Naval Facilities Engineering Systems Command Northwest
Silverdale, Washington

Final

Engineering Evaluation/Cost Analysis
Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor
Silverdale, Washington

August 2023

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Prepared for NAVFAC Northwest
by CH2M HILL, Inc.
Seattle, Washington
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Acronyms and Abbreviations

ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CSM	conceptual site model
EE/CA	Engineering Evaluation/Cost Analysis
GAC	granular activated carbon
GHG	greenhouse gas
IX	ion exchange
NAVFAC	Naval Facilities Engineering Systems Command
Navy	Department of the Navy
NBK	Naval Base Kitsap
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
ng/L	nanogram(s) per liter
NO_x	nitrogen oxides
O&M	operations and maintenance
PA	preliminary assessment
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutane sulfonate
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PM_{10}	particulate matter 10 micrometers or less in diameter
POE	point of entry
PRSC	post-removal site control
RAO	removal action objective
RI	remedial investigation
RPBA	reduced pressure backflow assembly
SAL	State Action Level
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SI	site inspection

SO_x	sulfur oxides
TBC	to be considered
USEPA	United States Environmental Protection Agency
UV	ultraviolet
WA DOH	Washington State Department of Health
WAC	Washington Administrative Code

SECTION 1

Introduction

This report presents an Engineering Evaluation/Cost Analysis (EE/CA) for a non-time-critical removal action to address perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) concentrations above the 2016 United States Environmental Protection Agency (USEPA) lifetime drinking water health advisory of 70 nanograms per liter (ng/L) [1] in private drinking water wells providing water supply for off-Base properties near Naval Base Kitsap (NBK) Bangor, in Silverdale, Washington. This EE/CA has been prepared under the Naval Facilities Engineering Systems Command (NAVFAC) Comprehensive Long-term Environmental Action—Navy 9000 Program, Contract Number N62470-16-D-9000, Contract Task Order 4300.

In response to Department of the Navy (Navy) policy memorandum *Perfluorinated Compounds (PFC)/ Polyfluoroalkyl Substances (PFAS) – Identification of Potential Areas of Concern (AOC)* (DASN, 2016), and as a result of the identification of confirmed PFAS release areas on-Base at NBK-Bangor (CH2M, 2020), drinking water samples have been collected from drinking water wells located within sampling areas in Silverdale, Washington, and analyzed for the presence of 18 PFAS including perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Concentrations of PFOA and PFOS were above a combined concentration of 70 ng/L for PFOA and PFOS in two of the drinking water wells. The wells are associated with two private residences referred to herein as Residence 1 and Residence 2. An emergency removal action was implemented in March 2020 (Navy, 2020) to supply bottled water for drinking and cooking to Residence 1 and Residence 2.[2]

At Residence 1, the combined concentrations of PFOA and PFOS exceeded 70 ng/L during the initial sampling event in February 2020. The combined concentration was 76.83 ng/L. Following the initial sampling event, the resident made a change to their drinking water fixture where the sample was collected. Following this change and the initial sample event, the Navy has sampled the drinking water well nine times, from November 2020 to October 2022. During five of the sample events, PFOA and PFOS were not detected; during four sample events, PFOA was detected during three sampling events ranging from 0.209 to 1.96 ng/L and PFOS was detected during one sampling event at 0.447 ng/L (**Table 1-1)**. The combined concentrations of PFOA and PFOS have not exceeded 70 ng/L since the initial sampling. Therefore, Residence 1 is not evaluated within this EE/CA as the current data does not indicate a long-term removal action is required to protect human health at this residence. Furthermore, based on this information, it is recommended that the emergency removal action (i.e., bottled water) be discontinued at Residence 1 along with further sampling due to concentrations consistently being below 70 ng/L. This recommendation has been communicated to Residence 1 during a phone conference and through a formal letter documenting the path forward.

At Residence 2, the combined concentrations of PFOA and PFOS have exceeded 70 ng/L during the initial sampling event in February 2020 and ten follow-up sampling events conducted from November 2020 through April 2023, ranging from 86.4 to 200 ng/L (**Table 1-1**).

While supply of bottled water is an effective short-term solution, this EE/CA is being completed to evaluate the short- and long-term effectiveness, implementability, and cost of removal action alternatives to protect human health exposure from ingestion of impacted groundwater supplied from the off-Base drinking water well at Residence 2, with total combined PFOA and PFOS concentrations above 70 ng/L.

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1 The EPA issued lifetime drinking water health advisories for PFOA and PFOS in May 2016 of 70 ppt, individually or combined. In June 2022, the EPA issued new, interim drinking water health advisories for PFOA and PFOS. Because these interim health advisories are below detectable limits and are non-regulatory levels, the Department of Defense (DOD) is instead looking to EPA to propose a regulatory drinking water standard, which is anticipated by the end of this year. DOD is currently evaluating its efforts to address PFAS in drinking water, and what actions we can take to be prepared to incorporate this standard.

2 If additional properties with exceedances are identified at a later date, the alternatives presented in this EE/CA will be evaluated individually for those additional properties.

1.1 Regulatory Background

This document is issued by the Navy, the lead agency responsible for environmental remediation at NBK-Bangor, working in coordination with the Washington State Department of Ecology and USEPA.

Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA) allows an authorized agency to conduct a removal action or arrange for removal of hazardous substances, pollutants, or contaminants at any time, or to take any other response measures consistent with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP), as deemed necessary to protect public health or welfare and the environment.

The NCP (Code of Federal Regulations [CFR] Title 40, Part 300) provides regulations for implementing CERCLA and SARA, including regulations addressing 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* (40 CFR 300.5).

Although PFAS are not classified as a hazardous substance, the NCP applies and is in effect for:

> *Releases into the environment of hazardous substances, and pollutants or contaminants which may present an imminent and substantial danger to public health or welfare of the United States* (40 CFR 300.3).

A removal action is being evaluated for the off-Base residential properties near NBK-Bangor to protect residents from ingestion of groundwater impacted with PFOA and/or PFOS at concentrations greater than the 70 ng/L. 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 discussed in Section 1.2.

On June 15, 2022, the EPA released interim updated lifetime drinking water health advisories for PFOA and PFOS. They also established final lifetime drinking water health advisories for hexafluoropropylene oxide dimer acid (HFPO-DA) and perfluorobutane sulfonic acid (PFBS). In coordination with the Department of Defense, the Navy is currently evaluating how we will address the new interim health advisories for PFOA and PFOS, as well as the new final health advisories for HFPO-DA and PFBS.

Community involvement requirements for removal actions include preparing an EE/CA and making it available for public review and comment for a 30-day period. Notifications of the public review and comment period must be published 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 is intended to fulfill requirements for non-time-critical removal actions 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 purpose of this EE/CA is as follows:

- 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 protect human health by preventing ingestion of drinking water impacted with PFOA and/or PFOS at levels greater than 70 ng/L. The nature and extent of PFOA and PFOS in groundwater and potential risks associated with future use of impacted groundwater are being evaluated separately.

This EE/CA compares the following removal action alternatives based on their effectiveness, implementability, and cost:

- Alternative 1 – No Additional Action Alternative (continue supplying bottled water to affected off-Base residences)
- Alternative 2 – Point-of-entry (POE) Water Treatment with Granular Activated Carbon (GAC) Treatment (remove PFOA and PFOS from drinking water well supplies)
- Alternative 3 – POE Water Treatment with Ion Exchange (IX) Treatment (remove PFOA and PFOS from drinking water well supplies)
- Alternative 4 – New (Replacement) Drinking Water Well Installation (install new well in an unimpacted aquifer, if available, and provide further site investigation, such as aquifer testing, PFAS analytical sampling, and data analysis [for example, using groundwater modeling])
- Alternative 5 – Connection to Public Water Supply

Alternatives are considered relative to the specific and unique characteristics of the residence[3], allowing the Navy to better evaluate and select the best remedial alternative for the residence. This approach provides the most streamlined means to present a transparent evaluation of alternatives given the unique and complex variables of the area (for example, location with respect to different water purveyors, site specific hydrogeological parameters, and confidence in being able to provide safe drinking water using residential groundwater).

3 If future data indicate that the combined concentration of PFOA/PFOS in drinking water from wells at additional residences is greater than the HA, the alternatives presented in this EE/CA will be evaluated individually for these additional properties.

Table 1-1. Analytical Data Summary for Affected

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

WELL ID	**KB-2RW108**												
LOCATION	**Residence 2**												
WELL DEPTH (feet bgs)	**84**												
SCREEN INTERVAL (feet bgs)	**79-84**												
SAMPLE ID	*KB-2RW108-0320*	*KB-2RW108-1020*	*KB-2RW108-0121*	*KB-2RW108-0421*	*KB-2RW108-0721*	*KB-2RW108-1021*	*KB-2RW108P-1021*	*KB-2RW108-0122*	*KB-2RW108-0522*	*KB-2RW108-0722*	*KB-2RW108-1022*	*KB-2RW108-0423*	*KB-2RW108P-0423*
SAMPLE DATE	3/11/20	10/26/20	1/20/21	4/5/21	7/7/21	10/19/21	10/19/21	1/25/22	5/3/22	7/19/22	10/12/22	4/19/23	4/19/23
CHEMICAL NAME													
PFAS (ng/L)													
11Cl-PF3OUdS	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
9Cl-PF3ONS	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
Adona	0.35 U	0.34 U	0.345 U	0.893 U	0.94 U	0.996 U	1.07 U	1.04 U	0.954 U	0.936 U	0.951 U	0.899 U	0.909 U
HFPO-DA	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
NEtFOSAA	0.44 U	0.43 U	0.431 U	1.34 U	1.41 U	1.49 U	1.61 U	1.56 U	1.43 U	1.40 U	1.43 U	1.35 U	1.36 U
NMeFOSAA	0.44 U	0.43 U	0.431 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFBS	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFDA	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFDoA	0.44 U	0.43 U	0.431 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFHpA	**1.72 J**	**0.85 J**	**1.05 J**	**1.06 J**	**1.45 J**	**4.27**	**4.07**	**4.65**	**3.06**	**4.15**	**4.19**	**4.62**	**4.72**
PFHxS	**0.13 J**	0.34 U	**0.116 J**	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFHxA	**2.16 J**	**0.97 J**	1.74 U	**1.84 J**	**3.04**	**4.67**	**4.64**	**5.31**	**4.04**	**5.63**	**5.05**	**5.75**	**6.02**
PFNA	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFOS	0.44 U	0.43 U	0.431 U	1.12 U	1.17 U	1.25 U	1.43 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFOA	**177.77**	**113.49**	**86.4**	**120**	**169**	**165**	**171**	**148**	**200**	**189**	**165**	**161**	**172**
PFTeDA	0.44 U	0.43 U	0.431 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFTrDA	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFUnA	0.35 U	0.34 U	0.345 U	1.12 U	1.17 U	1.25 U	1.34 U	1.3 U	1.19 U	1.17 U	1.19 U	1.12 U	1.14 U
PFOA + PFOS	**177.77**	**113.49**	**86.4**	**120**	**169**	**165**	**171**	**148**	**200**	**189**	**165**	**161**	**172**

Notes:

Detected concentrations are shown in **bold type**.

PFOS/PFOA concentrations greater than the 2016 USEPA lifetime health advisory are shaded gray.

9Cl-PF3ONS = 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid

11Cl-PF3OUdS = 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid

Adona = 4,8-dioxa-3H-perfluorononanoic acid

bgs = below ground surface

HFPO-DA = perfluoro-2-methyl-3-oxahexanoic acid

ID = identification

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

ng/L = nanogram(s) per liter

ND = not detected

NEtFOSAA = n-Ethyl perfluorooctanesulfonamidoacetic acid

NMeFOSAA = N-Methyl perfluorooctanesulfonamidoacetic acid

PFBS = perfluorobutanesulfonic acid

PFDA = perfluorodecanoic acid

PFDoA = perfluorododecanoic acid

PFHpA = perfluoroheptanoic acid

PFHxA = perfluorohexanoic acid

PFHxS = perfluorohexanesulfonic acid

PFNA = perfluorononanoic acid

PFOA = perfluorooctanoic acid

PFOS = perfluorooctane sulfonate

PFTeDA = perfluorotetradecanoic acid

PFTrDA = perfluorotridecanoic acid

PFUnA = perfluoroundecanoic acid

U = Analyte not detected or detected below the Detection Limit value

USEPA = United States Environmental Protection Agency

SECTION 2

Site Characterization

2.1 Site Background

NBK-Bangor is on the Kitsap Peninsula in Kitsap County, Washington, at a location along Hood Canal approximately 6 miles north of Silverdale, Washington (**Figure 2-1**). NBK-Bangor is approximately 7,200 acres in size. The land immediately surrounding NBK-Bangor is listed as predominantly rural residential (one dwelling per 5 acres). One area immediately southeast of NBK-Bangor is identified as urban industrial (Navy, 2015).

Naval activities began at NBK-Bangor in June 1944 when the U.S. Naval Magazine, Bangor, was established to provide a deep-water shipment facility for ordnance. From 1944 into the early 1970s, the Navy facility at Bangor was primarily used for shipment and storage of ordnance and demilitarization of unserviceable and dangerous ammunition. In February 1977, NBK-Bangor was commissioned as the West Coast homeport for the Trident Submarine Launched Ballistic Missile System. NBK-Bangor's current mission is to provide administrative and personnel support for submarine force operations and logistical support for other Navy activities (CH2M, 2020).

2.2 Summary of Previous Investigations and Removal Actions

This section presents a summary of previous on- and off-Base PFAS investigations and actions at NBK-Bangor to date.

2.2.1 On-Base Drinking Water Sampling

Drinking water at NBK-Bangor is obtained from four active on-Base water supply wells, which draw water from the Sea-level aquifer and are screened between 260 and 350 feet below ground surface (bgs). The on-Base supply wells were sampled in March and September 2014 for six PFAS through water distribution system sampling under the Third Unregulated Contaminant Monitoring Rule program; the six PFAS are PFOA, PFOS, PFBS, perfluoroheptanoic acid, perfluorohexane sulfonic acid, and perfluorononanoic acid (PFNA). At that time, the minimum reporting levels for Third Unregulated Contaminant Monitoring Rule sampling were 20, 40, 90, 10, 30, and 20 ng/L for the listed PFAS, respectively. PFAS were not detected above the reporting limit.

The two combined streams from the four on-Base wells were sampled for PFAS in November 2020 to comply with an Assistant Secretary of Defense memorandum, *PFAS Sampling of Department of Defense Drinking Water Systems*, dated March 2, 2020 (ASD, 2020) and were analyzed for 18 PFAS, including PFOA, PFOS, and PFBS via USEPA Method 537.1. The minimum reporting limit was 2.00 ng/L for the 18 PFAS included in the analysis. PFAS were not detected above the reporting limit.

2.2.2 On-Base Preliminary Assessment and Site Inspection

A preliminary assessment (PA) for PFAS at NBK-Bangor was conducted in 2020 to identify potential PFAS sources at NBK-Bangor and identify areas requiring further investigation (CH2M, 2020). Twenty-three areas were recommended for further evaluation in a site inspection (SI) as potential or confirmed PFAS release areas (**Figure 2-2**). Aqueous film forming foam or chrome plating waste (suspected to contain PFAS) is known to have been released or disposed of at 13 of the areas (identified as confirmed PFAS release areas). Additional details about the evaluated areas are available in the PFAS PA (CH2M, 2020). As of June 2023 the SI is in process and anticipated to be complete by the end of 2023; field activities were completed at the end of 2022.

2.2.3 Off-Base Drinking Water Sampling

A desktop evaluation of off-Base drinking water sources was conducted as part of the PA following the identification of confirmed PFAS release areas. The objective of this evaluation was to determine whether groundwater is used as drinking water within 1 mile downgradient of the confirmed PFAS release areas identified in the PA. The evaluation concluded that groundwater is used as drinking water near NBK-Bangor and that private drinking water wells are located within 1 mile downgradient of the confirmed PFAS release areas. In accordance with Navy policy (DASN, 2016), off-Base drinking water sampling was initiated in 2020. As of April 2023, drinking water samples have been collected from 342 off-Base private drinking water wells. PFOA and/or PFOS were detected in 95 private drinking water wells, of which two had detections greater than 70 ng/L combined PFOA and PFOS (**Figure 2-3**). PFBS was detected in 103 private drinking water wells. Known depths of private drinking water wells within 1 mile of NBK-Bangor range from 9 to 638 feet bgs and are screened in the Perched aquifer, Shallow aquifer, permeable interbed, and Sea-level aquifer.

2.2.4 Off-Base Emergency Removal Action for Drinking Water

Bottled water is supplied as an emergency removal action at the residences where PFOA and/or PFOS in drinking water supplied from private wells exceeded 70 ng/L combined PFOA and PFOS. Provision of bottled water began in March 2020 and will continue at Residence 2 until a long-term solution is implemented, which will be selected subsequent to the EE/CA.

2.3 Conceptual Site Model

A remedial investigation (RI) has not been completed for PFAS at NBK-Bangor; therefore, the conceptual site model (CSM) has not been fully developed. A fully developed CSM would include a description of the sources of PFAS, the nature and extent of PFAS-impacted groundwater, and its expected fate and transport over time. The presented CSM is preliminary. For the purposes of this EE/CA, the CSM discussion focuses on geology and hydrogeology of the area and information pertaining to the off-Base residential drinking water wells near NBK-Bangor with exceedances of 70 ng/L combined PFOA and PFOS. The CSM for PFAS at NBK-Bangor will continue to be refined as additional data are collected as part of ongoing SI activities.

2.3.1 Geology and Hydrogeology

NBK-Bangor lies within the Puget Sound Lowland, a broad structural trough, which includes glacial and nonglacial deposits overlying volcanic bedrock. The Vashon Glaciation (15,000 to 13,000 years ago) was the latest of a series of Puget Lobe glaciers to occupy the area. A 1981 report by Robinson et al. (1981) collected lithologic descriptions from borings ranging from 150 to 1,200 feet bgs and interpreted these descriptions in the context of the regional stratigraphy of the Kitsap Peninsula. This study identified five basic geologic units present at NBK-Bangor. The youngest and uppermost geologic unit, the Vashon Drift (Vashon Glaciation), is further subdivided into the following subunits (youngest to oldest): Vashon Recessional Outwash, Vashon Till, Vashon Advance Outwash, Esperance Sand, and Lawton Clay. The remaining four geologic units are (youngest to oldest) Salmon Springs Drift, Devil's Hole Formation, Bangor Formation, and the Fletcher Bay Sequence.

Six relevant hydro stratigraphic units have been identified in the region surrounding NBK-Bangor. In order of increasing depth, the hydrogeologic units are the Perched aquifer, the Vashon Till, the Shallow aquifer, the upper confining unit, the Sea-level aquifer, and the lower confining unit (modified from Kahle, 1998). Deeper units are frequently discontinuous because the glacial deposits in older units were frequently reworked or eroded by subsequent glacial periods.

The Perched aquifer is discontinuous; however, where present, it generally correlates to the Alluvium and Vashon Recessional Outwash geologic units. The Perched aquifer is separated from the Shallow aquifer by the underlying Vashon Till. The Shallow aquifer generally correlates to the Vashon Advance Outwash and Esperance Sand geologic units. The Shallow aquifer is underlain by the upper confining unit, which generally correlates to the Lawton Clay, Salmon Spring Drift, and upper and middle Devil's Hole Formation. The upper confining unit contains permeable interbeds that can yield appreciable amounts of water. The upper confining unit is underlain by the Sea-level aquifer, which generally correlates to the Lower Devil's Hole Formation and Upper Bangor Formation. The lower confining unit generally correlates to the Lower Bangor Formation.

A map of Shallow aquifer groundwater elevations by Kahle (1998) shows a north-south trending groundwater divide along the east boundary of NBK-Bangor and bends to the northeast, north of the Base. Based on this map, groundwater east of the divide flows toward Port Orchard Bay, and groundwater west of the divide flows toward Hood Canal; the surface water features are shown on **Figure 2-1**. Water levels within the aquifers at NBK-Bangor respond to tidal cycles. The maximum fluctuations in water levels are generally 4 to 5 feet along shorelines and less than 1.5 feet in areas further inland. Water levels may vary seasonally from 2 to 7 feet in Shallow aquifer wells, 3 to 4 feet in permeable interbed wells, and typically less than 3 feet in the Sea-level aquifer. Seasonal variability generally decreases with depth. Seasonal variability is not observed in deep aquifer wells (Kahle, 1998).

On-Base drinking water supply comes from wells screened in the Sea-level aquifer. Initial review of off-Base drinking water well records indicates that off-Base drinking water wells have a wide range of screened intervals (such as depths ranging from 9 to 638 feet bgs). Based on the screened intervals presented in available well logs, which have not been verified, the off-Base residential wells are anticipated to be screened in the Shallow aquifer, Sea-level aquifer, Perched aquifer, and the permeable interbeds. The drinking water well at Residence 2 is estimated to be screened within the shallow aquifer. Most other drinking water wells near Residence 2 are also assumed to be installed within the shallow aquifer as shown on the North to South cross-section (**Figure 2-4**).

2.3.2 Affected Media

The impacted media for this EE/CA is off-Base groundwater withdrawn and used as a drinking/potable water supply. The affected off-Base drinking water well near NBK-Bangor, Residence 2, has a total depth of 84 feet bgs. The well is screened from 79 to 84 feet bgs. Based on this information, the Residence 2 well may be screened within the Shallow aquifer, which is estimated to extend from approximately 70 to 150 feet bgs. Groundwater geochemistry is currently unknown and will be evaluated, as warranted, if a treatment alternative is selected.

2.3.3 Nature and Extent of Contamination

The SI has not yet been completed for PFAS at NBK-Bangor and an RI, if necessary, has not yet been started. Therefore, the nature and extent of PFAS near the impacted off-Base drinking water well has not been fully delineated. As of June 2023 the SI is in process for PFAS. A summary of current information follows. On-Base PFAS characterization is ongoing, and PFAS present in on-Base media will be addressed, as needed, in future investigation and remediation efforts.

Of the 342 off-Base drinking water wells sampled adjacent to NBK-Bangor through April 2023, water from two wells, those located at Residence 1 and Residence 2, have been found to have combined PFOA and PFOS concentrations greater than 70 ng/L combined PFOA and PFOS. As discussed in Section 1, Residence 1 is not evaluated in this EE/CA. At Residence 2, PFOS was not detected; PFOA was detected at concentrations from 86.4 ng/L to 200 ng/L. **Table 1-1** summarizes the available well depth and PFAS data in the one off-Base drinking water wells at Residence 2. The neighboring properties at Residence 2 have been sampled during the initial sampling and three follow-on sampling events: May and October 2022, and April 2023. The combined PFOA and PFOS concentrations measured in Residence 2 and neighboring parcels with wells screened within the permeable interbed or upper sea level aquifer are shown in **Figure 2-5**.

The remaining 340 off-Base drinking water wells sampled contain PFOA and PFOS below the detection limits or below 70 ng/L combined PFOA and PFOS (**Figure 2-3**). PFOA, PFOS, and PFBS were detected at samples within the following areas:

- North sampling area: 1 detection of PFOA and/or PFOS and 4 detections of PFBS out of 17 total samples
- West sampling area: 33 detections of PFOA and/or PFOS and 28 detections of PFBS out of 145 total samples
- South sampling area: 19 detections of PFOA and/or PFOS and 27 detections of PFBS out of 77 total samples
- East sampling area: 33 detections of PFOA and/or PFOS and 35 detections of PFBS out of 70 total samples
- Expanded sampling area: 8 detections of PFOA and/or PFOS and 11 detections of PFBS out of 33 total samples

Wells located on parcels sampled within the north, west, east, and expanded areas have not exceeded 70 ng/L combined PFOA and PFOS. Twelve of the 18 PFAS have been detected during the off-Base drinking water investigation, including 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid, 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid, N-ethylperflurooctanesulfonamidoacetic acid, N-methylperfluorooctanesulfonamidoacetic acid, PFBS, perfluorododecanoic acid, perfluorohexanesulfonic acid (PFHxS), perfluorohexanoic acid, PFNA, PFOS, PFOA, and perfluoroundecanoic acid.

2.3.4 Water Use

An interview questionnaire regarding household water use were completed by the residents at Residence 2. The information gathered from this questionnaire is summarized in **Table 2-1**. The information gathered was used to estimate approximate daily water demand for this residence (**Table 2-2**). The estimate suggest an average household water use of approximately 90 gallons daily.

The Washington State Department of Health (WA DOH) provides recommended methodologies for estimating potential residential water use and demands in their *Water System Design Manual*, revised June 2020 (WA DOH, 2020). The methodologies were used to develop estimates of potential residential water demands for Residence 2 based on representative single-family residential water use estimates using representative water usage values. These water demand estimates are applied in subsequent sections relative to sizing required water supply capacities.

2.4 Risk Assessment Summary

To date, a risk assessment has not been performed for the residential parcel being addressed in this EE/CA; however, for the purpose of this document, potential human health risk is presumed based on the combined concentrations of PFOA and PFOS greater than 70 ng/L in drinking water at one residential parcel near NBK-Bangor.

2.5 Determination of Removal Action Area

The one drinking water well at the off-Base property that is currently affected is included in this EE/CA is Residence 2. Residence 2 is located on an approximate 5-acre parcel along the southern border of NBK-Bangor.

The removal action area is defined as the residential drinking water system associated with the affected residence. The average daily use of the residential system is estimated to be about 90 gallons per day based on typical household activities and number of residents living in the home as described in **Section 2.3.4** (**Table 2-1** and **Table 2-2**).

Table 2-1. Water Use Survey Summary - July and August 2021

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

	Name	Residence 2
	Date of Communication	7/7/2021 and 8/24/2021
	Notes	Generally does not use much water.
	Water Delivery	Two 2.5-gallon jugs per month
	Septic or municipal waste?	Septic
Well Questions	**How is it housed?**	Pressure tank located in garage.
	Available space?	Yes
	Pressure tank?	Yes
	Well pumping rate?	Does not know
	Volume used per day?	Does not know
Water Usage	**How many adults use well water?**	1 adult
	How many children use well water?	0
	Does household person count change over year?	No
	Animals?	0
	Outdoor/irrigation water use?	Small garden (less than 50 square feet)
	Laundry done at home? Frequency?	Yes. Not often.
	Regular or low flow toilets?	Regular
	Regular or low flow shower heads? Frequency?	Regular
	Home business?	No
	Other household hobbies that use water?	No
	Dishwashing?	By hand only.
	Hot tub or pool?	No
	Wash cars at home?	No

Table 2-2. Water Usage Statistics

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

	Residence 2
Number of Adults	1
Number of Children	0
Units	gallons/week
Drinking/Food Prep	48
Personal Hygiene	98
Animals	0
Outdoor Irrigation	44
Laundry	38
Showers/Baths	350
Dishwashing	28
Total (gallons/day)	86
Total (gallons/week)	605
Total (gallons/year)	31,460
Total without irrigation (gallons/year)	29,172

Notes:
Values in this table have been rounded to the nearest gallon.
Statistics represent current usage and do not include future residents or usage values.
Source of typical water usage statistics: https://water.usgs.gov/edu/qa-home-percapita.html.
Outdoor irrigation value pertains to the entire United States and does not account for regional precipitation fluxes that alter outdoor irrigation patterns.
Usage Assumptions:
Adults drink 0.5 gallon per day.
Food washing/preparation occurs for 5 minutes per day, and sinks flow at 2.5 gallons per minute.
Regular-flow toilet flushes use 3 gallons, and low-flow toilet flushes use 1.6 gallons (per event). Four toilet flushes per person per day.
Other miscellaneous hygiene activities (hand washing, etc.) use 2 gallons per day per adult.
Outdoor gardens are watered every other day. It is assumed that 25 gallons are used per 100 square feet (per event). Per Table 2-1, assume garden size is 50 square feet.
Indoor plants use 0.5 gallon per week, assuming each residence contains five plants that are watered with 0.5 cup of water 3 times a week.
High-efficiency washing machines use 25 gallons and regular washing machines use 40 gallons (per event).
Shower duration of 10 minutes. All showers at these residences are regular-flow, which use 5 gallons per minute.
Dishwashing uses 17.5 gallons per event if done by hand and 16 gallons per event if done by machine.

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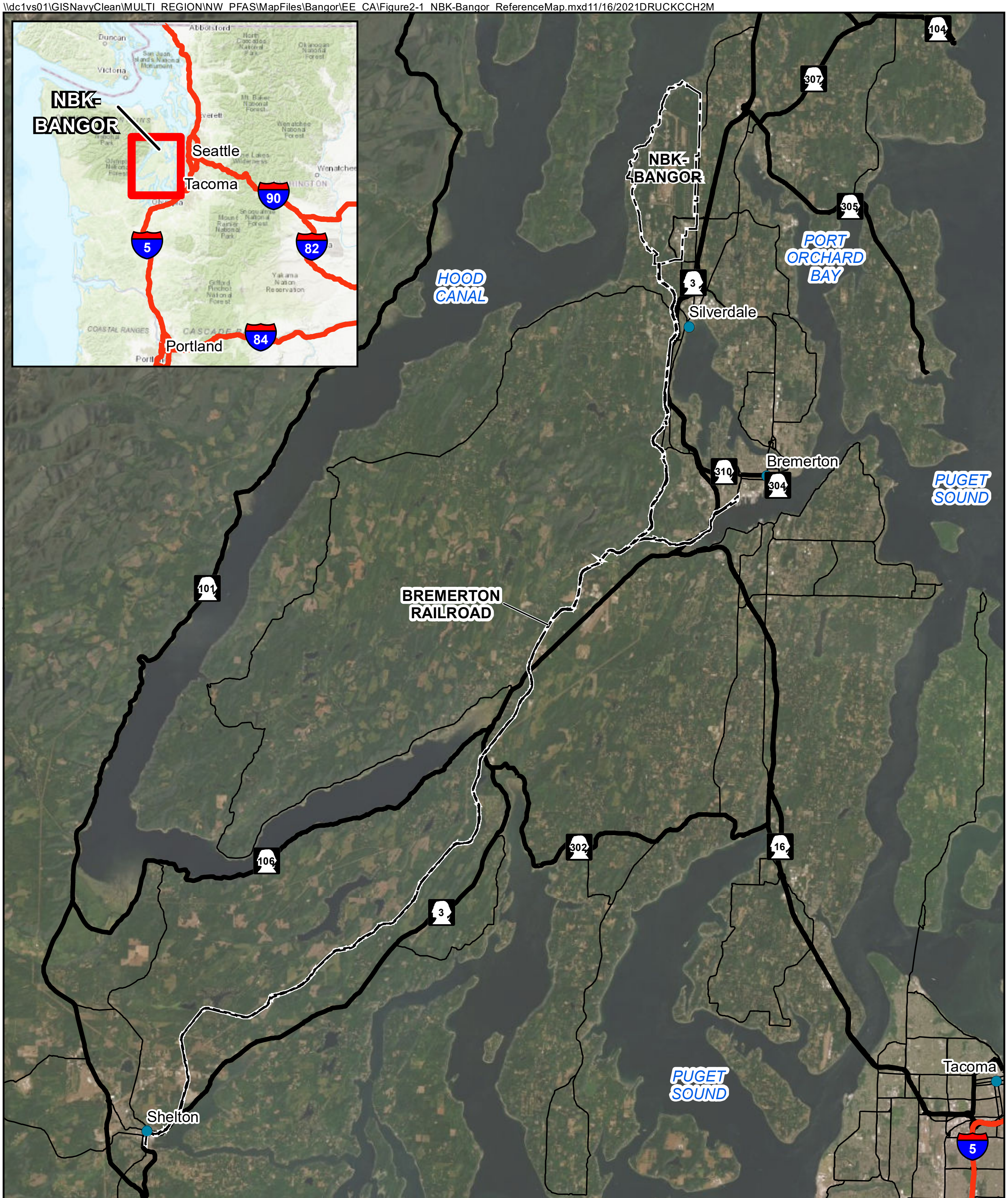


LEGEND

- City
- Freeway
- State Route
- Local Connecting Road
- Installation Boundary

Figure 2-1
NBK-Bangor Reference Map
Engineering Evaluation/Cost Analysis for Long-term
Solutions for Residential Drinking Water
Naval Base Kitsap-Bangor, Washington

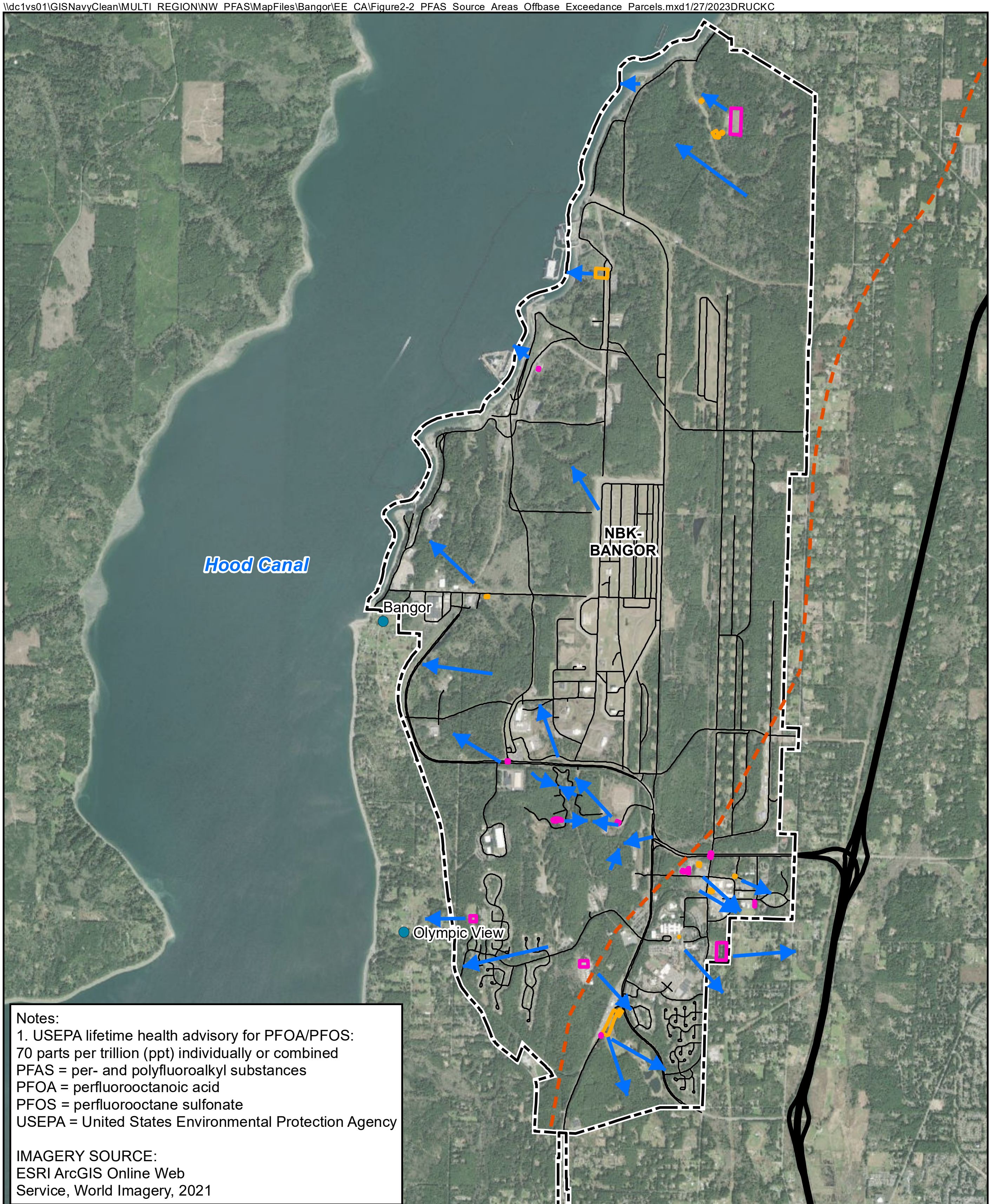
IMAGERY SOURCE:
ESRI ArcGIS Online Web Service,
World Imagery, 2020

0 2.5 5 Miles

1 inch = 5 mile

N

\\dc1vs01\GISNavyClean\MULTI_REGION\NW_PFAS\MapFiles\Bangor\EE_CA\Figure2-2_PFAS_Source_Areas_Offbase_Exceedance_Parcels.mxd1/27/2023DRUCKC



Notes:
1. USEPA lifetime health advisory for PFOA/PFOS: 70 parts per trillion (ppt) individually or combined
PFAS = per- and polyfluoroalkyl substances
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate
USEPA = United States Environmental Protection Agency

IMAGERY SOURCE:
ESRI ArcGIS Online Web Service, World Imagery, 2021

Legend
- City
- Groundwater Divide
- Anticipated Shallow Aquifer Groundwater Flow Direction
- Other Major Road
- Local Road
- Potential PFAS Release Area
- Confirmed AFFF Release Area
- Installation Boundary

N

0 0.4 0.8 Miles

1 inch = 0.8 miles

Figure 2-2
NBK-Bangor PFAS Release Areas, and off-Base Parcels with PFOA/PFOS Exceedances
Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water
NBK-Bangor, Silverdale, Washington

\\dc1vs01\GISNavyClean\MULTI_REGION\NW_PFAS\MapFiles\Bangor\EE_CA\Figure2-3__PFAS_Offbase_DW_Summary_July2021.aprx5/23/2023DRUCKCCH2M

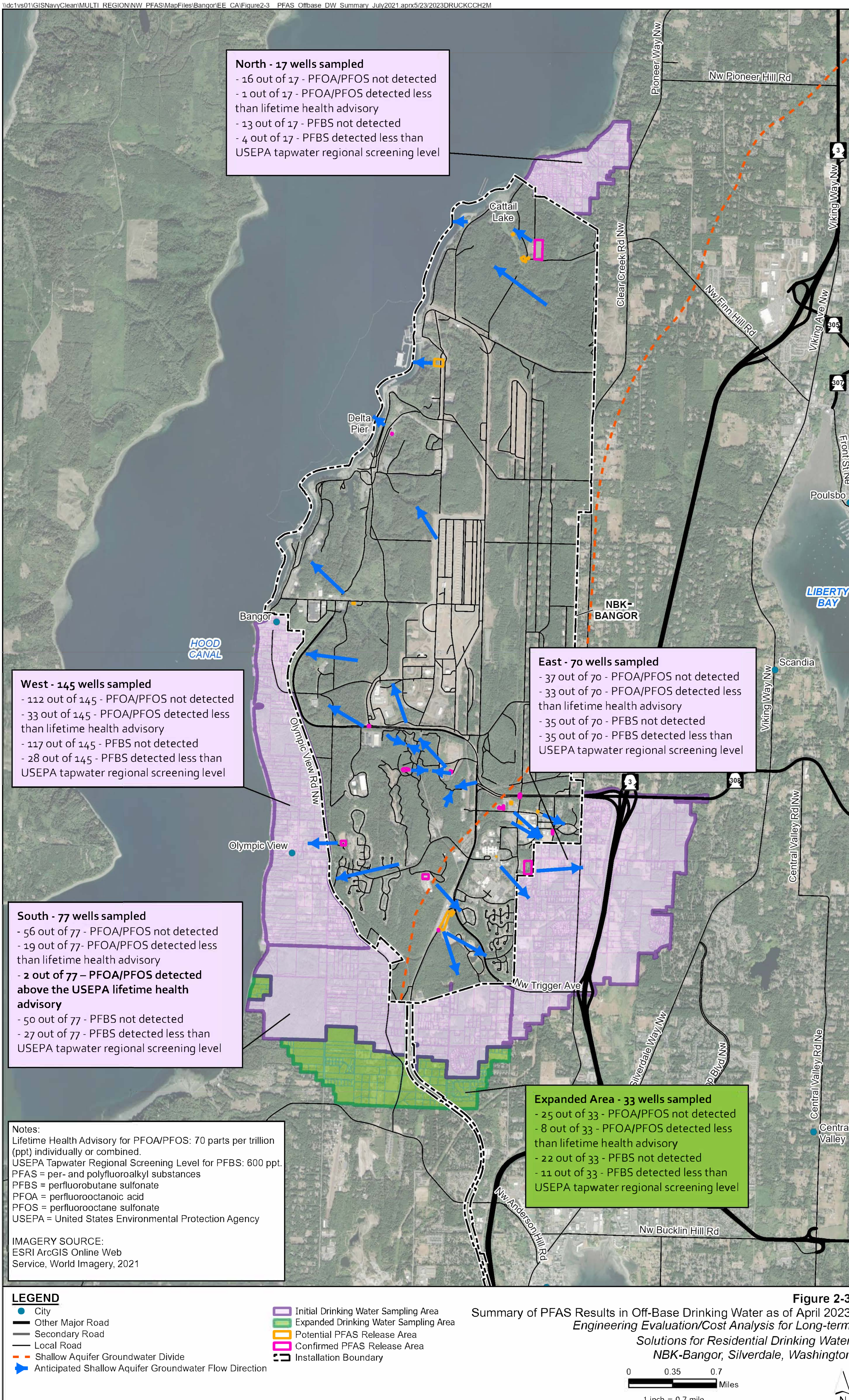
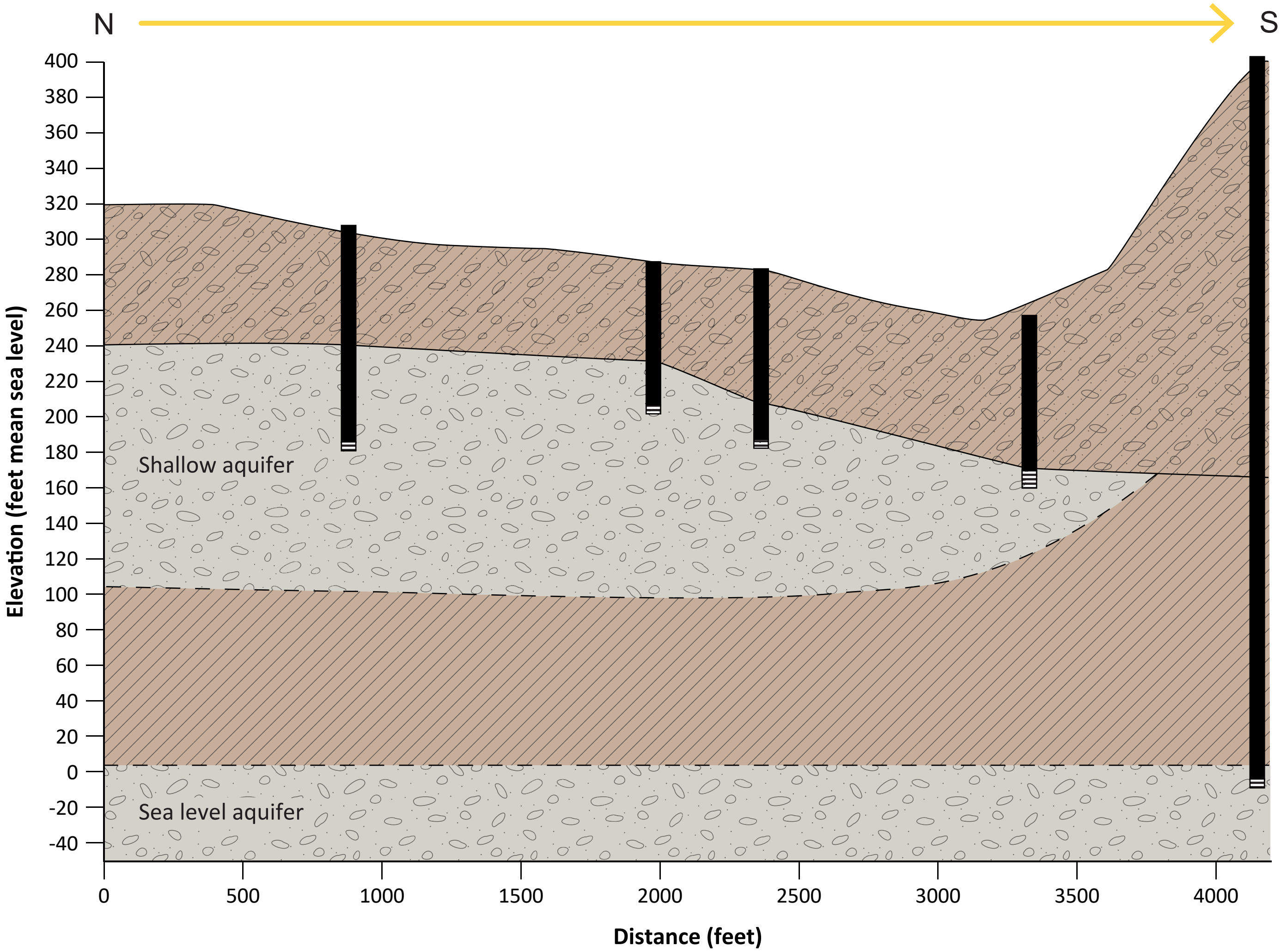


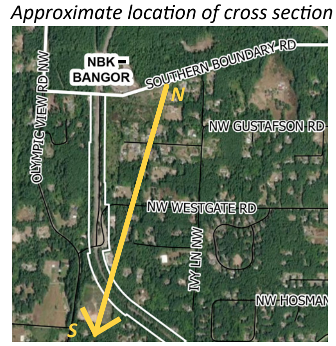
Figure 2-3
Summary of PFAS Results in Off-Base Drinking Water as of April 2023
Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water
NBK-Bangor, Silverdale, Washington



LEGEND

- Sand/clay/gravel mixture
- Clay dominated
- Sand/gravel
- Well
- Well screen

Approximate location of cross section



Notes:

1. Conceptual site model will be updated throughout the investigation.
2. Water-bearing zones have complex configurations at the site, such as areas that pinch and swell (see shallow aquifer).

Figure 2-4.
Summary Cross-Section near Residence 2
Engineering Evaluation/Cost Analysis for
Long-Term Solutions for Residential Drinking Water
NBK-Bangor
Silverdale, Washington

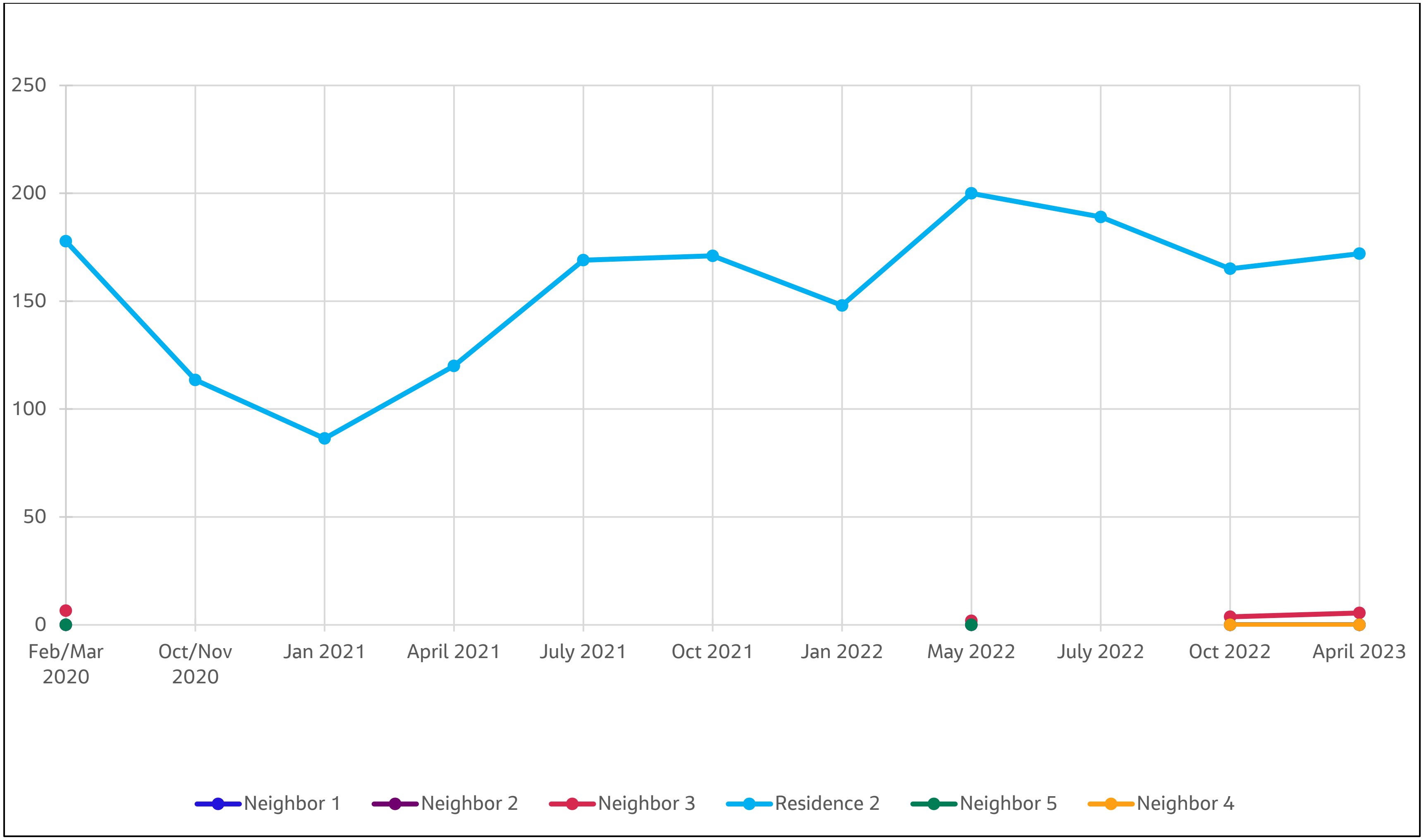


Figure 2.5: Residence 2 and Neighboring Parcel Concentrations

Identification of Objectives

3.1 Removal Action Objective and Scope

3.1.1 Removal Action Objective

The removal action objective (RAO) in this EE/CA addresses current human receptors ingesting groundwater used as drinking water at concentrations greater than the combined concentration of 70 ng/L for PFOA and PFOS. Therefore, the RAO only applies to the drinking water associated with Residence 2.

The RAO is to protect current human receptors from ingestion of PFOA and/or PFOS at concentrations greater than 70 ng/L combined PFOA and PFOS in groundwater used as drinking water.

To meet the RAO, the following removal action goal was established:

- Reduced resident exposure to PFOA and/or PFOS to a cumulative concentration below 70 ng/L combined PFOA and PFOS through treatment and/or provision of an alternative water supply (or if additional drinking water wells with concentrations in exceedances of future applicable screening levels are identified, the RAO will also apply to those parcels and drinking water wells).

The removal action goal was established based on 70 ng/L combined PFOA and PFOS because there are currently no Safe Drinking Water Act (SDWA) maximum contaminant levels, nor any Clean Water Act ambient water quality criteria for protection of human health, relative to any PFAS. For SDWA contaminants not subject to any national primary drinking water regulation, the SDWA authorizes USEPA to publish nonregulatory 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 SDWA contaminants in drinking water. In May 2016, USEPA issued a lifetime health advisory for two PFAS, specifically PFOA and PFOS. The 2016 United States Environmental Protection Agency lifetime health advisory applies to PFOA and PFOS (70 ng/L combined). In addition, applicable or relevant and appropriate requirements (ARARs) currently do not exist from either USEPA or Washington State relative to PFAS exposure through drinking water.

3.1.2 Removal Action Scope

This EE/CA is intended to address current resident exposure to PFOA and PFOS in drinking water for the off-Base private drinking water well near NBK-Bangor.[4] Additional action may be necessary to address PFOA and PFOS concentrations in groundwater, soil, surface water, and sediment within and around the installation; however, these impacts are not included in this removal action scope.

Removal action alternatives were scoped and developed to meet the RAO listed herein after a technology screening process. A preliminary screening of potential remedial technologies was performed before selecting alternatives for the EE/CA. The preliminary screening of technologies is included in **Table 3-1**. Remedial technologies and process options retained after screening were used to assemble removal action alternatives for this EE/CA. The scope of the engineering measures for each removal action that is retained for further evaluation as an alternative is defined as follows:

1. **Alternative 1 – No Additional Action:** Additional action would not be conducted and the site would remain in its current condition (that is, bottled water delivery to properties with drinking water above 70 ng/L combined PFOA and PFOS). This action alternative is applicable to Residence 2. Off-Base bottled water supply would be required until groundwater combined concentrations of PFOA and PFOS are below 70 ng/L in the drinking water well and the on-Base CSM indicates that PFOS and/or PFOA will not migrate to the well.

[4] If future data indicate that the combined concentration of PFOA/PFOS in drinking water from wells at additional residences is greater than 70 ppt, the alternatives presented in this EE/CA will be evaluated individually for these additional properties.

2. **Alternative 2 – POE Water Treatment with GAC:** This alternative would address PFOA and PFOS in groundwater before the potable water supply enters the supply plumbing for the house. This action would include the installation and ongoing maintenance of GAC treatment systems configured to remove PFOA and/or PFOS from the well water supply. This action alternative is applicable to Residence 2.
3. **Alternative 3 – POE Water Treatment with IX:** This alternative would address PFOA and PFOS in groundwater before the potable water supply enters the supply plumbing for the house. This action would include the installation and ongoing maintenance of IX treatment systems configured to remove PFOA and/or PFOS from the well water supply. This action alternative is applicable to Residence 2.
4. **Alternative 4 – New (Replacement) Drinking Water Well Installation:** This alternative would provide replacement drinking water wells for the existing drinking water wells. The new drinking water wells would serve as replacement water sources for the impacted residence, if drilled and screened in an appropriate aquifer not impacted by PFOA and/or PFOS above 70 ng/L and not hydraulically connected to the impacted well. Applicability for the new drinking water well option is residence specific and could potentially be feasible for Residence 2.
5. **Alternative 5 – Connection to Public Water Supply:** This alternative would address PFOA and/or PFOS impacts by supplying the impacted residence with water supply from a public water system that maintains water supply PFOA and/or PFOS levels below 70 ng/L. Potential public water supply options are residence dependent and include the Silverdale Water District system, where supply connections would be established and maintained under an agreement with the Silverdale Water District. This action alternative is applicable to Residence 2.

3.2 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 *Kitsap Daily News* along with a hard copy being made available in the Silverdale Public Library. The public comment period will be scheduled following approval of the EE/CA. Residents potentially impacted by the EE/CA will receive a copy of the EE/CA during the public comment period and have the opportunity to schedule a meeting with the Navy to discuss the alternatives and provide feedback. 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 also require a public comment period. If additional public comments are received on the Action Memorandum, they will also be included in the Responsiveness Summary. The Action Memorandum and EE/CA will be placed in the Administrative Record for NBK-Bangor.

Because this removal action has been designated as non-time-critical, as an interim removal action (provision of bottled water) is currently implemented, the start date of the removal action will be determined by factors other than the immediate urgency of the threat. Possible factors include weather, availability of resources, and site constraints. The total project period is anticipated to last 16 months from the beginning of the public comment period to completion of the associated construction completion documentation.

Critical milestone periods for the removal action are as follows:

- EE/CA public comment period – 30 days
- Action Memorandum public comment period – 30 days
- Design, work plan, subcontracting, and mobilization – 0 weeks for Alternative 1; 4 to 6 months for Alternatives 2 and 3; 6 months for Alternative 4; and 6 months to 1 year for Alternative 5
- Removal action construction – 0 weeks for Alternative 1; 2 to 4 months for Alternatives 2 and 3; 3 months for Alternative 4; and 6 to 8 months for Alternative 5

- CERCLA documentation – The final remedy will be documented as part of the onsite investigation and subsequent records of decision if a complete pathway from on-Base PFAS impacts is identified.
- Performance monitoring – Until PFAS on-Base remedial action eliminates the source and all PFOA and/or PFOS concentrations fall below 70 ng/L in off-Base groundwater, or as conditions merit, for all alternatives, except 5 (assumed to be 30 years for costing purposes)

3.3 Potential 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; these are “to be considered” (TBC). Chemical-specific ARARs currently do not exist from either USEPA or Washington State relative to PFAS exposure through drinking water supplied from private drinking water wells.

During the EE/CA process, CERCLA requires potential ARARs to be reviewed and identified for removal actions. ARARs are the basis for the development of RAOs for a site and include the laws, regulations, standards, criteria, and requirements that may apply to potable water supply alternatives developed for the off-Base private drinking water wells near NBK-Bangor. ARARs in this EE/CA are limited to remedies to address groundwater used as drinking water.

WA DOH has promulgated regulations with a State Action Level (SAL) for five PFAS for Group A Water Systems and these are currently being evaluated by the Navy for use as ARARs during applicable investigations; however, because they are specific to Group A Water Systems and are not relevant to the evaluation of alternatives for private drinking water wells, they are not considered ARARs for this evaluation.

3.3.1 Regulatory Setting

PFOA and PFOS are not currently identified as CERCLA hazardous substances; however, application of CERCLA criteria suggests that it is appropriate to consider them to be CERCLA pollutants because the Navy has provided alternative drinking water where 70 ng/L combined PFAS and PFOS has been exceeded (Navy, 2018a).

There are no promulgated federal, chemical-specific ARARs for PFOA and/or PFOS presence in drinking water. Currently, PFOA and/or PFOS are classified as unregulated or “emerging” chemicals, which have no SDWA regulatory standards. In the absence of ARARs, cleanup levels are based upon “…other reliable information…” (refer to 40 CFR 300.430(e)(2)(i)). Reliable information is derived from other TBC criteria, advisories or guidance (40 CFR 300.400(g)(3)). In May 2016, USEPA’s Office of Water issued a health advisory for PFOA and/or PFOS at 70 ng/L (USEPA, 2016a, 2016b). This health advisory is believed to offer a margin of lifetime protection from adverse health effects resulting from exposure to PFOA and/or PFOS in drinking water (USEPA, 2016a, 2016b). Health advisory levels are health-based concentrations above which the USEPA recommends action should be taken to reduce exposure to unregulated SDWA contaminants in drinking water. Therefore, in the absence of an ARAR, the health advisory value can be used as a trigger level to justify an appropriate response action.

Although federal regulations are being developed to address PFOA and PFOS; there are currently no requirements. The WA DOH has recently promulgated changes to Washington Administrative Code (WAC) 246-290, Group A Public Water Supplies; these changes include SALs for five PFAS: PFOA, PFOS, PFHxS, PFNA, and PFBS (WAC 246-290-315). The effective date of these SALs is January 1, 2022. The WA DOH SALs do not apply to private drinking water wells and are not identified as ARARs. If additional ARARs are identified at a later date, additional properties may be evaluated using the alternatives presented in this EE/CA.

3.3.2 ARARs Evaluation Process

Under CERCLA, ARARs include two sets of requirements as follows:

1. Those promulgated substantive standards that would be applicable requirements if the remediation were not being conducted under authority of CERCLA
2. Those substantive standards that are relevant and appropriate requirements of promulgated environmental regulations

Only the substantive requirements (for example, use of control/containment equipment, compliance with numerical standards) associated with ARARs apply to CERCLA onsite activities. ARARs associated with administrative requirements, such as permitting, are not applicable to CERCLA onsite activities (CERCLA, Section 121(e)(1), “Cleanup Standards,” “Permits and Enforcement”).

USEPA has affirmed that ARARs do not include occupational safety or worker protection requirements, although compliance with the Occupational Safety and Health Administration standards and other worker protection requirements in 40 CFR 300.150 of the NCP, is necessary, but it is not through the ARARs process (Federal Register Volume 55 Number 8679, March 8, 1990).

A requirement or cleanup standard under state and federal law may be either “applicable” or “relevant and appropriate,” but not both. Applicable and relevant and appropriate are defined according to the NCP (40 CFR 300.5) as follows:

- ‘Applicable’ requirements are those substantive standards that specifically address the situation at a CERCLA site and would legally apply to remedial actions in the absence of CERCLA authority. All jurisdictional prerequisites of the requirement must be met for the requirement to be applicable, including specific application to federal agencies (for example, through a waiver of federal sovereign immunity). Applicable requirements are those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by the state in a timely manner and that are more stringent than federal requirements may be applicable.
- ‘Relevant and appropriate’ requirements mean those environmental requirements such as cleanup standards that address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site (40 CFR 300.400(g)(2)). Relevant and appropriate requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations that are promulgated under federal or state environmental or facility siting laws that, while they may not be “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to a particular site.
- TBC requirements are other advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states that may be useful in developing CERCLA remedies but are not legally enforceable.

Potential ARARs for the actions to be taken to address PFOA and/or PFOS concentrations greater than 70 ng/L combined PFOA and PFOS in off-Base drinking water wells near NBK-Bangor were examined to determine if they fall into one of the following three categories defined by USEPA guidance:

- **Chemical-specific ARARs** are health or risk-based concentration limits or ranges for particular chemicals that may be found in, or discharged to, the ambient environment.
- **Action-specific ARARs** are requirements that govern particular technologies or activities. They typically set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities.
- **Location-specific ARARs** are requirements that apply based on the location of the site (for example, wetlands, floodplains, historic areas, native burial areas, and wildlife refuges) or siting restrictions (for example, industrial versus residential properties and native versus disturbed land).

In summary, an environmental requirement is applicable if the specific terms or jurisdictional prerequisites of a law or regulation directly address the circumstances at the site. If not applicable, an environmental requirement may nevertheless be relevant and appropriate if circumstances at the site are, based on best professional judgment, sufficiently similar to the problems or situations regulated by the requirement and the requirement's use is well suited to the site.

3.3.3 Potential ARARs Identified for Off-Base Residential Drinking Water Wells near NBK-Bangor

Table 3-2 presents potential federal and Washington State ARARs. The final remedy selection for the drinking water wells will be documented in an Action Memorandum.

3.4 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 assume that any spent treatment media (for example, GAC and IX resin), and any PFAS-impacted groundwater can be managed and characterized as nonhazardous and PFAS-containing. Soils excavated under Alternative 5, connection to public water, and drill cuttings under Alternative 4 are assumed for cost-estimating purposes to be characterized as nonhazardous and not PFAS-containing. Waste characterization testing will be conducted in accordance with the requirements of Washington Administrative Chapter 173-303 and the disposal facility's requirements. Used GAC and IX resin are considered single-use and will require offsite disposal. Nonhazardous waste, including PFAS-impacted soils, will be disposed of in an appropriately permitted disposal facility that is approved by the Navy. All CERCLA waste sent offsite during the removal action will be sent to facilities that have been reviewed by USEPA and found to be acceptable under the CERCLA Off-Site Rule (OSR; 40 CFR 300.440).

3.5 Public Water System and Supply Considerations

The impacted residence is located in Kitsap County, Washington within the boundaries of the Silverdale Water District retail water service area. Potential removal actions considered under Alternative 5 involve making a new water supply connection to Silverdale Water District water system to provide drinking water for the impacted residence.

As detailed in the Silverdale Water District *2013 Comprehensive Water System Plan* (2014), the Silverdale Water District provides municipal water supply and utility service to retail and wholesale customers within its designated water service area in and around the community of Silverdale within Kitsap County, Washington. The system relies on multiple groundwater supply wells to serve approximately 6,000 service connections. The *2013 Comprehensive Water System Plan* documents the existing and future service areas for the Silverdale Water District water system. Alternatives involving new Silverdale Water District water service connections and extensions to provide water supply would need to conform to the Silverdale Water District's Water System

Construction Standards and requirements, as detailed in the Water System Plan. This includes established standards and codes relating to water mains, water service lines, water meters, backflow prevention, and fire hydrants.

Table 3-1. Screening Remedial Alternatives

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
No Additional Action	None	None	No further action to address contaminated drinking water.	X		Retained for baseline comparison.
Institutional Controls	Administrative Restrictions or Engineering Controls	Land Use Controls (LUCs)	LUCs are implemented for property within potentially contaminated areas to restrict property use, well installation, and other intrusive activities.		X	The Department of the Navy (Navy) does not own impacted properties off-Base and will not restrict land use on these properties.
Water Treatment (Ex Situ)	Granular Activated Carbon (GAC) Filtration	Wellhead or Point of Entry (POE)	Water is treated at the wellhead or POE to each household using GAC. GAC adsorption is a well-established technology for removing perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) from drinking water. Water is passed through GAC beds to remove per- and polyfluoroalkyl substances (PFAS) via adsorption to the media, normally using two GAC vessels in series. POE-scale equipment and suppliers are readily available; the appropriate GAC must be obtained from a GAC supplier. Monitoring is conducted at midpoint and final effluent locations to determine when the GAC is spent and to verify treatment effectiveness. GAC has a finite lifespan, and must be removed/managed as a waste material when its effective treatment capacity is exhausted, and replaced with fresh GAC. Spent GAC can be regenerated offsite through thermal desorption, resulting in ultimate destruction of the PFOS/PFOA, or disposed offsite using appropriate technology.	X		GAC adsorption technology is well established and demonstrated for treatment of PFOS/PFOA, and is currently the most widely used technology for PFOS/PFOA removal. The POE process option allows treatment of all household water in one small-scale treatment system. Bench and/or pilot testing might be warranted to develop operating information. Periodic replacement and management (via offsite disposal and/or regeneration) of used GAC is required for this technology. The GAC/POE technology/process option is retained for further evaluation.
		Point of Use (POU) Treatment	Water is treated to remove PFOS/PFOA at the POU (for example, under kitchen sink) for potable purposes (that is, for cooking and drinking) via GAC adsorption. The mode of treatment is the same as in a GAC POE system, but the units are considerably smaller. Although "off-the-shelf" GAC POU units may not be ideal for PFOS/PFOA treatment (for example, insufficient GAC quantity, inappropriate GAC type, lack of intermediate sampling points), effective POU systems can be easily assembled from readily available vessels and an appropriate GAC type by commercial suppliers. These units have a finite lifespan, and the GAC must be replaced when its effective treatment capacity is exhausted, most vendors recommend at least annual sampling.		X	GAC adsorption is demonstrated to be effective for PFOS/PFOA treatment. POU GAC equipment is readily available and easily installed, but multiple POU systems per residence would be required to ensure protectiveness. Despite installing multiple POU units throughout the house at different water outlets, it would not be a practical solution because these units have limited treatment capacity (that is, only good for a fixed volume of water treated), need appropriate contact time with GAC for the treatment to be effective, and can only produce water at a certain flow rate. Like all GAC systems, periodic replacement and disposal of spent GAC would be required as part of this technology/process option. Also, additional sampling and analysis of each unit is required for all POU alternatives, increasing cost and complicating replacement of media/filters. For these reasons, the GAC POU technology/process option is not retained.
		On- or Off-Base Centralized Treatment Plant	Potable water is supplied from a centralized treatment plant built and maintained by the Navy. The treatment plant would use GAC adsorption for removal of PFOS/PFOA, as described.		X	GAC is an effective technology for removing PFOS/PFOA constituents. However, building a water plant off Base to support residents is not feasible because the Navy does not own off-Base property. Supplying off-Base residents with water from on Base also is not typically advisable as water supply is not within the Navy's mission and the potential exists for future emerging contaminants to be discovered that the Navy would then be responsible for as a water supplier. Additionally, restrictions would apply to this system for off-base residents located with an active public water service area. For these reasons, this option was not retained for further evaluation.

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
Water Treatment (Ex Situ) (cont.)	Ion Exchange (IX)	Wellhead or POE	Water is treated at the wellhead or POE using IX. IX has been shown to be effective for removal of PFAS. Water is passed through beds of IX resin, normally using two vessels in series, where PFAS compounds exchange with non-toxic ions (chloride) on the resin surface. The PFAS remain in the resin, while the chloride ions exit with the effluent water. POE-scale equipment and suppliers are readily available; the appropriate IX resin must be obtained from a resin supplier. Monitoring is conducted at midpoint and final effluent locations to determine when the IX capacity is spent and to verify treatment effectiveness. While regeneration of the IX resin is possible, it is highly unlikely that it would be practical for a POE system (because management/disposal of regenerant containing concentrated PFAS, brine, and any solvent used is problematic). Rather, the IX resin would likely be used until its effective capacity is exhausted, and then removed for proper disposal and replaced with fresh resin.	X		The use of IX to remove PFOS/PFOA is an effective technology. Bench and/or pilot testing might be warranted for selection of appropriate IX resin, and development of operating information. The POE process option allows treatment of all household water in one small-scale treatment system. Periodic replacement and disposal of spent IX resin is a requirement for this technology/process option. The IX/POE technology/process option is retained for further evaluation.
		POU Treatment	Water is treated to remove PFOS/PFOA at the POU (for example, under kitchen sink) for potable purposes (that is, for cooking and drinking) via IX. The mode of treatment is the same as in an IX POE system, but the units are considerably smaller. These units have a finite lifespan, and the IX resin must be replaced when its effective treatment capacity is exhausted.		X	Multiple POU systems per residence would be required to ensure protectiveness. Despite installing multiple POU units throughout the house at different water outlets, it would not be a practical solution as these units have limited treatment capacity (that is, only good for a fixed volume of water treated), need appropriate contact time with resins for the treatment to be effective and only can produce water at a certain flow rate. Periodic replacement and disposal of spent IX resin would be required as part of this technology/process option. Also, additional sampling and analysis of each unit is required for all POU alternatives, increasing cost and complicating replacement of media/filters. For these reasons, the IX POU technology/process option is not retained.
		On- or Off-base Centralized Treatment Plant	Potable water is supplied from a centralized treatment plant built and maintained by the Navy. The treatment plant would use IX, as described above.		X	IX is potentially an effective technology for removing PFOS/PFOA constituents. However, because it is less thoroughly demonstrated and widely used than GAC, a bench and/or pilot testing might be warranted. In addition, building a water plant off-Base to support residents is not feasible because the Navy does not own property off-Base. Supplying off-Base residents with water from on-Base is also not typically advisable as water supply is not within the Navy's mission and the potential exists for future emerging contaminants to be discovered that the Navy would then be responsible for as a water supplier. Additionally, restrictions would apply to this system for off-base residents located with an active public water service area. For these reasons, this option was not retained for further evaluation.

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
Water Treatment (Ex Situ) (cont.)	Reverse Osmosis (RO) or Nanofiltration (NF)	Wellhead or POE	Water is treated at the wellhead or POE to each household using RO or NF. Both of these technologies are membrane separation methods where high pressure is applied to push a water through a semi-permeable membrane, leaving contaminants behind in a concentrated (reject) stream. RO and NF differ in the size of molecule removed from water, with RO being capable of removing smaller molecules. The RO technology is well-demonstrated for PFOS/PFOA treatment; NF is less proven at the pilot scale, although it offers the potential for reduced fouling. POE-scale equipment and suppliers are readily available. The high-volume reject stream, as well as other membrane cleaning solutions, must be managed/disposed of.		X	The RO technology has been shown to be very effective for removal of PFOS/PFOA with very little potential for treatment failure. POE-scale RO equipment is commercially available, and the POE process option allows treatment of all household water in one small-scale treatment system. The main drawback of membrane separation technologies is that they generate a considerable volume of liquid residuals (reject stream and cleaning solutions) that must be managed properly, requiring offsite disposal, and this may not be practical or cost-effective. This management of liquid residuals is one of the major limitations of this technology. In addition, RO or NF may require pre-treatment to remove fouling and scaling substances (for example, iron or hardness filters). Because of the known need for costly well water pre-treatment for this option, as well as the disposal of significant volumes of residuals, this option is not retained (GAC and IX provide more cost-effective options that have similar effectiveness).
		POU Treatment	Water is treated to remove PFOS/PFOA at the POU (for example, under kitchen sink) for potable purposes (that is, for cooking and drinking) via RO or NF. The mode of treatment is the same as in a RO POE system, but the units are considerably smaller. RO POU units are readily available from commercial suppliers. The membrane units have a finite lifespan, and must be replaced periodically. RO POU units generate a concentrated reject stream that must be managed properly (RO POU units used for purposes other than PFOS/PFOA removal typically discharge reject to the drain, but this probably would not be allowed for the present application).		X	RO is demonstrated to be effective for PFOS/PFOA treatment. NF is less well-demonstrated. POU-scale RO equipment is readily available and easily installed by commercial suppliers, but multiple POU systems per residence would be required to ensure protectiveness. Despite the installation of multiple POU units throughout the house at different water outlets, it would not be a practical solution due to the limited treatment capacity of these units (that is, good for a fixed volume of water treated) and only can produce water at a certain flow rate. Also, maintaining sufficient pressure and flow rates through RO POU systems may require additional feature, such as a water storage tanks or booster pump, which may add to the size of these systems. RO normally requires pre-treatment to remove fouling substances. In addition to periodic disposal of the filter cartridge, the RO and NF process options generate a high-volume liquid waste stream that must be properly managed, probably via offsite disposal. Also, additional sampling and analysis of each unit is required for all POU alternatives, increasing cost and complicating replacement of media/filters. For these reasons, the RO/NF POU technology/process option is not retained.
		On- or Off-base Centralized Treatment Plant	Water would be supplied from a centralized treatment plant built and maintained by the Navy. The treatment plant would use RO filtration, as described above.		X	RO is an effective technology for removing PFOS/PFOA constituents. However, building a water plant off Base to support residents is not feasible because the Navy does not own off-Base property. Supplying off-Base residents with water from on Base is also not typically advisable as water supply is not within the Navy's mission and the potential exists for future emerging contaminants to be discovered that the Navy would then be responsible for as a water supplier. Additionally, restrictions would apply to this system for off-base residents located with an active public water service area. For these reasons, this option was not retained for further evaluation.

Table 3-1. Screening Remedial Alternatives
Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water
Naval Base Kitsap-Bangor, Washington

General Response Action	Remedial Technology	Process Options	Description	Primary Screening		
				Retain	Reject	Primary Screening Comments
Alternate Water Supply	New (Replacement) Drinking Water Well Installation	Install a well in a deeper, unimpacted aquifer	A well would be installed in a deeper aquifer, unimpacted by PFOA and PFOS.	X		Available geology and PFAS data near the affected off-Base parcels suggest PFAS contamination may be limited to the shallow and/or mid-level aquifer and that a confining layer may exist between these shallower aquifers and the deeper (sea-level) aquifer. Additional field data would need to be collected in the area to evaluate this option (including drilling a deeper well and performing an aquifer test). The new well option is retained for further evaluation at both parcels.
	Bottled Water	Supply bottled water	Bottled water would be supplied and delivered for potable purposes at a single POU (main sink) within the household. Bottled water is readily available for delivery to residential homes in the area.		X	While this technology is a component of the current condition and therefore will be included in the "No Action" alternative, it is not retained as a component of alternatives to the current condition for the reasons stated herein. Currently, bottled water is supplied to residents with drinking water above the United States Environmental Protection Agency lifetime health advisory as an emergency response to a complete exposure pathway to drinking water. As a long-term solution, supplying clean bottled water to residences likely would be effective where implemented; however, water can be consumed only from a single POU in the household. It would not be a practical solution because the volume is limited and inconvenient for the resident to use long term.
	City or Community Water Supply Lines	Extend water supply from Silverdale Water District to residents	Residential water supply would be connected from the Silverdale Water District to both of the affected off-Base area residences from nearby water lines. The Navy would need to facilitate water supply agreements with the Silverdale Water District and install water system piping and supply connection improvements such that the Silverdale Water District would then supply water to the residences.	X		While supplying an alternate water source prevents drinking/domestic water supply exposure to PFOS/PFOA without uncertainty. Silverdale Water District water has been determined to be PFAS-free non-detect for PFOA and PFOS. Therefore, this option is retained for further evaluation.
	Household Tank	Fill and maintain a water supply tank adjacent to the home	Provide an external household water storage tank connected to the house. Provide routine water refilling and chlorination by water truck from a potable water supply (such as the Silverdale Water District).		X	This option would not be approved for long-term residential use due to potential difficulties with water sanitation in the external water tank and connections. Therefore, this alternative was not retained.

Notes:
GAC = granular activated carbon
IX = ion exchange
LUCs = land use controls
NF = nanofiltration
PFAS = per- and polyfluoroalkyl substances
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate
POE = point of entry
POU = point of use
RO = reverse osmosis

Table 3-2. Potential Federal and Washington State ARARs and TBCs for the NBK-Bangor Off-Base Wells

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Media	Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Possible Application	Potential Relevancy
PFAS Chemical Criteria					
Groundwater	EPA Fact Sheet. PFOA & PFOS Drinking Water Health Advisory EPA-800-F-16-003. May 2016.	Chemical	Establishes lifetime health advisory levels for PFOS and PFOA in drinking water at 70 ppt.		TBC
Groundwater	Technical Fact Sheet. Drinking Water Health Advisories for Four PFAS (PFOA, PFOS, GenX chemicals, and PFBS). June 2022.	Chemical	Issuing of interim drinking water health advisories for PFOA (0.004 ppt) and PFOS (0.02 ppt) in drinking water.		TBC
"Water Well Construction Act of 1971" (Chapter 18.104 RCW, as amended); "Minimum Standards for Construction and Maintenance of Wells" (Chapter 173-160 WAC)					
Groundwater	"How Shall Each Water Well Be Planned and Constructed?" (WAC 173-160-161)	Action	Each well must be planned and constructed so that it will not provide a conduit for contaminating surface or groundwater.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the Requirements for the Location of the Well Site and Access to the Well?" (WAC 173-160-171)	Action	Wells will not be located in an area subject to ponding, will be protected from a 100-year flood, and be located certain minimum distances from known or potential sources of contamination.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the Requirements for Preserving the Natural Barriers to Ground Water Movement Between Aquifers?" (WAC 173-160-181)	Action	Identifies the requirements for preserving natural barriers to groundwater movement between aquifers, including providing permanent annular space seals.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the Minimum Standards for Resource Protection Wells and Geotechnical Soil Borings?" (WAC 173-160-400)	Action	Whatever measures are necessary to guard against contamination of groundwater will be taken for all resource protection (monitoring) wells.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the General Construction Requirements for Resource Protection Wells?" (WAC 173-160-420)	Action	Identifies the general construction requirements for resource protection wells, including that resource protection wells cannot be used to withdraw or inject water for other purposes or interconnect aquifers. Nested resource protection wells are not allowed. Cuttings, development waste, and IDW will be disposed of properly.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the Minimum Casing Standards?" (WAC 173-160-430)	Action	All casings shall conform to ASTM standards, or at least 304 or 316 stainless-steel, PTFE, or Schedule 40 PVC casing.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the Equipment Cleaning Standards?" (WAC 173-160-440)	Action	If drilling in potential contamination areas, the drill rig derrick and all drilling equipment must be decontaminated before and after well construction. All well construction materials including casing, screen(s), and filter pack must be free of contaminants prior to installation.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Are the Well Sealing Requirements?" (WAC 173-160-450)	Action	Identifies the well sealing requirements, including that all resource protection wells shall have a continuous seal between the borehole and permanent casing and the boring must be at least 4-inch-diameter larger than the permanent casing. Specific standards for bentonite and cement sealants are specified in the regulation.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Groundwater	"What Is the Decommissioning Process for Resource Protection Wells?" (WAC 173-160-460)	Action	Identifies specific types of decommissioning processes for resource protection wells.	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.	Applicable
Puget Sound Clean Air Agency Regulations					
Air	Regulation I, Section 9.5, Dust Control Measures	Action	Visible emissions of fugitive dust are not allowed, unless reasonable precautions are employed to minimize emissions, such as wetting construction roadways, covering truck loads, or curtailing activities during high winds,	Remediation activities (e.g., excavation) have the potential to create dust.	Applicable
"Solid Waste Management—Reduction and Recycling" (Chapter 70.95 RCW, as amended); "Solid Waste Handling Standards" (Chapter 173-350 WAC)					
Waste	"Owner Responsibilities for Solid Waste (WAC 173-350-025) "On Site Storage, Collection and Transportation Standards" (WAC 173-350-300)	Action	Establishes minimum functional performance standards for the proper handling and disposal of solid waste, including that the owner is responsible for properly collecting, transporting, and disposing of all solid waste generated.	Investigative and remedial actions that generate solid waste will be managed properly.	Applicable

Media	Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Possible Application	Potential Relevancy
“Hazardous Waste Management Act of 1976” (Chapter 70.105 RCW, as amended); “Dangerous Waste Regulations” (Chapter 173-303 WAC)					
Waste	“Designation of Dangerous Waste” (WAC 173-303-070)	Action	Establishes the method for determining if a solid waste is a dangerous waste. No listed wastes are present at these sites.	Investigative and remediation (including waste treatment) activities that generate wastes (e.g., drums, barrels, containers, bulk wastes, debris, and contaminated soil) must be evaluated to determine if they are dangerous waste.	Applicable
Waste	“Requirements for Generators of Dangerous Waste” (WAC 173-303-170)	Action	Establishes the requirements for dangerous waste generators. Requirements include determining if a waste is a dangerous waste. If the waste is dangerous waste, managing the waste in appropriately labeled containers, providing a 30-inch aisle space between container rows, inspecting the containers weekly, keeping the waste in compatible containers that are in good condition, and keeping the containers closed except when adding or removing waste. Staff must be properly trained, and emergency procedures must be in place. Dangerous waste must be properly transported and disposed of. The waste accumulation area where the containers are stored must be properly closed.	IDW and remediation wastes (e.g., contaminated soil and groundwater, personnel protective gear, treatment media) that are dangerous waste must be managed in a certain manner. Wastes generated during the remedial action are not expected to be dangerous waste.	Applicable
“National Historic Preservation Act” (46 USC 470 et. seq.); “Protection of Historic Properties” (36 CFR 800)					
Presence of historical properties	Federal: National Historic Preservation Act, 16 USC 470 et seq., 36 CFR Part 800	Location	Requires the identification of historic properties potentially affected by the agency undertaking, and assessment of the effects on the historic property and seek ways to avoid, minimize or mitigate such effects. Historic property is any district, site, building, structure, archaeological site, traditional cultural landscape, traditional cultural property, or object included in or eligible for the National Register of Historic Places, including artifacts, records, and material remains related to such a property.	The Navy will consult with the Washington State Historic Preservation Officer, the State Department of Archaeology and Historic Preservation, and the Tribe prior to the start of remedial construction and will work to avoid, minimize, or mitigate the impacts of construction on any historic properties, if present.	Applicable, if historic properties are potentially affected by remedial activities. (Most of the former wood treating facility has already been dismantled.)

Notes:

No Location-specific ARARs have been identified at this time. These could include regulations that protect cultural, historic, and Native American sites and artifacts, and those that protect critical habitats of federally endangered and threatened species, bald eagles, and migratory bird species.

ARAR = applicable or relevant and appropriate requirement
ASTM = ASTM International
EPA = United States Environmental Protection Agency
IDW = investigation-derived waste
NBK = Naval Base Kitsap
ng/L = nanogram(s) per liter
PFAS = per- and polyfluoroalkyl substances
PFBS = perfluorobutane sulfonic acid
PFHxS = perfluorohexanesulfonic acid
PFNA = perfluorononanoic acid
PFOA = perfluorooctanoic acid
ppt = part(s) per trillion
PTFE = polytetrafluoroethylene (Teflon)
PVC = polyvinyl chloride
RCW = Revised Code of Washington
TBC = to be considered
WAC = Washington Administrative Code

Description and Evaluation of Removal Action Alternatives

4.1 Description of Removal Action Alternatives

4.1.1 Alternative 1: No Additional Action

Additional action would not be conducted under this alternative; the site would remain in its current condition. Thus, bottled water would continue to be provided to affected off-Base residents whose drinking water contains PFOA and/or PFOS concentrations above 70 ng/L combined PFOA and PFOS.

4.1.1.1 Preliminary Implementation Activities

Because the continued supply of bottled water does not require further implementation activities, preliminary implementation activities are not required under this alternative.

4.1.1.2 Site Layout

Site layout information is not required for supplying bottled water to the off-Base private residences.

4.1.1.3 System Installation

Because installation requirements for supplying bottled water do not exist, system installation activities are not required under this alternative.

4.1.1.4 Operations and Maintenance

Continued maintenance activities include biweekly (every other week) bottled water supply delivery to the residence associated with the affected off-Base drinking water well. For the purposes of this EE/CA, bottled water supply needs at the off-Base private residence are assumed to be 35 gallons delivered each month. Alternative 1 bottled water volume assumptions include the following:

- **Alternative 1:** Residence 2 (one single-family residence): about 35 gallons delivered every month

Off-Base bottled water supply would be required until groundwater concentrations of PFOA and PFOS fell below 70 ng/L combined PFOA and PFOS in the drinking water wells and the on-Base CSM indicates that PFAS will not migrate to the wells. The assumed operating timeframe for cost analysis purposes for this EE/CA is 30 years to capture capital and long-term operations and maintenance (O&M) costs (**Appendix A**).

4.1.2 Alternatives 2 and 3: Point-of-entry Water Treatment

This section details POE treatment system removal action alternatives for PFAS. POE treatment of PFAS-impacted groundwater at the existing drinking water wells would reduce PFOA and PFOS concentrations to levels below 70 ng/L combined PFOA and PFOS at the wellhead, prior to whole-house use.

These alternatives would include the installation and continued maintenance of either GAC or IX POE treatment systems (Alternatives 2 and 3, respectively). These treatment systems would include vessels containing appropriate media for PFOA and PFOS removal.

4.1.3 Alternative 2: Point-of-entry Water Treatment with Granular Activated Carbon

GAC adsorption is an established technology for removing PFOA and PFOS (as well as other PFAS) from drinking water. Water can be treated at the wellhead or POE to the household using a small-scale GAC system. Water is passed through GAC media beds to remove PFAS via adsorption to the GAC media. GAC is a form of carbon processed to have a high surface area to adsorb pollutants. Given sufficient contact time for effective adsorption to occur, organic pollutants are attracted into and retained within the pores and surface of the GAC media. GAC is widely used in water treatment to adsorb and remove organic molecules such as PFOA and PFOS.

GAC treatment trains normally use two or more GAC vessels operating in series as shown on **Figure 4-1** (that is, in lead-lag configuration). Frequency of GAC media changeout and cost of GAC treatment depends on the type and characteristics of GAC used, the influent water quality (including PFAS concentrations, the type and concentrations of other organic and inorganic substances present, water temperature, and pH), flow rates, and the media contact times. Therefore, GAC systems must be appropriately sized, and appropriate GAC media selected. The well water characteristics and the space at the residence to accommodate the POE units could influence implementation and costs of the systems. Careful consideration should be made for appropriate pretreatment and post-treatment as necessary to enhance performance of GAC units and improve end-users experience. For example, to prevent premature fouling of the GAC media, prefilter cartridges might be required. Post-treatment, including water sterilizer (such as ultraviolet [UV] light) may also be appropriate. GAC has finite lifespans and pollutant adsorption capacity. Adsorption sites within the GAC progressively approach saturation as compounds are adsorbed, and the capacity for further adsorption declines. The media bed is considered exhausted and consumed when pollutants targeted for removal breakthrough and are detected between the lead and lag vessel at or greater than a predetermined concentration (that is, when cumulative PFOA and PFOS concentration in the intermediate sample exceeds 35 ng/L(half of the 70 ng/L)). Once breakthrough occurs, the exhausted media must be removed and replaced with fresh media. Details are provided herein regarding the preliminary implementation activities, general system layout, system installation, and O&M assumed for this EE/CA. Alternative 2 is evaluated for the following system:

- **Alternative 2:** GAC treatment of the drinking water well supply for Residence 2. The GAC changeout and monitoring frequency assumed in this EE/CA is based on data assumed for a single-family residence. However, the actual system performance may differ from these assumptions.

4.1.3.1 Preliminary Implementation Activities

Preliminary implementation activities would include further evaluation of the onsite homeowner-maintained water supply and plumbing system layout, characterization of system influent, media and POE systems, and design.

Before finalizing the design for the treatment systems, site visits would be required to further evaluate the existing water supply system and layout. The site visits would include drawings of system layout and potential installation space, and documentation of conversations with property owners. These initial site visits would also be used to collect water samples to analyze for select water quality parameters (such as pH, total and dissolved organic carbon, and iron). The specific GAC media and system sizing and design would be finalized after the site visits.

Property access agreements and requirements would need to be evaluated and finalized, and right-of-entry agreements are needed to support the construction of improvements within the property limits at the residence.

4.1.3.2 System Configuration

General flow diagrams of POE GAC treatment systems for a single-family residence are on **Figure 4-1.** The system configuration may vary during installation to accommodate conditions present at the residence. The POE GAC system would be connected to the existing well, pump, and water pressure tank system as appropriate.

POE-scale equipment and suppliers are readily available. The proposed POE GAC treatment train includes the following:

- 5-micron sediment prefilters
- GAC vessels plumbed in a lead-lag configuration with virgin coal-based activated carbon, such as Calgon FiltraSorb 400 or Evoqua UC1240LD

- Distribution piping, shutoff valves, flow totalizer, upgraded well pump, UV treatment system, and sampling ports housed in a heated treatment enclosure, additional system feed pumps (if needed)

In addition, the off-Base single-family residence POE GAC system would be housed in its own heated treatment enclosure. As shown on **Figure 4-1**, the POE GAC system would be connected to the existing well and pressurized water tank. The GAC system would include system valving and sample ports, a cartridge prefilter, flowmeter, and two GAC vessels plumbed in series. The GAC vessels are sized to provide a minimum 20-minute empty bed contact time (total) at a design flow rate of 20 gallons per minute. There would be a sampling port in between the lead-lag vessel.

4.1.3.3 System Installation

Before the system installation, the footprint of the proposed treatment train would be determined and a layout prepared so that the unit fits within the identified location per the site survey. If the system installation warrants excavation (that is, for piping or to create a level pad for the system housing), an archeological survey may also be required to ensure no adverse effect resulting from the installation.

System installation would include placing the GAC vessels and pre- and post-treatment units in position; installing connective plumbing, ports, valves, instrumentation, and supplemental pumping equipment or well pump upgrades if required; connecting power to electrical equipment; and loading the GAC vessels with media (if not supplied prefilled). Once connected to the water supply, the vessels and associated piping would be pressure-tested to ensure there are no leaks in the system.

For this EE/CA, installation costs are assumed to include installation of the complete system as shown on **Figure 4-1** and as described herein. For the purposes of this EE/CA, it is assumed that the subcontractor, who would be installing and maintaining the POE system, would be responsible for all changeout, profiling, and management of spent media (for costing purposes).

The cost of an underlying concrete pad and an approximate 7-foot by 7-foot by 9-foot outdoor enclosure to house the system is included in the capital cost estimate. The cost of the POE unit is included in the cost estimate (**Appendix A**).

4.1.3.4 Operations and Maintenance

To verify treatment effectiveness and determine when the GAC media is spent and due for replacement, PFAS water quality sampling and monitoring is conducted at influent (before the lead vessel), midpoint (between the lead and lag vessel), and final effluent (after the lag vessel) locations. Operating a GAC POE system would also include replacement of the GAC, as needed, to maintain effective treatment. The spent GAC in the lead vessel would be replaced with fresh media when the cumulative PFOA and PFOS concentration in the midpoint sample (between the lead and lag vessel) exceeds the project indicator limit of 35 ng/L (half of the 70 ng/L level) or after a predetermined operating time (Navy, 2018c). Then, the GAC vessel order would be changed using system valving so that the prior lag vessel is in the lead position and the vessel with fresh carbon is in the lag position. The GAC changeout and monitoring frequency assumed in this EE/CA is based on the data assumed for a single-family residence. However, the actual system performance may differ from these assumptions. The following sampling and changeout frequency have been assumed for a single-family residence GAC treatment unit:

- Monitoring – Monthly for the first year of operation and quarterly (four times per year) for the following 2 years of operation, which may be reduced after year 3 pending the results and trends evident in the initial monitoring.
- Changeout – The estimated average timeframe for prefilter and GAC changeout is every 6 and 9 months, respectively; however, actual changeout frequency would depend on the water quality and be determined by monitoring. Initial monitoring results (that is, until the first changeout) will be used to determine the water volume that the treatment system can effectively treat. Once the treatment volume is determined, the flow totalizer can be used as a tool to optimize changeouts.

Based on the results of the initial monitoring, a conservative timeframe would be established for GAC changeout. After the first 2 years of operation, monitoring would continue but the changeout and monitoring frequency may be reduced. The results of monitoring would continue to be used to update monitoring and changeout frequencies. However, for the cost analysis, reduction in monitoring and changeout frequency was not assumed after 3 years of operation. The used GAC would be appropriately disposed offsite in accordance with Navy policy and all federal, state, and local laws. For costing purposes only, it was assumed that used media would be disposed of via thermal treatment. The cost analysis for the EE/CA was carried out over 30 years to capture capital and long-term O&M costs (**Appendix A**).

4.1.3.5 Sustainability

Sustainability considerations for this alternative include the consumption of GAC media that would have to be managed offsite and appropriately disposed of when it is periodically replaced. The POE system infrastructure would need to be put in place at the residence. The social and economic burden includes increased homeowner water pumping and electricity costs for operating this system is also a consideration.

4.1.4 Alternative 3 :Point-of-entry Water Treatment with Ion Exchange

This POE alternative addresses PFOA and PFOS impact at the off-Base single-family residence by using IX technology for PFOA and PFOS (as well as other PFAS) removal. Water can be treated at the wellhead or POE using IX. The use of IX to effectively remove PFAS has been demonstrated through numerous studies and real-world treatment applications. IX is a treatment process that uses specialized resin that exchanges undesirable ions in water with benign ions on the resin surface to remove dissolved pollutants and produce a clean water product. The resins used in IX processes include small plastic, porous beads with a fixed ionic charge that facilitates the exchange of ions and associated pollutant removal. IX can involve cation exchange of positively charged ions, or anion exchange of ions that are negatively charged. Treatment and removal of PFOA and PFOS via IX uses anion exchange. IX resins are somewhat selective, but their treatment effectiveness may be influenced by water temperature and pH, flow rates, contact time, and types and concentrations of other organic and inorganic substances present. Specifically, for PFOA and PFOS removal using IX, water with high concentrations of total dissolved solids, iron, other dissolved organics, sulfates, and chlorides can potentially hinder the treatment and IX performance available from IX resins. The well water characteristics at the individual well and available space to accommodate the POE units could influence implementation and costs of the systems. Careful consideration should be made for appropriate pretreatment and post-treatment as necessary to enhance performance of IX units and improve end-user experience. For example, to prevent premature fouling of the media, a prefilter cartridge might be required as pretreatment step. A water sterilizer (such as UV light) may also be appropriate.

The off-Base drinking water system would include four IX vessels arranged in two parallel lead-lag trains, as shown on **Figure 4-2**. For effective removal, the appropriate IX resin must be obtained from a resin supplier. While regeneration of the IX resin is possible, it is not practical for a POE system given regeneration process chemical handling and disposal challenges. IX resins currently available for treatment of PFOA and PFOS are considered single-use. Consequently, the IX resin would be used until spent, and then removed, disposed of (in compliance with Navy policy or appropriate regulations in accordance with Navy policy and all federal, state, and accordance with local laws), and replaced.

Details are provided herein regarding the preliminary implementation activities, general system layout, system installation, and O&M assumed for this EE/CA. Alternative 3 is evaluated for the following system:

- **Alternative 3:** IX treatment of the drinking water well supply for Residence 2. The IX changeout and monitoring frequency assumed in this EE/CA is based on the data assumed for a single-family residence. However, the actual system performance may differ from these assumptions.

4.1.4.1 Preliminary Implementation Activities

Preliminary implementation activities for IX would be similar to that of GAC systems and would include all the elements presented in the GAC Preliminary Implementation Activities section (**Section 4.1.2.1**).

4.1.4.2 System Configuration

The general process flow diagram of a POE IX treatment system for a single-family residence is shown on **Figure 4-2**. The POE IX system would be connected to the existing well, pump, and water pressure tank system as appropriate.

POE-scale equipment and suppliers are readily available. The IX treatment system could include the following components:

- 5-micron sediment prefilters
- Four IX vessels plumbed in parallel trains of lead-lag configuration with and configured for single-use resins
- Distribution piping, shutoff valves, upgraded well pump, flow totalizer, UV treatment system, and sampling ports housed in a heated treatment enclosure, additional system feed pumps (if needed).

In addition, the off-Base single-family residence POE IX system would be housed in its own heated treatment enclosure. As shown on **Figure 4-2**, the POE IX system would be connected to the existing well and pressurized water tank. Upstream from the IX vessels on the inlet piping, there would be an isolation valve, influent sample port, 5-micron sediment prefilter, and a flowmeter. The IX system would include four IX vessels arranged in as two parallel lead-lag trains. These vessels are sized to provide a minimum 4-minute empty bed contact time (total) at a design flow rate of 20 gallons per minute. There would be a sampling port in between the lead-lag vessel. Downstream from the IX vessels, the system would have another isolation valve before connection with the main distribution piping to the house.

For the purposes of this EE/CA, it is assumed that the treatment medium used in each IX vessel is a single-use resin. This type of resin has been implemented successfully for removal of PFOA or PFOS at other sites. If selected as the preferred removal action, the final full-scale treatment media would be selected as part of the design, and selection would take into consideration of continuing studies developments of IX resins for PFAS treatment.

4.1.4.3 System Installation

Before system installation, the footprint of the proposed treatment train would be determined, and a layout prepared so that the unit fits within the identified location per the site survey. If the system installation warrants excavation (that is, for piping or to create a level pad for the system housing), an archeological survey might also be required to ensure no adverse effect results from the installation.

System installation would include placing the IX vessels and pre- and post-treatment units in position; installing connective plumbing, ports, valves, instrumentation, and supplemental pumping equipment or well pump upgrades if required; connecting power to electrical equipment; and loading the IX vessels with media (if not supplied prefilled). Once connected to the water supply, the vessels and associated piping would be pressure tested to ensure there are no leaks in the system.

For this EE/CA, installation costs are assumed to include installation of the complete system as shown on **Figure 4-2** and as described herein. For the purposes of this EE/CA, it is assumed that the subcontractor, who would be installing and maintaining the POE systems, would be responsible for all changeout, profiling, and management of spent media (for costing purposes).

The cost of an underlying concrete pad and an approximately 3-foot by 5-foot by 6-foot outdoor enclosure to house the system is included in the capital cost estimate. The cost of the POE unit is included in the cost estimate (**Appendix A**).

4.1.4.4 Operations and Maintenance

To verify treatment effectiveness and determine when the IX resin is spent and due for replacement, PFAS water quality sampling and monitoring is conducted at influent (before the lead vessel), midpoint (between the lead and lag vessel), and final effluent (after the lag vessel) locations. Under this alternative, system operations would include periodic monitoring at these three sample locations for PFAS. For the purposes of this EE/CA, the sampling frequency is assumed based on available PFAS concentration.

System maintenance would also include periodic replacement of the IX media, as needed, to maintain effective treatment. The spent IX in the lead vessel would be replaced by fresh media when the combined PFOA and PFOS concentration in the midpoint sample (between the lead and lag vessel) exceeds the project indicator limit of 35 ng/L or after a predetermined operating time (Navy, 2018c). Then, the IX vessel order would be changed using system valving, so that the prior lag vessel is in the lead position and the vessel with fresh media is in the lag position.

For this EE/CA, the following sampling and changeout frequency has been assumed based on established service life of typical resins in laboratory studies. However, the actual system performance may differ from these assumptions. The following sampling and changeout frequency have been assumed for a single-family residence IX treatment unit:

- Monitoring – Monthly for the first year of operation and quarterly (four times per year) for the following 2 years of operation, which may be reduced after year 3 pending the results and trends evident in the initial monitoring.
- Changeout – The estimated average timeframe for prefilter and IX changeout is every 6 and 9 months, respectively; however, actual changeout frequency would depend on the water quality and be determined by monitoring. Initial monitoring results (that is, until the first changeout) will be used to determine the water volume that the treatment system can effectively treat. Once the treatment volume is determined, the flow totalizer can be used as a tool to optimize changeouts.

Based on the results of the system operations monitoring, the IX changeout schedule would be updated. The revised changeout schedule could be more or less frequent than the assumptions used for costing in this EE/CA. However, for the cost analysis, reduction in monitoring and changeout frequency was not assumed. Based on the assumed single-use IX resin chosen for this EE/CA, used IX resin would be appropriately disposed offsite in accordance with Navy policy and all federal, state, and local laws. For costing purposes only, it was assumed that used media would be disposed of via thermal treatment. Other maintenance activities include semiannual changeout of the prefilter at the off-Base systems (included in the cost estimate in **Appendix A**). The cost analysis for the EE/CA was carried out over 30 years to capture capital and long-term O&M costs.

4.1.4.5 Sustainability

Sustainability considerations for this alternative include the consumption of IX resin that would have to be managed offsite and appropriately disposed of when it is periodically replaced. The POE system infrastructure would need to be placed at the residence. The social and economic burden includes increased homeowner water pumping and electricity costs for operating this system.

4.1.5 Alternative 4: New (Replacement) Drinking Water Well Installation

This alternative would provide a replacement drinking water well for the existing private drinking water well, which has concentrations of PFOA and/or PFOS above 70 ng/L. The new drinking water well would serve as replacement water source for the residence and would be drilled and screened in an appropriate aquifer not impacted by PFOA and/or PFOS above 70 ng/L.

The viability of this option is dependent on the affected residences' (parcels') geology, hydrogeology, and PFAS plume extent. Alternative 4 is evaluated for the following system:

- **Alternatives 4:** Installation and sampling of a new drinking water well at Residence 2.

There are no state or federal regulations that currently restrict the homeowners' use of their existing well. The Navy would give the resident the option to have their well decommissioned, used for non-potable uses (such as irrigation), and/or used for Navy's groundwater PFAS monitoring purposes. The use of the existing well for irrigation may be restricted in the future due to changes in regulation.

4.1.6 Alternative 4: New (Replacement) Drinking Water Well

Using available data for off-Base wells, a new water supply well option may be viable for the residential water supply wells impacted by PFOA and/or PFOS concentrations above 70 ng/L combined PFOA and PFOS.

The aquifers and confining units in this region are based on information interpreted from well records and regionally recognized hydro stratigraphic units. The Sea-level aquifer is separated from shallower water bearing units by at least 50 feet of clay dominated soil. A better understanding of the hydrogeology and PFOA and PFOS concentrations in groundwater in the Sea-level and deeper aquifer beneath the property is required to assess the viability of a new (replacement) drinking water well option in this area. Additional investigation work would need to be performed as outlined in the decision flow chart on **Figure 4-3** before the effectiveness of this alternative can be evaluated. Because of the uncertainty, if this alternative were chosen, contingency removal actions would need to be identified.

In addition to an initial investigation with new drinking water wells, better understanding of the nature and extent, and migration pathways, of PFOA and/or PFOS is also needed to better understand the potential risk for future PFOA and/or PFOS impacts to any new wells (and the aquifer that lies stratigraphically below the aquifer that the existing drinking water well is screened in) if they are used as a long-term residential water supply well. Routine groundwater monitoring would be needed to verify the PFOA and/or PFOS concentrations in any new drinking water well water remains below 70 ng/L combined PFOA and PFOS and contingency actions would need to be put in place in case concentrations approach or exceed 70 ng/L if the new well alternative is chosen as the preferred removal action.

4.1.6.1 Preliminary Implementation Activities

Extensive preliminary implementation activities would be required for this alternative because of the need for additional site investigation work to evaluate the viability of the alternative. The investigation work would include the following:

- Evaluate and finalize property access agreements, including right-of-entry agreements to support construction of improvements within private property limits.
- Obtain appropriate documentation from the Washington Department of Ecology and approvals to drill a new drinking water well.
- Drill one 12-inch diameter surface casing at least 5 feet into the suspected confining unit. A 6-inch diameter drinking water well would be installed within the surface casing to a depth within the aquifer that lies stratigraphically below the aquifer that the existing drinking water well is screened in. The 6-inch diameter drinking water well would be constructed to meet the specifications for a private drinking water well, which includes installing a seal between the upper and lower aquifer in the confining layer.
- Develop the drinking water well (for example, bailing, swabbing, and development pumping to remove dirt and debris and obtain low turbidity, high-quality water from the well) for initial use sampling.
- Sample the drinking water well for constituents in newly installed private drinking water wells (select metals [such as arsenic, barium, cadmium, calcium, chloride, chromium, copper, fluoride, iron, lead, magnesium, manganese, mercury, selenium, silver, sodium, and zinc], ions [such as nitrate, nitrite, and sulfate], pH, alkalinity, hardness, fecal coliform, and total coliform) and for PFAS to ensure PFOA and PFOS concentrations are below 70 ng/L combined PFOA and PFOS.
- Perform aquifer testing on the newly installed potential drinking water supply well (one 8-hour variable rate step test and one 72-hour continuous constant rate test), while monitoring the existing drinking water well and the new drinking water well. This testing would be performed to determine if a hydraulic connection exists between the aquifer in which the existing drinking water well is screened and the aquifer in which the newly installed monitoring drinking water well is screened. This could disrupt water supply from the existing drinking water supply well for the test duration. The concentrations of constituents, including PFAS, monitored by CH2M HILL, Inc. should be tracked before and after testing. The PFAS analytical list to be used

should include, at a minimum, the 18 parameters listed in USEPA 537.1 and other PFAS, which may not be included in the approved USEPA laboratory method but possess properties which allow the constituent to travel faster than PFOA and PFOS and can be used as an indicator.

- Analyze the hydraulic and analytical data from the testing. The creation of a groundwater model may be warranted to inform the evaluation and has been included in the scope of Alternative 4 for cost-estimating purposes. The results of the aquifer testing, and potential modeling output would be used to determine if a hydraulic connection exists between the aquifer in which the existing drinking water well is screened and the aquifer in which the newly installed drinking water well is screened.

The current drinking water well would be replaced with the new, deeper drinking water well if an appropriate water bearing unit is available.

4.1.6.2 Site Layout

The site layout would include construction of a new well and installation and connection of a new well pump to the existing home water piping. It is assumed the existing home piping can be used once connected to the new well and pump.

4.1.6.3 System Installation

The system installation would include installing a new well and new pump and connecting the new well pump to the existing home water piping.

4.1.6.4 Operations and Maintenance

O&M would include groundwater monitoring at the new well to confirm PFOA and/or PFOS concentrations remain below 70 ng/L combined PFOA and PFOS. Quarterly (four times per year) groundwater sampling of the well water for PFAS at a location prior to any treatment by the resident (for example, owner-installed water softeners) would be conducted for the first 2 years. If PFOA and/or PFOS remains nondetect, sampling frequency would be reduced to semiannually (twice per year) thereafter for 28 years.

The cost analysis for the EE/CA was carried out over 30 years to capture capital and long-term O&M costs and assumed quarterly (four times per year) sampling the first 2 years, and semiannually sampling (twice per year) for 28 years (**Appendix A**).

4.1.6.5 Sustainability

Sustainability considerations for this alternative are related to installing a new water supply well (drilling and infrastructure). Other sustainability impacts include installation of water lines from the new wells to the residence, operation of the pump, and impacts associated with routine groundwater sampling work (for example, travel).

4.1.7 Alternative 5: Connection to Public Water Supply

Alternative 5 would address PFOA and/or PFOS impacts by connecting the affected residence to a reliable potable water supply from an existing neighboring water system. Alternative 5 is evaluated for the following system:

- **Alternative 5:** Residence 2 would be connected to receive water from the Silverdale Water District public water system via new water service connection.

This alternative involves installing a new water service connection and piping to provide water supply from an existing Silverdale Water District water service main to Residence 2 as shown on **Figure 4-4**. Details are provided herein regarding the preliminary implementation activities, general system layout, system installation, and O&M needs, and sustainability implications for each alternative.

State or federal regulations currently do not restrict the homeowners' use of their existing well. The Navy would give the residents the option to have their well decommissioned, retained as a resource to support non-potable uses (such as irrigation), and/or used for Navy's groundwater PFAS monitoring purposes.

4.1.7.1 Preliminary Implementation Activities

Prior to final design and implementation of Alternative 5, the following actions would need to be completed:

- Site visits and engagement with owners and residents would need to be completed, and piping connection and implementation details would need to be agreed to.
- System design and sizing criteria would need to be formalized, including estimated residential demands and flows, hydraulic performance parameters, piping alignments, and construction requirements.
- Property access agreements and requirements would need to be evaluated and finalized, including existing public right-of-way utility franchise agreements between county and Silverdale Water District, private property construction and utility easements, and right-of-entry agreements to support construction of improvements within the property limits.
- Design alignments and routes for water system piping and service connection alignments would need to be surveyed, to include property and public right-of-way boundaries, topography, surface features, and existing above and below grade utility locations. Existing utility alignments, where available, is shown on **Figure 4-4** and are based on site reconnaissance and owner-provided information.
- Public work actions typically require permits. CERCLA response actions are exempted by law from the requirement to obtain Federal, State or local permits related to any activities conducted completely on-site.

4.1.7.2 Site Layout

Alternative improvements are illustrated on **Figure 4-4** and would generally include the following:

- Single-family residential water service connection and below grade high density polyethylene service line between an existing Silverdale Water District water service main and Residence 2, to include a service meter, isolation valving, and a RPBA to provide cross connection protection.

Connection from the water service line into Residence 2 interior plumbing. If desired, a connection may also be provided to support flexibility to be able to continue onsite irrigation using either water supplied from the existing private onsite well, or potable water supplied through the proposed water supply connection and line. This would typically involve installation of a double check valve assembly backflow prevention device to prevent well water from back feeding into the residential household water supply, and a three-way valve to allow irrigation flows to be supplied from either the onsite well or the public water system connection source, along with associated plumbing adjustments to existing well system piping and appurtenances to provide for continued well supply functionality. The use of the existing well for irrigation may be restricted in the future due to changes in regulation.

4.1.7.3 System Installation

The proposed water line and associated appurtenances would generally be installed below grade, typically with at least 3 feet of cover to protect against freezing and damage resulting from shallow surface excavations and improvements.

4.1.7.4 Operations and Maintenance

The Silverdale Water District would be responsible for O&M of the proposed system outside the Residence 2 property limits. The Residence 2 property owners would be responsible for O&M of the system within the limits of their private property. Water supply and delivery charges based on metered supply from the Silverdale Water District water system would become the responsibility of the property owners, subject to negotiated/standard water billing rate schedules. The property owner would also be responsible for annual RPBA inspections and testing, with results to be reported to the Silverdale Water District.

4.1.7.5 Sustainability

Sustainability considerations for this alternative are related to the materials and equipment required to construct the alternative. This alternative is significantly more labor intensive as compared to POE or new well installation alternatives.

4.2 Evaluation of Alternatives

4.2.1 Evaluation Criteria

The alternatives described in **Section 4.1** have been evaluated against the criteria of effectiveness, implementability, and cost as described in the *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993) with inclusion of sustainability considerations. These criteria are summarized in the following subsections.

4.2.1.1 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
  - Protects public health and community
  - Protects workers during implementation
  - Protects the environment
  - Complies with ARARs
- Ability to achieve removal objectives
  - Meets the expected level of treatment or containment
  - Has no residual effect concern
  - Maintains long-term control

4.2.1.2 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 considerations
  - 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
  - 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)

4.2.1.3 Cost

The ***cost*** criterion encompasses the lifecycle 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, 2, 3, 4, and 5. 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 0.3 percent (White House OMB, 2021).

The estimated costs are provided to an expected accuracy of +50 percent and -30 percent. The cost estimates are in 2021 dollars, and the unit pricing is based on costs from similar projects, vendor quotes, or engineering estimates. The cost estimate (**Appendix A**) is only an estimate of possible costs for budgeting purposes.

4.2.1.4 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, 2018b). Therefore, a sustainability assessment was conducted using SiteWise Version 3.2, a standalone tool that assesses the environmental footprint of a removal alternative to compare the overall lifecycle environmental impacts of each remedy (Battelle, 2018). The sustainability assessment provides an additional comparison criterion with respect to effectiveness, implementability, and costs that may allow options with smaller environmental impacts to be selected when all other criteria are met. The sustainability assessment is included in **Appendix B**. In addition, the environmental footprint of the selected alternative may be further evaluated in the design phase of the project to explore opportunities to optimize the environmental footprint of the project and integrate sustainable remediation best practices in the design, construction, and operation of the removal action.

4.2.2 Evaluation of Removal Action Alternatives

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

For the purposes of this EE/CA, the evaluation of Alternative 4 assumes that the hydrogeological evaluation performed on the deeper aquifer would indicate that PFAS are not detected in the deeper aquifer and there is no hydraulic connectivity between the surficial aquifer and the deeper aquifer.

Table 4-1. Evaluation of Removal Action Alternatives

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Alternative	Description	Effectiveness	Ease of Implementation	Cost
Alternative 1 - No Additional Action	Removal action would include continued actions already being implemented onsite. This includes supplying bottled water to the off-Base residents. No additional action is evaluated for both single family residences.	**Minimally Effective.** Is protective of human health. For current off-Base drinking water receptors, PFOA and/or PFOS impacted groundwater would not be used for drinking and cooking. Achieves RAO; however, this alternative 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 off-Base homes would be re-released to the environment in septic leach fields with no controls. This alternative is only minimally effective as it has long-term commitment for provision, however it is an effective alternative as short-term solution. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk and/or exceed the USEPA lifetime health advisory (HA). There are no potential short-term risks to site workers since the systems are already implemented. There are no potential short-term risks to the community under this alternative. Environmental impacts are primarily associated with bottle material production and disposal, as well as transportation of bottled water. The SiteWise evaluation indicates greenhouse gas, energy use, accident risk, and priority pollutant emissions are comparatively low.	**Moderately Easy.** Implementation is technically feasible. Off-Base drinking water (bottled water) is already being provided. Bottled water delivery is assumed to continue at the same average volumes currently used per household. However, there is currently only one vendor available in the area, which may affect the ease of implementation if they discontinue service.	Residence 2: Capital Cost $1,518.00 Total Present Value O&M Costs $56,404.74 Total Present Value $57,922.74
Alternative 2 - Point of Entry Water Treatment - Granular Activated Carbon	Removal action includes treatment of water at the POE to each residence 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 and removing PFOA and/or 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. Achieves RAO. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once a combined PFOA and PFOS concentration of 35 ng/L (half of the HA) is reached, and impacted treatment media is transported safely offsite and appropriately disposed offsite using a Navy-approved method. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk and/or exceed the HA, which Alternative 2 would remove. Potential short-term risks to site workers would be managed through provisions of proper PPE. There are no potential short-term risks to the community under this alternative. Environmental impacts are primarily associated with material production, transportation, and incineration (or other Navy-approved disposal methods) of GAC, and energy usage associated with the treatment systems. The SiteWise evaluation indicates greenhouse gas, water usage, and accident risk are comparatively high and priority pollutant emissions are comparatively moderate to high.	**Moderately Easy.** Implementation is technically feasible. System installation procedures and system components are well-established, available, and can be replaced easily. System installation timeframe is moderate (up to 6 to 10 months for work planning, design, subcontracting, and installation). GAC POE equipment installation does not require specialized equipment. PRSCs are required and include routine sampling and changeout frequencies, which could vary for each POE system based on water use, general water quality, and PFAS concentrations. However, a conservative sampling and changeout frequency is assumed for individual private resident POE: • System sampling: Monthly for the first year and quarterly (four times per year) for the first 2 years and may be reduced after 2 years pending the results of initial monitoring, at both residences.	Residence 2: Capital Cost $98,745.18 Total Present Value O&M Costs $1,287,110.14 Total Present Value $1, 385.855.32
Alternative 3 - Point of Entry Water Treatment - Ion Exchange	Removal action includes treatment of water at the POE to each residence using IX. During IX, 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.	**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 IX. Achieves RAO. Long-term protectiveness is achieved, provided that treatment media is changed out in a timely manner once a combined PFOA and PFOS concentration of 35 ng/L (half of the USEPA lifetime health advisory) is reached, and impacted treatment media is transported safely offsite and appropriately disposed offsite using a Navy-approved method. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk and/or exceed the HA, which Alternative 3 would remove. Potential short-term risks to site workers would be managed through provisions of proper PPE. There are no potential short-term risks to the community under this alternative. Environmental impacts are primarily associated with material production, transportation, and disposal through incineration (or other Navy-approved disposal method) of spent IX and energy usage associated with the treatment system. The SiteWise evaluation indicates greenhouse gas, energy use, priority pollutant emissions, and accident risk are comparatively high.	**Moderately Easy.** Implementation is technically feasible - components are well established, available, and can be completed with conventional equipment and equipment. System installation timeframe is moderate (up to 6 to 10 months for work planning, design, subcontracting, and installation). IX POE equipment installation does not require specialized equipment. PRSCs are required and include a conservative sampling and change-out frequency for individual private resident POE system based on water use, general water quality, and PFAS concentrations. However, a conservative sampling and change-out frequency is assumed for individual private resident POE: • System sampling: Monthly for the first year and quarterly (four times per year) for the first 2 years and may be reduced after 2 years pending the results of initial monitoring, at both residences.	Residence 2: Capital Cost $93, 258.41 Total Present Value O&M Costs $1,233,342.68 Total Present Value $1,326,601.09

Alternative	Description	Effectiveness	Ease of Implementation	Cost
Alternative 4 – New (Replacement) Drinking Water Well Installation	Removal action includes a new (replacement) drinking water well for affected residences, where applicable. Investigation includes drilling drinking water wells in a deeper, potentially unimpacted aquifer and testing these wells for PFAS and hydraulic properties (especially connections to shallower-impacted groundwater). If appropriate, the drinking water wells could be used by the residence as new drinking water wells.	**Minimally Effective**. This alternative is classified as potentially Minimally Effective because of the uncertainty whether a clean aquifer exists at depths where construction of a drinking water well is not cost prohibitive at the location of the effected off-Base residences. Available geology and PFAS data in the vicinity of the affected off-Base parcels suggest that a confining layer may exist between these shallower aquifers and the deeper aquifer. Additional field data would need to be collected in the area to evaluate this option (including drilling deeper wells and performing aquifer testing). The retention of this remedial option in the EE/CA will follow a decision-tree as additional data are collected (**Figure 4-3**). May achieve the RAO (if unimpacted water exists at a suitable depth and with continued monitoring to assess effectiveness). Long-term protectiveness may be achieved, provided that well monitoring continues to show PFAS concentrations below the HA in the drinking water wells. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk and/or exceed the HA. Potential short-term risks to site workers would be managed through provisions of proper PPE. Potential short-term risks to the community as a result of drilling and IDW transport. There would also be added traffic and noise impacts to the community during drilling, well development, and aquifer testing. Environmental impacts are primarily associated with production of materials and operation of mechanical drilling equipment, IDW transport and disposal, and installing transmission lines from the new wells. The SiteWise evaluation indicates the greenhouse gas emissions, energy use, accident risk, and the priority pollutant emissions as comparatively low and water usage is comparatively high.	**Moderately Hard**. Implementation is technically feasible. Components are well established and available and can be completed with conventional equipment. The investigation period would be about 9 months to determine if the option is appropriate/effective, with a short timeframe to assess the well. This alternative requires drilling and aquifer testing equipment, construction right of entries on private property and potential disruption of traffic and resident home use (during aquifer testing). PRSCs, including routine PFAS monitoring of the drinking water well, would be required.	Residence 2: Capital Cost $257,754.30 Total Present Value O&M Costs $518,338.16 Total Present Value $776, 092.46
Alternative 5 – Connection to Public Water Supply	Water supply lines from existing public water supply agencies would be extended to affected residences, where applicable. Public water connection is evaluated for single residence connection to Silverdale Water District water supply.	**Very Effective.** Protective of human health to current off-Base drinking water receptors because contaminated groundwater contaminated by PFOA and/or PFOS would no longer be used as a drinking water source, being replaced by the alternative supply of drinking water from the public water supply agencies. The alternative will include use of Silverdale Water District-supplied water. This water is not impacted by PFAS. Residence 2 will have the opportunity to continue using well water only for irrigation purposes, significantly reducing risk to human health. Use of isolation valves and backflow prevention assemblies at these residences further ensure that drinking water is not impacted by well water. Potential short-term risks to site workers would be managed through provisions of proper PPE. Achieves RAO. No residual effect concerns because impacted groundwater would no longer be used for drinking water purposes. Provides a permanent, long-term solution. Although there are no chemical-specific ARARs, the contaminant concentrations pose potential unacceptable risk and/or exceed the HA. Alternative 5 would eliminate potential exposure. Potential short-term risks to the community as a result of transporting construction materials and equipment would be managed by ensuring trucks are not overloaded and that loads are appropriately secured and covered as they transport materials and equipment to/from the site. There would also be added traffic and noise impacts to the community due to construction activities involved in installing water lines in county roads. Traffic control will be used to reduce the impact to the flow of traffic. Environmental impacts are primarily associated with production of materials and operation of mechanical construction and earthwork equipment. The SiteWise evaluation indicates the greenhouse gas emissions, energy use, the priority pollutant emissions, and accident risk as comparatively low and water usage as comparatively moderate due to material production of the water main.	**Moderately Easy.** Implementation is technically feasible. Components are well established and available and can be completed with conventional equipment. Water line installation timeframe is a moderate timeframe (around 10 to 14 months for work planning, design, permitting, subcontracting, and construction). Implementation for Residence 2 is Moderately Easy because it requires minimal line extension for the connection and an existing water main supply main connection point is in the vicinity of the affected residence. This alternative requires earthmoving equipment, access to rights-of-way, construction right of entries on private property, potential disruption of traffic, associated construction excavation and backfill, and transportation of associated construction materials. Additionally, implementation requires coordination with the Silverdale Water District.	Residence 2: Capital Cost $201,722.95 Total Present Value O&M Costs $0 Total Present Value $201,722.95

Notes:
ARAR = Applicable or Relevant and Appropriate Requirements
GAC = granular activated carbon
HA = USEPA lifetime health advisory
IDW = investigation-derived waste
IX = ion exchange
NBK = Naval Kitsap-Bangor
Navy = Department of the Navy
ng/L = nanogram(s) per liter
O&M = Operations and Maintenance
PFAS = per- and polyfluoroalkyl substances
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonic acid
POE = point of entry
POU = point of use
PPE = personal protective equipment
PRSC = Post-Removal Site Controls
RAO = removal action objective
USEPA = United States Environmental Protection Agency

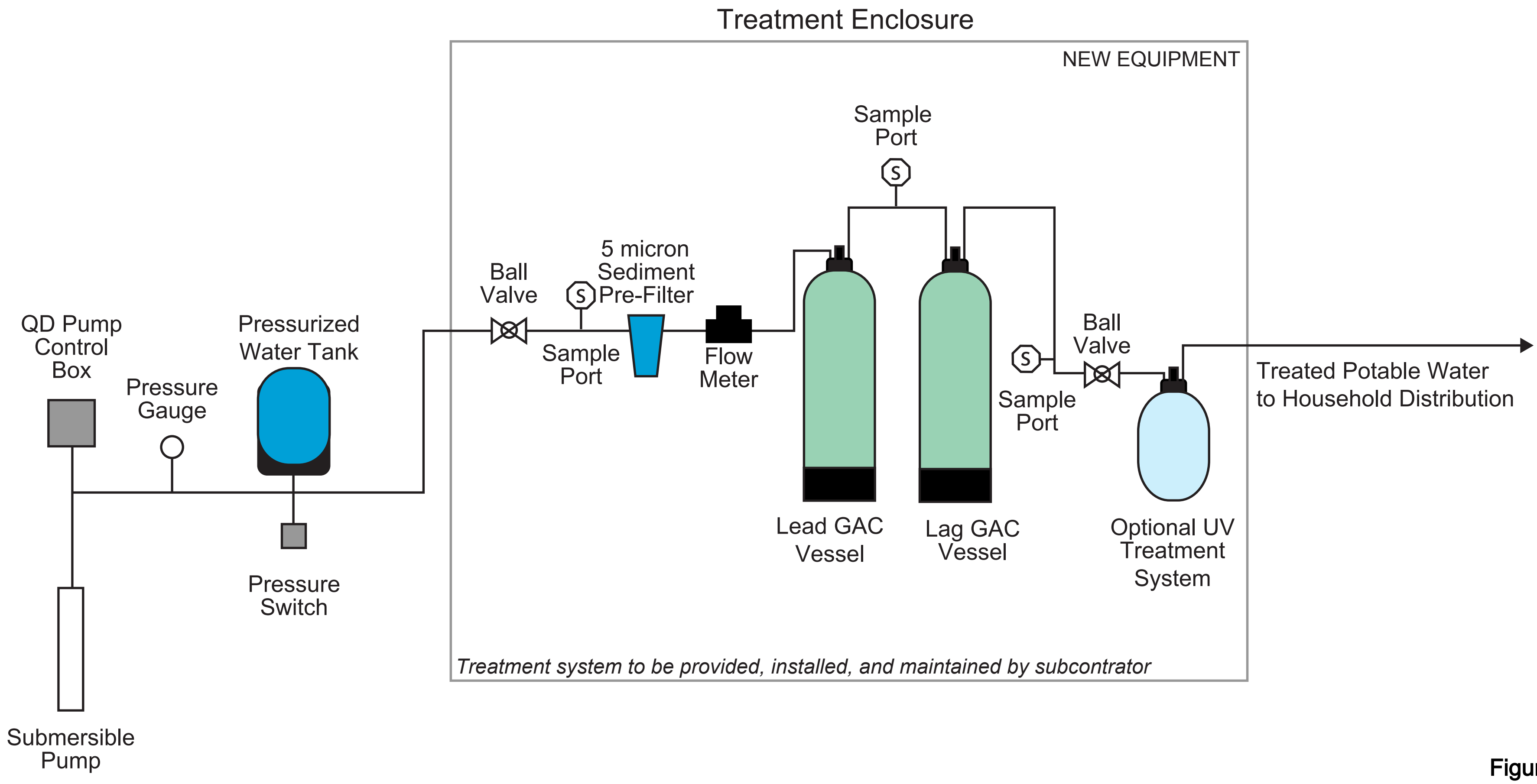


Figure 4-1
Single Family Home Drinking Water
Granulated Activated Carbon Treatment System
Engineering Evaluation/Cost Analysis for
Long-term Solutions for Residential Drinking Water
Naval Base Kitsap-Bangor, Washington

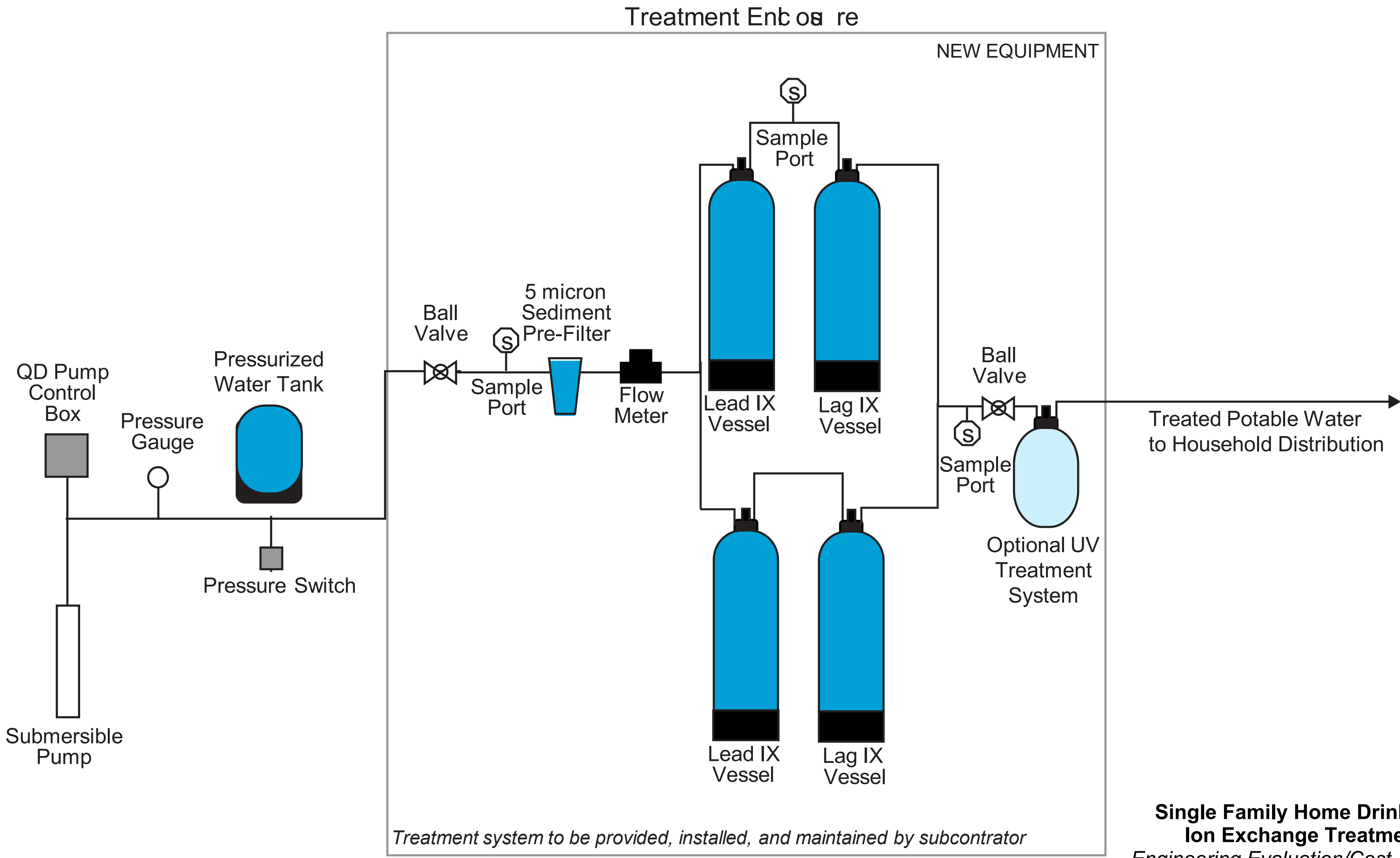
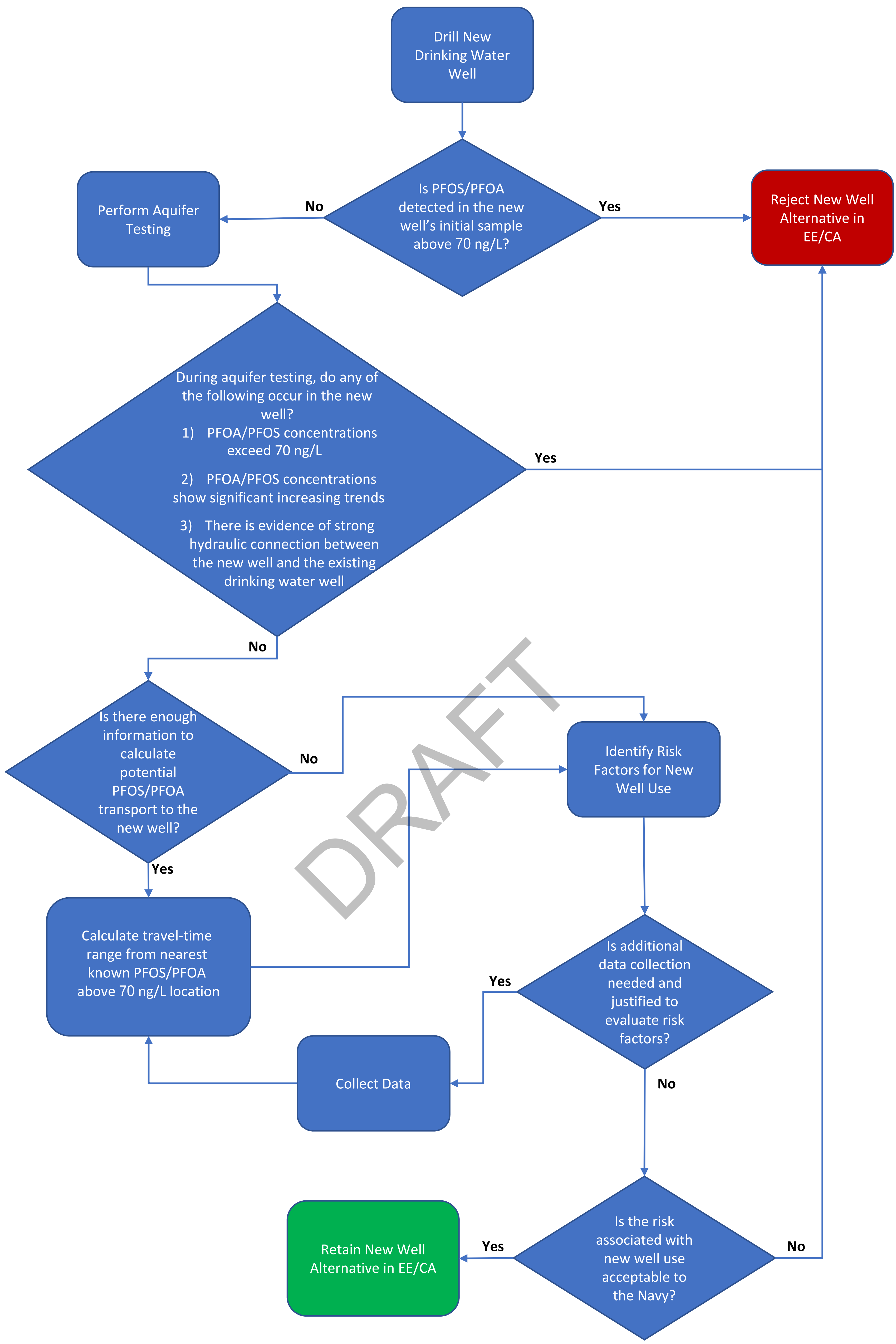
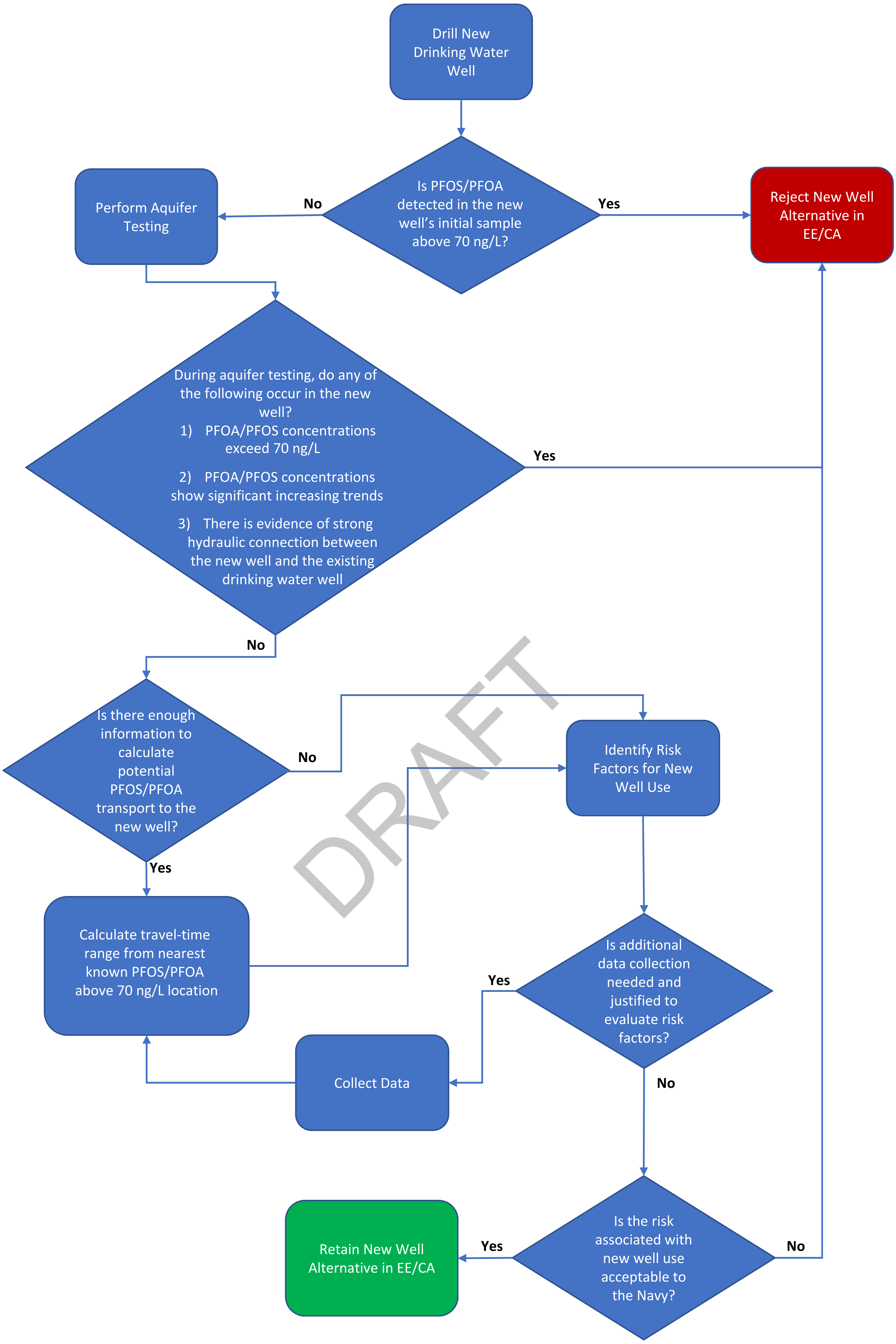


Figure 4-2
Single Family Home Drinking Water
Ion Exchange Treatment System
Engineering Evaluation/Cost Analysis for
Long-term Solutions for Residential Drinking Water
Naval Base Kitsap-Bangor, Washington



Notes:
EE/CA = Engineering Evaluation/Cost Analysis
ng/L = nanograms per liter
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate

Figure 4-3
NBK-Bangor New Residential Well
Remedial Alternative Decision Tree
Engineering Evaluation/Cost Analysis for
Long-term Solutions for Residential Drinking Water
Naval Base Kitsap-Bangor, Washington



Notes:
EE/CA = Engineering Evaluation/Cost Analysis
ng/L = nanograms per liter
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonate

Figure 4-3
NBK-Bangor New Residential Well
Remedial Alternative Decision Tree
Engineering Evaluation/Cost Analysis for
Long-term Solutions for Residential Drinking Water
Naval Base Kitsap-Bangor, Washington

Naval Facilities Engineering Systems Command

Engineering Evaluation/Cost Analysis
Long-term Solutions for Residential Drinking Water
Naval Base Kitsap Bangor
Silverdale, Washington

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Comparative Analysis of Removal Action Alternatives

Section 5 evaluates the alternatives by providing a comparative analysis related to their effectiveness, ease of implementation, and cost, to assist the decision-making process by which a removal action will be selected. **Section 4** described the alternatives in detail and provided alternative evaluation in **Table 4-1**. In this section, the alternatives are compared to one another for each of the three criteria.

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

If additional impacted off-Base drinking water wells are identified at a later date, the future long-term solution evaluations will be conducted consistent with this EE/CA on a property-by-property basis. It is anticipated with the exception of implementability of Alternative 5 that the alternatives evaluation will be consistent for all properties within the sampling area.

5.1 Effectiveness

The RAO and long-term protectiveness are achieved under Alternatives 1, 2, 3, and 5 and are potentially achieved under Alternative 4. While the RAO is achieved under Alternative 1, it is considered comparatively **minimally effective**; because water may continue to be used for non-potable purposes and therefore rereleased to the environment in septic leach fields with no controls. Therefore, this alternative does not contribute to the effective performance of a potential future groundwater remedy. Alternative 4 is also considered **minimally effective** and it is unknown if the RAO would be achieved due to the uncertainty of whether an aquifer groundwater with concentrations below 70 ng/L combined PFOA and PFOS, suitable for drinking water, exists at depths where construction of a drinking water well is practical at the location of the affected off-Base residence. For Alternative 4, until the PFOA and PFOS source and fate and transport conceptual model are identified, there is a risk that groundwater used as the replacement water source could become impacted with PFOA and/or PFOS under long-term pumping.

The RAO is achieved under Alternatives 2 and 3, and both alternatives are considered **effective** because PFOA and/or PFOS are removed from the groundwater supply through treatment. However, these alternatives have associated maintenance and monitoring requirements that must be conducted in a timely manner to maintain effectiveness.

The RAO is achieved under Alternative 5 and the alternative is considered **very effective** because PFOA- and/or PFOS-impacted groundwater is no longer used to provide water to affected residences, thus eliminating receptor exposure (based on current Silverdale Water District water quality). In addition, PFOA and/or PFOS would not be released back into the environment through disposal of wastewater (via the septic system) as is the case for Alternative 1. Alternative 5 is the most flexible with respect to adaptability to environmental conditions as it removes the use of groundwater as the source of drinking water at impacted residence. The installation of the water line also provides a contingency for potential additional properties to connect to the main if these properties have future PFAS exceedances.

5.2 Implementability

All of the alternatives are technically feasible and can be implemented with components that are well established, available, and easily replaced. Alternatives 1, 2, and 3 are all considered **moderately easy** to implement. Alternative 1 assumes bottled water delivery to continue at the same average volumes currently used per household. Alternative 1 has post-removal site control (PRSC) requirements as it requires delivery of bottled water to homes. Continued ease of implementation is reliant on continued availability of bottled water service (there is currently only one vendor available in the area). Alternative 2 is a well-established technology and would require design, and installation of equipment for the POE treatment. Alternative 2 has PRSC requirements as it requires media changeout, waste management, and routine sampling to verify the continued viability of the groundwater as a drinking water source for the residence. Alternative 3 has similar requirements to Alternative 2. In addition, Alternative 5 for Residence 2 is also considered **moderately easy** to implement. Alternative 5 for Residence 2 requires minimal line extension for the connection and an existing water main supply main connection point is in the vicinity of the affected residence.

Alternative 5 is straight-forward to design for Residence 2. Alternative 5 has the greatest impact on the surrounding community during implementation because of the transport of materials during construction. However, impacts could be mitigated through best management practices. Alternative 5 once implemented, has no significant long-term implementation requirements for the Navy as Silverdale Water District would have the ownership of the water lines up to the resident property lines.

Alternative 4 is also considered **moderately hard** to implement. Alternative 4 requires well drilling equipment and testing, as well as construction right of entries on private property. For Alternative 4, the time it would take for the additional investigation (drilling, well installation, aquifer testing, sampling), and the significant investigation-derived waste volume and disposal coordination, adds to the complexity of the implementation of this alternative. Alternative 4 has PRSC requirements as it requires routine sampling to verify the continued viability of the groundwater as a drinking water source for the residence.

5.3 Cost

The detailed cost estimates for the alternatives are provided in **Appendix A** and summarized in **Table 5-1** by Alternative. Generally, Alternatives 1, 4, and 5 are the least expensive alternatives. Alternative 2 and 3 are the most expensive alternatives. Except for Alternative 5, the other alternatives generally have costs associated with long-term PRSCs over 30 years.

5.4 Sustainability

A SiteWise evaluation was performed to assess relative environmental impacts of the different alternatives (**Appendix B**). SiteWise uses various emission factors from governmental or non-governmental research sources to determine the environmental impact of each activity. The following quantitative metrics were calculated by the tool:

- Greenhouse gases (GHGs) reported as metric tons of carbon dioxide equivalents, including carbon dioxide, methane, and nitrous oxide
- Energy usage (expressed as millions of British Thermal Units)
- Water usage (gallons of water)
- Air emissions of criteria pollutants including metric tons of nitrogen oxides (NO_X), sulfur oxides (SO_X), and particulate matter 10 micrometers or less in diameter (PM_{10})
- Accident risk (risk of injury and risk of fatality)

The results from the assessment are presented in detail in **Appendix B** and summarized as follows:

- **GHG:** Alternative 3 had the highest GHG footprints of all of the alternatives primarily due to electricity use to operate the UV system and production and disposal of the resin. Alternative 2 had the second highest GHG use footprints also due to electricity use and material production and disposal (GAC). Alternatives 5, 4, and 1 had the lowest GHG use footprints (in that order). Alternative 5's footprints can primarily be attributed to material production, Alternative 4's footprints to equipment use and material production, and Alternative 1's footprint to transportation of bottled water.

- **Energy Use.** Alternative 3 had the highest Energy use footprint of all of the alternatives primarily due to electricity use to operate the UV system and production and disposal of the resin. Alternative 4 had the second highest energy use footprint primarily due to material production. Alternatives 2, 5, and 1 had the lowest GHG and Energy use footprints (in that order). Alternative 2’s footprints can primarily be attributed to electricity use and material production and disposal (GAC), Alternative 5’s footprints to material production, and Alternative 1’s footprint to transportation of bottled water.
- **Water Use.** Alternatives 5 and 1 had the highest water use footprints (in that order) due to potable water consumption. Alternatives 2 and 3 had the next highest water use footprints due to groundwater consumption and electricity use (cooling water at power plant) for the point source treatments systems. Alternative 4 had the lowest water use footprint due to groundwater consumption and electricity use (cooling water at power plant).
- **Criteria Air Pollutants**. Alternative 3 had the highest NO_X, SO_X, and PM10 footprints, compared with the other alternatives, due to equipment use and material production. Alternative 2 had the second highest NO_X, SO_X, and PM10 footprints, also due to equipment use and material production. Alternatives 5, 4, and 1 had the lowest NO_X, SO_X, and PM10 footprints (in that order). Alternative 5’s footprints can primarily be attributed to material production, Alternative 4’s footprints to equipment use and material production, and Alternative 1’s footprint to transportation of bottled water.
- **Accident Risks**. Alternatives 2 and 3 had the highest accident risk footprints due to transportation of personnel and onsite labor hours (categorized as equipment use and misc.) during monitoring activities. Alternative 4 had the next highest accident risk footprints due to onsite labor hours (categorized as equipment use and misc.). Alternatives 1 and 5 had the lowest accident risk footprints.

Table 5-1. Removal Action Alternative Comparison by Alternative

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Alternative	Does Alternative Meet RAO?	Effectiveness Score	Ease of Implementation Score	Cost Score	Capital Cost	Total Present Value Cost	Total Score
Alternative 1 - No Additional Action							
Residence 2 - Bottled Water	Yes	1	3	5	$ 1,518.00	$ 57,922.74	9
Alternative 2 - Point of Entry Water Treatment: Granular Activated Carbon							
Residence 2 - Point of Entry - GAC	Yes	3	3	1	$ 98,745.18	$ 1,385,855.32	7
Alternative 3 - Point of Entry Water Treatment: Ion Exchange							
Residence 2 - Point of Entry - IX	Yes	3	3	1	$ 93,258.41	$ 1,326,601.09	7
Alternative 4 - New (Replacement) Drinking Water Well							
Residence 2 - New Replacement Drinking Water Well	Maybe[a,b]	2	2	3	$ 257,754.30	$ 776,092.46	7
Alternative 5 - Connection to Public Water Supply							
Residence 2 - Connection to Silverdale Water District	Yes	5	3	5	$ 202,000.00	$ 201,722.95	13

Notes:

[a] There is a potential risk these groundwater sources could become impacted by PFAS in the future. A better understanding of the nature and extent, fate and transport of PFAS from NBK-Bangor will be developed in the on-site CERCLA investigation. Until the CSM can be verified, continued monitoring of the water source is required.

[b] Additional investigation, included in the alternative, is require to assess if the alternative meets RAOs.

Effectiveness

5: Very Effective

3: Effective

1: Minimally effective

Ease of Implementation

5: Easiest

4: Easy

3: Moderately Easy

2: Moderately Hard

1: Hard

Cost

5: $0 to $250,000

4: $250,000 to $500,000

3: $500,000 to $750,000

2: $750,000 - $1,000,000

1: greater than $1,000,000

CSM = conceptual site model

GAC = granular activated carbon

IX = ion exchange

NBK = Naval Base Kitsap

PFAS = per- and polyfluoroalkyl substances

RAO = removal action objective

Recommended Removal Action Alternative

Based on evaluation of the alternatives, the recommended removal action alternatives for the off-Base drinking water parcel is:

- **NBK-Bangor Residence 2:** Alternative 5 – connection to existing Silverdale Water District public water system main line. Alternative 5 is considered very effective because it eliminates impacted groundwater 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. The alternative extends a water service connection from an existing Silverdale Water District water main to the residence home. System installation would be carried out in accordance with Silverdale Water District requirements. Under this alternative, it is assumed that the off-Base private drinking water wells could remain in place for irrigation use. The use of this well for irrigation may be restricted in the future due to changes in regulation. While it has slightly greater sustainability impacts and implementation requirements than the other alternatives, this alternative is a solution that provides for unlimited use of drinking water at the off-Base residences, with no PRSCs or periodic O&M.

Navy, USEPA, and state representatives had an 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. The Action Memorandum will also be available for public comment. If additional public comments are received on the Action Memorandum, they will also be included in the Responsiveness Summary. The Action Memorandum and EE/CA will be included in Administrative Record.

References

Assistant Secretary of Defense (ASD). 2020. *Memorandum: Per- and Polyfluoroalkyl Substances Sampling of Department of Defense Drinking Water Systems.* March 2.

Battelle Analytical Services (Battelle). 2013. *SiteWise Version 3.2*. NAVFAC Engineering Service Center. August.

CH2M HILL, Inc. (CH2M). 2020. *Preliminary Assessment for Per- and Polyfluoroalkyl Substances (PFAS)*. Final. December.

Department of the Navy (Navy). 2015. *Fourth Five-Year Review, Naval Base Kitsap at Bangor, Silverdale, Washington*. Final. September.

Navy. 2018a. A Comprehensive Strategy to Manage and Address Perfluorinated Compounds (PFC)/Perfluoroalkyl Substances (PFAS) issues. September 21, 2018.

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

Navy. 2018c. *Sampling and Analysis Plan, Time-Critical Removal Action, Point-of-Use Treatment System Monitoring, Ault Field and Outlying Landing Field Coupeville, Naval Air Station Whidbey Island, Oak Harbor and Coupeville, Washington*. Prepared by CH2M. Final. April.

Navy. 2020. *Emergency Response Action Memorandum, Naval Kitsap Bangor, Silverdale Washington.* March.

Deputy of the Navy Office of the Assistant Secretary Energy, Installations, and Environment (DASN). 2016. *Policy Memo: Perfluorinated Compounds (PFC)/Perfluoroalkyl Substances (PFAS) – Identification of Potential Areas of Concern (AOC).* June 20.

Kahle, S.C. 1998. *1998 Hydrogeology of Naval Submarine Base Bangor and Vicinity, Kitsap County, Washington*.

Robinson, Noble, and Carr. 1981. *Ground Water Hydrology at The Naval Submarine Base, Bangor, Washington*. Volume I. July.

Silverdale Water District. 2014. *2013 Comprehensive Water System Plan*. Prepared by HDR Engineering, Inc. August. https://www.swd16.org/Documents%20and%20Forms/2013_Water_System_Plan.pdf.

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

USEPA. 2016a. Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS). EPA 822-R-16-004. May.

USEPA. 2016b. Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). EPA 822-R-16-005. May.

Washington State Department of Health (WA DOH). 2020. *Water System Design Manual*. June.

White House Office of Management and Budget (White House OMB). 2021. *Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses – Real Discount Rates: Real Interest Rates on Treasury Notes and Bonds of Specified Maturities*. Circular No. A-94, Appendix C. Revised December 2020. Accessed November 2021. https://www.whitehouse.gov/wp-content/uploads/2020/12/2020_Appendix-C.pdf.

Appendix A
Cost Estimate

Table A-1. Engineer's Cost Estimate for Alternative 1: No Additional Action - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
CAPITAL COST					
Work Planning Documents					
APP-SSHP	Lump Sum	1	$1,200.00	$1,200.00	Assumes minor updates to existing documents.
Work Planning Documents Total				**$1,200.00**	
CAPITAL COST SUBTOTAL				***$1,200.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$180.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Project Management (10% of Capital Cost Sub, Contingency, General Conditions & Performance Bond)		*10%*		$138.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$1,518.00**	
ANNUAL OPERATIONS AND MAINTENANCE (O&M)					
Bottled Water Supply	Month	12	$115.00	$1,380.00	September 2021 delivery totals from Crystal Spring Invoices.
O&M Cost Annual Subtotal				***$1,380.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$207.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$207.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL O&M COSTS PER YEAR				**$1,794.00**	
Total Years of O&M				30	
TOTAL O&M COST FOR 30 YEARS				**$53,820.00**	
Discount Rate				-0.3%	Office of Management and Budget, Circular A-94 2021.
TOTAL PRESENT VALUE OF O&M COST				**$56,404.74**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$57,922.74**	
			+50%	$86,884.11	
			-30%	$40,545.92	

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.

APP-SSHP = Accident Prevention Plan-Site Safety and Health Plan

O&M = Operation and Maintenance

UFP-SAP = Uniform Federal Policy-Sampling and Analysis Plan

WMP-EPP = Waste Management Plan-Environmental Protection Plan

Source: United States Environmental Protection Agency (USEPA). 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. July.

Table A-2. Engineer's Cost Estimate for Alternative 2: Point of Entry Water Treatment with Granular Activated Carbon Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
CAPITAL COST					
Work Planning Documents					
UFP-SAP, WMP-EPP, APP-SSHP	Lump Sum	1	$18,000.00	$18,000.00	Includes draft and final submission with site-specific system design and AHAs for system installation.
Construction Completion Report	Lump Sum	1	$14,400.00	$14,400.00	Includes draft and final submission for system installation.
Work Planning Documents Total				**$32,400.00**	
Site Preparation					
Mobilization/Demobilization	Each	1	$1,200.00	$1,200.00	Prior Experience (Fentress); 1 each
Site Visit and Documentation	Each	1	$1,800.00	$1,800.00	Prior Experience (Fentress); 1 each
Site Access Agreements	Each	1	$576.00	$576.00	Right of Entry Forms; assumes 4 hours Jacobs support at $120/hour for each agreement, one need for each property
Site Preparation Total				**$3,576.00**	
System Installation					
Point of Entry GAC System with media included	System	2	$6,412.50	$12,825.00	Assume 2 vessels, Pentair GAC; CARBTROL Quote 11/3/21
UV disinfection system	System	1	$3,000.00	$3,000.00	Quote Sept 2021; Pelican Water https://www.pelicanwater.com/uv/viqua-pro-uv/
Upgraded Well Pump	System	1	$545.00	$545.00	https://www.homedepot.com/p/Everbilt-1-HP-Submersible-3-Wire-Motor-20-GPM-Deep-Well-Potable-Water-Pump-EFSUB10-253HD/205617972
Flow Totalizer with Remote Capabilities	System	1	$174.00	$174.00	https://www.homedepot.com/p/Streamlabs-Smart-Home-Water-Monitor-UFMT-1000/305141000#overlay
Installation of GAC systems by certified plumber	Day	1	$1,880.00	$1,880.00	Plumbing crew. $30/Filter
Process Piping Allowance	System	1	$1,500.00	$1,500.00	
Electrician allowance	Hour	5	$120.00	$600.00	
Miscellaneous Items Allowance	System	1	$600.00	$600.00	Items purchased from the hardware store such as electrical components, flow valves etc. Based on prior experience.
Shed/Building Allowance	System	1	$2,020.00	$2,020.00	Assume 7-ft x7-ft x9-ft Rubbermaid shed for housing treatment equipments. Assumes no or minimal earthwork required. Includes concrete pad and electrical hookup.
System Installation Total				**$23,144.00**	
CAPITAL COST SUBTOTAL				***$59,120.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$8,868.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$5,912.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)

Table A-2. Engineer's Cost Estimate for Alternative 2: Point of Entry Water Treatment with Granular Activated Carbon Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$1,478.00	Industry Average
Project Management (8% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*10%*		$7,537.80	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*6%*		$4,522.68	Navy Estimating Guidance.
Construction Oversight (10% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*15%*		$11,306.70	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$98,745.18**	
ANNUAL OPERATIONS AND MAINTENANCE (O&M) YEAR 1					
Monitoring event labor	Events	12	$960.00	$11,520.00	[8 h/event (2 hr monitoring + 2 h travel + 4 h pre-/post-monitoring work] x [$100/h] with 120% inflation
Sediment Filter Changeout	Events	2	$510.00	$1,020.00	[4 h/event (2 hr monitoring + 2 h travel) x [$100/h] $30/Filter with 120% inflation
UV Lightbulb Replacement	Events	0.5	$300.00	$150.00	Biennial change-out; https://www.espwaterproducts.com/uvmax-pro20-1/
Monitoring event expenses	Events	12	$330.00	$3,960.00	[$50 sample shipping + $50 equipment/supplies + $175 travel] x 120% Inflation
Monitoring event analytics	Events	12	$2,160.00	$25,920.00	[4 samples/system (3 sample points + 1 QC sample)] x [($283 per sample based on costing CLEAN 9000 x 120%) + $200 waste profile]
GAC and filter Changeout	Events	1.3	$2,620.00	$3,406.00	GAC: [500-lb GAC/system/change-out (assumes lead vessel replaced and lag vessel rotated to lead position)] x [$3/lb GAC x 120% Inflation]; Labor: [4 hr/visit] x [$205/hr]; Cost basis prior experience.
Used GAC Disposal	Events	1.3	$2,810.00	$3,653.00	[37.6 CF of used GAC/changeout] x [$52.4/CF (based on $7/gal CERCLA rate for incineration)] + [$200/event for mobilization/demobilization] + [$175/event per system for profiling]. 120% inflation
Miscellaneous Items Allowance	Lump Sum	1	$500.00	$500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc.
On-call service	Hour	4	$205.00	$820.00	On-call rate for Culligan for pilot tests is $205. Assume one 4-hr service call per system per yr per system.
POE System Reporting	Each	1	$4,800.00	$4,800.00	One TM per year documenting sampling activities, results, repairs and changeouts. Assumes data validation, database management, and preparation of one TM per year (40 hours per event at average rate of $120/hr.)
O&M Cost Annual Subtotal (Year 1)				***$55,749.00***	

Table A-2. Engineer's Cost Estimate for Alternative 2: Point of Entry Water Treatment with Granular Activated Carbon Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$8,362.35	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$5,574.90	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$8,362.35	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$446.33	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS PER YEAR (YEAR 1)				**$78,494.93**	
ANNUAL OPERATIONS AND MAINTENANCE (O&M) YEARS 2-30					
Monitoring event labor	Events	4	$960.00	$3,840.00	[8 h/event (2 hr monitoring + 2 h travel + 4 h pre-/post-monitoring work] x [$100/h] with 120% inflation
Sediment Filter Changeout	Events	2	$510.00	$1,020.00	[4 h/event (2 hr monitoring + 2 h travel) x [$100/h] $30/Filter with 120% inflation
UV Lightbulb Replacement	Events	0.5	$300.00	$150.00	Biennial change-out; https://www.espwaterproducts.com/uvmax-pro20-1/
Monitoring event expenses	Events	4	$330.00	$1,320.00	[$50 sample shipping + $50 equipment/supplies + $175 travel] x 120% Inflation
Monitoring event analytics	Events	4	$2,160.00	$8,640.00	[4 samples/system (3 sample points + 1 QC sample)] x [($283 per sample based on costing CLEAN 9000 x 120%) + $200 waste profile]
GAC and filter Changeout	Events	1.3	$2,620.00	$3,406.00	GAC: [500 lb GAC/system/change-out (assumes lead vessel replaced and lag vessel rotated to lead position)] x [$3/lb GAC x 120% Inflation]; Labor: [4 hr/visit] x [$205/hr]; Cost basis prior experience.
Used GAC Disposal	Events	1.3	$2,810.00	$3,653.00	[37.6 CF of used GAC/change-out] x [$52.4/CF (based on $7/gal CERCLA rate for incineration)] + [$200/event for mobilization/demobilization] + [$175/event per system for profiling]. 120% inflation
Miscellaneous Items Allowance	Lump Sum	1	$500.00	$500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc.
On-call service	Hour	4	$205.00	$820.00	On-call rate for Culligan for pilot tests is $205. Assume one 4-hr service call per system per yr per system.
POE System Reporting	Each	1	$4,800.00	$4,800.00	One TM per year documenting sampling activities, results, repairs and changeouts. Assumes data validation, database management, and preparation of one TM per year (40 hours per event at average rate of $120/hr.)

Table A-2. Engineer's Cost Estimate for Alternative 2: Point of Entry Water Treatment with Granular Activated Carbon Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
O&M Cost Annual Subtotal (Years 2-30)				***$28,149.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$4,222.35	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$2,814.90	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$4,222.35	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$308.33	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS PER YEAR (YEARS 2-30)				**$39,700.00**	Excluding Year 1
Years of O&M				29	Excluding Year 1
O&M COSTS PER YEAR (YEARS 2-30)				**$1,151,300.00**	
TOTAL O&M COST FOR 30 YEARS				**$1,229,794.93**	
Discount Rate				-0.3%	Office of Management and Budget, Circular A-94 2021.
TOTAL PRESENT VALUE OF O&M COST				**$1,287,110.14**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$1,385,855.32**	
			+50%	$2,078,782.98	
			-30%	$970,098.72	

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

AHA = Activity Hazard Analysis
APP-SSHP = Accident Prevention Plan-Site Safety and Health Plan
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CF = cubic foot
ft = foot
GAC = granular activated carbon
hr = hour(s)
lb = pound(s)
O&M = Operation and Maintenance
POE = point of entry
QC = quality control
TM = technical memorandum
UFP-SAP = Uniform Federal Policy-Sampling and Analysis Plan
USEPA = United States Environmental Protection Agency
UV = ultraviolet
WMP-EPP = Waste Management Plan-Environmental Protection Plan

Source: United States Environmental Protection Agency (USEPA). 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. July.

Table A-3. Engineer's Cost Estimate for Alternative 3: Point of Entry Water Treatment with Ion Exchange Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
CAPITAL COST					
Work Planning Documents					
UFP-SAP, WMP-EPP, APP-SSHP	Lump Sum	1	$18,000.00	$18,000.00	Includes draft and final submission with site-specific system design and AHAs for system installation
Construction Completion Report	Lump Sum	1	$14,400.00	$14,400.00	Includes draft and final submission for system installation
Work Planning Documents Total				**$32,400.00**	
Site Preparation					
Mobilization/Demobilization	Each	1	$1,200.00	$1,200.00	Prior Experience (Fentress); 1 each
Site Visit and Documentation	Each	1	$1,800.00	$1,800.00	Prior Experience (Fentress); 1 each
Site Access Agreements	Each	1	$576.00	$576.00	Right of Entry Forms; assumes 4 hours Jacobs support at $120/hour for each agreement, one need for each property
Site Preparation Total				**$3,576.00**	
System Installation					
Point of Entry Ion Exchange System with IX resins included	Vessel	4	$2,440.00	$9,760.00	Four 11-inch-diameter vessels from PentAir for the IX system ($1,216 per vessel). https://www.pelicanwater.com/water-filters/whole-house-water-filter/; $375/CF resin
UV disinfection system	System	1	$3,000.00	$3,000.00	Quote Sept 2021; Pelican Water https://www.pelicanwater.com/uv/viqua-pro-uv/
Upgraded Well Pump	System	1	$545.00	$545.00	https://www.homedepot.com/p/Everbilt-1-HP-Submersible-3-Wire-Motor-20-GPM-Deep-Well-Potable-Water-Pump-EFSUB10-253HD/205617972
Flow Totalizer with Remote Capabilities	System	1	$174.00	$174.00	https://www.homedepot.com/p/Streamlabs-Smart-Home-Water-Monitor-UFMT-1000/305141000#overlay
Installation of IX systems by certified plumber	Day	1	$1,880.00	$1,880.00	Plumbing crew. $30/Filter
Process Piping Allowance	System	1	$1,500.00	$1,500.00	
Electrician allowance	Hour	5	$120.00	$600.00	
Miscellaneous Items Allowance	Systems	1	$600.00	$600.00	Items purchased from the hardware store such as electrical components, flow valves etc. Based on prior experience.
Shed/Building Allowance	Systems	1	$1,800.00	$1,800.00	Assume 3-ft x 5-ft x 6-ft Rubbermaid shed for housing treatment equipment. Assumes no or minimal earthwork required. Includes concrete pad and electrical hookup.
System Installation Total				**$19,859.00**	
CAPITAL COST SUBTOTAL				***$55,835.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$8,375.25	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)

Table A-3. Engineer's Cost Estimate for Alternative 3: Point of Entry Water Treatment with Ion Exchange Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$5,583.50	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$1,395.88	Industry Average
Project Management (8% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*10%*		$7,118.96	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*6%*		$4,271.38	Navy Estimating Guidance.
Construction Oversight (10% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*15%*		$10,678.44	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$93,258.41**	
ANNUAL OPERATIONS AND MAINTENANCE (O&M) YEAR 1					
Monitoring event labor	Events	12	$960.00	$11,520.00	[8 h/event (2 hr monitoring + 2 h travel + 4 h pre/post monitoring work] x [$100/h] with 120% inflation
Monitoring event expenses	Events	12	$330.00	$3,960.00	[$50 sample shipping + $50 equipment/supplies + $175 travel] x 120% Inflation
Monitoring event analytics	Events	12	$2,160.00	$25,920.00	[4 samples/system (3 sample points + 1 QC sample)] x [($283 per sample based on costing CLEAN 9000 x 120% inflation) + $200 waste profile] with 120% inflation
Resin Changeout	Events	1.3	$2,930.00	$3,809.00	IX Resin: [6.5 CF/system/change-out (assumes lead vessel replaced and lag vessel rotated to lead position)] x $375/CF (estimate from Purolite, including transportation costs)];
Sediment Pre-Filter Changeout	Events	2	$860.00	$1,720.00	Sediment filter: [$30/filter]; Labor: [4 h/visit] x [$205/h]; Cost basis prior experience. 120% Inflation
Used Resin Disposal	Events	1.3	$860.00	$1,118.00	[6.5 CF of used resin/changeout] x [$52.4/CF (based on $7/gal CERCLA rate for incineration)] + [$200/event for mobilization/demobilization] + [$175/event per system for profiling]. 120% inflation
UV Lightbulb Replacement	Events	0.5	$300.00	$150.00	Biennial changeout; https://www.espwaterproducts.com/uvmax-pro20-1/
Miscellaneous Items Allowance	Lump Sum	1	$500.00	$500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc.
On-call service	Hour	4	$205.00	$820.00	On-call rate for Culligan for pilot tests is $205. Assume one 4-hr service call per system per yr per system.

Table A-3. Engineer's Cost Estimate for Alternative 3: Point of Entry Water Treatment with Ion Exchange Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
POE System Reporting	Each	1	$4,800.00	$4,800.00	One TM per year documenting sampling activities, results, repairs and changeouts. Assumes data validation, database management, and preparation of one TM per year (40 hours per event at average rate of $120/hr.)
O&M Cost Annual Subtotal (Year 1)				***$54,317.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$8,147.55	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$5,431.70	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$8,147.55	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$433.93	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS PER YEAR (YEAR 1)				**$76,477.73**	
ANNUAL OPERATIONS AND MAINTENANCE (O&M) YEARS 2-30					
Monitoring event labor	Events	4	$960.00	$3,840.00	[8 h/event (2 hr monitoring + 2 h travel + 4 h pre/post monitoring work] x [$100/h] with 120% inflation
Monitoring event expenses	Events	4	$330.00	$1,320.00	[$50 sample shipping + $50 equipment/supplies + $175 travel] x 120% Inflation
Monitoring event analytics	Events	4	$2,160.00	$8,640.00	[4 samples/system (3 sample points + 1 QC sample)] x [($283 per sample based on costing CLEAN 9000 x 120% inflation) + $200 waste profile] with 120% inflation
Resin Changeout	Events	1.3	$2,930.00	$3,809.00	IX Resin: [6.5 CF/system/change-out (assumes lead vessel replaced and lag vessel rotated to lead position)] x $375/CF (estimate from Purolite, including transportation costs)];
Sediment Pre-Filter Changeout	Events	2	$860.00	$1,720.00	Sediment filter: [$30/filter]; Labor: [4 h/visit] x [$205/h]; Cost basis prior experience. 120% Inflation
Used Resin Disposal	Events	1.3	$860.00	$1,118.00	[6.5 CF of used resin/changeout] x [$52.4/CF (based on $7/gal CERCLA rate for incineration)] + [$200/event for mobilization/demobilization] + [$175/event per system for profiling]. 120% inflation
UV Lightbulb Replacement	Events	0.5	$300.00	$150.00	Biennial changeout; https://www.espwaterproducts.com/uvmax-pro20-1/
Miscellaneous Items Allowance	Lump Sum	1	$500.00	$500.00	Items purchased from the hardware store such as piping, electrical components, flow valves etc.
On-call service	Hour	4	$205.00	$820.00	On-call rate for Culligan for pilot tests is $205. Assume one 4-hr service call per system per yr per system.

Table A-3. Engineer's Cost Estimate for Alternative 3: Point of Entry Water Treatment with Ion Exchange Treatment - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
POE System Reporting	Each	1	$4,800.00	$4,800.00	One TM per year documenting sampling activities, results, repairs and changeouts. Assumes data validation, database management, and preparation of one TM per year (40 hours per event at average rate of $120/hr.)
O&M Cost Annual Subtotal (Years 2-30)				***$26,717.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$4,007.55	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$2,671.70	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$4,007.55	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$295.93	Industry Average on O&M items performed by subcontractor.
TOTAL O&M COSTS PER YEAR (YEARS 2-30)				**$38,000.00**	Excluding Year 1
Years of O&M				29	Excluding Year 1
O&M COSTS PER YEAR (YEARS 2-30)				**$1,102,000.00**	
Total O&M Cost for 30 Years				**$1,178,477.73**	
Discount Rate				-0.3%	Office of Management and Budget, Circular A-94 2021.
Total Present Value of O&M Costs				**$1,233,342.68**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$1,326,601.09**	
			+50%	$1,989,901.63	
			-30%	$928,620.76	

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.

AHA = Activity Hazard Analysis
APP-SSHP = Accident Prevention Plan-Site Safety and Health Plan
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CF = cubic foot
ft = foot
hr = hour(s)
IX = ion exchange
lb = pound(s)
O&M = Operation and Maintenance
POE = point of entry
QC = quality control
TM = technical memorandum
UFP-SAP = Uniform Federal Policy-Sampling and Analysis Plan
USEPA = United States Environmental Protection Agency
UV = ultraviolet
WMP-EPP = Waste Management Plan-Environmental Protection Plan

Source: United States Environmental Protection Agency (USEPA). 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. July.

Table A-4. Engineer's Cost Estimate for Alternative 4: New (Replacement) Drinking Water Well - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
CAPITAL COST					
Work Planning Documents					
UFP-SAP, WMP-EPP, APP-SSHP	Lump Sum	1	$14,400.00	$14,400.00	Includes scoping plus draft and final submission. Will include well conversion and long-term sampling plan. Based on effort for existing project documents.
Construction Completion Report	Lump Sum	1	$12,000.00	$12,000.00	Includes documentation of well conversion. Based on effort for existing project documents.
Work Planning Documents Total				**$26,400.00**	
Construction of Drinking Water Well					
Documentation and approvals	Hour	4	$144.00	$576.00	Assumes 4 hours labor needed per well to pursue permitting documentation and approval from the Department of Ecology
Drilling and well construction	FT	500	$62.00	$31,000.00	Assume installation of one new drinking water well, up to 500 fbg
Pump	Each	1	$960.00	$960.00	Grundfos model 16S10-10, 16 gpm max pumping rate, 4-inch diameter, 1 HP, 230V, 3-wire
Pump Installation	Each	1	$1,200.00	$1,200.00	Yellow Jacket quote for installation of aquifer testing pump with 120% escalation
Connection to Home	Each	1	$6,800.00	$6,800.00	Engineers Estimate; assumes new well adjacent to existing well and will be connected to existing piping to home (equipment and labor), assumed up to 100 LF
Field Oversight	per hour	8	$120.00	$960.00	one staff, 8-hr day per well
Construction of Drinking Water Well Total				**$41,496.00**	
Aquifer Testing					
Aquifer testing mobilization: Misc equipment and supplies, support trucks, AHA, charteing, personnel	Lump Sum	1	$15,480.00	$15,480.00	OLF Coupeville 2020 aquifer test and escalation
Aquifer testing: Furnish, install pump and discharge hose. Assumes pumping on 6" well	Each	1	$4,320.00	$4,320.00	OLF Coupeville 2020 aquifer test and escalation
Generator rental and fuel	Lump Sum	1	$4,200.00	$4,200.00	OLF Coupeville 2020 aquifer test and escalation
Portable lighting	Lump Sum	1	$1,440.00	$1,440.00	OLF Coupeville 2020 aquifer test and escalation
Step rate test	Hour	12	$372.00	$4,464.00	Ault Field 2018 residential aquifer test and escalation
Constant rate test	Hour	72	$186.00	$13,392.00	OLF Coupeville 2020 aquifer test and escalation
Temporary storage tank	Each	1	$3,600.00	$3,600.00	OLF Coupeville 2020 aquifer test and escalation
Water truck	Day	7	$432.00	$3,024.00	OLF Coupeville 2020 aquifer test and escalation
Forklift	Day	7	$600.00	$4,200.00	OLF Coupeville 2020 aquifer test and escalation

Table A-4. Engineer's Cost Estimate for Alternative 4: New (Replacement) Drinking Water Well - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Temporary pump and associated appurtenances to transfer water from the temporary tank to the water truck	Day	7	$180.00	$1,260.00	OLF Coupeville 2020 aquifer test and escalation
55-gallon drums	Each	15	$90.00	$1,350.00	Ault Field 2018 residential aquifer test and escalation
Decon pad construction and materials	Lump Sum	1	$1,080.00	$1,080.00	Ault Field 2018 residential aquifer test and escalation
Decontamination	Hour	2	$372.00	$744.00	Ault Field 2018 residential aquifer test and escalation
IDW management	Hour	78	$264.00	$20,592.00	OLF Coupeville 2020 aquifer test and escalation
Taxes	Percentage	9.00%	$79,146.00	$7,123.14	As of December 2020 in Kitsap-Bangor
Aquifer Testing Total				**$86,269.14**	
Groundwater Modeling					
M&IE travel day	Day	10	$44.25	$442.50	Current GSA rate
M&IE full day	Day	22	$59.00	$1,298.00	Current GSA rate
Per Diem - Lodging	Day	22	$96.00	$2,112.00	Current GSA rate
Aquifer test labor	Hour	176	$130.30	$22,932.80	Mid-level Hydrogeologist
Evaluate aquifer test data	Hour	24	$130.30	$3,127.20	Mid-level Hydrogeologist
Develop GW flow model	Hour	100	$130.30	$13,030.00	Mid-level Hydrogeologist
Run simulations/develop output	Hour	40	$130.30	$5,212.00	Mid-level Hydrogeologist
Prepare technical memorandum	Hour	40	$130.30	$5,212.00	Mid-level Hydrogeologist
Groundwater Modeling Total				**$53,366.50**	
CAPITAL COST SUBTOTAL				***$207,531.64***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$31,129.75	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Project Management (8% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*8%*		$19,092.91	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$257,754.30**	
Operations and Maintenance (O&M) Years 1-30[a]					
Routine Sampling for PFAS - first 2 years	Each	2	$12,320.00	$24,640.00	4 times per year first 2 years. 1 PFAS sample plus 1 QC sample per event, 1 household. Total samples/ year = 8. $282.88 per sample (Test America MSA). 1 day per sampling event, 2 field staff. Average rate of field staff is $100/hr. with 120% inflation
Routine Reporting of Sampling Results - first 2 years	Each	2	$11,520.00	$23,040.00	Four TMs per year documenting sampling activities and results. Assumes data validation, database management, and preparation of one TM per quarter (20 hours per quarter at average rate of $120/hr.) with 120% inflation

Table A-4. Engineer's Cost Estimate for Alternative 4: New (Replacement) Drinking Water Well - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Routine Sampling for PFAS - remaining years	Each	28	$6,160.00	$172,480.00	Semiannual sampling. 1 PFAS sample plus 1 QC sample per event, 1 household. Total samples/ year = 4; $282.88 per sample (Test America MSA). 1 day per sampling event, 2 staff. Average rate of field staff is $100/hr. with 120% inflation
Routine Reporting of Sampling Results - remaining years	Each	28	$5,760.00	$161,280.00	Two TMs per year documenting sampling activities and results. Assumes data validation, database management, and preparation of one TM per quarter (20 hours per event at average rate of $120/hr.) with 120% inflation
O&M Cost Annual Subtotal				***$381,440.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$57,216.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Technical Support (15%)		*15%*		$57,216.00	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL O&M COSTS				**$495,900.00**	
Total Years of O&M				30	
Discount Rate				-0.3%	Office of Management and Budget, Circular A-94 2021.
Total Present Value of O&M Costs				**$518,338.16**	
TOTAL PRESENT VALUE of ALTERNATIVE				**$776,092.46**	
			+50%	$1,164,138.69	
			-30%	$543,264.72	

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.

APP-SSHP = Accident Prevention Plan-Site Safety and Health Plan
CF = cubic foot
fbg = feet below ground
gpm = gallon per minute
HP = horsepower
hr = hour(s)
LF = linear foot
Navy = Department of the Navy
PFAS = Per- and Polyfluoroalkyl Substances
QC = quality control
TM = technical memorandum
UFP-SAP = Uniform Federal Policy-Sampling and Analysis Plan
USEPA = United States Environmental Protection Agency
WMP-EPP = Waste Management Plan-Environmental Protection Plan

Source: United States Environmental Protection Agency (USEPA). 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. July.

Table A-5. Engineer's Cost Estimate for Alternative 5: Connection to Public Water Supply - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
CAPITAL COST					
Work Planning Documents					
UFP-SAP, WMP-EPP, APP-SSHP	Lump Sum	1	$24,000.00	$24,000.00	Includes scoping plus draft and final submission.
Project Approvals, Construction Completion Report	Lump Sum	1	$18,000.00	$18,000.00	Includes draft and final submission. Project approvals to Dept. of Health
Work Planning Documents Total				**$42,000.00**	
Site Preparation					
Mobilization/Demobilization	Each	1	$8,719.50	$8,719.50	20% of Construction activities
Demand Calculations and Hydraulic Modeling	Lump Sum	1	$12,000.00	$12,000.00	Engineer Estimate (Fentress) and 120% inflation
Utility Clearance	per day	1	$4,320.00	$4,320.00	From CTO4041 Project 695610 project cost; assume cleared in 1 day and 120% inflation
Engineer Site Visit for planning/design	Each	1	$1,800.00	$1,800.00	Prior Experience and 120% inflation
Site Access Agreements	Each	1	$576.00	$576.00	Right of Entry Forms; assumes 4 hours Jacobs support at $120/hr. for each agreement
Archeological Survey	per hour	24	$174.00	$4,176.00	Jacob's archeologist (Matt Steinkamp/PDX) performs site survey (1 day, with travel day before and day after); assumes finding is no adverse effect
Archeological Survey - Travel Expenses	per trip	1	$803.00	$803.00	Rental car, gas, hotel, per diem for 3-day trip (Washington PD/MIE)
Erosion and Sediment Controls	LF	490	$3.00	$1,470.00	Both sides of the length of trenching, silt fence
Dust Control	SF	8000	$0.20	$1,600.00	Synthetic liquid sprayed by truck
Vegetative Clearing	SF	4000	$0.50	$2,000.00	Light clearing of existing vegetation (with trees <6-inch diameter)
City/Navy Coordination	Lump Sum	1	$9,600.00	$9,600.00	Engineer Estimate (assumes 80 hours at $120 per hour for coordination between Navy, City, and resident)
Site Preparation Total				**$47,064.50**	
System Installation					
Trenching and Installing water service line	LF	130	$30.00	$3,900.00	
Water Meter and Connection Charges	Lump Sum	1	$15,387.50	$15,387.50	Silverdale Water District Connection Charge 2021. Capital Facilities Charge and Service Installation Charge for 5/8-inch Meter. Front footage charge (min)
Three-way valve	Each	1	$850.00	$850.00	One three-way valve
Water service backflow preventation assemblies	Lump Sum	1	$2,500.00	$2,500.00	One Reduced Pressure Backflow Assembly and one Double Check Valve Assembly
Trenching and Installing water service line	LF	360	$30.00	$10,800.00	Includes tie-in
Test chlorination	Lump Sum	1	$290.00	$290.00	Test strips, tabs, labor
Gravel Restoration, Cleanup	SF	8000	$0.50	$4,000.00	Gravel road restoration after installing water service line

Table A-5. Engineer's Cost Estimate for Alternative 5: Connection to Public Water Supply - Residence 2

Engineering Evaluation/Cost Estimate for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Description of Service/items	Unit	Quantity	Unit Price	Total	Assumptions
Landscaping and hydroseeding	SF	4000	$0.20	$800.00	Landscape restoration after installing water service line
System Installation Total				**$38,527.50**	
CAPITAL COST SUBTOTAL				***$127,592.00***	
Contingency (15% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*15%*		$19,138.80	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
General Conditions (10% - US EPA July 2002 A Guide to Developing and Documenting Cost Estimates During the Feasibility Study)		*10%*		$12,759.20	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Performance Bond (2% of Capital Cost Sub, Contiengency & General Conditions)		*2%*		$3,189.80	Industry Average
Project Management (8% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*8%*		$13,014.38	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
Design Costs (6% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*6%*		$9,760.79	Navy Estimating Guidance.
Construction Oversight (10% of Capital Cost Sub, Contiengency, General Conditions & Performance Bond)		*10%*		$16,267.98	USEPA Guidance on Cost Estimates for Feasibility Studies (July, 2000)
TOTAL CAPITAL COSTS				**$201,722.95**	
			+50%	$302,584.43	
			-30%	$141,206.07	

Operations and Maintenance (O&M) Year 1-30 - Not Applicable (Silverdale Water District is responsible for maintenance; resident is responsible for water usage costs once installed).

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.

< = less than

APP-SSHP

LF = linear foot

Navy = Department of the Navy

SF = square foot

UFP-SAP = Uniform Federal Policy-Sampling and Analysis Plan

USEPA = United States Environmental Protection Agency

WMP-EPP = Waste Management Plan-Environmental Protection Plan

Source: United States Environmental Protection Agency (USEPA). 2000. A Guide to Developing and Documenting Cost Estimates During the Feasibility Study. July.

Appendix B
SiteWise Evaluation

Sustainability Analysis for Residential Drinking Water, Naval Base Kitsap-Bangor Washington

1.1 Introduction

This appendix presents the approach taken and results obtained from a sustainability analysis performed as part of the Engineering Evaluation/Cost Analysis (EE/CA) for a non-time-critical removal action to address perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) in drinking water wells for off-Base properties near Naval Base Kitsap-Bangor, in Silverdale, Washington. The following alternatives were developed to address potential risks to human health from exposure to impacted groundwater. A detailed summary of the alternatives is provided in the EE/CA.

- Alternative 1 – No Additional Action
- Alternative 2 – Point of Entry Water Treatment: Granular Activated Carbon (GAC)
- Alternative 3 – Point of Entry Water Treatment: Ion Exchange (IX)
- Alternative 4 – New (Replacement) Drinking Water Well Installation
- Alternative 5 – Connection to Public Water Supply

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 3.2 (Battelle, 2018) for all alternatives.

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. The data entered into the SiteWise tool represent the total 30-year timeframe for this evaluation.

- Alternative 1 – No Additional Action
  - Materials: Assume plastic water bottles are reusable.
  - Transportation of Equipment: Shipment via on-road truck – 30 miles round trip, approximately 0.2 tons per trip x 12 trips per year x 30 years (10,800 miles total).
  - Potable Water Consumption: Estimate 40 gallons per month × 12 months × 30 years = 14,400 gallons.
- Alternative 2 – Point of Entry Water Treatment: GAC
  - Materials: Production of GAC (virgin) 500 lb GAC per 9 months x 30 years (40 changeouts, 20,000 lb total)
  - Disposal: Incineration/thermal treatment of 500 lb GAC per system per 9 months 30 years (20,000 lb – proxy "regenerated GAC" for impacts)
  - Transportation of personnel:
    - Monthly sampling for 1 year, 150 miles round trip, 1 light duty truck, 2 travelers, shared vehicle (12 trips total)
    - Quarterly sampling for 29 years, 150 miles round trip, 1 light duty truck, 2 travelers, shared vehicle (116 trips total)
  - Transportation of Equipment: Vessel shipment via on-road truck – 300 miles one-way, approximately 0.25 tons per trip x 40 trips. Spent GAC to return to source for incineration/ regeneration (12,000 miles total, 0.25-ton load both directions).
  - Electricity use: Power for UV system, approximately 450 kilowatt hours (kwh) per year (13,500 kwh total)
  - Labor: Monthly sampling for one year and quarterly sampling for 29 years, 2 people per event, 1 day per event, 10 hours per day (2,560 hours)
  - Laboratory Costs: $25,920 for 1 year, and $8,640 per year for 29 years ($276,480 total)
  - Resource use (Groundwater): Estimate 5 gallons per month × 12 months × 30 years = 1,800 gallons
- Alternative 3 – Point of Entry Water Treatment: Ion Exchange (IX)
  - Materials: Production of resin 1,130 lb per 9 months X 30 years. (40 changeouts, 45,200 lbs)
  - Disposal: Disposal of IX resin via incineration (proxy "regenerated GAC" for impacts) (45,200 lbs)
  - Transportation of personnel:
    - Monthly sampling for 1 year, 150 miles round trip, 1 light duty truck, 2 travelers, shared vehicle (12 trips total)
    - Quarterly sampling for 29 years, 150 miles round trip, 1 light duty truck, shared vehicle (116 trips total)
  - Transportation of Equipment: Vessel shipment via on-road truck – 300 miles one-way, approximately 0.6 tons per trip 30 years; spent resin to travel similar distance for incineration. (12,000 miles total, 0.6-ton load both directions).
  - Electricity use: Power for UV system, approximately 450 kilowatt hours (kwh) per year (13,500 kwh total)
  - Labor: Monthly sampling for one year and quarterly sampling for 29 years, 2 people per event, 1 day per event, 10 hours per day (2,560 hours)

- Laboratory Costs: $25,920 for 1 year, and $8,640 per year for 29 years ($276,480 total)
- Resource use (Groundwater): Estimate 5 gallons per month × 12 months × 30 years = 1,800 gallons

- Alternative 4 – New (Replacement) Drinking Water Well Installation
  - Installation:
    - Material Production: Well materials, 1 PVC well of 6 inch diamter to 500 feet and associated sand, bentonite, cement, concrete, and steel
    - Transportation of personnel: 7 days to install and conduct aquifer test, crew of 4 people driving 30 miles roundtrip per day, 28 trips total
    - Transportation of equipment and materials: Drill rig and materials – 25 tons × 50 miles each way
    - Equipment use: Drilling: Sonic, 500 feet, 16 hours
    - Waste Handling: 600 gallons (2.5 tons) of groundwater to non-hazardous disposal area 300 miles away
    - Onsite labor hours: 4 people × 5 days × 10 hour days = 280 hours, construction laborers
    - Water disposed to wastewater treatment facility: 600 gallons
  - O&M:
    - Transportation of personnel: 64 trips, 2 people per trip, 150 miles per trip shared car
      - Electricity use: 1 hp pump operating 0.5 hour per day, 365 days per year, for 30 years (5,475 hours)
    - Onsite labor hours: 36 trips × 10 hour days x 2 staff = 720 hours
    - Laboratory Cost: $20,304
    - Resource use (Groundwater): Estimate 5 gallons per month × 12 months × 30 years = 1,800 gallons

- Alternative 5 – Connection to Public Water Supply Residence 1
  - Installation:
    - Material Production:
      - Service lines: 490 feet of 1-inch copper pipe, approximately 0.2 tons of “medium impact material” (400 pounds)
      - 8,000 square foot area, 6 inches deep (4,000 cubic feet of gravel)
    - Transportation of personnel: 2 days to install, crew of 4 people driving 30 miles roundtrip per day, (8 trips total)
    - Transportation of equipment and materials:
      - Heavy equipment – 25 tons × 50 miles each way, empty return each time
      - Gravel – 1.5 tons per CY, 150 CYs, 225 tons, 12 trips x 50 miles x 19 tons each trip, empty return
    - Equipment use:
      - Trenching: 490 feet using an excavator to an average of 3 feet deep, 2 feet wide (110 cubic yards moved twice)
      - Site work: Dozer working 6 inches of 12,000 square foot area for gravel and landscaping (222 cubic yards)
    - Onsite labor hours: 4 people × 2 days × 10 hour days = 80 hours, construction laborers

- O&M:
  - Potable Water Consumption: Estimate 5 gallons per month × 12 months × 30 years = 1,800 gallons

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 compliance, contaminant reduction, site reuse, cost effectiveness) of each of the alternatives.

The following is a comparison of the alternatives for each metric. Details for each alternative are provided in **Table B-2** through **Table B-6**.

GHG. Alternative 3 had the highest GHG footprint of all of the alternatives primarily due to electricity use to operate the UV system and production and disposal of the resin. Alternative 2 had the second highest GHG footprint also due to electricity use and material production and disposal (GAC). Alternatives 5, 4, and 1 had the lowest GHG footprints (in that order). Alternative 5's footprints can primarily be attributed to material production, Alternative 4's footprints to equipment use and material production, and Alternative 1's footprint to transportation of bottled water.

Energy Use. Alternative 3 had the highest Energy use footprint of all of the alternatives primarily due to electricity use to operate the UV system and production and disposal of the resin. Alternative 4 had the second highest energy use footprint primarily due to material production. Alternatives 2, 5, and 1 had the lowest GHG and Energy use footprints (in that order). Alternative 2's footprints can primarily be attributed to electricity use and material production and disposal (GAC), Alternative 5's footprints to material production, and Alternative 1's footprint to transportation of bottled water.

Water Use. Alternatives 5 and 1 had the highest water use footprints (in that order) due to potable water consumption. Alternatives 2 and 3 had the next highest water use footprints due to groundwater consumption and electricity use (cooling water at power plant) for the point source treatments systems. Alternative 4 had the lowest water use footprint due to groundwater consumption and electricity use (cooling water at power plant).

Criteria Air Pollutants (NO_X, SO_X, PM_{10}). Alternative 3 had the highest NO_X, SO_X, and PM_{10} footprints, compared with the other alternatives, due to equipment use and material production. Alternative 2 had the second highest NO_X, SO_X, and PM_{10} footprints, also due to equipment use and material production. Alternatives 5, 4, and 1 had the lowest NO_X, SO_X, and PM_{10} footprints (in that order). Alternative 5's footprints can primarily be attributed to material production, Alternative 4's footprints to equipment use and material production, and Alternative 1's footprint to transportation of bottled water.

Accident Risks. Alternatives 2 and 3 had the highest accident risk footprints due to transportation of personnel and onsite labor hours (categorized as equipment use and misc.) during monitoring activities. Alternative 4 had the next highest accident risk footprints due to onsite labor hours (categorized as equipment use and misc.). Alternatives 1 and 5 had the lowest accident risk footprints.

1.4 Uncertainty

The SiteWise tool calculates environmental and risk footprints based on industry averages, published emissions factors, and generalized data sources. Proxies or assumptions were made that contribute to uncertainty including:

- Using regenerated GAC as a proxy for thermal treatment of GAC and IX resin.
- Ductile iron pipe and copper pipe is not included in SiteWise, however the impact was expected to be slightly lower than steel, therefore a "moderate impact material" was used as a proxy.
- Distance traveled for the waste treatment and 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 during the design phase of the projects to explore opportunities to optimize the environmental performance of the project and integrate sustainable remediation best practices in the design, construction, and operation of the alternative.

Navy Green and Sustainable Remediation Best Management Practices (NAVFAC, 2016), will be considered in the remedial action. Specific best management practices for these alternatives include:

- Choose vendors with production and distribution centers near the site, to minimize fuel consumption associated with delivery.
- Design the remedy with consideration of resiliency to extreme weather events.
- Include using equipment with emissions control devices or managing work such that engine idle time is minimized.

1.6 References

Battelle. 2018. *SiteWise Version 3.2*. NAVFAC Engineering Service Center. October.

Naval Facilities Engineering Systems Command (NAVFAC). 2016. *Technical Memorandum TM-NAVFAC-EXWC-EV-1601 Green and Sustainable Remediation Best Management Practices.* September.

Tables

Table B-1. Comparison of Quantitative Environmental Footprint Metrics

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Remedial Alternatives	GHG Emissions	Total Energy Used	Water Consumption	Total NO_x Emissions	Total SO_x Emissions	Total PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
Alternative 1 – No Additional Action	3.04E+01	3.97E+02	1.44E+04	9.57E-03	1.74E-04	8.63E-04	8.42E-05	6.78E-03
Alternative 2 – Point of Entry Water Treatment : Granular Activated Carbon (GAC)	2.31E+02	2.85E+03	8.69E+03	6.56E-01	5.01E-01	5.98E-02	7.21E-04	9.81E-02
Alternative 3 – Point of Entry Water Treatment : Ion Exchange (IX)	2.90E+02	4.57E+03	8.69E+03	8.54E-01	7.66E-01	9.30E-02	7.21E-04	9.81E-02
Alternative 4 – New (Replacement) Drinking Water Well Installation	3.81E+01	4.54E+03	3.88E+03	6.85E-02	5.07E-02	7.81E-03	2.52E-04	3.62E-02
Alternative 5 – Connection to Public Water Supply	9.72E+01	2.47E+03	1.62E+04	2.71E-01	4.33E-01	9.37E-02	8.58E-05	1.30E-02

Relative Impact

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	Total NOx emissions	Total SOx Emissions	Total PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury
Alternative 1 – No Additional Action	Low	Low	High	Low	Low	Low	Low	Low
Alternative 2 – Point of Entry Water Treatment : Granular Activated Carbon (GAC)	High	Medium	Medium	High	Medium	Medium	High	High
Alternative 3 – Point of Entry Water Treatment : Ion Exchange (IX)	High	High	Medium	High	High	High	High	High
Alternative 4 – New (Replacement) Drinking Water Well Installation	Low	High	Low	Low	Low	Low	Medium	Medium
Alternative 5 – Connection to Public Water Supply	Medium	Medium	High	Medium	Medium	High	Low	Low

Notes:

GHG = greenhouse gases

MMBTU = million British Thermal Unit

NO_x = oxides of nitrogen

PM_{10} = particulate matter with particle sizes of 10 microns or smaller in aerodynamic diameter

SO_x = oxides of sulfur

Table B-2. SiteWise Results for Alternative 1 – No Additional Action

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Phase	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
Residence 2	Consumables	0.00E+00	0%	0.00E+00	0%	NA	NA	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	NA	NA	NA	NA
	Transportation-Personnel	0.00E+00	0%	0.00E+00	0%	NA	NA	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	NA	0.0E+00	NA
	Transportation-Equipment	3.04E+01	100%	3.97E+02	100%	NA	NA	9.6E-03	100%	1.7E-04	97%	8.5E-04	98%	8.4E-05	100%	6.8E-03	100%
	Equipment Use and Misc	4.08E-03	0%	1.66E-02	0%	1.44E+04	100%	7.9E-06	0%	4.8E-06	3%	1.3E-05	2%	0.0E+00	NA	0.0E+00	NA
	Residual Handling	0.00E+00	0%	0.00E+00	0%	NA	NA	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	NA	0.0E+00	NA
	Total	**3.04E+01**	**100%**	**3.97E+02**	**100%**	**14,400**	**100%**	**9.57E-03**	**100%**	**1.74E-04**	**100%**	**8.63E-04**	**100%**	**8.42E-05**	**100%**	**6.78E-03**	**100%**

Notes:

GHG = greenhouse gases

MMBTU = million British Thermal Unit

NA = not applicable

NO_x = oxides of nitrogen

PM_{10} = particulate matter with particle sizes of 10 microns or smaller in aerodynamic diameter

SO_x = oxides of sulfur

Table B-3. SiteWise Results for Alternative 2 Point of Entry Water Treatment : Granular Activated Carbon (GAC)

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Phase	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
Residence 2	Consumables	59	26%	4.08E+02	14%	NA	NA	3.6E-02	6%	4.8E-02	10%	6.1E-03	10%	NA	NA	NA	NA
	Transportation-Personnel	11	5%	1.33E+02	5%	NA	NA	4.4E-03	1%	1.4E-04	0%	6.3E-04	1.0%	3.0E-04	42%	2.4E-02	25%
	Transportation-Equipment	34	15%	4.42E+02	16%	NA	NA	1.1E-02	2%	1.9E-04	0%	9.5E-04	2%	1.9E-04	26%	1.5E-02	15%
	Equipment Use and Misc	128	55%	1.87E+03	65%	8,685	100%	6.0E-01	92%	4.5E-01	90%	5.2E-02	87.3%	2.3E-04	32%	5.9E-02	60%
	Residual Handling	0	0%	0.00E+00	0%	NA	NA	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%
	Total	**231**	**100%**	**2.85E+03**	**100%**	**8.7E+03**	**100%**	**6.6E-01**	**100%**	**5.0E-01**	**100%**	**6.0E-02**	**100%**	**7.2E-04**	**100%**	**9.8E-02**	**100%**

Notes:

GHG = greenhouse gases

MMBTU = million British Thermal Unit

NA = not applicable

NO_x = oxides of nitrogen

PM_{10} = particulate matter with particle sizes of 10 microns or smaller in aerodynamic diameter

SO_x = oxides of sulfur

Table B-4. SiteWise Results for Alternative 3 – Point of Entry Water Treatment : Ion Exchange (IX)

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Phase	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
Residence 2	Consumables	117	41%	2.13E+03	47%	NA	NA	2.3E-01	28%	3.1E-01	41%	3.9E-02	42%	NA	NA	NA	NA
	Transportation-Personnel	11	4%	1.33E+02	3%	NA	NA	4.4E-03	1%	1.4E-04	0%	6.3E-04	1%	3.0E-04	42%	2.4E-02	25%
	Transportation-Equipment	34	12%	4.44E+02	10%	NA	NA	1.1E-02	1%	1.9E-04	0%	9.5E-04	1%	1.9E-04	26%	1.5E-02	15%
	Equipment Use and Misc	128	44%	1.87E+03	41%	8,685	71%	6.04E-01	71%	4.5E-01	59%	5.2E-02	56%	2.3E-04	32%	5.9E-02	60%
	Residual Handling	0	0%	0.00E+00	0%	NA	NA	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%
	Total	**290**	**100%**	**4.57E+03**	**100%**	**8.7E+03**	**100%**	**8.5E-01**	**100%**	**7.7E-01**	**100%**	**9.3E-02**	**100%**	**7.2E-04**	**100%**	**9.8E-02**	**100%**

Notes:

GHG = greenhouse gases

MMBTU = million British Thermal Unit

NA = not applicable

NO_x = oxides of nitrogen

PM_{10} = particulate matter with particle sizes of 10 microns or smaller in aerodynamic diameter

SO_x = oxides of sulfur

Table B-5. SiteWise Results for Alternative 4 – New (Replacement) Drinking Water Well Installation

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Phase	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
Residence 2	Consumables	21	54%	4.29E+03	95%	NA	NA	1.1E-02	16%	1.6E-02	31%	2.2E-03	28%	NA	NA	NA	NA
	Transportation-Personnel	6	15%	7.26E+01	2%	NA	NA	2.4E-03	3%	7.5E-05	0%	3.4E-04	4%	1.6E-04	2%	1.3E-02	2%
	Transportation-Equipment	0	1%	4.64E+00	0%	NA	NA	1.1E-04	0%	2.0E-06	0%	9.9E-06	0%	7.8E-07	0%	6.3E-05	0%
	Equipment Use and Misc	11	29%	1.66E+02	4%	3,882	100%	5.5E-02	80%	3.5E-02	69%	5.3E-03	67%	9.3E-05	41%	2.3E-02	41%
	Residual Handling	0	1%	5.70E+00	0%	NA	NA	1.4E-04	0%	2.4E-06	0%	1.2E-05	0%	2.3E-06	0%	1.9E-04	0%
	Total	**38**	**100%**	**4.54E+03**	**100%**	**3.9E+03**	**100%**	**6.9E-02**	**100%**	**5.1E-02**	**100%**	**7.8E-03**	**100%**	**2.5E-04**	**100%**	**3.6E-02**	**100%**

Notes:

GHG = greenhouse gases

MMBTU = million British Thermal Unit

NA = not applicable

NO_x = oxides of nitrogen

PM_{10} = particulate matter with particle sizes of 10 microns or smaller in aerodynamic diameter

SO_x = oxides of sulfur

Table B-6. SiteWise Results for Alternative 5 – Connection to Public Water Supply

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington

Phase	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
Residence 2	Consumables	3	48%	5.93E+01	55%	NA	NA	1.3E-02	84%	1.7E-02	98%	6.7E-03	96%	NA	NA	NA	NA
	Transportation-Personnel	1	16%	1.42E+01	13%	NA	NA	4.7E-04	3%	1.5E-05	0%	6.7E-05	1%	1.6E-05	47%	1.3E-03	27%
	Transportation-Equipment	2	33%	3.06E+01	28%	NA	NA	7.4E-04	5%	1.3E-05	0%	6.6E-05	1%	5.5E-06	16%	4.4E-04	9%
	Equipment Use and Misc.	0	3%	4.49E+00	4%	1,800	100%	1.39E-03	9%	4.1E-04	2%	1.8E-04	3%	1.2E-05	36%	3.1E-03	64%
	Residual Handling	0	0%	0.00E+00	0%	NA	NA	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%	0.0E+00	0%
	Total	**7**	**100%**	**1.09E+02**	**100%**	**1.8E+03**	**100%**	**1.6E-02**	**100%**	**1.8E-02**	**100%**	**7.0E-03**	**100%**	**3.4E-05**	**100%**	**4.8E-03**	**100%**

GHG = greenhouse gases

MMBTU = million British Thermal Unit

NA = not applicable

NO_x = oxides of nitrogen

PM_{10} = particulate matter with particle sizes of 10 microns or smaller in aerodynamic diameter

SO_x = oxides of sulfur

Figure

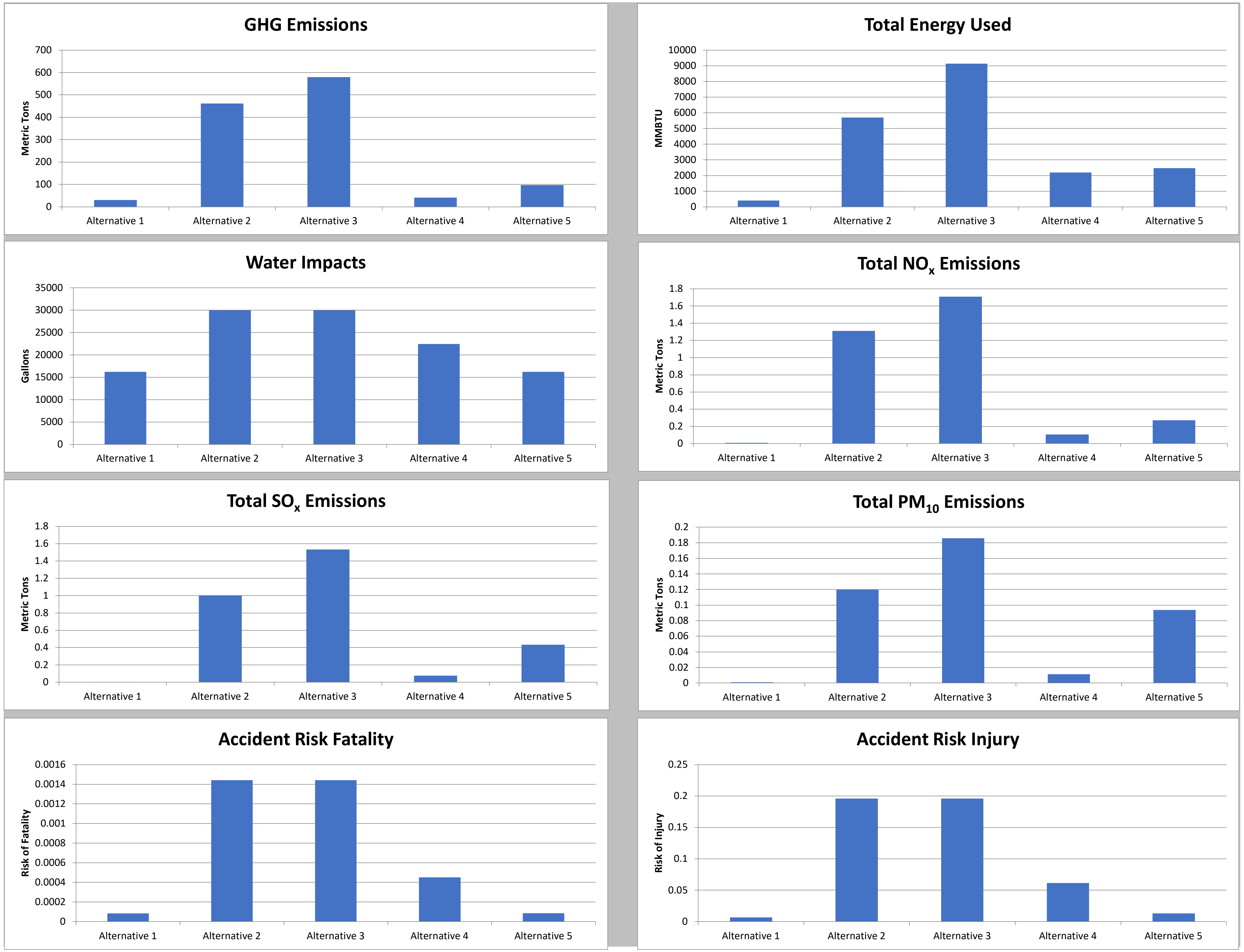

Figure B-1. Comparison of Quantitative Environmental Footprint Metrics

Engineering Evaluation/Cost Analysis for Long-term Solutions for Residential Drinking Water

Naval Base Kitsap-Bangor, Washington