aquifer which extends to a depth of approximately 17 to 30 feet below ground surface at the installation. The Yorktown-Eastover aquifer underlies this unit. No monitoring wells or water supply wells at the Base have been installed to determine the total depth of the Yorktown-Eastover aquifer, but the approximate thickness of the unit is 100 feet based on *The Virginia Coastal Plain Hydrogeological Framework* (USGS, 2006).

Basewide groundwater flow at NAS Oceana is generally southwest in the southern half of the facility, to the northeast in the northern half, and to the west-northwest in the eastern portion of the Base. However, flow direction in the Surficial/Columbia aquifer is generally toward surface water bodies and drainage ditches. Therefore, the flow direction is highly variable due to complex drainage patterns. Based on the limited data set for monitoring wells currently installed in the Yorktown aquifer, the Yorktown aquifer appears to follow the flow patterns of the Surficial/Columbia aquifer with flow to the north at the northern half of the facility and to the southwest within the southern half of the facility.

2.3.3 Nature and Extent of Contamination

The off-Base private drinking water well was sampled in May and October 2018. The concentration of total PFOA and PFOS in the off-Base private drinking water well was 67.9 ppt in May 2018 and 130 ppt in October 2018. The affected property is located to the north of NAS Oceana along Southern Boulevard and is considered downgradient of NAS Oceana based on the groundwater flow in the northern half of NAS Oceana which is to the northeast within the Surficial/Columbia aquifer.

2.4 Risk Assessment Summary

To date, no risk assessment has been performed for the parcel being addressed in this EE/CA. However, a screening-level risk assessment has been performed for the off-base parcels sampled as part of the SI, in accordance with current Navy policy on PFAS (NAVFAC, 2017). This screening-level risk assessment indicated potable use of groundwater at any of the residences adjacent to the Base, where a potable well was sampled, would not result in potential unacceptable human health risks associated with PFAS (CH2M, 2018). However, one parcel was resampled following the screening-level risk assessment because the original detection was very close to the Lifetime Health Advisory level and the confirmation sample had detections of PFOA and PFOS (combined) above the USEPA Lifetime Health Advisory. Additionally, for those parcels with PFAS not detected at levels above the USEPA Lifetime Health Advisory, groundwater will continue to be used as a drinking water source unless measures are taken to provide an alternate water supply. This EE/CA only addresses human exposure to PFOA and PFOS above the USEPA Lifetime Health Advisory in off-Base drinking water at one parcel; other exposure pathways will be evaluated and addressed, as necessary, as part of other actions.

2.5 Development of Cleanup Goal

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

2.6 Determination of Removal Action Area

The off-Base private drinking water well with exceedances of the USEPA Lifetime Health Advisory is located on a commercial property to the north of NAS Oceana. The removal action area is the private drinking water well system present at the off-Base private property.

\\brooksidefiles\GIS_SHARE\ENBG\00_Proj\N\Navy\CLEAN\MIDLANT\NASOceana\MapFiles\395094_EECA\Figure 2-1 - Installation Location Map.mxd4/1/2019ce075706

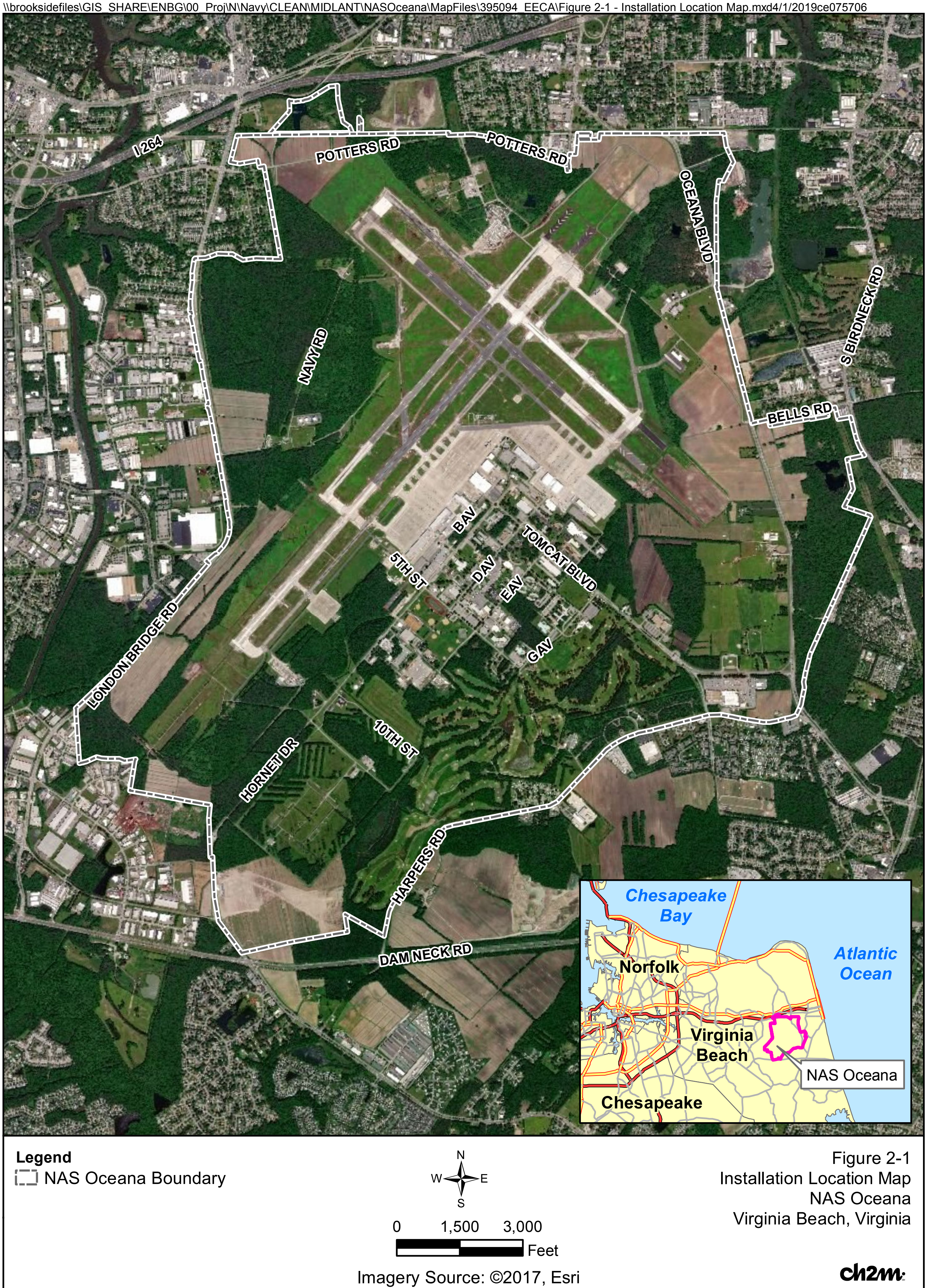

Figure 2-1
Installation Location Map
NAS Oceana
Virginia Beach, Virginia

SECTION 3

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 current and future human receptors ingesting groundwater used as drinking water containing levels of PFOA and PFOS above the USEPA Lifetime Health Advisory. Therefore, the RAO only applies to the one private drinking water well located on the privately-owned property.

The RAO is as follows:

- Protect current and future human health receptors from ingestion of PFOA and PFOS at levels above the USEPA 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 PFOS in drinking water to a cumulative concentration equal to or less than the USEPA Lifetime Health Advisory of 70 ppt through treatment or provision of an alternative water supply.

The PRG was established based on the USEPA Lifetime Health Advisory since there are currently 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. Accordingly, 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 and future receptor exposure to PFOA and PFOS above the USEPA Lifetime Health Advisory in drinking water for the off-Base private drinking water well near NAS Oceana which exceeds the USEPA Lifetime Health Advisory. Additional action may be necessary to address PFAS detected at levels exceeding screening criteria 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 as the investigations of these media have not yet been completed.

Removal action alternatives were scoped and developed to meet the RAO listed in Section 3.2.1. 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 USEPA Lifetime Health Advisory.
2. Point of Entry Treatment: This alternative would address PFOA and PFOS at the individual private property with drinking water concentrations greater than the USEPA Lifetime Health Advisory before the potable water supply enters the distribution piping for the building. The following three treatment technologies are being considered under this alternative:
   a. GAC Treatment – This action would include the installation of GAC vessels, implemented in series, for PFOA and PFOS removal.
   b. IX Treatment – Installation of IX vessels for PFOA and PFOS removal. The off-Base drinking water treatment system would include two IX vessels, operated in series.
   c. RO Treatment – Installation of RO membranes for PFOA and PFOS removal. The off-Base drinking water treatment system would include two RO membranes implemented in series.
3. Connection to City Water – This action alternative would address PFOA and PFOS impacts by providing the privately-owned property with concentrations of PFOA/PFOS greater than the USEPA Lifetime Health Advisory access to City water. A service line from the water main would be installed to the privately-owned building with drinking water concentrations of PFOA/PFOS greater than the USEPA Lifetime Health Advisory.

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. The Administrative Record file for the site will be made available for public review at the same time the EE/CA is made available. 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 NAS Oceana.

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 12 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
- Contract/award, work plan, and mobilization—3 months
- Removal action—0 week (for Alternative 1), 2 months (for Alternatives 2a, 2b, 2c, and 3)
- CERCLA documentation—6 months

3.4 Applicable or Relevant and Appropriate Requirements

The removal action will, to the extent practicable, comply with 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 off-Base private property (**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 off-Base private property (**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 the off-Base private property (**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, PFAS-containing groundwater will be characterized as nonhazardous, PFAS-containing, and dewatering of excavation areas will not be required. 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 and can be reused onsite. Waste characterization testing, if needed, will be conducted in accordance with the requirements of state and federal regulations. In accordance with Navy recommendations for NAS Oceana, 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 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, 2017).

3.6 City of Virginia Beach Considerations

The City of Virginia Beach water has been previously tested for PFAS under UCMR3 and neither PFOA or PFOS were detected. During development of the EE/CA, the City of Virginia Beach planning department informed the Navy the 12-inch water main running along Southern Boulevard, adjacent to the one off-Base parcel with PFOA/PFOS exceedances of the USEPA Lifetime Health Advisory, is located within an abandoned railroad right-of-way which is City of Virginia Beach property rather than a public right-of-way. Per the City of Virginia Beach planning department, the ultimate use of this corridor along Southern Boulevard is still undetermined; however, there is a reasonable possibility that any new service line installed via connection to the 12-inch water main running along Southern Boulevard may need to be abandoned and relocated in the future. Therefore, for cost estimating purposes in this EE/CA, the service line connection for the off-Base property is assumed to be connected to the 12-inch water main along First Colonial Road, which is approximately 370 feet from the off-Base property.

Table 3-1. - Removal Alternatives Screening
Engineering Evaluation and Cost Analysis for Private Drinking Water
NAS Oceana, Virginia Beach, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
No Further Action	Continued bottled water supply.	Bottled water	No further action to address drinking water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory. Bottled water would continue to be provided as this intervention is already in progress.	X		Retained for baseline comparison in the Engineering Evaluation/Cost Analysis and also retained because this step has already been implemented at the site to mitigate the exposure pathway to PFOA and PFOS.
Institutional Controls	Administrative Restrictions or Engineering Controls	Land Use Controls (LUCs)	LUCs are implemented for property within areas containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory to restrict property use, well installation, and other intrusive activities.		X	This action is not feasible because off-Base drinking water receptors require access to water for potable use. Complications may exist because the Navy does not own the off-Base property and would require property owner agreement to establish LUCs.
Water Treatment (Ex Situ)	Granular Activated Carbon (GAC) Filtration	Wellhead or Point of Entry (POE)	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 perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). GAC can be reactivated through thermal desorption, resulting in ultimate destruction of the PFOA and PFOS.	X		This technology has been tested on the field scale at multiple Navy facilities for off-Base private properties with exceedances of the Lifetime Health Advisory. The technology has been shown to be effective during treatability testing. Disposal or reactivation 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 reactivation 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 for the building. Additionally, this approach would not prevent re-release of water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory used for toilets because systems would not be installed to address water used for that purpose, extending the time to achieve regulatory site closure because of the potential for untreated water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory 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 PFOA/PFOS breakthrough. For these reasons, this alternative was not retained.
	Ion Exchange	Wellhead or POE	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 PFOA/PFOS constituents, allowing the PFOA/PFOS to remain in the resin, while non-toxic ions are added to the water exiting the treatment process. Ion exchange resins can be "reactivated" by flushing with a solvent/brine mixture thereby removing PFOA/PFOS 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 reactivation of ion exchange resins is a requirement for this option. However, field demonstrations of this technology have shown a 99.9998% reduction in the volume of liquid containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory. This technology has been shown to be effective for removal of PFOA/PFOS constituents; therefore, this treatment option has been retained for further evaluation.
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 reactivation 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 for the building. Additionally, this approach would not prevent re-release of water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory used for toilets because systems would not be installed to address water used for this purpose, extending the time to achieve regulatory site closure due to the potential for untreated water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory 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.
	Reverse Osmosis (RO) or Nanofiltration	Wellhead or POE	Water would be treated at the wellhead or POE using reverse osmosis or nanofiltration. For both of these technologies, a membrane acts as a sieve, allowing PFOA/PFOS-free water to flow through the membrane, while PFOA/PFOS do not flow through.	X		Wastes from RO and nanofiltration would contain more concentrated levels of PFOA/PFOS and would require discharge through the septic leach field at the building, or containment and offsite disposal. Technology has a relatively high cost for O&M compared to other remedial technologies. However, this technology has been shown to be very effective for removal of PFOA/PFOS 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 for the building. Additionally, this approach would result in re-release of water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory used for toilets because systems would not be installed to address water used for this purpose. 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.

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
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 PFOA/PFOS onto the carbon, reducing mobility.		X	While commercially available products will reduce mobility, the PFOA/PFOS plume at NAS Oceana 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	Based on the data collected to date, the deepest potable aquifer (Yorktown) has detections of PFOA/PFOS at levels above the USEPA Lifetime Health Advisory. All deeper aquifers are brackish and not suitable for potable supply wells.
Alternate Water Supply from Outside of Plume	Water Supply Lines	Extend water supply lines from City of Virginia Beach	Water supply line from the City of Virginia Beach would be run via the water main to the affected properties.	X		While supplying an alternative water source would not result in reduction of toxicity, mobility, or volume of PFOA/PFOS, 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 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 water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory used for toilets because bottled water would not be used for this purpose, extending the time to achieve regulatory site closure due to the potential for untreated 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 best professional judgment based on information from the SI and experience with current scientific knowledge of potential treatment for PFOA and PFOS above the USEPA Lifetime Health Advisory 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 USEPA Lifetime Health Advisory.

Site Preparation

Because bottled water does not require implementation activities, no pre-implementation activities are required under this alternative.

Site Layout and System Installation

There is no site layout information required for supplying bottled water to the impacted building off-Base.

Because there are no installation requirements for supplying bottled water, no system installation activities are required under this alternative.

Operations and Maintenance

Maintenance activities would require bottled water supply to the off-Base private property every two weeks. For the purposes of this EE/CA, demand required at the off-Base private property is assumed to remain consistent with what is currently being implemented.

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

This alternative is a point of entry (POE) alternative and addresses PFOA and PFOS impacts at the individual private property with drinking water concentrations greater than the USEPA Lifetime Health Advisory before the potable water supply enters the distribution piping for the building. This alternative would include the installation of GAC vessels, implemented in series, for PFOA and PFOS removal.

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 PFOA and PFOS. GAC adsorption capacity depends on influent water quality, and GAC 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 reactivated offsite to remove adsorbed contaminants and restore adsorption capacity such that the media can be reused.

Details are provided below regarding the pre-implementation activities, system layout and installation, and operations and maintenance (O&M).

Site Preparation

Prior to installation of the GAC treatment system, an access agreement would need to be signed between the Navy and parcel owner.

Site Layout and System Installation

The general layout of a GAC treatment system for an off-Base property is depicted on **Figure 4-1**; however, the system configuration may vary during installation to meet conditions present at the property. As shown on **Figure 4-1**, the POE GAC system will be housed in its own treatment shed. The GAC system will be 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 will be installed. The GAC system will consists of two 2-cubic-foot GAC vessels plumbed in series, with a lead and lag setup. Downstream from the GAC vessels, the system will include a ball valve and an ultraviolet (UV) disinfection unit, prior to connection with the main distribution piping to the building. The contractor installing the GAC treatment system will make a pre-installation visit to the building to evaluate the site conditions and then provide detailed specifications for the system to be installed.

For the purposes of this EE/CA, it is assumed that the treatment medium used in each GAC vessel is virgin coal-based activated carbon. 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 will be installed on the piping between the two GAC vessels and at the effluent of the lagging GAC vessel.

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 select PFAS. For the purposes of this EE/CA, it is assumed that off-Base GAC sampling would occur on a quarterly basis.

System maintenance would include replacement of the GAC, as needed, to maintain effective treatment. The GAC would be changed at the off-Base system when the cumulative PFOA and PFOS concentration in the intermediate sample (between the lead and lag vessels) exceeds a project indicator limit (PIL) of 35 ppt (half of the PRG), as determined by system operations monitoring. The assumed timeframe for GAC change-out for the purposes of this EE/CA is semi-annually.

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 this EE/CA, it is assumed that the used GAC will be taken offsite for reactivation. Other maintenance activities include semiannual change-out of the pre-filter and annual maintenance on the UV unit at the off-Base property system.

The POE GAC system is anticipated to be run in perpetuity. 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 impacted private property with drinking water concentrations greater than the USEPA Lifetime Health Advisory before the potable water supply enters the distribution piping for the building. The alternative includes the installation of IX vessels for PFOA and PFOS removal. The off-Base drinking water system 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 facilitate 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 PFOA and PFOS 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 PFOA and PFOS removal using IX, water with high concentrations of total dissolved solids (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 reactivated to restore its IX capacity such that it can be reused. Currently, resins available for POE treatment of PFOA and PFOS are considered single use and must be removed and disposed of; they are not viable for reactivation.

Details are provided below regarding the site preparation, site layout, system installation, and O&M.

Site Preparation

Prior to finalizing the design for the IX system, a site visit would be required to evaluate the existing system layout for the off-Base property. The site visit will include a drawing of the existing system layout and potential installation space, and documentation of conversations with the owner of the property with the private drinking water well.

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

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

Site Layout and System Installation

The general layout of a POE IX treatment systems is shown on **Figure 4-2** for the off-Base property; however, the system configuration may vary during installation to meet conditions present at the property.

As shown on **Figure 4-2**, the off-Base POE IX system will be housed in its own treatment shed. 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, a ball valve, sample port, 25-micrometer sediment pre-filter, and a flow meter will be installed. 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 consist of a ball valve and a UV disinfection unit, prior to connection with the main distribution piping to the building.

For the purposes of this EE/CA, it is assumed that the treatment medium used in each IX vessel is a single-use resin, which has been implemented successfully for removal of PFOA and PFOS 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 reactivation. A sample port will be installed on the piping between the two IX vessels and at the effluent of the lagging IX vessel.

The IX vessels will be installed in series, with a lead and lag vessel, similar to the POE GAC system. Other components of the POE GAC system, including piping, ball valves, flow meters, sample ports, and UV treatment system, will be similar to the GAC system installation.

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 include installation of the IX vessels, including resin, piping, and a sample port; and back flushing and pressure testing of the system once installed prior to startup.

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. For the purposes of this EE/CA, it is assumed that IX sampling would occur on a quarterly basis for the off-Base system.

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 PFOS concentration in the intermediate sample (between the lead and lagging vessel) exceeds a PIL of 35 ppt (half of the PRG), as determined by system operations monitoring. Based on laboratory studies, 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. Based on the service life for two 1.5-cubic-foot vessels (180,000 gallons), the IX resin in the off-Base system 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 system for the purposes of this EE/CA is biannually, based on average usage.

The IX 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. 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 unit at the off-Base system.

The POE IX system is anticipated to be run in perpetuity. 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 individual private property with drinking water concentrations greater than the USEPA 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 PFOS removal. The off-Base drinking water system would include two RO membranes implemented in series.

This alternative consists of RO treatment of water at the POE at the privately-owned property with drinking water concentrations greater than the USEPA Lifetime Health Advisory.

RO is a membrane treatment process in which water is forced through semipermeable 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 PFOA and PFOS 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 off-Base property. The site visit submittals will include drawings of the proposed system layout and potential installation space, and documentation of conversations with the owner of the property with the private drinking water well.

During the site visit, a sample would be collected from the existing system, 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, ORP, free chlorine, and turbidity.

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

Site Layout and System Installation

The general layout of a POE RO treatment system for the off-Base property is depicted on **Figure 4-3;** however, the final system configuration may vary to meet conditions present at the property.

As shown on **Figure 4-3** for the off-Base property system, the POE RO system will be housed in its own treatment shed. The RO treatment system would be installed as a preassembled unit that can be operated up to 1,000 gallons per day. 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 the off-Base property will need a water softener system installed. 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, a UV disinfection unit will be installed, 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.

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 the building. The tank will be housed in the additional treatment shed installed at the 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 for the off-Base property which have shown more than 99 percent removal for PFOA and PFOS in a laboratory setting (Tang et al., 2006). 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 PFOA and PFOS treatment. A sample port will be installed on the piping prior to (influent) and after (effluent) the RO membrane system.

System installation of the POE RO treatment system would include installing a prefabricated RO unit, sediment filters, calcite filters, and water softeners; a treatment building to house the RO components; and associated piping, ball valves, flow meters, sample ports, and UV treatment system.

Other system installation components will include the installation and electrical hook-up of 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 building distribution system (upgradient from the UV system). Once all components are connected, the system would be pressure tested to ensure there are no leaks in the system.

For this EE/CA, system installation costs are assumed to include installation of the 5-micrometer sediment filters, water softener, prefabricated RO units, including membranes, the calcite filter, two treatment buildings, the 500- and 3,000-gallon storage tanks, piping, and associated valves needed to connect the storage tanks to the RO unit; and pressure testing of the system once installed prior to startup.

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 the purposes of this EE/CA, it is assumed that RO sampling would occur on a quarterly basis for the off-Base system. 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 client.

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 5 years. The RO membrane 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. 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 unit, water softener, and calcite filter.

The POE RO system is anticipated to be run in perpetuity. 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 PFOS impacts by providing the private property with concentrations greater than the USEPA Lifetime Health Advisory, access to City water. A service line from the water main would be installed to the privately-owned building with drinking water concentrations greater than the USEPA Lifetime Health Advisory.

Based on the limitations discussed in Section 3.6 regarding access to the main line along Southern Boulevard, the service line would be run from the main line to the off-Base potable water system and a service connection would be made as part of this alternative. Under this alternative, it is assumed that the off-Base private drinking water well would remain in place but would no longer be used as the water supply for the off-Base property.

Details are provided below regarding the site preparation, site layout, system installation, and O&M.

Site Preparation

A site visit would be required to evaluate the service line connection for the off-Base property, and to confirm construction, routing, and preparation (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 building, etc.), and documentation of conversations with the owner of the property with a private drinking water well.

Once the final system is designed, the system layout details would be provided to the City of Virginia Beach 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 and System Installation

The general layout of the service line to the off-Base property is depicted on **Figure 4-4**. The off-Base service line will be 1-inch and approximately 370 feet. The service line will include a meter box, valves, flow meter (provided by the City of Virginia Beach), and back flow prevention, and will be connected to the existing structure plumbing and facility distribution piping.

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

For installation of the service line, it is assumed that the line will be placed in a trench 2 feet wide by 3 feet deep. A total of 83 cubic yards of soil will be removed to accommodate installation of the service line. The pipes will be installed as 1-inch-diameter Polyvinyl Chloride (PVC) pipe for the off-Base connection. In addition to the piping, a meter box, valves, flow meter, and backflow preventer will be installed at the service line, in compliance with all applicable City of Virginia Beach requirements. The trench will be backfilled with the excavated native material (83 cubic yards 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 a total of 100 square feet will be restored with 6 inches of topsoil, seed, and erosion matting, and 740 square feet will be restored with asphalt.

Following installation of the service line, the newly installed system will be pressure tested and disinfected prior to connection to the building. Installation also will include the costs of connection fees paid to the City of Virginia Beach 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 Virginia Beach will be responsible for repairs to lines from the meter to the main.

The off-Base property 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 service line.

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 3.6 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 (2019). 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 3.6 percent (White House OMB, 2018).

The estimated costs are provided to an expected accuracy of +50 percent and -30 percent and are only an estimate of possible costs for budgeting purposes. The cost estimates are in 2019 dollars, and the unit pricing is based on costs from similar projects, vendor quotes, or engineering estimates.

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 is not an NCP requirement for remedial alternatives, but is performed in support of the analysis of effectiveness, implementability, and costs. 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, implementation, and cost.

Table 4-1. Evaluation of Removal Action Alternatives

Engineering Evaluation and Cost Analysis for Residential Drinking Water

NAS Oceana, Virginia Beach, Virginia

Alternative	Description	Effectiveness	Implementation	Cost
Alternative 1 - No Further Action	Removal action would include continued implementation of actions already being implemented. This includes supply of bottled water to the off-Base privately owned property.	**Minimally Effective.** Is protective of human health, but allows for redistribution of water containing PFOA/PFOS levels above the USEPA Lifetime Health Advisory in septic systems and allows potential for incidental ingestion. Although there are no chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs), action is being taken based on exceedances of the USEPA Lifetime Health Advisory in accordance with Navy policy. 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. Environmental impacts are primarily associated with material production and transportation of bottled water. 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 off-Base.	**Easiest.** Implementation is technically feasible. The off-base drinking water is already being provided.	Capital Cost $0 Future Cost $21,750 Total Cost $21,750
Alternative 2a - Point of Entry - Granular Activated Carbon	Removal action includes treatment of water at the point of entry to the privately-owned building using granular activated carbon (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 reactivated through thermal desorption, of disposed of via incineration, resulting in ultimate destruction of the PFOA and PFOS.	**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. Although there are no chemical-specific ARARs, action is being taken based on exceedances of the lifetime health advisory in accordance with Navy policy. Achieves removal objective for current drinking water receptors. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once project indicator limits (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 off-base.	**Moderately easy.** Implementaion is technically feasible - components are well established, available, and can be completed with conventional equipment. System installation timeframe is relatively short (less than 3 months). GAC equipment installation does not require any specialized equipment. Post-Removal Site Controls (PRSCs) are required and include different sampling and changeout frequencies associated with the system.	Capital Cost $35,500 Future Cost $256,670 Total Cost $292,170
Alternative 2b - Point of Entry - Ion Exchange	Removal action includes treatment of water at the point of entry to the privately-owned buidling 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. Although there are no chemical-specific ARARs, the concentrations pose potential unacceptable risk, which Alternative 2b would remove. Achieves removal objective for current off-Base drinking water receptors. 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 off-Base.	**Moderately easy.** Implementaion is technically feasible - components are well established, available, and can be completed with conventional equipment. System installation timeframe is relatively short (less than 3 months). IX equipment installation does not require specialized equipment. PRSCs are required and include realitvely infrequent sampling and changeout associated with the off-Base system.	Capital Cost $47,810 Future Cost $233,470 Total Cost $281,280

Alternative	Description	Effectiveness	Implementation	Cost
Alternative 2c - Point of Entry - Reverse Osmosis (RO)	Removal action includes treatment of water at the point of entry to the privately-owned buidling using RO. During RO, a membrane acts as a sieve, allowing PFOA and PFOS-free water to flow through the membrane while PFOA and PFOS 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 PFOA and PFOS.	**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. Although there are no chemical-specific ARARs, action is being taken based on exceedances of the lifetime health advisory in accordance with Navy policy. Achieves removal objective for current off-Base drinking water receptors. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once PALs 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 off-Base.	**Moderately difficult.** Implementation is technically feasible - components are well established, available, and can be completed with conventional equipment. System installation timeframe is moderate (approximately 6 months). 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.	Capital Cost $126,840 Future Cost $5,305,450 Total Cost $5,432,290
Alternative 3 - City Water Connection	Water Supply lines from the City of Virginia Beach would be run to the impacted off-Base property with drinking water concentrations of PFOA/PFOS greater than the Lifetime Health Advisory.	**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 Virginia Beach. There would be added traffic and noise impacts to the community. Although there are no chemical-specific ARARs, action is being taken based on exceedances of the lifetime health advisory in accordance with Navy policy. Achieves removal objective for current off-Base drinking water receptors. 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 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.	**Easy.** Implementation is technically feasible. Components are well established and available, and can be completed with conventional equipment. Water line installation timeframe is a relatively short (less than 3 months). This alternative requires earth moving equipment, access to rights of way, and potential disruption of traffic. Additionally, implementation requires coordination with the City of Virginia Beach. There are no PRSCs required.	Capital Cost $94,980 Future Cost $0 Total Cost $94,980

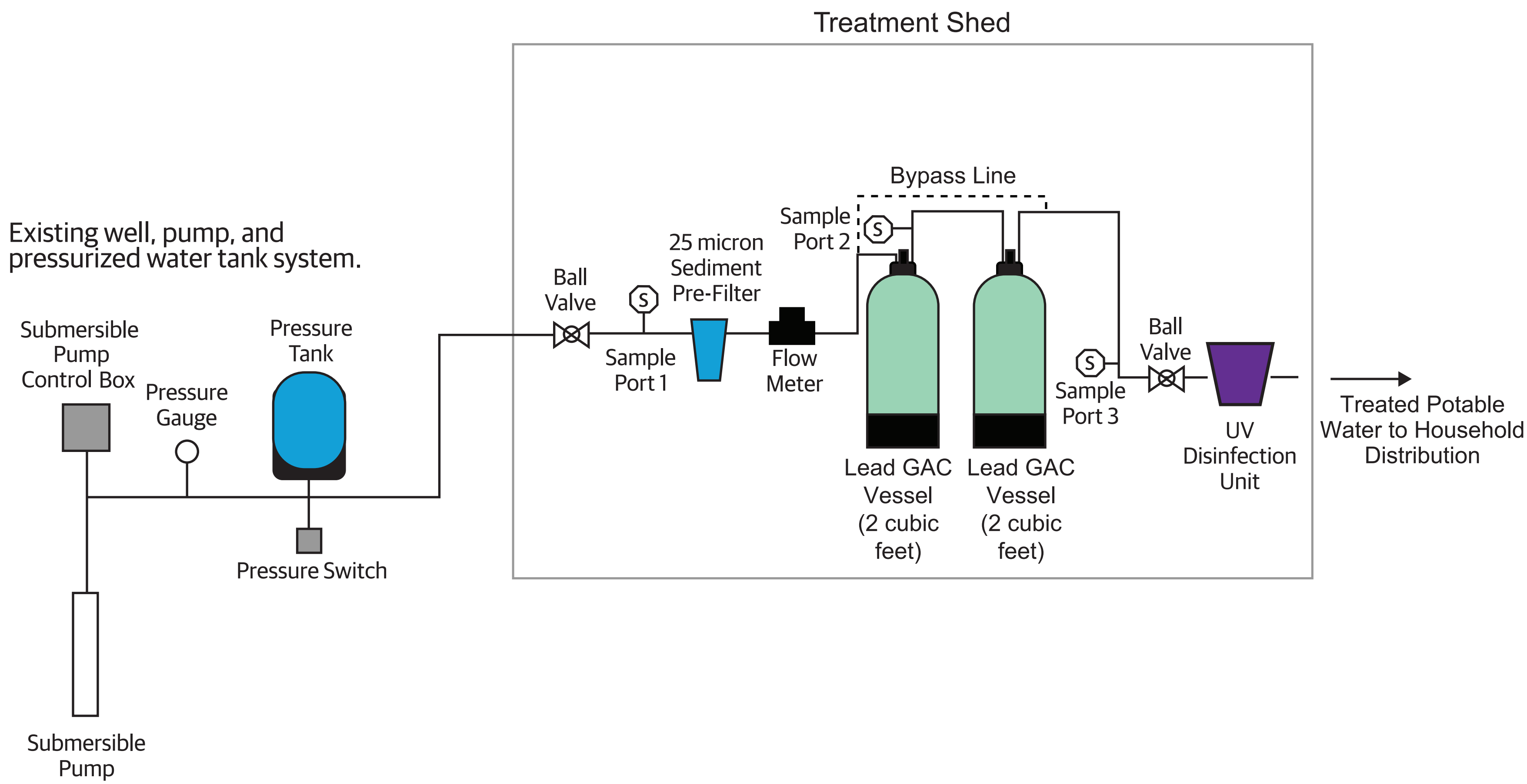

Figure 4-1
Privately Owned Point of Entry Granular Activated Carbon Treatment System
Engineering Evaluation and Cost Analysis for Private Drinking Water
NAS Oceana
Virginia Beach, Virginia

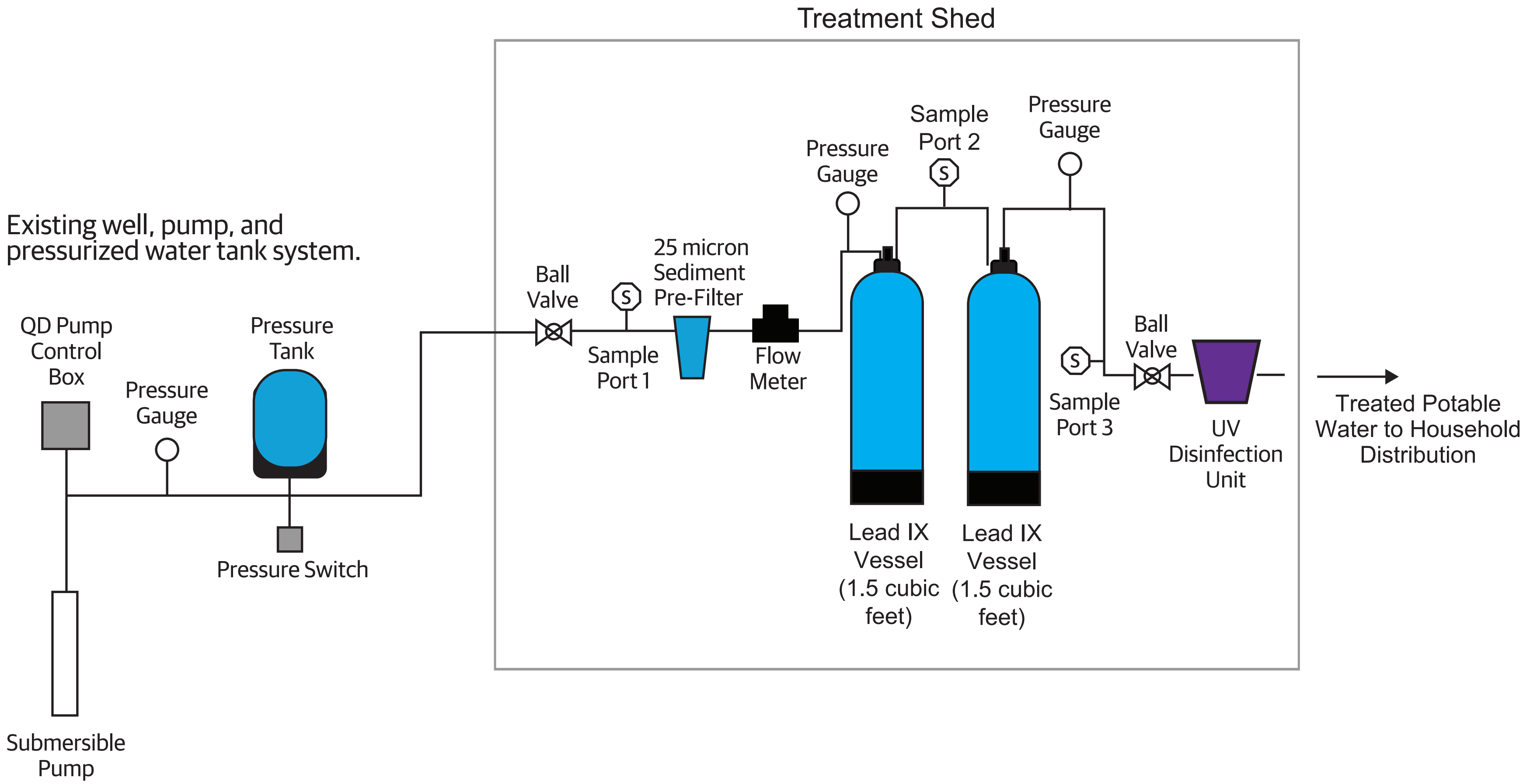

Figure 4-2
Privately Owned Point of Entry Ion Exchange Treatment System
Engineering Evaluation and Cost Analysis for Private Drinking Water
NAS Oceana
Virginia Beach, Virginia

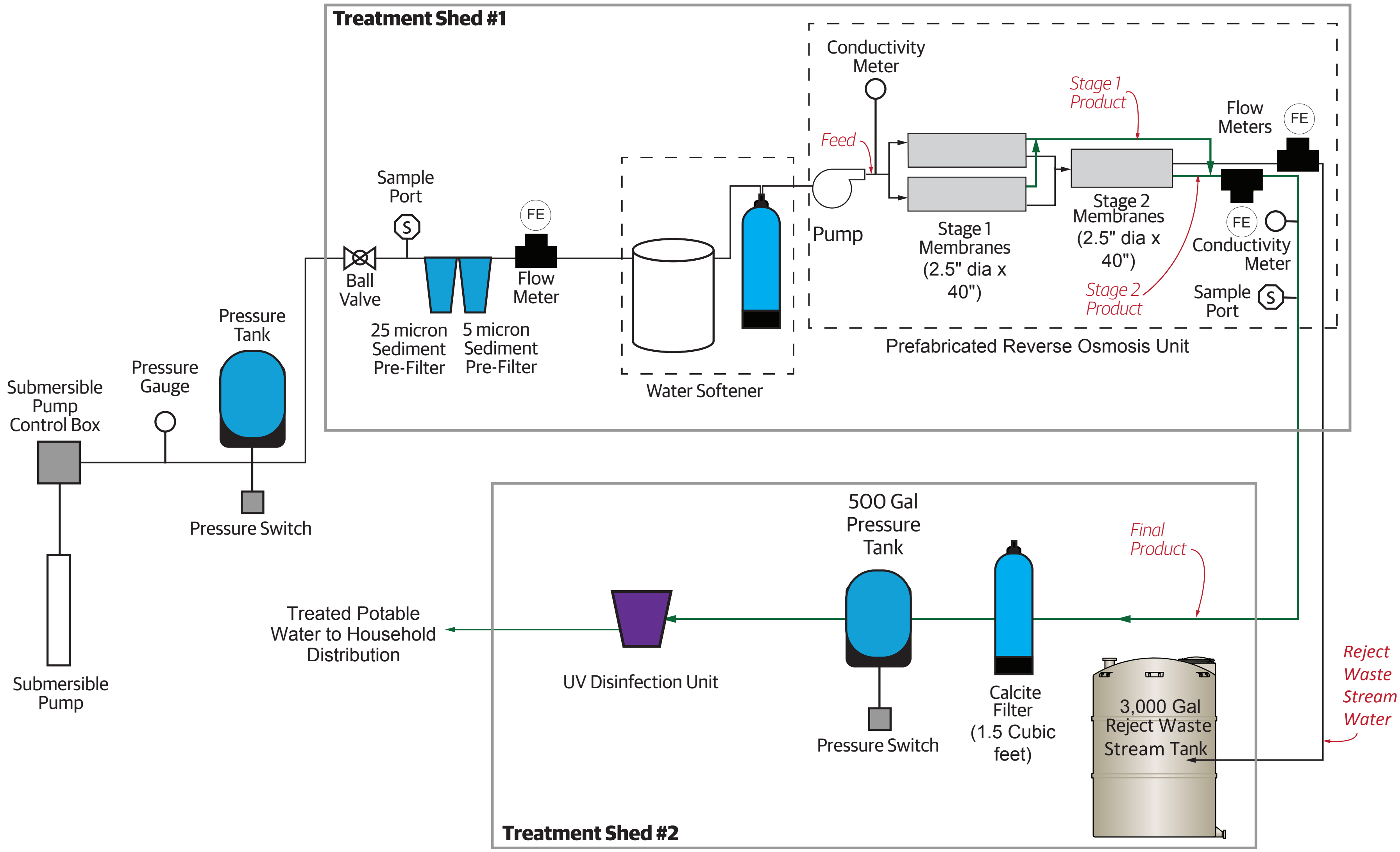

Figure 4-3
Privately Owned Point of Entry Reverse Osmosis Treatment System
Engineering Evaluation and Cost Analysis for Private Drinking Water
NAS Oceana
Virginia Beach, Virginia

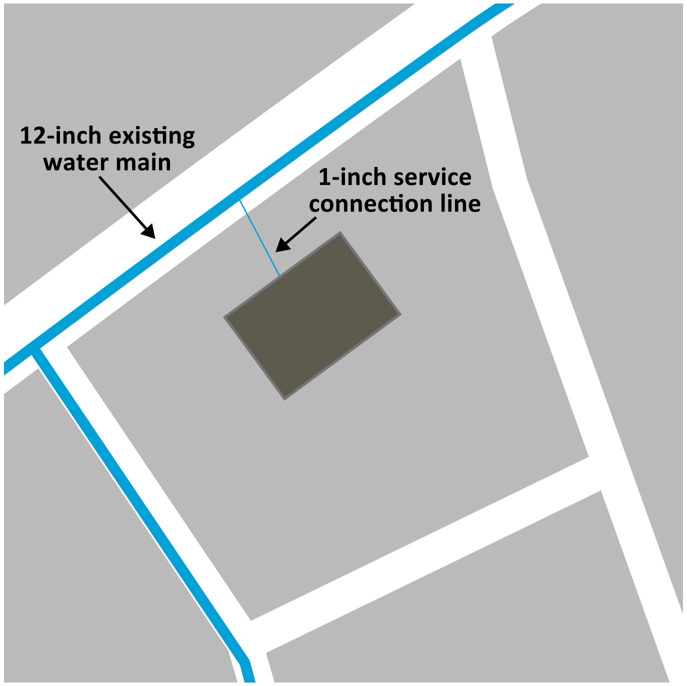

Figure 4-4.
City Water System Connection
Engineering Evaluation and Cost Analysis
for Private Drinking Water
NAS Oceana
Virginia Beach, Virginia

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 is protective of human health but allows redistribution of water containing PFOA and PFOS at level exceeding the USEPA Lifetime Health Advisory in septic systems and allows for potential incidental ingestion; 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 for the off-Base parcel, it does not address ingestion that may occur for inadvertently using water with concentrations of PFOA and PFOS exceeding the USEPA Lifetime Health Advisory from the tap or incidental ingestion when brushing teeth and showering. It also provides less long-term control and does not contribute to the effective performance of a future groundwater remedy, if any, because PFOA and PFOS in water used for non-potable purposes at the impacted off-Base property would be re-released to the environment in the septic leach field 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 through media treatment. Alternative 3 is considered very effective and is protective of human health because groundwater with concentrations of PFAS exceeding the USEPA Lifetime Health Advisory is no longer used to provide water to the private property, thus eliminating receptor exposure. Additionally, because water used for non-potable purposes under Alternatives 2a through 2c and 3 does not contain PFOA or PFOS, the constituents would not be released back into the environment through disposal of wastewater (i.e. septic system).

Under Alternative 1, there are no additional short-term risks to workers because bottled water is already being provided to the off-Base parcel. Alternatives 2a, 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 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 less effective than the other alternatives in addressing exposure to PFOA and PFOS at concentrations exceeding the USEPA Lifetime Health Advisory. The risk of ingestion from the presence of PFOA and PFOS in groundwater is potentially not completely addressed 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 USEPA 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 are 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 not achieved because the groundwater with concentrations of PFOA and/or PFOS exceeding the USEPA Lifetime Health Advisory may incidentally be used as drinking water. Additionally, under Alternative 1, groundwater with concentrations of PFOA and/or PFOS exceeding the USEPA Lifetime Health Advisory continues to be disposed of through existing septic systems and, therefore, does not maintain long-term control of PFOA and PFOS or contribute to the effective performance of any necessary long-term remedy because the PFOA and PFOS may be redistributed in the waste streams.

5.2 Implementability

Alternative 1 is the easiest to implement, Alternatives 2a and 2b are moderately easy to implement, Alternative 2c is moderately difficult to implement, and Alternative 3 is easy 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.

Alternative 1 requires no implementation because the system is already in place and functional; therefore, Alternative 1 is the easiest to implement. Alternatives 2a and 2b are moderately easy to implement in comparison to Alternative 2c which requires the most implementation efforts of the POE systems because it requires additional installation of equipment such as storage tanks and water softeners. Alternative 3 is considered moderately easy to implement even though it requires earth-moving equipment, access to rights-of-way, and coordination with the City of Virginia Beach, it does not require any post-removal site controls (PRSCs). Alternative 3 also has the greatest impact on the surrounding community during implementation because of the pipe trench excavation 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 PRSC requirements. Alternative 2b has the lowest PRSC requirements, including infrequent media change-out and sampling, and minimal waste management. Alternative 2a has a slightly higher PRSC requirement, due to variable and frequent, media change-out and sampling. Alternative 1 requires biweekly delivery of bottled water to homes, and Alternative 2c requires monthly collection and disposal of PFAS-contaminated waste stream water, thus increasing PRSC requirements.

5.3 Cost

Alternatives 1 and 3 are the least expensive alternatives, and Alternative 2c is the most expensive alternative primarily due to the O&M cost associated with monthly disposal of reject water from the system. Of the three POE Alternatives (2a through 2c), Alternative 2a has the lowest capital and overall costs. 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 higher than Alternative 3 and lower than Alternative 2c. 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, 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 lowest GHG emissions, energy use, and accident risk with priority pollutant emission levels similarly comparable to Alternatives 2a and 2b and PM_{10} emissions comparable to Alternative 2c.

Table 5-1. Removal Action Alternative Comparison
Engineering Evaluation and Cost Analysis for Private Drinking Water
NAS Oceana, Virginia Beach, Virginia

Alternative	Effectiveness	Implementation	Cost	Total Score
Alternative 1 - No Further Action	1	5	5	11
Alternative 2a - Point of Entry - Granular Activated Carbon	3	3	3	9
Alternative 2b - Point of Entry - Ion Exchange	3	3	3	9
Alternative 2c - Point of Entry - Reverse Osmosis	3	2	1	6
Alternative 3 - City Water Connection	5	4	4	13

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

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

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

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 groundwater with concentrations of PFOA and/or PFOS exceeding the USEPA Lifetime Health Advisory used as the source of drinking water at the site, eliminates the potential for migration of PFOA and PFOS 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 less effective because groundwater containing PFOA and PFOS exceeding the USEPA Lifetime Health Advisory can still inadvertently be consumed as drinking water, and wastewater will still contain PFOA and PFOS, 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. Alternative 1 is considered the easiest to implement because the system is already in place; however, the alternative has similar PRSCs requirements to Alternative 2a and elevated PRSCs requirements as compared to Alternatives 2b and 3. Alternatives 2a and 2b are moderately easy to implement. Alternative 2c is moderately difficult to implement because it is a more extensive system compared to Alternatives 2a and 2b and has elevated PRSCs requirements associated with monthly disposal of reject water from the systems. Alternative 3 is easy to implement even though it requires earth-moving equipment, access to rights-of-way, and coordination with the City of Virginia Beach, it does not require any PRSCs.

Alternatives 1 and 3 are the least expensive alternatives, and Alternative 2c is the most expensive alternative. Additionally, Alternative 3 does not have any costs associated with long-term PRSCs, whereas Alternatives 1 and 2a through 2c have PRSC costs that are assumed to extend over a 30-year period.

Based on evaluation of the alternatives, the recommended removal action alternative is Alternative 3, Connection to City Water. Alternative 3 would address PFOA and PFOS impacts by providing the private property with concentrations greater than the USEPA Lifetime Health Advisory access to City water. A service line would be installed to the privately-owned building with drinking water concentrations greater than the USEPA Lifetime Health Advisory. System installation would be carried out in accordance with the City of Virginia Beach Considerations, as detailed in Section 3.6. The end result of Alternative 3 is a solution that provides for unlimited use of drinking water at the off-Base property, 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). 2018. *Basewide Per- and Polyfluoroalkyl Substances Site Inspection Report, Naval Air Station Oceana, Virginia Beach, Virginia.* August.

City of Virginia Beach. 2016. *It's Our Future: A Choice City, 2016 City of Virginia Beach Comprehensive Plan*. May.

Naval Facilities Command Mid-Atlantic Environmental (NAVFAC). 2017. *2016 Consumer Confidence Report NAS Oceana*. January.

Department of the Navy (Navy). 2017. *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*.

Navy. 2019. *Emergency Response Action Memorandum, Solid Waste Management Unit 11, Former Fire-fighting Training Area, Naval Air Station Oceana, Virginia Beach, Virginia*. April.

Tang, C. Y., Fu, Q.S., Robertson, A.P., Criddle, C.S. and Leckie, J.O. (2006). *Use of reverse osmosis membranes to remove perfluorooctane sulfonate (PFOS) from semiconductor wastewater.* Environmental Science Technology 40(23): 7343-7349.

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

United States Geological Survey (USGS). 2006. *The Virginia Coastal Plain Hydrogeologic Framework Professional Paper 1731*.

White House Office of Management and Budget (White House OMB). 2018. *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 November 2018. Accessed March 2019. https://www.whitehouse.gov/wp-content/uploads/2018/12/M-19-05.pdf.

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
Engineering Evaluation and Cost Analysis for Private Drinking Water
Naval Air Station Oceana, Virginia Beach, Virginia

Media	Requirement	Prerequisite	Citation	ARAR/TBC Determination	Comment
No Federal Chemical-Specific ARARs apply.					

Table A1-2
Virginia Chemical-Specific ARARs
Engineering Evaluation and Cost Analysis for Private Drinking Water
Naval Air Station Oceana, Virginia Beach, Virginia

Media	Requirement	Prerequisite	Citation	ARAR Determination	Comment
No Virginia Chemical-Specific ARARs apply.					

Table A1-3
Federal Location-Specific ARARs
Engineering Evaluation and Cost Analysis for Private Drinking Water
Naval Air Station Oceana, Virginia Beach, 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	NAS Oceana is located in the Atlantic Migratory Flyway. If migratory birds listed in the Act, or their nests or eggs, are identified at NAS Oceana, operations will not destroy the birds, nests, or eggs.

Table A1-4
Virginia Location-Specific ARARs
Engineering Evaluation and Cost Analysis for Private Drinking Water
Naval Air Station Oceana, Virginia Beach, Virginia

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comment
No Virginia Location-Specific ARARs apply.					

Table A1-5
Federal Action-Specific ARARs
Engineering Evaluation and Cost Analysis for Private Drinking Water
Naval Air Station Oceana, Virginia Beach, Virginia

Action	Requirement	Prerequisite	Citation	ARAR Determination	Comment
No Federal Action-Specific ARARs apply.					

Table A1-6
Virginia Action-Specific ARARs
Engineering Evaluation and Cost Analysis for Private Drinking Water
Naval Air Station Oceana, Virginia Beach, 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	Relevant and Appropriate	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, Naval Air Station Oceana

1.1 Introduction

This appendix presents the approach taken and results obtained from a sustainability analysis performed for off-base drinking water near Naval Air Station (NAS) Oceana, Virginia Beach, 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 at one off-base property contaminated with perfluorooctanonic acid (PFOA) and/or perfluorooctane sulfonic acid (PFOS) at levels greater than the United States Environmental Protection Agency (USEPA) Lifetime Health Advisory 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 supplying bottled water to off-base property
- Alternative 2 – Point of Entry 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. One off-base system is 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 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: Assume plastic bottles are reusable.
  - Transportation of Equipment: Biweekly bottled water deliveries – 50 gallons per house per month x 1 house x 8.34 pounds per gallon 30 miles roundtrip (417 pounds per trip, 23,400 miles total).
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 1 off-base well × 12 months × 30 years = 2.52 million gallons.
- Alternative 2a – Point of Entry Treatment - GAC
  - Materials: Production of GAC (virgin) 4 cubic feet per system per year x 1 system x 30 years (120 cubic feet total). Proxy “reactivated GAC” for disposal impacts
  - Transportation of personnel: one off-base system sampled quarterly (120 trips total)
  - Transportation of Equipment: Vessel shipment via on-road truck –Change-outs 1 per year 300 miles one-way, approximately 3.75 tons of material for system per year, spent GAC to return to source for incineration/reactivation (18,000 miles total, 3.75-ton load both directions).
  - Electricity use: Power for ultraviolet (UV) system, approximately 450 kilowatt-hours (kWh) per system per year (13,500 kWh total)
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 1 off-base well × 12 months × 30 years = 2.52 million gallons.
- Alternative 2b – Point of Entry Treatment - IX
  - Materials: Production of resin – Biennial change-outs of 3 cubic feet of single-use resin per system x 1 system x 30 years (45 cubic feet total).
  - Transportation of personnel: One off-base system sampled quarterly (120 trips total)
  - Transportation of Equipment: Vessel shipment via on-road truck–500 miles one-way, 0.7 ton material each load, spent resin to travel similar distance for incineration, 15 trips.
  - Electricity use: Power for UV system, approximately 450 kWh per system per year (13,500 kWh total)
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 1 off-base well × 12 months × 30 years = 2.52 million gallons.
- Alternative 2c – Point of Entry Treatment - RO
  - Materials: RO filter and components have negligible material impacts compared with waste treatment.
  - Transportation of personnel: One off-base system sampled quarterly (120 trips total)
  - Transportation of Equipment:
    - Initial tank/component shipment:

        - 500 gallon and 3,000 gallon tanks plus associated piping and equipment, 3 tons total, one load per off-base system, 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 and RO system, approximately 900 kWh per system per year (27,000 kWh total)
  - Residual management: Disposal of reject water from RO membranes: approximately 1,800 gallons (7.5 tons) per system per month via incineration to treatment plant 50 miles away (648,000 gallons total or 2,700 tons disposed, transport 7.5 tons × 1 load × 12 months × 30 years = 360 trips).
  - Resource use (Groundwater): Estimate 7,000 gallons per off-base well per month × 1 off-base well × 12 months × 30 years = 2.52 million gallons.
- Alternative 3 – Connection to City Water
  - Installation:
    - Service lines – 370 feet of 1- to 2-inch copper pipe, approximately 1.5 tons of "medium impact material".
    - Transportation of personnel: 4 days to install, crew of 4 people driving 30 miles roundtrip per day, 250 feet production per day, 16 trips total
    - Transportation of equipment and materials: Heavy equipment – 25 tons × 50 miles, pipe 1 trip × 100 miles × 1.5 tons each trip, empty load back
    - Equipment use: trenching using an excavator to an average of 3 feet deep, 2 feet wide (83 cubic yards moved twice)
    - Onsite labor hours: 4 people × 4 days × 10 hour days = 160 hours, construction laborers
  - Operations: Estimate 7,000 gallons per off-base well per month × 1 off-base well × 12 months × 30 years = 2.52 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 the alternatives, primarily from disposal of the concentrate (reject) water from the RO membranes, with lesser impacts from equipment use and transportation. Alternatives 2a and 2b had the second highest GHG and energy use footprints followed by Alternative 1 and Alternative 3. The primary driver for GHG and energy use for alternatives 1, 2a, and 2c is transportation of equipment and materials while equipment use, primarily from electricity requirements, was the second largest contributor.

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

Criteria Air Pollutants (NO_X, SO_X, PM_{10}). Alternative 2c had the highest NO_X, SO_X, and PM_{10} footprints, compared with the other alternatives, primarily from equipment use (electricity requirements) between 42 and 99 percent of the total footprint) with lesser impacts from residual handling and transportation of equipment. Alternatives 2a and 2b had similar criteria air pollutant footprints. The majority of the impacts are from electricity to power the UV systems. Alternative 3 had the second highest PM_{10} footprint due to the equipment use during installation of the service lines. Alternative 1 had the lowest criteria air pollutant footprints.

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. Alternatives 1, 2a, and 2b had similar accident risk footprints, primarily from transporting water, replacement IX resin, or GAC, and Alternative 2c had the highest footprint from transportation of 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 reactivated 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.

Specific best management practices for each alternative are as follows:

- Use alternative energy sources to power the UV light, such as solar to supplement grid power, or purchase green power where it is available.
- Implement an idle reduction plan (limit idling for onsite vehicles and heavy equipment).
- Choose vendors with production and distribution centers near the site, to minimize fuel consumption associated with delivery.

- Choose suppliers that will take back scraps or unused materials.

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 Private Drinking Water
Naval Air Station Oceana
Virginia Beach, 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	16	202	2.52E+06	4.87E-03	8.62E-05	4.33E-04	8.42E-05	6.78E-03
Alternative 2A - Point of Entry Treatment - Granular Activated Carbon (GAC)	41	530	2.53E+06	2.01E-02	2.35E-02	1.18E-02	1.97E-04	1.58E-02
Alternative 2B - Point of Entry Treatment - Ion Exchange (IX)	32	455	2.53E+06	1.87E-02	2.38E-02	1.17E-02	1.73E-04	1.39E-02
Alternative 2C - Point of Entry Treatment - Reverse Osmosis (RO)	80	1,103	2.53E+06	3.63E-02	3.83E-02	2.27E-02	3.66E-04	2.95E-02
Alternative 3 – Connection to City Water	8	72	2.52E+06	1.58E-02	1.37E-02	1.97E-02	1.96E-05	4.10E-03

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	Low	Low	High	Low	Low	Low	Low	Low
Alternative 2A - Point of Entry Treatment - Granular Activated Carbon (GAC)	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium
Alternative 2B - Point of Entry Treatment - Ion Exchange (IX)	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium
Alternative 2C - Point of Entry Treatment - Reverse Osmosis (RO)	High	High	High	High	High	High	High	High
Alternative 3 – Connection to City Water	Low	Low	High	Medium	Medium	High	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 Private Drinking Water
Naval Air Station Oceana
Virginia Beach, 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	0	0%	0	0%	NA		0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	NA		NA	
	Transportation-Personnel	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%
	Transportation-Equipment and Materials	16	100%	202	100%	NA		4.9E-03	100%	8.6E-05	100%	4.3E-04	100%	8.4E-05	100%	6.8E-03	100%
	Equipment Use and Miscellaneous	0	0%	0	0%	2.52E+06	100%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%
	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	**16**		**202**		**2.52E+06**		**4.9E-03**		**8.6E-05**		**4.3E-04**		**8.4E-05**		**6.8E-03**	
2a - GAC	Material Production	5	13%	37	7%	NA		3.3E-03	16%	4.4E-03	19%	5.4E-04	5%	NA		NA	
	Transportation-Personnel	2	5%	25	5%	NA		8.2E-04	4%	2.6E-05	0%	1.2E-04	1%	5.6E-05	29%	4.5E-03	29%
	Transportation-Equipment and Materials	27	65%	349	66%	NA		8.4E-03	42%	1.5E-04	1%	7.5E-04	6%	1.4E-04	71%	1.1E-02	71%
	Equipment Use and Miscellaneous	7	17%	120	23%	2.53E+06	100%	7.6E-03	38%	1.9E-02	81%	1.0E-02	88%	0.0E+00	0%	0.0E+00	0%
	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	**41**		**530**		**2.53E+06**		**2.0E-02**		**2.4E-02**		**1.2E-02**		**2.0E-04**		**1.6E-02**	
2b - IX	Material Production	1.8	5%	32	7%	NA		3.5E-03	19%	4.7E-03	20%	5.8E-04	5%	NA		NA	
	Transportation-Personnel	2.0	6%	25	6%	NA		8.2E-04	4%	2.6E-05	0%	1.2E-04	1%	5.6E-05	32%	4.5E-03	32%
	Transportation-Equipment and Materials	21.3	66%	278	61%	NA		6.7E-03	36%	1.2E-04	0%	6.0E-04	5%	1.2E-04	68%	9.4E-03	68%
	Equipment Use and Miscellaneous	7.0	22%	120	26%	2.53E+06	100%	7.6E-03	41%	1.9E-02	80%	1.0E-02	89%	0.0E+00	0%	0.0E+00	0%
	Residual Transport and Disposal	0.0	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	**32.1**		**455**		**2.53E+06**		**1.9E-02**		**2.4E-02**		**1.2E-02**		**1.7E-04**		**1.4E-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	2	2%	25	2%	NA		8.2E-04	2%	2.6E-05	0%	1.2E-04	1%	5.6E-05	15%	4.5E-03	15%
	Transportation-Equipment and Materials	11	13%	139	13%	NA		3.3E-03	9%	5.9E-05	0%	3.0E-04	1%	2.9E-05	8%	2.4E-03	8%
	Equipment Use and Miscellaneous	14	18%	240	22%	2.53E+06	100%	1.5E-02	42%	3.8E-02	99%	2.1E-02	92%	0.0E+00	0%	0.0E+00	0%
	Residual Transport and Disposal	54	67%	699	63%	NA		1.7E-02	46%	3.0E-04	1%	1.5E-03	7%	2.8E-04	77%	2.3E-02	77%
	Total	**80**		**1,103**		**2.53E+06**		**3.6E-02**		**3.8E-02**		**2.3E-02**		**3.7E-04**		**2.9E-02**	
3 - City Water	Material Production	1	17%	39	54%	NA		4.1E-03	26%	6.8E-03	50%	1.4E-03	7%	NA		NA	
	Transportation-Personnel	0	3%	3	5%	NA		1.1E-04	1%	3.5E-06	0%	1.6E-05	0%	3.7E-06	19%	3.0E-04	7%
	Transportation-Equipment and Materials	0	6%	6	8%	NA		1.5E-04	1%	2.6E-06	0%	1.3E-05	0%	1.2E-06	6%	9.4E-05	2%
	Equipment Use and Miscellaneous	6	73%	24	34%	2.52E+06	100%	1.1E-02	73%	6.9E-03	50%	1.8E-02	93%	1.5E-05	75%	3.7E-03	90%
	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	**8**		**72**		**2.52E+06**		**1.6E-02**		**1.4E-02**		**2.0E-02**		**2.0E-05**		**4.1E-03**	

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
Naval Air Station Oceana
Virginia Beach, Virginia

Appendix C
Cost Estimate

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

Engineering Evaluation and Cost Analysis for Private Drinking Water

NAS Oceana, Virginia Beach, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Operations and Maintenance (O&M) Years 1-30					
Bottled Water Supply	Each	30	$ 840.00	$ 25,200.00	$70/month based (CH2M, 2019). Bottled water supplied every 2 weeks.
Subtotal				***$ 25,200.00***	
Contingency (15%)		15%		$ 3,780.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 2,520.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 3,780.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 630.00	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 35,910.00**	
Total O&M Cost Per Year				$ 1,197.00	
Total Years of O&M				30	
Discount Rate				3.6%	Office of Management and Budget, Circular A-94 2019.
Total Present Value of O&M Costs				**$ 21,750.00**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 21,750.00**	
			+50%	$ 32,625.00	
			-30%	$ 15,225.00	

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
Engineering Evaluation and Cost Analysis for Private Drinking Water
NAS Oceana, Virginia Beach, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Pre-Construction Planning/Engineering/Procurement	Lump Sum	1	$ 10,000.00	$ 10,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 10,000.00**	
Site Preparation					
Mobilization/Demobilization	Each	1	$ 1,000.00	$ 1,000.00	Engineer Estimate
Site Visit	Each	1	$ 1,500.00	$ 1,500.00	Engineer Estimate
Water Quality Sampling	Each	1	$ 143.00	$ 143.00	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 $143/sample location. Costs for labor to perform sampling are included in the site visit.
Site Preparation Total				**$ 2,643.00**	
System Installation					
Installation of GAC system by certified plumber	Each	1	$ 4,975.00	$ 4,975.00	Includes 25-micron pre-filter, (2) appropriately sized GAC vessels plumbed in series, hoses and/or pipes, shutoff valves, sample ports, totalizing meter, and miscellaneous parts to remove perfluorinated compounds from well water to non-detectible levels. Costs based on CLEAN 9000 CTO WE01 PO 10006-7-107203.
Installation of UV disinfection unit by certified plumber	Each	1	$ 3,945.00	$ 3,945.00	Includes insulating piping and chlorinating lines. Costs based on CLEAN 9000 CTO WE01 PO 10006-7-107203.
Additional Electrical Modifications Allowance	Each	1	$ 885.00	$ 885.00	Costs based on CLEAN 9000 CTO WE01 PO 10006-7-107203.
System Installation Total				**$ 9,805.00**	
Subtotal				***$ 22,448.00***	
Contingency (15%)		15%		$ 3,367.20	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 2,244.80	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 28,060.00***	
Performance Bond (2%)		2%		$ 561.20	Industry Average
Subtotal				***$ 28,621.20***	
Project Management (8%)		*8%*		$ 2,289.70	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 1,717.27	Navy Estimating Guidance.
Construction Oversight (10%)		10%		$ 2,862.12	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 35,500.00**	
Operations and Maintenance (O&M) Years 1-30					
Quarterly Sampling for PFAS	Each	30	$ 5,600.00	$ 168,000.00	4 times per year, 3 samples per well plus 1 QC sample per well. Total samples/ year = 16. $275 per sample based on costing of CLEAN 9000 CTO WE01. 1 day per sampling event, 4 sampling events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
GAC Change Out	Each	60	$ 1,550.00	$ 93,000.00	$1,550 per system based on current costs of NALF Fentress pilot system GAC changeout (Culligan, 2018). 2 changeouts per year. Includes disposal via reactivation. Includes semiannual replacement of sediment filters.
Miscellaneous Items Allowance	Each	30	$ 250.00	$ 7,500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of miscellaneous items for NALF Fentress pilot system installation (Culligan, 2018).
On call service	Each	30	$ 205.00	$ 6,150.00	On call rate for Culligan for NALF Fentress pilot tests is $205. Assume 1 service call per year.
UV unit and sediment filter maintenance	Each	30	$ 840.00	$ 25,200.00	$840/building for annual maintenance of UV and sediment filter, based on current NALF Fentress pilot test (Culligan, 2018). 1 building, includes disposal of used filters.
Subtotal				***$ 299,850.00***	
Contingency (15%)		15%		$ 44,977.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 29,985.00	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 44,977.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 4,136.25	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 423,926.25**	
Total O&M Cost Per Year				$ 14,130.88	
Total Years of O&M				30	
Discount Rate				3.6%	Office of Management and Budget, Circular A-94 2019.
Total Present Value of O&M Costs				**$ 256,670.00**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 292,170.00**	
			+50%	$ 438,255.00	
			-30%	$ 204,519.00	

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

Engineering Evaluation and Cost Analysis for Private Drinking Water

NAS Oceana, Virginia Beach, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Pre-Construction Planning/Engineering/Procurement	Lump Sum	1	$ 15,000.00	$ 15,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 15,000.00**	
Site Preparation					
Mobilization/Demobilization	Each	1	$ 1,000.00	$ 1,000.00	Engineer Estimate
Site Visit	Each	1	$ 1,500.00	$ 1,500.00	Engineer Estimate
Water Quality Sampling	Each	1	$ 143.00	$ 143.00	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 $143/sample locations. Costs for labor to perform sampling are included in the site visit.
Site Preparation Total				**$ 2,643.00**	
System Installation					
Ion Exchange System with IX resins included	Each	1	$ 6,000.00	$ 6,000.00	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).
Installation of IX systems by certified plumber	Each	1	$ 5,275.00	$ 5,275.00	Based on costs for installation of the NALF Fentress pilot systems (Culligan, 2018). Includes installation of equipment, and sterilization of lines.
Miscellaneous Items Allowance	Each	1	$ 1,320.00	$ 1,320.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of system installation costs.
System Installation Total				**$ 12,595.00**	
Subtotal				***$ 30,238.00***	
Contingency (15%)		15%		$ 4,535.70	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 3,023.80	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 37,797.50***	
Performance Bond (2%)		2%		$ 755.95	Industry Average
Subtotal				***$ 38,553.45***	
Project Management (8%)		*8%*		$ 3,084.28	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 2,313.21	Navy Estimating Guidance.
Construction Oversight (10%)		10%		$ 3,855.35	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 47,810.00**	
Operations and Maintenance (O&M) Years 1-30					
Quarterly Sampling for PFAS	Each	30	$ 5,600.00	$ 168,000.00	4 times per year, 3 samples per building plus 1 QC sample per building, 1 building. Total samples/ year = 16. $275 per sample based on costing of CLEAN 8012 CTO WE7G. 1 day per sampling event, 4 sampling events per year. Average rate of field staff is $75/hr (P2 rate on Navy Contract).
Resin Change Out	Each	15	$ 1,125.00	$ 16,875.00	$375/CF of resin (estimate from Purolite, including transportation costs). Total CF required is 3 CF per building, 1 building = 3 CF of resin.
Used Resin Disposal	Each	15	$ 522.00	$ 7,830.00	3 CF of used resin per changeout event. $200 for mobilization/demobilization per event. $175 per event per building for profiling. $7/gallon for incineration based on BOA rates, $49/CF of material disposed.
Miscellaneous Items Allowance	Each	30	$ 1,320.00	$ 39,600.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of costs of system installation costs.
On call service	Each	30	$ 205.00	$ 6,150.00	On call rate for Culligan for NALF Fentress pilot tests is $205. Assume 1 service call per building per year.
UV unit and sediment filter maintenance	Each	30	$ 1,150.00	$ 34,500.00	$840/building for annual maintenance of UV and sediment filter, based on current NALF Fentress pilot test (Culligan, 2018). Assume an additional $310 per year for semiannual maintenance and disposal of sediment filter. 1 building. Includes disposal of used filters.
Subtotal				***$ 272,955.00***	
Contingency (15%)		15%		$ 40,943.25	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 27,295.50	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 40,943.25	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 3,463.88	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS				**$ 385,600.88**	
Total O&M Cost Per Year				$ 12,853.36	
Total Years of O&M				30	
Discount Rate				3.6%	Office of Management and Budget, Circular A-94 2018.
Total Present Value of O&M Costs				**$ 233,470.00**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 281,280.00**	
			+50%	$ 421,920.00	
			-30%	$ 196,896.00	

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

Engineering Evaluation and Cost Analysis for Private Drinking Water

NAS Oceana, Virginia Beach, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Pre-Construction Planning/Engineering/Procurement	Lump Sum	1	$ 15,000.00	$ 15,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 15,000.00**	
Site Preparation					
Mobilization/Demobilization	Each	1	$ 2,000.00	$ 2,000.00	Engineer Estimate
Site Visit	Each	1	$ 1,500.00	$ 1,500.00	Engineer Estimate
Water Quality Sampling	Each	1	$ 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 ($20). Costs for labor to perform sampling are included in the site visit.
Site Preparation Total				**$ 5,000.00**	
System Installation					
Treatment Shed to Building Tanks (14' x 24')	Each	1	$ 6,220.00	$ 6,220.00	https://www.woodtex.com/sheds/original-storage-shed/
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.
Electrical Hook Up for Treatment Shed	Each	1	$ 900.00	$ 900.00	Based on electrical modification costs during installation of the pilot studies (Culligan, 2018).
5-micron inline sediment filter	Each	1	$ 150.00	$ 150.00	http://www.purewaterproducts.com/products/wh101
Water Softener (40,000 grain)	Each	1	$ 600.00	$ 600.00	http://www.purewaterproducts.com/products/bw403
Prefabricated RO system (600 GPD)	Each	1	$ 2,268.00	$ 2,268.00	http://www.purewaterproducts.com/watts-r12-whole-house-ro.
RO System Installation	Each	1	$ 5,275.00	$ 5,275.00	Based on costs for installation of the NALF Fentress pilot systems (Culligan, 2018). Includes installation of equipment, and sterilization of lines.
Initial RO Membranes (DowFilmtech TW30-2540)	Each	1	$ 600.00	$ 600.00	$200/membrane, 3 membranes per building. Includes delivery. http://www.filterwater.com/
Calcite pH adjustment Filter	Each	1	$ 700.00	$ 700.00	http://www.purewaterproducts.com/products/bw002
500-gallon pressured tank	Each	1	$ 2,595.00	$ 2,595.00	http://www.purewaterproducts.com/products/ro914
3,000 gallon unpressurized storage tank	Each	1	$ 1,175.95	$ 1,175.95	https://www.rainharvest.com/norwesco-3000-gallon-above-ground-water-tank-102-inch.asp.
Miscellaneous Items Allowance	Each	11	$ 2,640.00	$ 29,040.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 50% of system installation costs.
System Installation Total				**$ 65,023.95**	
Subtotal				***$ 85,023.95***	
Contingency (15%)		15%		$ 12,753.59	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 8,502.40	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 106,279.94***	
Performance Bond (2%)		2%		$ 2,125.60	Industry Average
Subtotal				***$ 108,405.54***	
Project Management (5%)		*5%*		$ 5,420.28	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		*6%*		$ 6,504.33	Navy Estimating Guidance.
Construction Oversight (6%)		6%		$ 6,504.33	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 126,840.00**	
Operations and Maintenance (O&M) Years 1-30					
Quarterly Sampling for PFAS	Each	30	$ 5,600.00	$ 168,000.00	4 times per year, 2 samples per building plus 1 QC sample per building, 1 building. Total samples/ year = 6. $275 per sample based on costing of CLEAN 8012 CTO WE7G. 1 day per sampling event, 2 sampling events per year. Average rate of field staff is $75/hr.
RO Change Out	Each	6	$ 600.00	$ 3,600.00	$200/membrane, 3 membranes per building, 1 building. Includes delivery. http://www.filterwater.com/
Used Resin Disposal	Each	6	$ 669.00	$ 4,014.00	6 CF of used membranes per changeout event. $200 for mobilization/demobilization per event. $175 per event per building for profiling. $7/gallon for incineration based on CERCLA rates, $49/CF of material disposed.
Disposal of Reject	Each	30	$ 196,375.00	$ 5,891,250.00	2,250 gallons per month per building. 1 building. 27,000 gallons per year to be disposed of. $600 for mobilization/demobilization per event, 12 events per year. $175 per year per building. $7/gallon for incineration based on CERCLA rates.
Calcite filter and Water softener annual maintenance	Each	30	$ 150.00	$ 4,500.00	1.5 CF per container, 1 container. $50/0.5 CF including shipping "https://www.freshwatersystems.com/p-764-calcite-ph-neutralizer-12-cu-ft-ups-box.aspx"
Miscellaneous Items Allowance	Each	30	$ 1,320.00	$ 39,600.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc. Based on 25% of system installation costs.
On call Service	Each	30	$ 205.00	$ 6,150.00	On call rate for Culligan for NALF Fentress pilot tests is $205. Assume 1 service call per building per year.
UV unit and sediment filter maintenance	Each	30	$ 1,150.00	$ 34,500.00	$840/building for annual maintenance of UV and sediment filter, based on current NALF Fentress pilot test (Culligan, 2018). Assume an additional $310 per year for semiannual maintenance and disposal of sediment filter. 1 building. Includes disposal of used filters.
Subtotal				***$ 6,151,614.00***	
Contingency (15%)		15%		$ 922,742.10	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 615,161.40	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$ 922,742.10	EPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2%)		2%		$ 150,430.35	Industry Average on O&M items performed by subcontractor.

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

Engineering Evaluation and Cost Analysis for Private Drinking Water

NAS Oceana, Virginia Beach, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
TOTAL O&M COSTS				**$ 8,762,689.95**	
Total O&M Cost Per Year				$ 292,089.67	
Total Years of O&M				30	
Discount Rate				3.6%	Office of Management and Budget, Circular A-94 2019.
Total Present Value of O&M Costs				**$ 5,305,450.00**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 5,432,290.00**	
			+50%	$ 8,148,435.00	
			-30%	$ 3,802,603.00	

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

Engineering Evaluation and Cost Analysis for Private Drinking Water

NAS Oceana, Virginia Beach, Virginia

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Work Planning Documents					
Pre-Construction Planning/Engineering/Procurement	Lump Sum	1	$ 5,000.00	$ 5,000.00	Includes draft and final submission.
Work Planning Documents Total				**$ 5,000.00**	
Site Preparation					
Mobilization/Demobilization	Lump Sum	1	$ 700.00	$ 700.00	Engineer Estimate
Site Visit and Document of Existing System	Each	1	$ 800.00	$ 800.00	Engineer Estimate
Utility Locates	Each	1	$ 1,000.00	$ 1,000.00	Engineer Estimate
Erosion and Sediment Controls	Lump Sum	1	$ 1,250.00	$ 1,250.00	Engineer Estimate
City of VA Beach Coordination	Lump Sum	1	$ 7,500.00	$ 7,500.00	Engineer Estimate. Includes coordination with City to obtain private easements to cross the adjacent properties and $5,000 cost for direct payments to the affected property owners.
Site Preparation Total				**$ 11,250.00**	
System Installation					
Water Capital Recovery Fee	Lump Sum	1	$ 2,267.00	$ 2,267.00	5/8 inch. https://www.vbgov.com/government/departments/public-utilities/Pages/Mandatory-Connection-Fees.aspx
Mobilization/Demobilization	Lump Sum	1	$ 2,500.00	$ 2,500.00	Engineer Estimate
Submittals	Lump Sum	1	$ 1,500.00	$ 1,500.00	Engineer Estimate
Service Lines	LF	370	$ 23.85	$ 8,824.50	1-inch PVC, Schedule 40. RS Means (2019) - 22 11 13.74 1880 (material) x 2 for small project
Service Line Meters (1" bronze, threaded) and Residential Water Tap Fee	Each	1	$ 493.00	$ 493.00	5/8 inch. https://www.vbgov.com/government/departments/public-utilities/Pages/Mandatory-Connection-Fees.aspx
Service Lines meter boxes, valves, flow meter and back flow prevention	Each	1	$ 1,200.00	$ 1,200.00	Allowance
Header Excavation	CY	83	$ 12.42	$ 1,030.86	Installed via trenching 2 feet wide, 3 feet deep. RS Means (2018) - G 1030 805 1320 (75%) X 2 for small project
Installation of Headers	LF	370	$ 8.02	$ 2,967.40	RS Means (2018) - 22 11 13.23 1200 (labor & equipment) + 2 for small project
Backfill of Header Excavation	CY	83	$ 2.07	$ 171.81	Use existing material from excavation, Placed to 95 % maximum density. RS Means (2018) - G 1030 805 1320 (25%) x 2 for small projecdt
Top Soil	CY	2	$ 45.00	$ 90.00	6 inch placement on all disturbed areas. Allowance
Hydro Seed, with mulch & fertilizer	SF	100	$ 0.70	$ 69.50	Utility mix, 7#/MSF. RS Means (2018) - 32 92 19.14 5400 ($69.50/msf)
Revegetation Matting	SF	100	$ 0.92	$ 92.20	Paper, biodegradable mesh. RS Means (2018) - 31 25 14.16 0070 (0.83/sy) x 10 for small project
Asphalt (replacement over trench, 6" thick)	SF	740	$ 19.44	$ 14,385.60	RS Means (2018) - 32 12 16.13 1080 ($87.50/sy) x 2 for small project
Pressure Testing and Chlorination of lines	Lump Sum	1	$ 2,500.00	$ 2,500.00	Engineer Estimate
Construction Completion Report	Lump Sum	1	$ 2,500.00	$ 2,500.00	Includes draft and final submission.
System Installation Total				**$ 40,600.00**	
Subtotal				***$ 56,850.00***	
Contingency (15%)		15%		$ 8,530.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10%)		10%		$ 5,690.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Subtotal				***$ 71,070.00***	
Performance Bond (2%)		2%		$ 1,430.00	Industry Average
Subtotal				***$ 72,500.00***	
Project Management (10%)		*10%*		$ 7,250.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6%)		6%		$ 4,350.00	Navy Estimating Guidance.
Construction Oversight (15%)		15%		$ 10,880.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$ 94,980.00**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$ 94,980.00**	
			+50%	$ 142,470.00	
			-30%	$ 66,490.00	

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.