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| Baseline Human Health Risk Assessment  Bremerton Gas Works Superfund Site  Prepared for: Cascade Natural Gas Corporation |
| Anchor QEA Project No. 201014-01.01•   October 30, 2020 • **DRAFT** |

Prepared by

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Acronyms

µg/dL microgram per deciliter

µg/L microgram per liter

µg/m3 microgram per cubic meter

µg/mg microgram per milligram

µm micron

ABS dermal absorption factor

ADAF age-dependent adjustment factor

AF adherence factor

ALM Adult Lead Methodology

AOC Administrative Order on Consent

ARAR Applicable or Relevant and Appropriate Requirement

bgs below ground surface

BHHRA Baseline Human Health Risk Assessment

Cascade Cascade Natural Gas Corporation

CDC Centers for Disease Control and Prevention

CERCLA Comprehensive Environmental Response, Compensation,  
and Liability Act

cm centimeter

cm2 square centimeter

COPC contaminant of potential concern

cPAH carcinogenic polycyclic aromatic hydrocarbon

CSM conceptual site model

CTE central tendency exposure

D/F dioxin/furans

DNR Washington State Department of Natural Resources

DQO data quality objective

DU data usability

EC exposure concentration

Ecology Washington State Department of Ecology

Eco-SSL ecological soil screening level

EDL estimated detection limit

EPA U.S. Environmental Protection Agency

EPC exposure point concentration

FoD frequency of detection

FR Federal Register

g/day gram per day

g/g grams/gram

GI gastrointestinal

g/kg/day gram per kilogram per day

HI hazard index

HQ hazard quotient

IEUBK Integrated Exposure Uptake Biokinetic

IRIS Integrated Risk Information System

ISA initial study area

IUR inhalation unit risk

kg kilogram

kg/g kilogram per gram

kg/mg kilogram per milligram

LADI lifetime average daily intake

L/cm3 liter per cubic centimeter

L/m3 liter per cubic meter

m3/kg cubic meters per kilogram

MDAC minimum data acceptability criterion

MDL method detection limit

mg milligram

mg/µg milligram per microgram

mg/cm2 milligram per square centimeter

mg/cm2‑event milligram per square centimeter per event

mg/day milligram per day

mg/kg milligram per kilogram

mg/kg-day milligram per kilogram per day

mg/m3 milligram per cubic meter

MGP manufactured gas plant

MTCA Model Toxics Control Act

MLLW mean lower low water

NAPL non-aqueous phase liquid

NCP National Contingency Plan

OSWER Office of Solid Waste and Emergency Response

PAH polycyclic aromatic hydrocarbon

PCB polychlorinated biphenyl

PPRTV Provisional Peer Reviewed Toxicity Value

QAPP quality assurance project plan

PWN Port Washington Narrows

RAGS Risk Assessment Guidance for Superfund

RATM Risk Assessment Technical Memorandum

RfC reference concentration

RfD reference dose

RI/FS Remedial Investigation/Feasibility Study

RL reporting limit

RME reasonable maximum exposure

RSL regional screening level

SCO sediment cleanup objective

SF slope factor

Site Bremerton Gas Works Superfund Site

SMS Sediment Management Standard

TCE trichloroethylene

TCRA Time Critical Removal Action

TEF toxic equivalence factor

TEQ toxic equivalent

UCL upper confidence limit

VC vinyl chloride

VF volatilization factor

VI vapor intrusion

VI-COPC vapor intrusion chemicals of potential concern

VISL vapor intrusion screening level

VOC volatile organic compound

WAD weak acid dissociable

# Introduction

This Baseline Human Health Risk Assessment (BHHRA) presents an evaluation of potential risks to human health at the Bremerton Gas Works Superfund Site (Site) as part of the Remedial Investigation/Feasibility Study (RI/FS). Specifically, this BHHRA is intended to evaluate potential risks to human health caused by exposure to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) hazardous substances at the Site. This BHHRA is being performed by Cascade Natural Gas Corporation (Cascade) under an Administrative Order on Consent (AOC) with the U.S. Environmental Protection Agency (EPA) under the CERCLA program.

The goal of the RI/FS is to conduct a scientifically sound, comprehensive investigation of the Site following the appropriate EPA guidance (EPA 1988) and the principles outlined in EPA’s *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites Document* (2005a) in order to provide the basis for scientifically based decisions about the future condition of the Site.

This BHHRA fulfills one of the four objectives established in the RI/FS Work Plan (Aspect and Anchor QEA 2017). That objective is to achieve the RI/FS goals by identifying complete, and reasonably potentially complete, exposure pathways and identifying potential current and future human health risks posed by the contaminants of potential concern (COPCs) present at the Site.

This BHHRA was developed in accordance with EPA’s Risk Assessment Guidance for Superfund (RAGS) documents and Office of Solid Waste and Emergency Response (OSWER) Directives (EPA 1989, 1991a, 1994a, 2001, 2003a, 2004, 2009a, 2014a). This BHHRA also uses other relevant EPA guidance documents as referenced in specific sections.

## Objectives

The 1990 National Contingency Plan (NCP) (55 Federal Register [FR] 8665-8865, March 8, 1990) requires the completion of a site-specific baseline risk assessment as part of the RI (Section 300.430(d)(1)). Specifically, the NCP states that the baseline risk assessment should “characterize the current and potential threats to human health and the environment that may be posed by contaminants migrating to groundwater or surface water, releasing to air, leaching through soil, remaining in the soil, and bioaccumulating in the food chain” (Section 300.430(d)(4)).

The primary objective of this BHHRA is to determine whether Site media pose potential unacceptable risks to human receptors under current and likely future Site use scenarios and, if so, to aid in decisions regarding remedial actions for the Site.

The following are additional BHHRA objectives:

Provide risk managers with an understanding of the actual and potential risks to human health from the Site

Provide a basis for developing preliminary remediation goals as appropriate

Provide a basis for comparing the effectiveness of various remedial alternatives and identify uncertainties associated with that assessment

To achieve the objectives, the steps of a BHHRA are as follows:

1. Identify COPCs
2. Identify complete and reasonably potentially complete exposure pathways
3. Identify potential current and future human health risks posed by the COPCs present at the Site
4. Quantitatively characterize the cancer risks and noncancer hazards to human receptors (human populations potentially exposed to Site media) resulting from potential exposure to COPCs, and identify those contaminants and exposure pathways potentially posing unacceptable risks and those that contribute the majority of the unacceptable risk
5. Characterize uncertainties associated with the risk assessment

## Project Background

This BHHRA follows the approach that was documented in the Risk Assessment Technical Memorandum (RATM; Anchor QEA and Aspect 2020). Details on Site background, previous investigations, and the environmental setting of the Site were provided in the RI Work Plan (Aspect and Anchor QEA 2017). The human receptors, exposure pathways, and exposure parameters proposed for this BHHRA were originally identified in the RATM that was approved by EPA on June 3, 2020 (EPA 2020a). The RATM human health exposure pathways, exposure parameters, and conceptual site model (CSM) were refined from previous versions presented in the RI Work Plan based on working group meetings with EPA, the Suquamish Tribe, and Cascade on October 6, October 30, and December 6, 2018. A summary of the working group meeting decisions is included in Attachment A.

Assumptions and methodologies incorporated herein are consistent with EPA guidance for risk assessment. In some cases, where guidance does not prescribe specific assumptions, conservative values were incorporated at the direction of EPA that are more likely to overestimate than underestimate exposure and associated risks.

## Organization

In accordance with EPA guidance (EPA 1989), this BHHRA incorporates the following four steps of the baseline risk assessment process as well as a discussion of overall uncertainties: 1) data collection and evaluation; 2) exposure assessment; 3) toxicity assessment; and 4) risk characterization. This BHHRA is organized as follows:

**Section 1 – Introduction** presents the introduction, project background, and the organization of this document.

**Section 2 – Site Description** presents the Site setting, including a summary of its history, historical and current groundwater use, and a description of current and future land use.

**Section 3 – Data Evaluation** summarizes the available data for the Site, presents the data treatment rules, and identifies the COPCs for further evaluation in this BHHRA.

**Section 4 – Exposure Assessment** presents potentially complete routes of exposure and potentially exposed populations, which are summarized in the CSM, for further evaluation in this BHHRA.

**Section 5 – Toxicity Assessment** evaluates the potential hazard and toxicity of the COPCs selected for quantitative evaluation in this BHHRA.

**Section 6 – Risk Characterization** presents the potential cancer risks and noncancer hazards and identifies the contaminants potentially posing unacceptable risks to human health.

**Section 7 – Uncertainty Analysis** discusses the uncertainties that are inherent in performing a BHHRA and the uncertainties specific to this BHHRA.

**Section 8 – Summary** summarizes the findings of this BHHRA and identifies chemicals and pathways that contribute to the majority of risk at the Site.

**Section 9 – References** lists the references used in this BHHRA.

# Site Description

The Site is located on industrial upland property and adjacent marine aquatic lands on the south shore of the Port Washington Narrows (PWN) in Bremerton, Kitsap County, Washington. The Site location is depicted in Figure 2-1. A gas works (manufactured gas plant or MGP) formerly operated on a portion of the Site (the Former Gas Works). The Site, which consists of the areal extent of contamination as defined in the AOC, includes portions of three upland properties (referred to in this BHHRA as the McConkey Property, the Penn Plaza Property, and the Sesko Property).

The Former Gas Works was located between Thompson Drive and Pennsylvania Avenue on approximately 2.8 acres of property (Former Gas Works Property). The historical street addresses for the Former Gas Works included 1720 and 1800 Thompson Drive. The location of the Former Gas Works Property relative to current parcel boundaries is shown in Figure 2-2. As a result of a boundary line adjustment in 1992, the Former Gas Works Property includes portions of the following two existing tax parcels:

**Kitsap County Parcel No. 3711-000-001-0409 (McConkey Property).** This parcel is owned by the McConkey Family Trust. The Former Gas Works covered the entire parcel. No current or historical street address has been identified for this parcel.

**Kitsap County Parcel No. 3741-000-022-0101 at 1701 Pennsylvania Avenue (Sesko Property).** This parcel is owned by Natasha Sesko. The Former Gas Works covered the northwestern portion of this parcel.

The PWN is located north of the McConkey and Sesko Properties. The PWN consists of aquatic lands owned by the State of Washington and managed by the Washington State Department of Natural Resources (DNR).

This BHHRA evaluates human health exposure in the upland Site and the marine initial study area (ISA). The ISA comprises intertidal and subtidal areas in the general vicinity of the Former Gas Works Property.

## Environmental Setting

The Site environmental setting is described in the RI Work Plan Section 2.4 (Aspect and Anchor QEA 2017).

## History and Current Status

A detailed Site history, including current and historical property use and operations on the properties comprising the Site, adjoining properties, and aquatic lands, was presented in the RI Work Plan (Aspect and Anchor QEA 2017). A summary of that information is provided in the following paragraphs.

The Former Gas Works was constructed in 1930 and 1931, and manufactured gas was produced using the carbureted water-gas process from 1931 until approximately 1958. In the 1940s, a standby plant for producing gas by blending liquified petroleum (butane) and air was installed. The blended-gas plant was expanded in 1958, when the MGP was shut down, and blended-gas production continued (using propane) until 1963. The Former Gas Works included gas production, processing, and storage in the uplands, and a dock that extended over the tidelands for the import of coal, coke briquettes, and fuel, and export of carbureted-water gas tar, a byproduct of the manufactured gas process. During handling, briquettes were spilled on the beach and are still evident. The eastern extent of the Former Gas Works was defined by a creek ravine (herein referred to as the Former Ravine). Figure 2-3 depicts the historical features associated with the Former Gas Works.

Filling of the Former Ravine began prior to the Former Gas Works operations. Subsequent filling included placement of residual materials from the Former Gas Works operations, placement of fill by neighbors, and potentially placement of refuse from an incinerator owned by the City of Bremerton. The Former Gas Works structures were dismantled between approximately 1963 and 1972.

The post-gas works operations on the industrial upland property included metal fabrication and sandblasting, parking and equipment storage, self storage, bulk petroleum storage and distribution, and junkyard operations (including boat maintenance, automobile salvage, and metal reclamation; Aspect and Anchor QEA 2017).

Source materials, as described in the RI Data Report (Aspect and Anchor QEA 2020), have been observed within the intertidal area (approximately -4 feet mean lower low water [MLLW] to ordinary high water) adjacent to the Former Gas Works Property. These occurrences were addressed in the 2010 and 2013 Time Critical Removal Actions (TCRAs). The 2010 TCRA adjacent to the Ravine Fill Area was implemented to address a historical pipe and sediments exhibiting sheen. The Ravine Fill Area is shown in Figures 2-3 and 2-4. Following the partial removal of the historical pipe, the surficial area that exhibited sheen was covered with a reactive clay mat cap. The 2013 TCRA adjacent to the Bluff Area was implemented to address sporadic surficial occurrences of sheen, solid hydrocarbon material, and coke briquettes. Bluff Area samples are identified in Section 3.1.2.1. During the 2013 TCRA, solid hydrocarbon material and coke briquettes were removed where practicable, and the sediments exhibiting sheen were capped with a reactive clay mat.

A three-dimensional graphical CSM illustrating potential historical sources and migration of contaminants at the Site is provided in Figure 2-4. This figure graphically depicts the key physical conditions at the Site that are related to current and future exposure media. Included are historical contaminant sources from the Former Gas Works and adjacent properties, fate and transport features, paved and unpaved soil surfaces, stormwater/combined sewer overflow conveyances, and sediment caps placed during the 2010 and 2013 TCRAs.

## Access and Use

### Current Use and Access

The Former Gas Works Property is in an area of industrial-zoned properties that includes properties formerly used by Atlantic Richfield Company (ARCO) and SC Fuels for bulk petroleum storage and distribution (Former ARCO Property and Former SC Fuels Property). Surrounding this industrial property core are residential properties and a marina. The zoning is shown in Figure-2-2. The Former Gas Works Property is immediately adjacent to intertidal sediments and surface water within the PWN, which can be accessed by the public.

Currently, only a single, heated structure (known as Building 6) is located over or near the subsurface vapor sources at the Site. The southern portion of Building 6 is a storage facility, with individual self-storage units accessed from an interior hallway. There are also two unheated buildings located over or adjacent to subsurface vapor sources: Building 4 (currently vacant) and Building 5 (used for storage). Building locations are shown in Figure 2-2.

Tribal commercial, subsistence, and ceremonial fisheries have historically occurred in Dyes Inlet and the PWN (Figure 2-1). The Suquamish Tribe has stated that “Suquamish tribal members fully intend to continue to fish these areas for cultural, subsistence and commercial purposes” (Suquamish Tribe 2014). The Suquamish Tribe has stated that its members use “the Washington Commercial Shellfish Growing Area Classification to determine the suitability of bivalve harvests (i.e., clams, oysters)” (Suquamish Tribe 2011). For purposes of human shellfish consumption, the marine area adjacent to the Former Gas Works Property is designated by the Washington State Department of Health as “Unclassified” due to the proximity of combined sewer overflows, which precludes shellfish harvesting. However, according to the Suquamish Tribe, the harvest of finfish and other marine invertebrates (i.e., crab and sea cucumber) is not restricted adjacent to the Site (Suquamish Tribe 2011).

### Future Use and Access

While there are no current plans for development, future use of the upland portion of the Site could include the construction and use of additional structures over subsurface vapor sources.

Reclassification of the shellfish harvesting designation may occur in the future if nearby combined sewer overflows are rerouted.

## Groundwater Use

Water services at the Site and surrounding area are supplied by the City of Bremerton. The closest public water supply wells are located over 1 mile from the Site. The use of private wells within the Bremerton Water Service Area, which encompasses the Site, is not allowed. There are no drinking water wells near the Site that are listed in the Washington State Department of Ecology (Ecology) database.

The Site is located adjacent to the PWN, a saltwater body. The extent of saltwater intrusion and the potability of Site groundwater, and its potential future use as a drinking water source, are being evaluated as part of the RI.

# Data Evaluation

Recent chemistry data are available for various media (soil, groundwater, soil gas, surface sediment, surface water, and shellfish [clam] tissue) collected from the Site and background areas. The following subsections summarize the available data (Section 3.1), data treatment (Section 3.2), and the selection of COPCs (Section 3.3).

## Available Data

The BHHRA dataset includes only those samples and matrices needed to quantitatively evaluate the human health exposure pathways described in Section 4. People may be exposed to substances at the Site either through direct exposure to soil, groundwater, vapor, surface sediment, and surface water, or indirectly through the consumption of shellfish collected from the Site. Therefore, soil, groundwater, soil gas, surface sediment, surface water, and shellfish tissue chemistry data from the Site and background areas are relevant for this BHHRA.

The degree to which the data adequately represent Site-related contamination and the expected human exposures at the Site are of primary importance. Additionally, it is important to consider whether the data quality criteria goals are acceptable, as well as the source, documentation, analytical methods, detection limits, and level of review and data validation. These usability factors were evaluated for each dataset to determine whether it was reasonable to include all data for use in this BHHRA. This information is presented in the RI Data Report (Aspect and Anchor QEA 2020).

### Data Usability

The existing Site characterization data have been reviewed in terms of data usability (DU) for the RI/FS. This includes data for the Former Gas Works Property and available data for sediments and tissue within PWN, Dyes Inlet, and nearby portions of Puget Sound.

The minimum data acceptability criterion (MDAC) and DU evaluation criteria were used to evaluate available data in the RI Data Report (Aspect and Anchor QEA 2020). The DU categories include the following:

**DU-1.** These data meet all of the MDAC requirements and are considered reasonably representative of Site conditions. These high-quality datasets have been collected using recent, regulatory-approved quality assurance project plans (QAPPs) or equivalent.

**DU-2.** These data meet most or all of the MDAC requirements. These datasets may have been collected using regulatory-approved QAPPs or equivalent, but generally have been collected less recently than DU-1 data. These data may provide useful Site reference values or help delineate the nature and extent of contamination.

**DU-R.** These data either do not meet the MDAC requirements and/or have been superseded by recent higher quality results.

Data quality evaluation and assignment of a DU category for work conducted under the Administrative Settlement Agreement and Order on Consent (including the 2013 Time Critical Removal Evaluation and the RI Data Acquisition) are provided in the RI Data Report (Aspect and Anchor QEA 2020).

### BHHRA Dataset

The Site and marine ISA BHHRA dataset consists of results from the Time Critical Removal Evaluation and RI Data Acquisition programs described in the RATM (Anchor QEA and Aspect 2020) and RI Data Report (Aspect and Anchor QEA 2020). Table 3‑1 summarizes the samples included in the BHHRA dataset. This section briefly describes the BHHRA dataset for each exposure medium.

#### Soil

Human receptors may potentially be exposed to surface and subsurface soils at the Site (Section 4.2). Construction/excavation workers could be exposed to surface soils (0 to 3 feet below ground surface [bgs]) and subsurface vadose soils from 3 to 10 feet bgs. Occupational workers could be exposed to surface soils between 0 to 0.5 foot bgs. Future residents could be exposed to surface soils between 0 and 3 feet bgs.

The RI Data Acquisition soil samples used in this BHHRA are summarized in Table 3-2, including 72 samples collected between August 2017 and July 2018. Twenty-two surface soil samples from 0 to 0.5 foot bgs, 27 additional surface soil samples from 0 to 3 feet bgs, and 23 subsurface soil samples from 3 to 10 feet bgs have been collected at the Site.

Figure 3-1 shows the sample locations used for the construction/excavation worker (upland areas) soil dataset. Figure 3-2 shows the sample locations used for the occupational worker soil dataset. Figure 3-3 shows the sample locations used for the resident soil dataset. Surface soil samples for both the 0 to 0.5 foot and 0 to 3 feet bgs intervals were collected from 12 locations along the northern vegetated Bluff Area and 10 locations in the vicinity of historical and existing buildings. Five additional surface soil samples in the 0 to 3 feet bgs interval from test pits and trenches were also collected from this area.

#### Groundwater

There is currently no human exposure to Site groundwater. Future residents may potentially be exposed to Site groundwater, through its use as tap water, if water supply wells are developed at the Site (Section 4.2).

The RI Data Acquisition groundwater samples used in this BHHRA are summarized in Table 3-3. One hundred forty-seven groundwater samples were collected from 29 monitoring wells located throughout the Site between January 2018 and March 2020. The monitoring well locations are shown in Figure 3-4. All groundwater wells are assumed to be potable, pending future determination for shoreline wells.

#### Vapor

A vapor intrusion (VI) assessment was conducted to evaluate current and potential future risks to human health through inhalation of vapors migrating into existing and potential future structures from subsurface vapor sources. The VI assessment consisted of a soil gas survey, conducted between October 21 and October 31, 2019. The approach for the VI assessment was described in the Work Plan Addendum (Aspect and Anchor QEA 2019).

The VI assessment explorations consisted of the following:

Sub-slab Soil Gas Explorations: Four sub-slab soil gas samples (SSG-1 through SSG‑4) were collected from beneath existing buildings where vapor sources[[1]](#footnote-2) are known to exist in the subsurface.

Exterior Soil Gas Explorations: Eight exterior soil gas samples[[2]](#footnote-3) (ESG-1 through ESG-8) were collected from soil borings advanced to evaluate the presence, nature, and extent of volatile contaminants in soil gas near subsurface vapor sources.

The soil gas sample locations are shown in Figure 3-5. All the soil gas samples were submitted for laboratory analysis of the VI contaminants of potential concern (VI‑COPCs), which include the following:

Volatile organic compounds (VOCs)

Cyanide (as hydrogen cyanide)

Benz(a)anthracene

The VI-COPCs for the VI assessment are those that EPA has determined to be volatile and potentially toxic,[[3]](#footnote-4) and that have been detected in soil and/or groundwater at the Site, except for Aroclor 1260.[[4]](#footnote-5)

#### Sediment

Human receptors may potentially be exposed to intertidal (above -4 feet MLLW)[[5]](#footnote-6) surface sediments in the ISA (Section 4.2.). Construction/excavation workers in beach areas, and future Tribal shellfish collectors, may be exposed to surface sediment (0 to 3 feet bgs). Recreational beach users may be exposed to surface sediment (0 to 4 inches bgs).

All ISA surface sediment sample locations are shown in Figure 3-6. Both subtidal and intertidal surface sediment samples were conservatively used in the sediment COPC screen. This included 200 total samples. The RI Data Acquisition surface sediment samples used in the BHHRA exposure datasets are summarized in Table 3-4. For the intertidal human health exposures, 87 surface sediment samples within the 0 to 3 feet bgs interval were collected between July 2013 and August 2019, including 70 samples from the 0 to 4 inch bgs range.

Figure 3-7 shows the sample locations used for the recreational beach user dataset. Figure 3-8 shows the sample locations used for the construction/excavation worker (beach areas) and Tribal shellfish collectors/consumers.

#### Surface Water

Human receptors may be exposed to marine water at the ISA while using the intertidal beach area (Section 4.2). Recreational users, construction/excavation workers (beach areas), and future Tribal shellfish collectors may be exposed to surface water.

The RI Data Acquisition surface water samples used in the BHHRA are summarized in Table 3-5. Sixteen surface water samples were collected from depths of 3 to 29 feet in the offshore portion of the ISA between June 2017 and January 2018. Figure 3-9 shows the surface water sample locations.

#### Shellfish (Clam) Tissue

Future Tribal shellfish collectors may be exposed to shellfish tissue collected from the ISA (Section 4.2). For this BHHRA, shellfish consumed by the Suquamish Tribe sourced from the ISA are conservatively represented by clams, as described in Section 4.2.6.

The RI Data Acquisition shellfish (clam) tissue samples used in the BHHRA are summarized in Table 3-6. Shellfish (clam) samples were collected on August 1, 2019, from two areas in the ISA. Three composite samples each of 20 manila littleneck clams (*Venerupis philippinarum*) and 15 native littleneck clams (*Leukoma staminea*) were collected from the beach adjacent to the Former Gas Works (Area 1) and from the Eastern Beach (Area 2) for a total of 6 samples for each species. Figure 3-10 shows the shellfish sample areas.

### Background Data

In some cases, the same hazardous substances, pollutants, and contaminants detected in media within the Site are also background constituents that are not related to Site releases. These constituents should also be included in the risk assessment, particularly when their concentrations exceed risk-based concentrations. In cases where background levels are high or present health risks, this information is important to the risk manager to accurately communicate to the public. Background information is also important to risk managers because the CERCLA program generally does not clean up to concentrations below natural or anthropogenic background levels. Background levels are considered as part of the risk characterization step, as applicable. The applicable background data include the following:

Soil and Groundwater:

For soil and groundwater, natural background concentrations of arsenic and other trace elements, but not organic compounds, have been established by Ecology under the Model Toxics Control Act (MTCA) program (Ecology 1994). The Site is in an urban area, and local soil and groundwater conditions are impacted by anthropogenic sources, including atmospheric deposition. There are relevant RI/FS data available to characterize upgradient anthropogenic background conditions.

In addition to the RI/FS data, urban background soil concentrations of polycyclic aromatic hydrocarbons (PAHs) from six neighborhoods in Seattle, Washington, were each characterized with 20 randomly distributed samples collected using a regulatory-approved QAPP (Ecology 2011a).

Site-specific groundwater data from samples collected upgradient of the Site are also used to characterize background concentrations, particularly for redox-sensitive trace element COPCs.

Sediment:

For Puget Sound sediment, natural background concentrations have been established using 70 samples from reference areas that were analyzed for metals, PAHs, and dioxin/furans (D/F), as well as other chemicals (USACE 2009). These data were collected using a regulatory-approved QAPP and incorporated in relatively recent EPA decision making (EPA 2014b). In addition, the dataset has been integrated by Ecology in sediment cleanup guidance (2019) that may be an Applicable or Relevant and Appropriate Requirement (ARAR).

A Site-specific data quality objective (DQO) has been developed to determine if anthropogenic background sediment concentrations can be determined and applied to the Site.

Surface Water:

Ecology (2011b) has characterized toxic chemicals in Puget Sound, including PAHs and arsenic, using sampling and analyses methods documented in a regulatory-approved QAPP. These data are suitable for a background comparison to Site surface water data.

Shellfish (Clam) Tissue:

Non-urban locations in Puget Sound were used to calculate background concentrations for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in clam tissue for use in setting remediation goals in the Lower Duwamish Waterway (EPA 2014b). The studies used to establish these values are documented in the Lower Duwamish Waterway FS (AECOM and Windward 2012). The samples from these studies were collected under an EPA Region 10 approved QAPP and were obtained from Padilla/Fidalgo Bay, Salsbury Point, Dungeness Bay, and Freshwater Bay. The non-urban clam sample locations are shown in Figure 3-11. Using the exposure point concentration (EPC) calculation methods and Suquamish Tribe exposure assumptions described in Section 4.4.13.3, risk from subsistence consumption of non-urban Puget Sound clams is determined using the study data identified by AECOM and Windward (2012). PAH risk from consumption of Site clams is compared to risk calculated from reference clam concentrations developed for non-urban areas.

## Data Treatment

This section provides a summary of the data treatment rules applied to the BHHRA dataset. “Data treatment” refers to methods used to select and combine data for use and evaluation. The data treatment rules used in this BHHRA include the following:

Field duplicates. Field duplicates were excluded from the BHHRA dataset. Field duplicates were not included in COPC screening, EPC calculations, or risk estimates.

Nondetect reporting. Individual nondetect results were reported as the method detection limit (MDL), or the estimated detection limit (EDL) for high-resolution analytical methods. If the MDL or EDL was not available, the reporting limit (RL) was used.

Chemical sums. Totals are calculated as the sum of all detected results and half of the limit of nondetected results (U=1/2). If all constituents included in the summation had nondetect results, the highest MDL/EDL was reported as the sum, and the total was qualified as a nondetect (“U”).

Toxic equivalents. Toxic equivalence factors (TEFs) for mammals were used to calculate total D/F and polychlorinated biphenyl (PCB) toxic equivalents (TEQs) (Van den Berg et al. 2006). TEFs for human health were used to calculate total cPAH TEQ (EPA 1993a) for consistency with EPA HHRA guidance. These TEQs are evaluated for human health exposures in this BHHRA. The TEFs are presented in Table 3-7.

### Calculation of Exposure Point Concentrations

To quantify exposures to COPCs by human receptors, an EPC is calculated to provide an estimate of the concentration of the COPC at the exposure point or points over the exposure period for each receptor. The EPC is the concentration term for each medium in the intake equations presented in Section 4.4.

The following describes the general approach for selecting EPCs:

EPCs are estimated using the 95% upper confidence limit (UCL) of the mean, calculated using EPA’s ProUCL (current version) for all data distributions, except that the 95% UCL is not selected as the EPC where data were limited as follows:

For chemicals with less than eight results, the maximum concentration is selected as the EPC.

For chemicals with eight or more results, but less than four detects, the maximum concentration is selected as the EPC.

The EPC are selected from the 95% UCL results based on ProUCL’s recommendations as follows:

If the recommended UCL is greater than the maximum detected result, the maximum detected result will be selected as the EPC.

If ProUCL recommends more than one UCL, the highest value is selected as the EPC.

If ProUCL recommends a UCL based on Land’s H-statistic (H-UCL), the 95% Chebyshev (Mean, Sd) UCL is selected as alternative UCL.

If ProUCL recommends a UCL based on KM H-UCL, nondetect results for the COPC are identified as detected at the MDL/EDL and ProUCL is used to identify an alternative UCL.

Consistent with ProUCL guidance, nondetect concentrations are entered into ProUCL at the associated MDL/EDL for calculating 95% UCLs from datasets with nondetect concentrations. The ProUCL outputs for the different datasets are included in Attachment B.

## Chemical Screening Criteria and Selection of Contaminants of Potential Concern

This section presents the screening levels and the screening process used to identify the COPCs for soil, groundwater, soil gas, sediment, surface water, and shellfish. The COPC selection process for soil, groundwater, sediment, and surface water in this BHHRA is consistent with the process used in the approved RATM (Anchor QEA and Aspect 2020).

The purpose of the COPC screening process is to identify chemicals observed in the Site media that are the most likely to contribute significantly to potential human health risk (EPA 1989, 1993b). Soil gas VI-COPCs were identified in the Work Plan Addendum (Aspect and Anchor QEA 2019). Shellfish (clam) COPCs (PAHs) were identified in the working groups involving the Suquamish Tribe, EPA, and Cascade (see Attachment A).

### Selection of Screening Levels and Description of Screening Process

This section presents the screening levels and screening process to identify COPCs for soil, groundwater, soil gas, sediment, and surface water for evaluation in the risk characterization step of this BHHRA (see Section 6). The COPC screening process was conducted using the BHHRA-specific (described in Section 3.1) soil, groundwater, soil gas, sediment, and surface water data collected from the Site and marine ISA.

#### Screening Levels

The screening levels for COPCs were specified in the RATM (Anchor QEA and Aspect 2020) and conservatively consisted of the lowest of the human health or ecological screening levels. Natural background is not considered except for sediment cPAH TEQ, D/F TEQ, and PCB congener TEQ for which no other screening levels are available. Tables 3-8 through 3-12 present the screening levels selected for each medium.

The screening levels applied to determine the list of COPCs by media were as follows:

**Soil:** Lowest of residential regional screening level (RSL) or ecological soil screening level (Eco-SSL). Applied to all soil sample depths. The soil COPC screening levels are shown in Table 3-8.

**Groundwater:** Lowest of tap water RSL or surface water COPC screening level. The groundwater COPC screening levels are shown in Table 3-9.

**Soil Gas:** The EPA vapor intrusion screening levels (VISLs) for the protection of human health in residential and commercial/industrial exposure scenarios. The soil gas screening levels are summarized in Table 3-10. The VI-COPCs evaluated in the VI assessment are those that EPA has determined to be volatile and potentially toxic,[[6]](#footnote-7) and that have been detected in soil and/or groundwater at the Site, with exception of Aroclor 1260 as described in Section 3.1.2.3. For soil gas, the following two screening levels were identified to aid in exposure evaluations:

Current use: The EPA Target Sub-slab and Near-source Soil Gas Concentrations for commercial (occupational worker) exposure scenario

Potential future use: The EPA Target Sub-slab and Near-source Soil Gas Concentrations for a residential exposure scenario

The commercial/industrial VISLs are applied to the sub-slab soil gas to evaluate current risk to occupational workers using existing buildings (Buildings 4, 5, and 6) overlying subsurface vapor sources. These VISLs are applicable to the current use of those buildings. The occupational and residential VISLs are also applied to the sub-slab soil gas samples and exterior soil gas samples to evaluate potential future risk from VI.

**Sediment:** Lowest of Sediment Management Standard (SMS) sediment cleanup objective (SCO). If no SCO is available, the lowest of either the National Oceanic and Atmospheric Administration effect range-low or EPA Ecological Benchmarks were used. EPA’s natural background is used if no other screening level is available. Applied to all intertidal and subtidal surface sediment sample depths (Figure 3-6). The sediment COPC screening levels are shown in Table 3-11.

**Surface Water:** Lowest of EPA or Washington State human health or aquatic life water quality criteria, or if not available, the EPA Ecological Benchmarks were used. The surface water COPC screening levels are shown in Table 3-12.

#### Screening Process

As presented in Figure 3-12, the COPC screening steps for all media except soil gas are as follows:

1. Eliminate chemicals that are essential nutrients or conventional.
2. Retain detected chemicals as COPCs that are known Class A human carcinogens.
3. Eliminate chemicals with maximum concentrations below their respective screening levels and with a frequency of detection (FoD) less than 5%, unless the MDL, or EDL for high-resolution methods, is greater than the screening level. A chemical with a maximum nondetect concentration above its screening level was retained as an uncertain COPC.
4. Retain as COPCs the chemicals with maximum detected concentrations exceeding their respective COPC screening levels.

In Step 1, chemicals identified as conventional parameters or essential nutrients (e.g., calcium, iron, magnesium, sodium, and potassium) were eliminated as COPCs (EPA 1989).

In Step 2, any detected chemical that is a known Group A human carcinogen was retained as a COPC, regardless of its concentration or FoD, and will be further evaluated in the baseline risk assessment.

In Step 3, for chemicals not identified as conventional parameters or essential nutrients in Step 1, an FoD screen was conducted by medium. Chemicals with an FoD of less than 5% and no screening level were eliminated. Chemicals with a maximum concentration below their respective screening level and with an FoD of less than 5% were eliminated as COPCs unless the MDL, or EDL for high-resolution methods, was above the screening level. If the MDL/EDL exceeded the screening level, then the chemical was identified as an uncertain COPC.

In Step 4, the maximum detected concentrations for each chemical retained from Steps 1 through 3 for each medium were compared to the selected screening level. A chemical with a maximum detected concentration above its screening level was retained as a COPC. Maximum concentrations based on nondetected constituents were evaluated at the MDL, or EDL for high-resolution methods. A chemical with a maximum nondetected concentration above its screening level was retained as an uncertain COPC. A chemical without a screening level was retained as an uncertain COPC.

Soil gas samples are screened on a point-by-point basis to identify VI-COPCs presenting potential current risk to occupational workers or potential future risk to occupational workers or residents.

As a result of the screening process, the chemicals were placed into one of the following three categories:

**COPC**: Chemicals with a maximum detected concentration above their screening levels were carried forward for evaluation. In addition, all known human carcinogens detected in Site media were retained as COPCs regardless of the detected concentration or the availability of screening levels for those chemicals.

**Eliminated as COPC**: Chemicals with maximum concentrations below their respective screening levels and with an FoD less than 5% were eliminated as COPCs and will not be further evaluated.

**Uncertain COPC**: Chemicals without a screening level but with an FoD greater than 5%, or chemicals with an FoD less than 5% but with an MDL/EDL greater than their respective screening levels, will be evaluated in the uncertainty section of the risk assessment.

### COPCs by Media

This section presents the results of the COPCs screen by media, following the procedures described in Section 3.3.1.2. The COPC tables in this section include the FoD, maximum detected concentrations, range of detection limits, and the screening levels. These tables also provide a short description of the results, indicating whether a chemical is identified as a COPC, eliminated from further analysis, or identified as an uncertain COPC. Chemicals identified as COPCs are evaluated further in Section 6, and uncertain COPCs are discussed in Section 7. The chemicals identified as COPCs are summarized in Table 3‑19.

#### Soil

The chemicals identified as COPCs from potential direct exposure to the Site soil are summarized in Table 3-13. Of the 182 soil chemicals and chemical totals screened, 40 chemicals were identified as COPCs on the basis of the maximum concentration exceeding the COPC screening level. Thirty chemicals were identified as uncertain COPCs in soil because the FoD was less than 5% but the MDL (or EDL for high-resolution methods) exceeded the COPC screening level. Seven chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there was no screening level for this chemical. The remaining 105 chemicals were eliminated because the chemical was either a conventional or non-RI chemical, the maximum detected concentration was below its COPC screening level, or the FoD was less than 5% and no screening level was available. Chemicals identified as uncertain COPCs are discussed further in Section 7.1.3.

#### Groundwater

The chemicals identified as COPCs from potential direct exposure to Site groundwater are summarized in Table 3-14. Of the 160 groundwater chemicals and chemical totals screened, 48 chemicals were identified as COPCs on the basis of the maximum concentration exceeding the COPC screening level. Forty-five chemicals were identified as uncertain COPCs because the FoD was less than 5% but the MDL/EDL exceeded the COPC screening level. Eight chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there are no screening levels for these chemicals. The remaining 59 chemicals were eliminated because the chemical was either a conventional or non-RI chemical, the maximum detected concentration was below its COPC screening level, or the FoD was less than 5% and no screening level was available. Chemicals identified as uncertain COPCs are discussed further in Section 7.1.3.

#### Soil Gas

The statistical summary of soil gas results is shown in Table 3-15 and the sub-slab soil gas and exterior soil gas point-by-point screens are shown in Table 3-16. Of the 77 chemicals screened,[[7]](#footnote-8) 10 VI-COPCs had concentrations exceeding the VISL for industrial or residential exposure. No VI-COPCs exceeded the industrial VISL in sub-slab samples. Six VI-COPCs exceeded the industrial VISL in exterior samples, and 10 chemicals exceeded the residential VISL in sub-slab or exterior gas samples.

The VI-COPCs identified for potential future resident and occupational workers are dependent on potential future buildings and land use at the Site.

#### Sediment

The chemicals identified as COPCs from potential direct exposures to Site sediment are summarized in Table 3-17. Of the 250 sediment chemicals and chemical totals screened, 34 chemicals were identified as COPCs on the basis of the maximum concentration exceeding the COPC screening level or because the chemical is an EPA-known carcinogen (Group A carcinogen). Three chemicals were identified as uncertain COPCs in sediment because the FoD was greater than 5% and the MDL/EDL exceeded the COPC screening level, but the maximum detected concentrations were below the COPC screening level. Fifteen chemicals were identified as uncertain COPCs because the FoD is less than 5%, but the MDL/EDL exceeded the COPC screening level. Forty-seven chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there is no screening level for this chemical. The remaining 149 chemicals were eliminated because the chemical was either a conventional or non-RI chemical, the maximum detected concentration was below its COPC screening level, or the FoD was less than 5% and no screening level was available. Chemicals identified as uncertain COPCs are discussed further in Section 7.1.3.

The FoDs for Aroclor 1254 and total PCB Aroclors were 34% and 40%, respectively. The Aroclor 1254 COPC screening level is based on an EPA Region 3 BTAG Benchmark. The total PCB Aroclor COPC screening level is based on the Washington State SMS SCO, a state ARAR. Only two samples, one in the intertidal and one in the subtidal, exceeded the SMS criteria for PCB Aroclors (compared to SMS Marine SCO on a dry-weight basis) and the maximum exceedance factor was 1.3.

PCBs are not MGP- or Site-related chemicals. Sediment bioaccumulative chemicals were reviewed during the working group meetings, and it was determined that PAHs were the Site-related bioaccumulative chemicals of importance (see Attachment A). For these reasons, PCBs have not been retained as COPCs.

#### Surface Water

The chemicals identified as COPCs from potential direct exposures to Site surface water are summarized in Table 3-18. Of the 220 surface water chemicals and chemical totals screened, 4 chemicals were identified as COPCs on the basis of the maximum concentration exceeding the COPC screening level. Twenty-two chemicals were identified as uncertain COPCs because the FoD was less than 5% but the MDL/EDL exceeded the COPC screening level. Two chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there is no screening level for this chemical. The remaining 192 chemicals were eliminated because the chemical was either a conventional or non-RI chemical, the maximum detected concentration was below its COPC screening level, or the FoD was less than 5% and no screening level was available. Chemicals identified as uncertain COPCs are discussed further in Section 7.1.3.

#### Shellfish (Clam) Tissue

All PAHs tested in shellfish (clams) are considered COPCs. Shellfish (clams) were collected from the ISA as part of RI Data Acquisition. Collection of shellfish (clams) was identified as a data gap during the RATM working group meetings between the Suquamish Tribe, EPA, and Cascade (Attachment A). Working group outcomes determined that PAHs are the only Site-related bioaccumulative compounds that required characterization of clams for the BHHRA (Aspect and Anchor QEA 2019).

# Exposure Assessment

Identification of potentially exposed populations, pathways of exposure, and exposure media are important components of this BHHRA and serve as the basis for the exposure pathway CSM that has been developed for the Site and ISA. According to EPA (1989), an exposure assessment includes the following three primary tasks:

**Characterization of the exposure setting.** This step includes identifying the characteristics of populations that can influence their potential for exposure, including their location and activity patterns, current and potential future land use considerations, and the possible presence of sensitive subpopulations.

**Identification of exposure pathways.** Exposure pathways are identified for each population that may potentially be exposed to chemicals originating from the Site.

**Quantification of exposure.** The magnitude, frequency, and duration of exposure for each pathway are determined. This step consists of estimating EPCs and calculating chemical intakes.

## Identification of Exposure Pathways

Exposure pathways are defined as the routes through which chemicals may enter the human body. To determine whether an exposure pathway is complete and, therefore, exposure can occur, the following four elements must be evaluated:

Source of chemical release

Release or transport mechanism (or media in cases involving media transfer)

Exposure point (a point of potential human contact with the contaminated exposure medium)

Exposure route (e.g., ingestion or dermal contact) at the exposure point

If any of these elements are missing, the pathway is considered incomplete and exposure will not occur. The definitions of all possible exposure pathway designations are as follows:

**Complete Exposure Pathway – Quantitative Evaluation.** There is a source, a release and transport mechanism from a source, an exposure point where contact can occur, and an exposure route through which contact can occur. These complete exposure pathways are quantitatively evaluated in this BHHRA.

**Complete Exposure Pathway – Qualitative Evaluation.** There is a source, a release and transport mechanism from a source, an exposure point where contact can occur, and an exposure route through which contact can occur. However, because of the low exposure potential for this exposure pathway, the pathway was evaluated qualitatively in this BHHRA.

**Incomplete Exposure Pathway.** There is either no source, no release or transport mechanism from a source, no exposure point where contact can occur, and/or no exposure route through which contact can occur for the given receptor. Pathways considered incomplete were not evaluated further in this BHHRA.

## Identification of Potentially Exposed Human Populations

Based on the current and future uses of the Site, the following receptors were identified for quantitative evaluation of risks in this BHHRA:

Current/Future Construction/Excavation Worker (Upland Areas)

Current/Future Occupational Worker

Current/Future Recreational Beach User

Current/Future Construction/Excavation Worker (Beach Areas)

Future Resident

Future Tribal Shellfish Consumer

This section discusses the human receptor categories included in the approved RATM (Anchor QEA and Aspect 2020). The receptor categories and exposure pathways for these receptors are presented in the BHHRA exposure pathway CSM figures for current and future conditions (see Figure 4-1). The BHHRA exposure pathway CSM figures describe potential contaminant sources, transport mechanisms, potentially exposed populations, exposure pathways, and routes of exposure. The exposure pathway designations as described in the preceding section are included in the exposure pathway CSM figures, and these exposure pathway CSM figures are used to memorialize the pathways that were agreed upon by Cascade, the Suquamish Tribe, and EPA to be quantitatively evaluated in this BHHRA.

The identified receptors, exposure routes, exposure pathways, and the rationale for selection are summarized in Table 4-1. A summary of each of the receptor categories and the exposure scenario associated with their activities in and adjacent to the Site is presented in the following sections. Specific and detailed information on the exposure parameters selected for each receptor and exposure medium are presented in Section 4.4.13.

### Construction/Excavation Worker (Upland Areas)

The construction/excavation worker receptor category addresses workers performing utility upgrades or maintenance, or other activities that involve the disturbance of soil at the Former Gas Works Property, including the bluff, and the properties in the vicinity. Typical construction worker activities (e.g., grading or excavation for building foundations) are expected to extend down to approximately 3 feet in depth. Some construction activities could also result in exposure to Site-related COPCs through direct contact with and incidental ingestion of subsurface soil (from the surface to the deepest interval sample within the vadose zone, but not deeper than 10 feet bgs).

As shown in Figure 4-1, incidental ingestion and dermal contact with surface and subsurface soil (0 to 10 feet bgs), and inhalation of soil fugitive dust and soil vapor (ambient), are complete exposure pathways for quantitative evaluation for the construction/excavation worker in the upland areas. These workers do not come in contact with Site groundwater, vapor (indoor), surface water, or surface sediment, and potential exposures to these media are considered incomplete exposure pathways for this receptor group.

### Occupational Worker

The occupational worker receptor category includes employees in the upland area who are both indoors and outdoors during the business day and may be exposed to Site soil and vapor (indoor). The Former Gas Works Property and the properties in the vicinity are zoned for industrial uses (Figure 2-2). Therefore, as shown in Figure 4-1, incidental ingestion and dermal contact with surface soil (0 to 0.5 foot bgs), and inhalation of soil fugitive dust and soil vapor (ambient), while working in the upland portion of the Site are complete exposure pathways for quantitative evaluation for the occupational worker in the upland areas. Inhalation of vapor (indoor) is a potentially complete exposure pathway and is evaluated qualitatively. The occupational worker scenario assumes that workers do not dig in the upland soil or frequent the beach portion of the Site during typical work activities. These workers do not come in contact with Site groundwater, surface water, or surface sediment, and potential exposures to these media are considered incomplete exposure pathways for this receptor group.

### Recreational Beach User

Shoreline recreational users represent visitors to the Site beach areas. The activities included under this exposure scenario include beach play and other recreational activities. Beach users are assumed to access the Site beach (sediments above -4 feet MLLW) from adjacent beach areas and not from the upland area of the Site. Therefore, as shown in Figure 4-1, dermal contact with and incidental ingestion of surface water and sediment (0 to 4 inches below mudline) are complete exposure pathways for current and future beach users. These receptors do not come in contact with Site groundwater, vapor (indoor), or soil, and potential exposures to these media are considered incomplete exposure pathways for this receptor group.

### Construction/Excavation Worker (Beach Areas)

This construction/excavation worker receptor category addresses workers involved in short-term construction or related activities that might occur in the beach areas (sediments above -4 feet MLLW) of the Site. This scenario relates to workers performing utility upgrades, maintenance, or other activities that involve the disturbance of sediment in the beach area adjacent to the Former Gas Works Property.

As shown in Figure 4-1, incidental ingestion and dermal contact with surface sediment (0 to 3 feet below mudline) and surface water are complete exposure pathways for quantitative evaluation for the construction/excavation worker in the beach areas. These workers do not come in contact with Site groundwater, vapor (indoor), or soil, and potential exposures to these media are considered incomplete exposure pathways for this receptor group.

### Resident

The resident receptor category addresses potential future residents at the Site. The Former Gas Works Property and the properties in the vicinity are zoned for industrial uses, and this is expected to remain the case for the foreseeable future. However, the potential for exposure of future residents is appropriate to evaluate as part of the BHHRA to understand potential implications should properties within the Site be converted to residential uses. No water supply wells are located on or near the Former Gas Works Property, but consumption of groundwater and other residential uses have been retained as a potential pathway for screening, pending further evaluation of groundwater beneficial uses.

As shown in Figure 4-1, incidental ingestion and dermal contact with upland surface soils (0 to 3 feet bgs), inhalation of soil fugitive dust and vapor (ambient), ingestion and dermal contact with groundwater and inhalation of groundwater vapors while using groundwater for domestic use (i.e., drinking, bathing, cooking, and laundry) are complete exposure pathways for quantitative evaluation for the future resident. Inhalation of vapor (indoor) is a potentially complete exposure pathway and is evaluated qualitatively.

### Tribal Shellfish Consumers

The Tribal shellfish consumer receptor group includes Suquamish Tribe members harvesting shellfish from the ISA in the future. The portions of the PWN adjacent to the Former Gas Works Property are currently closed to shellfish harvesting by the Washington State Department of Health (due to water quality concerns associated with combined sewer overflows and other non-Site-related concerns). However, exposure associated with shellfish harvesting is evaluated to understand potential future risks should the shellfish harvest restrictions be lifted. Future consumers of shellfish may be exposed to Site-related COPCs through ingestion of shellfish tissue and dermal contact with and incidental ingestion of sediment (0 to 3 feet bgs; maximum depth of excavation assumed to be limited by water infiltration, sediments above -4 feet MLLW), and marine surface water during harvesting activities.

In the working group meetings (Attachment A), the Suquamish Tribe provided guidance to develop this scenario, which uses shellfish consumption as the primary route of exposure to COPCs. EPA and the Suquamish Tribe have emphasized the importance of having robust estimates of human health risks associated with seafood consumption, particularly from the potential future consumption of clams harvested at the Site. Clams are important for several reasons:

The Site is located within the traditional seafood harvesting areas of the Suquamish Tribe.

The beaches in the ISA are suitable for the growth and harvest of clams,[[8]](#footnote-9) notwithstanding ongoing water quality concerns related to sewage discharges.

The consumption rate documented by the Suquamish Tribe for clams is much greater than that for other types of seafood potentially associated with the Site.

Clams have the potential to bioaccumulate sediment contaminants, including PAHs (Rust et al. 2004, Replinger et al. 2017).

The Suquamish Tribe (2000) identifies seven groups of fish consumed by its members. Group E includes a range of commonly consumed Puget Sound shellfish species including clams, oysters, mussels, shrimp, and crab, and Group G includes other shellfish. The total combined consumption rate for Groups E and G will be applied to characterize exposure to clams harvested at the Site (see Section 4.4.13.3).

While members of the Suquamish Tribe (2000) also consume fish, it is at a much lower rate than shellfish. In addition, pelagic and demersal fish are mobile, wide-ranging, and metabolize PAHs. Therefore, exposures of people to Site PAHs via bioaccumulation in fish are considered insignificant and will not be evaluated.

Because the Suquamish Tribe shellfish consumption rates are substantially higher than those for recreational non-tribal populations, it is assumed the Tribal shellfish consumer scenario will be protective of recreational non-tribal shellfish consumers, and the latter are not evaluated in this BHHRA.

As shown in Figure 4-1, incidental ingestion and dermal contact with surface sediment (0 to 3 feet below mudline) and surface water, and ingestion of shellfish (clam) tissue, are complete exposure pathways for quantitative evaluation. This receptor category will not come in contact with Site soil, vapor (indoor), or groundwater, and potential exposures to these media are considered incomplete exposure pathways for this receptor group.

## Exposure Point Concentrations

To quantify exposures to COPCs by human receptors, an EPC is calculated to provide an estimate of the concentration of the COPC at the exposure point or points over the exposure period for each receptor. The EPC is the concentration term for each medium in the intake equations presented in Section 4.4.

EPCs are calculated using the method described in Section 3.2.1. Sections 4.3.1 through 4.3.6 describe the datasets that were used to calculate EPCs for this BHHRA and the tables where this information is presented. In some instances, chemicals identified as COPCs are non-detect in a given dataset. These COPCs are presented in the EPC tables but are not included in the risk characterization tables (Section 6.2).

### Soil

EPCs for Site soil were calculated from soil data for the surface soil intervals (0 to 0.5 foot bgs and 0 to 3 feet bgs), and combined surface and subsurface interval (0 to 10 feet bgs). As described in Section 4.2, human receptors that may be exposed to soil include construction/excavation workers (upland areas, 0 to 10 feet bgs), occupational workers (0 to 0.5 foot bgs), and potential future residents (0 to 3 feet bgs). EPCs for soil are presented in Tables 4-2 through 4-4.

### Groundwater

EPCs for groundwater were calculated on a Site-wide basis and from each well individually. These EPC may be refined after the potability evaluation to exclude samples from non-potable wells. As described in Section 4.2, human receptors that may be exposed to Site groundwater include potential future residents who may consume groundwater as drinking water and use groundwater for other domestic uses (i.e., bathing, dishwashing, and laundry) that could result in dermal exposure and inhalation exposure to volatile compounds. The Site-wide EPCs are presented in Table 4-5. EPCs for the individual wells are included in Attachment F, Tables F1-1 through F1-29.

### Soil Gas

A point-by-point screen is used to evaluate potential VI risk. The soil gas concentration in each sub-slab and exterior soil gas sample is compared to the commercial and residential VISL. The point-by-point screen is included in Table 3-16.

### Sediment

EPCs for sediment in the ISA were calculated from intertidal sediment data (above ‑4 feet MLLW), for both the 0 to 4 inches and 0 to 3 feet below mudline surface sediment intervals. As described in Section 4.2, human receptors that may be exposed to sediments include recreational users (0 to 4 inches), construction/excavation workers (beach areas) (0 to 3 feet), and Tribal shellfish consumers during shellfish collection (0 to 3 feet). EPCs for sediment are presented in Tables 4-6 and 4-7.

### Surface Water

EPCs for Site surface water were calculated from unfiltered marine surface water samples collected from within the ISA boundary of PWN. As described in Section 4.2, human receptors that may be exposed to surface water include recreational users, construction/excavation workers (beach areas), and Tribal shellfish consumers during shellfish collection. EPCs for surface water are presented in Table 4-8.

### Shellfish Tissue

EPCs for Site shellfish (clam) tissue were calculated from composite shellfish samples that were collected from the ISA during RI Data Acquisition (Aspect and Anchor QEA 2020). Clam samples were collected from two intertidal areas within the ISA (Figure 3‑10). Site EPCs for clam are presented in Table 4-9.

Background PAH EPCs for clam tissues were calculated using composite clam samples determined to represent non-urban conditions (EPA 2014b). Background clam EPCs are presented in Attachment G, Table G1-1.

## Estimation of Chemical Intake

A chemical may be incorporated into the body through ingestion, absorption, or inhalation. For the ingestion and absorption exposure routes, the dose is defined as the amount of a chemical that is ingested or absorbed by the body and is expressed in units of milligrams of chemical per kilogram of body weight per day (mg/kg-day). For the inhalation exposure route (soil fugitive dust and vapor), the exposure concentrations (ECs) are used; these are set equal to the concentrations of chemicals in ambient air, in units of micrograms per cubic meter (µg/m3).

The dose is calculated differently when evaluating carcinogenic effects than when evaluating noncancer effects. Each is described as follows:

**Carcinogenic Effects**: The dose is based on the estimated exposure duration, extrapolated over an estimated 70-year lifetime, representing the lifetime average daily intake (LADI). This is consistent with the cancer slope factors (SFs), which are based on lifetime exposures, and on the assumptions that the risk of carcinogenic effects is cumulative and continues even after exposure has ceased.

**Noncancer Effects**: The dose is averaged over the estimated exposure period and is expressed as a chronic daily intake (CDI). The CDI is used to represent the potential for adverse health effects over the period of exposure.

Appropriate age classes have been selected for each exposure scenario from the following two categories: adults and children (infants and young children 0 to 6 years of age). For the receptors that include exposure of children, who are identified as a sensitive age class, cancer risks will be calculated for each age class individually and for combined exposures from childhood through adulthood. This will account for the increased exposure and susceptibility associated with childhood exposures. For noncancer hazards, which do not average exposures over a lifetime of exposure, the hazard estimates for children alone will provide the evaluation of this sensitive age class.

CERCLA-based HHRA exposure assessments are conducted for both the reasonable maximum exposure (RME) and, if warranted to assess uncertainty in risk estimates, also the central tendency exposure (CTE), considering both current and future land use conditions (EPA 1989).[[9]](#footnote-10) The RME is defined as the highest exposure that is reasonably expected to occur at a site but that is still within the range of possible exposures. High-end estimates are used, based on 95th or 90th percentiles for sensitive exposure parameters (such as those related to contaminant concentrations in exposure media, contact rate, exposure frequency, and duration) and average values for other variables. Only RME scenarios are used to characterize risk in this BHHRA.

Sections 4.4.1 through 4.4.11 provide the equations used to calculate exposure, followed by a discussion of the selection of parameter values. For all exposure parameters, the rationale for the selection of each RME value is presented in Tables 4-10 through 4-17 and discussed in the following sections.

### Incidental Ingestion of Soil

The following equation was used to calculate intake doses associated with the incidental ingestion of soil:

where:

Cs = chemical concentration in soil (milligrams per kilogram [mg/kg])

CF1= conversion factor 1 (10-6 kilograms per milligram [kg/mg])

IRS = ingestion rate of soil (milligrams per day [mg/day])

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kilograms [kg])

AT = averaging time (days)

This BHHRA incorporates the EPA-recommended default relative bioavailability (RBA) for arsenic of 60% in calculating the CDI and LADI for incidental ingestion of arsenic in soil (EPA 2012). This factor was only applied to the soil (and sediment) ingestion pathway for arsenic; it accounts for the differences in bioavailability of a contaminant between the medium of exposure (soil/sediment) and the media associated with the toxicity value (e.g., the arsenic toxicity values are derived from drinking water studies).

### Dermal Contact with Soil

The following equation was used to calculate intake doses associated with dermal contact with soil:

where:

Cs = chemical concentration in soil (mg/kg)

CF1 = conversion factor 1 (10-6 kg/mg)

SA = skin surface area available for contact (square centimeter [cm2])

AF = soil-to-skin adherence factor (milligram per square centimeter per event [mg/cm2‑event])

ABS = dermal absorption factor (unitless)

EF = exposure frequency (days/year)

ED = exposure duration (years)

EV = event frequency (events/day)

BW = body weight (kg)

AT = averaging time (days)

The dermal absorption factor (ABS) term provides chemical-specific dermal absorption factors for soil contact. Table 4-18 presents the ABS values used in this BHHRA (EPA 2004, 2020b).

### Inhalation of Soil Volatiles and Fugitive Dust

The following equation was used to calculate the EC associated with the inhalation of soil fugitive dust and soil vapor in ambient air:

where Ca:

where:

Ca = chemical concentration in air (µg/m3)

ET = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

AT = averaging time (days)

Cs = chemical concentration in soil (mg/kg)

CF1 = conversion factor 1/24 (day/hours)

CF2 = conversion factor 1 (1,000 micrograms per milligram [µg/mg])

PEF = particulate emission factor from soil (cubic meters per kilogram [m3/kg])

VF = volatilization factor (chemical-specific, m3/kg)

Chemical-specific VFs were obtained from the RSL calculator and are included in Attachment C. The construction/excavation worker (upland area) VFs were calculated using the RSL calculator for construction worker “soil – other construction activities” with the construction/excavation worker (upland area) exposure parameters and the Site area of 2.8 acres for the VF unlimited reservoir. The occupational worker and future resident VFs are the same and were calculated using the Seattle, Washington, climatic zone and Site area of 2.8 acres.

### Ingestion of Groundwater

The following equation was used to calculate intake doses associated with the ingestion of groundwater:

where:

CW = chemical concentration in groundwater (micrograms per liter [µg/L])

CF1 = conversion factor 1 (10-3 milligrams per microgram [mg/µg])

IRW = ingestion rate of water (liters/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

Trichloroethylene (TCE) and vinyl chloride (VC) have specific cancer intake/risk equations to account for their unique carcinogenicity (EPA 2020c). To incorporate these in this BHHRA, intake adjustment factors were developed from the TCE- and VC-specific equations presented in the EPA RSL Users Guide (2020c). The groundwater ingestion TCE and VC intake adjustment factors shown below were applied to LADI calculated without age-dependent adjustment factors (ADAFs) for the age groups indicated:

TCE

VC

Significant figures of the adjustment factors used in the calculation have been shortened for presentation in this text.

### Dermal Contact with Groundwater

The following equations were used to calculate intake doses associated with dermal contact with groundwater.

Where DAevent for organics when the event duration is less than or equal to t\*:

Where DAevent for organics when the event duration is greater than t\*:

Where DAevent for inorganics:

where:

DAevent = dermally absorbed dose per event (mg/cm2-event)

SA = skin surface area available for contact (cm2)

EV = event frequency (events/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

FA = fraction absorbed water

Kp = dermal permeability coefficient (cm/hour)

CGW = chemical concentration in groundwater (µg/L)

Ʈevent = lag time per event (hours/event)

tevent = event duration (hours/event)

t\* = time to reach steady-state

CF1 = conversion factor 1 (10-3 mg/µg)

CF2 = conversion factor 2 (10-3 liter per cubic centimeter [L/cm3])

B = relative contribution of permeability coefficient

Groundwater COPC dermal chemical-specific parameters are included in Attachment D.

TCE and VC have specific cancer intake/risk equations to account for their unique carcinogenicity (EPA 2020c). To incorporate these in this BHHRA, intake adjustment factors were developed from the TCE- and VC-specific equations presented in the EPA RSL Users Guide (2020c). The groundwater dermal contact TCE and VC intake adjustment factors shown below were applied to LADI calculated without ADAFs for the age groups indicated:

TCE

VC

Significant figures of the adjustment factors used in the calculation have been shortened for presentation in this text.

### Inhalation of Vapor Associated with Groundwater

The following equation was used to calculate the EC associated with the inhalation of volatiles in domestic groundwater.

where:

CGW = chemical concentration in groundwater (µg/liter)

ET = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

K = 0.5 (liter per cubic meter [L/m3])

CF1 = conversion factor 1/24 (day/hours)

AT = averaging time (years)

TCE and VC have specific cancer intake/risk equations to account for their unique carcinogenicity (EPA 2020c). To incorporate these in this BHHRA, intake adjustment factors were developed from the TCE- and VC-specific equations presented in the EPA RSL Users Guide (2020c). The groundwater inhalation of volatiles TCE and VC intake adjustment factors shown below were applied to EC calculated without ADAFs for the age groups indicated:

TCE

VC

Significant figures of the adjustment factors used in the calculation have been shortened for presentation in this text.

### Incidental Ingestion of Sediment

The following equation was used to calculate intake doses associated with the incidental ingestion of sediment:

where:

Cs = chemical concentration in sediment (mg/kg)

CF1= conversion factor 1 (10-6 kg/mg)

IRS = ingestion rate of sediment (mg/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

This BHHRA incorporates the EPA-recommended default RBA for arsenic of 60% in calculating the CDI and LADI for incidental ingestion of arsenic in sediment (EPA 2012). This factor was only applied to the sediment (and soil) ingestion pathway for arsenic. It accounts for the differences in bioavailability of a contaminant between the medium of exposure (soil/sediment) and the media associated with the toxicity value (e.g., the arsenic toxicity values are derived from drinking water studies).

### Dermal Contact with Sediment

The following equation was used to calculate intake doses associated with dermal contact with sediment:

where:

Cs = chemical concentration in sediment (mg/kg)

CF1 = conversion factor 1 (10-6 kg/mg)

SA = skin surface area available for contact (cm2)

AF = soil-to-skin adherence factor (mg/cm2‑event)

ABS = dermal absorption factor (unitless)

EF = exposure frequency (days/year)

ED = exposure duration (years)

EV = event frequency (events/day)

BW = body weight (kg)

AT = averaging time (days)

The ABS term provides chemical-specific dermal absorption factors for sediment contact. Table 4-18 presents the ABS values used in this BHHRA (EPA 2004, 2020c).

### Ingestion of Surface Water

The following equation was used to calculate intake doses associated with the incidental ingestion of surface water:

where:

CW = chemical concentration in surface water (µg/L)

CF1 = conversion factor 1 (10-3 mg/µg)

IRW = ingestion rate of water (liter/hour)

ET = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

### Dermal Contact with Surface Water

The following equations were used to calculate intake doses associated with dermal contact with surface water:

Where DAevent for organics when the event duration is less than or equal to t\*:

Where DAevent for organics when the event duration is greater than t\*:

Where DAevent for inorganics:

where:

DAevent = dermally absorbed dose per event (mg/cm2-event)

SA = skin surface area available for contact (cm2)

EV = event frequency (events/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

FA = fraction absorbed water

Kp = dermal permeability coefficient (cm/hour)

Cw = chemical concentration in surface water (µg/L)

Ʈevent = lag time per event (hours/event)

tevent = event duration (hours/event)

t\* = time to reach steady-state

CF1 = conversion factor 1 (10-3 mg/µg)

CF2 = conversion factor 2 (10-3 L/cm3)

B = relative contribution of permeability coefficient

Surface water COPC dermal chemical-specific parameters are included in Attachment D.

### Consumption of Shellfish

The following equation was used to calculate intake doses associated with the consumption of shellfish (clams):

where:

Ccl = chemical concentration in clam tissue (mg/kg; wet-weight basis)

CF1 = conversion factor 1 (10-3 kilogram per gram [kg/g])

IRcl = ingestion rate of clam (grams per day; wet-weight basis)

FI = fraction ingested from Site

Loss = cooking loss (grams/gram [g/g])

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days)

### Calculation of Intake for Mutagenic COPCs

Certain carcinogens are identified as operating via a mutagenic mode of action. To account for susceptibility of infants and young children to exposure to mutagenic chemicals, EPA recommends using age-dependent adjustment factors (ADAFs) for carcinogenic compounds having a mutagenic mode of action (EPA 2005b). The ADAFs are used to adjust the intake values for each medium that an infant or child may be exposed to. These adjustments reflect the potential for early-life exposures to make a greater contribution to cancers appearing later in life.

The ADAFs recommended for use by EPA for carcinogens operating under a mutagenic mode of action are as follows:

For exposures before 2 years of age, a 10-fold adjustment

For exposures between 2 years and less than 16 years of age, a 3-fold adjustment

No adjustment for individuals of greater than 16 years of age

The COPCs evaluated in this BHHRA that are characterized as exhibiting a mutagenic mode of action and incorporate ADAFs are the carcinogenic PAHs in soil, groundwater, surface water, surface sediment, and shellfish (clam) tissue. The groundwater COPCs TCE and VC are also characterized as mutagens. These COPCs are evaluated with unique chemical-specific intake equations that account for mutagenicity (see Sections 4.4.4 through 4.4.6).

### Population-Specific Exposure Assumptions

The following subsections present the exposure parameters used in this BHHRA to calculate chemical intakes for each receptor population quantitatively evaluated in this BHHRA. Site‑specific values were not available for some of the exposure scenarios included in this BHHRA. Therefore, default values representative of the general United States population, or values representing best professional judgement based on knowledge of the Site or regional precedents, were used. The following exposure parameters were used in this BHHRA and are based on standard CERCLA default parameters, when applicable:

Adult and child body weights (except for the Tribal scenarios)

Resident and occupational worker exposure frequencies

Resident and occupational worker exposure duration

Resident and occupational worker soil ingestion rates

Resident and occupational worker skin surface areas

Resident drinking water ingestion rate

Resident and worker time for soil/sediment exposures

Lifetime length in years (EPA 2014a)

In addition, default soil ingestion rates are used as sediment ingestion rates in this BHHRA because there are no default sediment ingestion rates recommended by EPA CERCLA risk assessment guidance for construction or recreational exposure scenarios. The uncertainties in the use of soil ingestion rates as estimates of sediment ingestion rates will be discussed in Section 7.2.1.1.

All exposure parameters that were used to estimate cancer risks and noncancer hazards in this BHHRA are presented in Tables 4-10 through 4-17 for the RME scenarios. These tables are presented in the Risk Assessment Guidance for Superfund D format, consistent with EPA CERCLA Guidance (EPA 2001). The exposure parameters represent potential exposures at the Site and ISA, consistent with the user categories previously discussed.

All occupational worker and resident exposure parameters were based on default values. The exposure parameters for construction/excavation workers (upland and beach areas), recreational beach users, and Tribal shellfish consumers are not based solely on standard default CERCLA exposure factors. The exposure parameters for these receptors are presented and discussed in Sections 4.1.13.1 through 4.1.13.3.

#### Construction/Excavation Worker (Upland and Beach Areas)

There is no Site-specific information on exposure parameters for construction workers at the Site. Construction work in the upland and intertidal portions of the Site is expected to occur separately, by separate individuals, and the upland and intertidal construction workers are evaluated separately in this BHHRA. Their exposure parameters are the same and are discussed together in this section.

Upland and intertidal construction work at the Site will be short term and construction projects are anticipated to last less than 6 months. A 6-month exposure duration has been used in this BHHRA. The exposure frequency is 5 days per week for the 6-month exposure duration, or 125 days per year.

The soil and sediment ingestion rate of 330 mg/day is based on the default construction worker soil ingestion rate (EPA 2002). The 8-hour workday and 3,527 cm2 surface area for head, forearms, and hands are default worker parameters (EPA 2014a). These will be used for exposures to soil for the upland construction worker and exposures to sediment and surface water for the beach construction worker. The skin adherence factors are 0.3 mg/cm2-event for both soil and sediment. The soil adherence factor is the construction worker default adherence factor (EPA 2002) and the sediment adherence factor is based on the value for “reed gatherers,” which involved periodic contact with tidal sediments.

#### Recreational Beach User

There is no Site-specific information on recreational beach use at the Site. A recreational user scenario was developed as part of the Removal Evaluation Work Plan completed in 2013 (Anchor QEA and Aspect 2013). The exposure frequency used for the Removal Evaluation Work Plan has been used for this BHHRA for consistency. The exposure frequency is 65 days per year. This exposure frequency represents the 95th percentile for children from birth to 6 years of age who engage in playing and digging in the sand adjacent to the water. It is based on a King County survey of established parks (Lake Union, Lake Washington, and Lake Sammamish) with sandy beaches (Parametrix 2003). These King County parks are likely to have higher visitation rates than the beach adjacent to the Site.

The exposure durations are 6 years for the child and 20 years for the adult based on the residential default values (EPA 2014a). The child and adult skin surface areas of 2,373 cm2 and 6,032 cm2, respectively, are the residential default values for head, hands, forearms, lower legs, and feet (EPA 2014a). The soil to skin adherence factor for sediment is 0.2 mg/cm2-event for children based on the geometric mean value for children playing in wet soil (EPA 2004). This value is consistent with the Intertidal Beach Play Scenario included in the Removal Evaluation Work Plan (Anchor QEA and Aspect 2013).

For this chemical intake estimate, the adult soil to skin adherence factor for sediment is 0.3 mg/cm2-event based on the value for “reed gatherers,” which involved periodic contact with tidal sediments. The child and adult sediment ingestion rates are 200 and 100 mg/day, respectively. These are the default residential soil ingestion rates and are consistent with the rates used in the Removal Evaluation Work Plan (Anchor QEA and Aspect 2013).

The incidental surface water ingestion rate for both children and adults is 0.004 liter per hour, which is the mean water ingestion rate while wading and splashing (EPA 2011). This value was selected because it most closely represents the types of activities that are assumed to result in exposure to this medium. The event time for the assumed recreational beach user scenario is 1 hour per event. This value assumes that surface water exposure occurs for a fraction of the time spent recreating at the tidally inundated beach.

#### Tribal Subsistence Shellfish Collection and Consumption

There is no Site-specific information on shellfish collection at the Site. Shellfish collection is anticipated to be completed by adults and children. Child and adult body weights of 16.8 kg and 79 kg, respectively, were adopted from the *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region* (Suquamish Tribe 2000). These are the mean (male and female) body weights for the different age classes. The exposure frequency for clam ingestion is 365 days per year and the exposure duration is 70 years, the values that were requested by the Suquamish Tribe. The exposure frequency for collection-related activities assumes that shellfish harvesting will occur day or night. Tide levels below 8 feet MLLW, where the harvest area is exposed, occur for at least several hours each day. Because a portion of the harvest area will be exposed every day, the exposure frequency is 365 days per year. The exposure duration of 70 years was selected from EPA (2007a). The adult exposure duration is 64 years and the child exposure duration is 6 years.

Dermal contact with surface water and sediments was expected to occur to the head, hands, forearms, lower legs, and feet of adults, which is consistent with EPA guidance for residential soil exposures (EPA 2004, 2014a). The sediment ingestion rate is based on the daily residential soil default ingestion rate of 100 mg/day for adults and 200 mg/day for children. The skin adherence factor selected for dermal exposures to surface sediment is 0.3 mg/cm2-event, based on the value for “reed gatherers,” which involved periodic contact with tidal sediments.

The surface water exposure time was assumed to be 6 hours per day, the approximate time period between high and low tide levels, which is anticipated to be a conservative exposure period for clamming on a tidally inundated beach. The incidental surface water ingestion rate is 0.004 liter per hour, which is the mean water ingestion rate while wading and splashing (EPA 2011). This value was selected because it most closely represents the types of activities that are assumed to result in exposure to this medium.

There is no Site-specific information available for shellfish consumption rates for Suquamish Tribe seafood consumers within the Site. This BHHRA uses the clam consumption rates presented in Table 4-17 for the child and adult age classes considered for this exposure pathway. These consumption rates have been adopted from information provided in the *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region* (Suquamish Tribe 2000) as presented in the *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia* (EPA 2007a).

The Suquamish Tribe reported consumption rates for different categories of seafood. For adults, the 95th percentile shellfish (Groups E and G) consumption rate of 498.4 grams per day (g/day) has been adopted. For children, the Suquamish Tribe child 95th percentile total consumption rate is 7.3 grams per kilogram per day (g/kg/day) (Suquamish Tribe 2000), which is 122.6 g/day assuming an average body weight for children age 0 to 6 years of 16.8 kg. The ingestion rate was multiplied by the fraction of shellfish (64.8%) in the total average children’s fish consumption rates (Suquamish Tribe 2000) to obtain a total ingestion rate for shellfish of 79.5 g/day.[[10]](#footnote-11)

# Toxicity Assessment

The toxicity assessment step of a BHHRA evaluates the types of adverse health effects associated with contaminant exposures and the relationship between magnitude of exposure and severity of adverse health effects. Potential health effects are contaminant-specific and may include risk of developing cancer over a lifetime or other noncancer health effects, such as changes in the normal function of organs within the body (e.g., changes in the effectiveness of the immune system). Some contaminants are capable of causing both cancer and noncancer health effects.

Available scientific data for a chemical (or group of chemicals) are compiled in order to derive toxicity values based on the dose/response relationships. These data are used to estimate the incidence or potential for adverse effects in an exposed population based on site-specific exposure assumptions (where available) or conservative EPA default exposure assumptions.

This section summarizes the toxicity values used in this risk assessment for individual chemicals and chemical classes; identifies surrogates for those chemicals without toxicity values; and discusses those chemicals for which no toxicity values or surrogates could be identified. As part of the toxicity assessment, chemicals are generally separated into categories based on their toxicological endpoints, primarily based on whether a chemical exhibits potentially carcinogenic or noncancer health effects.

## Sources of Toxicity Values

The toxicity values for COPC were obtained from EPA RSL (EPA 2020b). Consistent with EPA guidance (EPA 2003a) and the RSL Users Guide (EPA 2020c), the RSL toxicity values are obtained from the following sources according to the following hierarchy:

1. The Integrated Risk Information System (IRIS) database available through the EPA Environmental Criteria and Assessments Office in Cincinnati, Ohio. IRIS, prepared and maintained by EPA, is an electronic database containing peer-reviewed health risk and EPA regulatory information on specific chemicals.
2. EPA Provisional Peer Reviewed Toxicity Values (PPRTVs), provided by the Office of Research and Development, National Center for Environmental Assessment, Superfund Health Risk Technical Support Center, which develops these values on a chemical-specific basis when requested under the EPA Superfund program.
3. The Agency for Toxic Substances and Disease Registry minimal risk levels, which represent estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.
4. The California Environmental Protection Agency Office of Environmental Health Hazard Assessment toxicity values for the state of California.
5. PPRTV Assessment Appendix screening toxicity values.
6. The EPA Superfund program’s [Health Effects Assessment Summary Table](https://epa-heast.ornl.gov/).

Soil, groundwater, sediment, surface water, and shellfish COPCs were quantitatively evaluated on the basis of their carcinogenic and/or noncancer potential. The toxicity values used for evaluating exposure to chemicals with carcinogenic and noncancer effects were the SF and reference dose (RfD), respectively, for soil, groundwater, sediment, surface water, and shellfish (clam) tissue, or the inhalation unit risk (IUR) and reference concentration (RfC), respectively, for air. Cancer toxicity data for COPCs are presented in Section 5.2, and noncancer toxicity data for COPCs are presented in Section 5.3.

## Toxicity Values for Evaluating Carcinogenic Effects

Oral cancer SFs and IURs will be used to estimate the risk of cancer associated with exposure to a carcinogen. The oral SF represents an upper-bound, generally approximating a 95% UCL, on the increased cancer risk from a lifetime exposure by ingestion. SFs are expressed in units of proportion (of a population) affected (mg/kg‑day)‑1. An IUR is an upper-bound excess lifetime cancer risk estimated to result from continuous inhalation exposure at a concentration of 1 μg/m3 in air.

In addition to the numerical estimates of carcinogenic potential, a cancer weight-of-evidence descriptor is used by EPA to describe a substance’s potential to cause cancer in humans and the conditions under which the carcinogenic effects may be expressed. Under EPA’s 2005 Guidelines for Carcinogen Risk Assessment (EPA 2005c), a narrative approach, rather than the alphanumeric categories, is used to characterize carcinogenicity. The following five standard weight-of-evidence descriptors are used:

**Group A “Human Carcinogen”:** This group is used only when there is sufficient evidence from epidemiologic studies to support a causal association between exposure to the agents and cancer.

**Group B “Probable Human Carcinogen”:** This group includes agents for which the weight of evidence of human carcinogenicity based on epidemiologic studies is limited and includes agents for which the weight of evidence of carcinogenicity based on animal studies is sufficient. The group is divided into two subgroups. Usually, Group B1 is reserved for agents for which there is limited evidence of carcinogenicity from epidemiological studies. It is reasonable, for practical purposes, to regard an agent for which there is sufficient evidence of carcinogenicity in animals as if it presented a cancer risk to humans. Agents for which there is sufficient evidence from animal studies, and for which there is inadequate evidence or no data from epidemiologic studies, would usually be categorized under Group B2.

**Group C “Possible Human Carcinogens”:** This group is used for agents with limited evidence of carcinogenicity in animals in the absence of human data. It includes a wide variety of evidence. For example, 1) a malignant tumor response in a single well-conducted experiment that does not meet conditions for sufficient evidence; 2) tumor responses of marginal statistical significance in studies having inadequate design or reporting; 3) benign but not malignant tumors with an agent showing no response in a variety of short-term tests for mutagenicity; and 4) responses of marginal statistical significance in a tissue known to have a high or variable background rate.

**Group D “Not Classifiable as to Human Carcinogenicity”:** This group is generally used for agents with inadequate human and animal evidence of carcinogenicity or for which no data are available.

**Group E “Evidence of Noncarcinogenicity for Humans”:** This group is used for agents that show no evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiologic and animal studies.

Cancer toxicity data and classification for COPCs for the oral and dermal pathways are presented in Table 5-1 and for the air inhalation pathway in Table 5-2. Table 5-2 includes available IUR for soil and groundwater COPCs only. In this BHHRA, cPAHs were evaluated individually rather than as a class of chemicals. However, cPAH TEQ is shown in the toxicity value and risk characterization tables for reference.

## Toxicity Values for Evaluating Noncancer Effects

Noncancer health effects will be evaluated using RfDs developed by EPA. The RfD and RfC provide quantitative information for use in risk assessments for health effects known or assumed to be produced through a nonlinear (possibly threshold) mode of action:

The RfD, expressed in units of mg/kg-day, is defined as an estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

The inhalation RfC, expressed in units of milligrams per cubic meter (mg/m3), is analogous to the oral RfD but provides a continuous inhalation exposure estimate and considers toxic effects for both the respiratory system (portal of entry) and effects peripheral to the respiratory system (systemic effects).

The use of RfDs and RfCs is based on the concept that there is a range of exposures that exist up to a finite value, or threshold, that can be tolerated without producing a toxic effect. This BHHRA uses available chronic RfDs and RfCs for the oral and inhalation exposure routes, respectively. RfDs and RfCs are presented in Tables 5-3 and 5-4, respectively. Table 5-4 includes available RfCs for soil and groundwater COPCs only.

In situations where exposures to human receptors have a 1-year duration or less, EPA Superfund guidance allows for the use of subchronic RfDs and RfCs to evaluate noncarcinogenic hazards (EPA 2002). The construction worker receptors fall under this category. For these receptors, the BHHRA uses available subchronic RfDs and RfCs for the oral and inhalation exposure routes, respectively. The subchronic RfDs and RfCs were obtained from the RSL and were selected from the hierarchy described previously.

For COPCs without a subchronic RfD or RfC, the chronic RfD or RfC was used when recommended by the EPA RSL website. The RfDs and RfCs used for subchronic exposures are included in Tables 5-3 and 5-4, respectively.

## COPCs with Surrogate Toxicity Values

For certain COPCs that do not have toxicity values, appropriate surrogates based on structural or toxicological similarities were identified. In addition, trivalent chromium toxicity values were used to evaluate total chromium.

Surrogate toxicity values are noted in Tables 5-1 through 5-4 and are discussed as follows:

Cyanide toxicity values are used for evaluation of cyanide (weak acid dissociable [WAD]).

Acenaphthene toxicity values are used for evaluation of acenaphthylene.

Pyrene toxicity values are used for evaluation of benzo(g,h,i)perylene.

Pyrene toxicity values are used for evaluation of phenanthrene.

Diethyl phthalate toxicity values are used for evaluation of dimethyl phthalate.

3-Methylphenol cancer and chronic noncancer toxicity values are used for evaluation of 3-Methylphenol & 4-Methylphenol (m&p-Cresol) because it is the most conservative of the 3- and 4-methylphenol chronic toxicity information.

4-Methylphenol subchronic noncancer toxicity values are used for evaluation of 3‑Methylphenol & 4-Methylphenol (m&p-Cresol) because it is the most conservative of the 3- and 4-methylphenol chronic toxicity information.

m-Xylene toxicity values are used for evaluation of m,p-Xylene.

## Dermal Assessment

Dermal contact with contaminants can result in direct toxicity at the site of application and contribute to systemic toxicity. EPA has developed a process for making route-to-route (oral to dermal) extrapolations to account for the lack of specific dermal toxicity factors. This accounts for the fact that most oral SFs and RfDs are expressed as the amount of contaminant administered per unit time and body weight, whereas exposure estimates for the dermal pathway are expressed as an absorbed (ABS) dose (EPA  2004).

Dermal SFs were derived in accordance with EPA’s Supplemental Guidance for Dermal Risk Assessment (EPA 2004). The SF that reflects the absorbed dose was calculated by using the following equation:

where:

SFABS = absorbed cancer SF

SFo = oral cancer SF

ABSGI = gastrointestinal (GI) absorption efficiencies

Oral and dermal SFs are presented in Table 5-1.

Dermal RfDs were derived in accordance with EPA’s *Supplemental Guidance for Dermal Risk Assessment* (EPA 2004). The RfD that reflects the absorbed dose was calculated by using the following equation:

where:

RfDABS = absorbed reference dose

RfDo = oral reference dose

ABSGI = GI absorption efficiencies

EPA recommends adjusting oral toxicity values only when evidence suggests that GI absorption is less than 50%. GI absorption efficiencies were obtained from EPA’s *Supplemental Guidance for Dermal Risk Assessment* (EPA 2004). Oral and dermal RfDs are presented in Table 5-3.

# Risk Characterization

The risk characterization step in a BHHRA provides estimates of the magnitude of the potential adverse health effects. The risk characterization step combines the information developed in the exposure and toxicity assessment steps (presented in Section 4 and Section 5, respectively) to calculate potential cancer risks and noncancer hazards. The methods used to calculate both cancer risks and noncancer hazards are presented in Section 6.1, followed by the risk characterization results for each receptor and exposure scenario evaluated in this BHHRA.

## Risk Characterization Methodology

The methods used to calculate potential cancer risks and noncancer hazards from exposure to carcinogenic COPCs and noncancer COPCs are fundamentally different. The following sections provide additional details on the methods used to estimate cancer risks and noncancer hazards from exposure to COPCs in Site media.

### Cancer Risk Estimates

Cancer risk estimates are theoretical probabilities for COPCs to cause carcinogenic responses. For carcinogenic chemicals, the potential cancer risks are estimated by multiplying the estimated LADI of each carcinogenic COPC by its SF using the following equation:

where:

Risk = estimated chemical-specific individual excess lifetime cancer risk (unitless)

SF = route- and chemical-specific carcinogenic SF (mg/kg-day)-1

LADI = lifetime average daily intake (mg/kg-day)

For inhalation of soil fugitive dust and vapors, the potential cancer risks are estimated by a slightly modified equation (EPA 2009a):

where:

Risk = estimated chemical-specific individual excess lifetime cancer risk (unitless)

IUR = inhalation unit risk (μg/m3)-1

EC = exposure concentration (μg/m3)

The calculated risk is an estimated upper-bound incremental probability of an individual developing excess cancer over a lifetime with exposures to contaminated media from the Site. Initially, cancer risks are estimated separately for exposure to each COPC for each exposure pathway and receptor category. However, cancer risks from exposure to multiple carcinogens are assumed to be additive (EPA 1989). Individual cancer risk estimates then are summed across chemicals and exposure pathways applicable to a receptor population to obtain the total excess lifetime cancer risk for that population. Cancer risk estimates are expressed in scientific or engineering notation; a cancer risk of 1 x 10-6 is equivalent to 1E-6 or 0.000001 or one in one million.

The calculated risk estimates are compared to EPA’s acceptable risk range of 10-4 (one in ten thousand) to 10-6 (one in one million) established in the National Contingency Plan (EPA 1990). EPA uses this acceptable risk range to manage risks as part of a CERCLA cleanup program (EPA 1991b).

Excess cancer risks are summed for all carcinogenic COPCs within each exposure scenario. Exposure scenarios where the same receptor is exposed via multiple pathways, as shown in the current and future exposure pathway CSM (see Figure 4-1), are addressed by summing the risk across all appropriate pathways. Excess cancer risks are reported to one significant digit (EPA 1989). A cancer risk of 1 x 10-6 will be used as the point of departure for characterizing risk levels.

### Noncancer Hazard Estimates

For chemicals with noncancer effects, a critical chemical dose (e.g., an RfD) must be exceeded before adverse health effects are observed. The potential for adverse noncancer effects is assessed by comparing the estimated intake (e.g., CDI) of a substance to its RfD. This is accomplished by calculating the ratio of the estimated CDI to the RfD to obtain a hazard quotient (HQ) using the following equation:

where:

HQ = estimated chemical-specific hazard quotient (unitless)

CDI = chemical-specific chronic daily intake (mg/kg-day)

RfD = route- and chemical-specific reference dose (mg/kg-day)

For inhalation of soil fugitive dust and vapors, the potential noncancer hazards are estimated by a slightly modified equation (EPA 2009a):

where:

HQ = estimated chemical-specific hazard quotient (unitless)

RfC = reference concentration (μg/m3)

EC = exposure concentration (μg/m3)

EPA recommends using the HQ approach to quantify the potential for noncancer health effects (EPA 1989). HQs are not risk probabilities; the likelihood of an adverse effect may not increase linearly as the HQ increases. An HQ greater than 1 only indicates potential adverse health effects from the chemical exposure. Consistent with EPA guidance (EPA 1989), HQs can only be combined to calculate a hazard index (HI) if appropriate, based on the mechanisms of action and target organs of the COPCs. HQs for COPCs that are associated with the same target organ or similar toxicological effects are summed together to obtain an HI for that organ or toxicological effect and are reported separately.

Noncancer HQs are summed for all noncarcinogenic COPCs to calculate an HI for each exposure scenario. Furthermore, because noncancer hazards are appropriately evaluated based on the target organ toxicity for each COPC, a target organ-specific analysis of noncancer hazards will be presented. Noncancer hazards (HIs and HQs) are reported to one significant digit (EPA 1989).

### Risk Calculation for Lead

Lead was identified as a soil COPC for the Site. An RfD was not identified for lead because potential risk from exposure to lead is evaluated through comparison with benchmark concentrations that are based on blood lead levels deemed protective by EPA. Because of the difficulty in accounting for pre-existing body burdens of lead and the apparent lack of a threshold, EPA determined that it is inappropriate to develop an RfD (EPA 1994a, 1994b).

EPA has determined that the two most sensitive subpopulations to exposure to lead are children and the developing fetus of a pregnant woman. EPA has developed the following two models: the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children (Version 1.1, Build 11; EPA 2010) and the Adult Lead Methodology (ALM; EPA 2009b). These models provide the basis of the EPA RSL soil screening levels for residential and industrial exposure scenarios of 400 mg/kg and 800 mg/kg, respectively.

EPA provides caveats for the use of the IEUBK and ALM models, including exposure frequency of at least 1 day a week for a duration of at least 3 months (EPA 2003b). All Site soil exposure scenarios have exposure frequencies and durations meeting the requirements for use of the IEUBK and ALM models. The ALM model was used to evaluate soil lead exposures to construction/excavation workers (upland areas) and occupational workers. The IEUBK model was used to evaluate soil lead exposure to future child residents. Details on the use of the IEUBK and ALM models for the lead risk characterization are provided in Attachment E1. IEUBK model output files are provided in Attachment E2. The ALM model output files are provide in Attachment E3.

The Centers for Disease Control and Prevention (CDC) has identified a blood lead concentration of 5 micrograms per deciliter (µg/dL) as the reference level representing the 97.5th percentile of blood lead levels in children in the United States (CDC 2012). Previously, CDC (1991) identified a blood lead concentration of 10 µg/dL as the level of concern above which significant health effects may occur. The concentration of lead in the blood is used as an index of the total dose of lead regardless of the route of exposure (EPA 1994b). An acceptable risk is currently defined by EPA as a less than 5% probability of the population exceeding a blood lead concentration of 10 µg/dL (EPA 1998, 2020d). However, recent EPA directives indicate that this level may not be protective and include summaries of adverse effects observed in children with blood lead levels less than 10 µg/dL. For this reason, the CDC blood lead level of 5 µg/dL was used in this BHHRA as the threshold to determine risk for applicable scenarios.

## Risk Characterization Results

The risk characterization results for the Site and ISA are presented in this section. Excess cancer risks are summed for all carcinogenic COPCs within each exposure scenario. Exposure scenarios where the same receptor is exposed via multiple pathways, as shown in the exposure pathway CSM (see Figure 4-1), are addressed by summing the risk across all appropriate pathways. Noncancer HQs are summed for all noncarcinogenic COPCs to calculate an HI for each exposure scenario. Furthermore, because noncancer hazards are appropriately evaluated based on the target organ toxicity for each COPC, a target organ-specific analysis of noncancer hazards is presented. Excess cancer risks and noncancer hazards (HIs and HQs) are reported to one significant digit (EPA 1989).

### Construction/Excavation Worker (Upland Areas)

Construction/excavation workers (upland) were evaluated for subchronic exposure to Site surface soil (0 to 3 feet bgs) and subsurface soil (0 to 10 feet bgs) consistent with the exposure pathway CSM for this receptor. As shown in Tables 6-1 and 6-2, the total cumulative RME cancer risk from exposure to surface soil and subsurface soil is above 1 x 10-6 but within EPA’s acceptable risk range. The RME HI is above the threshold value of 1. These results are summarized as follows:

RME soil cancer risks: adult (4 x 10-5)

RME soil noncancer HIs: adult (70)

Three COPCs with estimated cancer risks above 1 x 10-6 include arsenic, benzo(a)pyrene, and naphthalene. For RME noncancer hazards, the arsenic HQ is greater than the threshold of 1 and benzo(a)pyrene and naphthalene HQs are greater than 10. The estimated RME noncancer HIs by target organ (shown in Table 6-3) indicate that HIs are less than the threshold of 1 for all organs except blood, dermal, developmental, nervous, and respiratory. Exposure to lead in soil was found to result in blood levels in the fetus of adult workers below threshold levels of concern.

### Occupational Worker

Occupational workers were evaluated for chronic exposure to Site surface soil (0 to 0.5 foot bgs) consistent with the exposure pathway CSM for this receptor. Potential future VI risk was evaluated qualitatively. As discussed in the following sections, the estimated total RME cancer risks from exposure to soil are above the upper end of EPA’s acceptable risk range, and the RME HI is above the threshold value of 1. VI does not present an unacceptable risk to current occupational uses of existing buildings. Risks and noncancer hazards from exposure to each medium are summarized in this section.

#### Exposure to Soil

As shown in Tables 6-4 and 6-5, cumulative RME cancer risks from exposure to surface soil are above EPA’s acceptable risk range. The estimated RME HI is greater than the threshold of 1. These results are summarized as follows:

RME soil cancer risks: adult (4 x 10-4)

RME soil noncancer HI: adult (3)

For occupational workers, RME cancer risks for benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-c,d)pyrene, and D/F TEQ are above 1 x 10-6, but within EPA’s acceptable risk range, and arsenic cancer risk is above the upper end of EPA’s acceptable risk range. For RME noncancer HI, the arsenic HQ is greater than the threshold of 1. The estimated RME noncancer HIs by target organ (shown in Table 6-6) indicate that HIs are greater than the threshold of 1 for blood and dermal. Exposure to lead in soil was found to result in worker fetus blood levels below threshold levels of concern.

#### Exposure to Vapor

The point-by-point soil gas screen is shown in Table 3-16. The results for the sub-slab soil gas samples collected from beneath Building 4 (SSG-4), Building 5 (SSG-3), and Building 6 (SSG-1 and SSG-2) did not identify concentrations above the commercial screening levels, which are applicable to the current use of those buildings. This VI‑COPC screen indicates that there are no current risks to occupational workers from inhalation of indoor air while working in existing buildings. Figure 6-1 summarizes the VI screen.

Six VI-COPCs exceeded the commercial VISL in the exterior soil gas samples. Carbon tetrachloride, chloroform, and m,p-xylenes exceeded but were less than twice the commercial VISL. Benzene, ethylbenzene, and naphthalene exterior soil gas concentrations were 611, 61, and 31 times higher than the VISL, respectively. Exterior soil gas from ESG-3, ESG-4, and ESG-7 had VI-COPC exceeding commercial VISL. Future risk to occupational workers from the exterior areas may be further evaluated based on future land use.

### Recreational Beach User

Recreational beach users were evaluated for chronic exposure to surface sediment (0 to 4 inches below mudline) and surface water consistent with the exposure pathway CSM for this receptor. Exposures to adults and children were evaluated. As discussed in the following sections, the estimated total RME cancer risks from exposure to sediment, and sediment and surface water combined, are above 1 x 10-6 and the RME HIs are below the threshold value of 1. Cancer risks and noncancer hazards from exposure to each medium and the cumulative exposure are summarized in this section.

#### Exposure to Sediment

As shown in Tables 6-7 and 6-8, the adult, child, and combined adult/child total cumulative RME cancer risks from exposure to surface sediment are above 1 x 10-6 but within EPA’s acceptable risk range. The estimated RME HIs are less than the threshold of 1 for the adult and child. These results are summarized as follows:

RME sediment cancer risks: adult (8 x 10-6), child (2 x 10-5), and adult/child (3 x 10-5)

RME soil noncancer HIs: adult (0.04) and child (0.2)

The following have cancer risks above 1 x 10-6 but within EPA’s acceptable risk range: Adult, child, and combined adult/child arsenic and benzo(a)pyrene; child and combined adult/child benzo(a)anthracene and dibenzo(a,h)anthracene; and combined adult/child benzo(b)fluoranthene.

The ISA arsenic EPC is less than twice the marine sediment natural background concentration, indicating that a significant portion of ISA arsenic risk may be attributable to background arsenic.

#### Exposure to Surface Water

As shown in Tables 6-9 and 6-10, the adult, child, and combined adult/child total cumulative RME cancer risks from exposure to surface water are significantly below EPA’s acceptable risk range. The estimated RME HIs are also significantly less than the threshold of 1 for the adult and child. These results are summarized as follows:

RME surface water cancer risks: adult (1 x 10-8), child (1 x 10-8), and adult/child (2 x 10-8)

RME surface water noncancer HIs: adult (0.00009) and child (0.0003)

#### Cumulative Exposure from All Pathways

The combined cumulative cancer risk and noncancer hazards from exposure to sediment and surface water are summarized in Table 6-11. Adult, child, and adult/child RME cancer risks are above 1 x 10-6 but within EPA’s acceptable risk range. The estimated RME HIs are less than the threshold of 1 for the adult and child. The cumulative results are summarized as follows:

RME sediment and surface water cancer risks: adult (8 x 10-6), child (2 x 10-5), and adult/child (3 x 10-5)

RME sediment and surface water noncancer HIs: adult (0.04) and child (0.2)

The estimated RME noncancer hazards by target organ (shown in Table 6-12) indicate that HIs are less than the threshold of 1 for all organs.

### Construction/Excavation Worker (Beach Areas)

Construction/excavation workers (beach areas) were evaluated for subchronic exposure to ISA surface sediment (0 to 3 feet below mudline) and surface water consistent with the exposure pathway CSM for this receptor. As shown in Tables 6-13 through 6-15, the total cumulative RME cancer risk from exposure to surface sediment and surface water is below 1 x 10-6. The RME HIs are below the threshold value of 1. Risks and noncancer hazards from exposure to each medium and the cumulative exposure are summarized in this section.

#### Exposure to Sediment

As shown in Table 6-13, cumulative RME cancer risk from exposure to sediment is below 1 x 10-6. The estimated RME HI is less than the threshold of 1. These results are summarized as follows:

RME sediment cancer risks: adult (6 x 10-7)

RME sediment noncancer HI: adult (0.3)

All individual COPC estimated cancer risks are less than 1 x 10-6.

#### Exposure to Surface Water

As shown in Table 6-14, cumulative RME cancer risk from exposure to surface water is significantly below EPA’s acceptable risk range. The estimated RME HI is also significantly less than the threshold of 1. These results are summarized as follows:

RME surface water cancer risks: adult (3 x 10-9)

RME surface water noncancer HIs: adult (0.001)

#### Cumulative Exposure from All Pathways

The combined cumulative cancer risk and noncancer hazards from exposure to sediment and surface water are summarized in Table 6-15. RME cancer risks are below 1 x 10-6. The estimated RME HI is less than the threshold of 1. The cumulative results are summarized as follows:

RME sediment and surface water cancer risks: adult (6 x 10-7)

RME sediment and surface water noncancer HI: adult (0.3)

The estimated RME noncancer hazards by target organ (shown in Table 6-16) indicate that HIs are less than the threshold of 1 for all organs.

### Resident

Future residents were evaluated for chronic exposure to Site surface soil (0 to 3 feet bgs) and use of groundwater for tap water, consistent with the exposure pathway CSM for this receptor. Exposures to adults and children were evaluated. Potential future VI risk was evaluated qualitatively. As discussed in the following sections, the estimated total RME cancer risks from exposure to soil, groundwater, and both media combined are above the upper end of EPA’s acceptable risk range for adults and children, and the RME HIs are above the threshold value of 1. VI may present a potential future risk to residents. Risks and noncancer hazards from exposure to each medium and the cumulative exposure are summarized in this section.

#### Exposure to Soil

As shown in Tables 6-17 and 6-18, the adult, child, and combined adult/child total cumulative RME cancer risks from exposure to surface soil are above EPA’s acceptable risk range. The estimated RME HIs are greater than the threshold of 1 for the adult and child. These results are summarized as follows:

RME soil cancer risks: adult (5 x 10-4), child (3 x 10-3), and adult/child (3 x 10-3)

RME soil noncancer HIs: adult (5) and child (40)

For both the adult and child and combined adult/child, several COPC estimated cancer risks are above 1 x 10-6, but within the acceptable risk range. The COPCs with estimated cancer risks above the upper end of EPA acceptable risk range include the following:

Adult, child, and combined adult/child arsenic and benzo(a)pyrene

Child and combined adult/child, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene

For RME noncancer HIs, adult individual COPC HQs are less than or equal to 1, and when added together are above an HI of 1. Child antimony and D/F TEQs have HQ greater than 1 and arsenic and benzo(a)pyrene have HQ of 10.

Exposure to lead in soil was found to result in 7.4% probability of blood lead levels in children above the 5 µg/dL threshold level of concern. There may be risk to future resident children from exposure to lead. The lead evaluation is discussed in Section 6.1.3 and IEUBK model outputs are included in Attachment E.

#### Exposure to Groundwater

As shown in Tables 6-19 through 6-20, adult, child, and combined adult/child total cumulative RME cancer risks from exposure to Site-wide groundwater are above EPA’s acceptable risk range. The estimated RME HIs are greater than the threshold of 1 for the adult and child. These results are summarized as follows:

RME Site-wide groundwater cancer risks: adult (1 x 10-2), child (5 x 10-3), and adult/child (2 x 10-2)

RME Site-wide groundwater noncancer HIs: adult (300) and child (400)

For the both the adult and child and combined adult/child, several COPCs are above 1 x 10-6, but within the acceptable risk range. Combined adult/child 1-methylnaphthalene, adult benzo(a)pyrene, and adult and child benzo(a)anthracene cancer risks are equal to 1 x 10-4 . The COPCs with estimated cancer risks above the upper end of EPA’s acceptable risk range include the following:

Adult, child, and combined adult/child and benzene and naphthalene

Adult and combined adult/child ethylbenzene

Combined adult/child benzo(a)anthracene

Child and combined adult/child benzo(a)pyrene

For both adult and child RME noncancer HIs, cyanide (WAD), manganese, m,p-xylene, and 2-methylnaphthalene have HQ above 1, benzene has HQ above 10, and naphthalene has HQ equal to 300.

Risk calculations for individual wells are included in Attachment F2 and summarized in Table 6-21. Combined child/adult RME cancer risk for individual wells ranges from 4 x 10-5 in MW-103-90, to 1 x 10-1, well above EPA’s acceptable risk range, in MW-09 and MW-11. Noncancer HI ranged from below the HI threshold of 1 to 1,000 in well MW-14 and 2,000 in MW-09 and MW-11. Monitoring wells MW-09, MW-11, and MW-14 are located in areas of source material.

#### Exposure to Vapor

There are no residential buildings currently on the Site. The point-by-point soil gas screen is shown in Table 3-16. The results of the VI-COPC screen identified naphthalene in sub-slab soil gas samples, and nine VI-COPCs in the exterior soil gas samples with concentrations exceeding the residential VISL.

This COPC screen indicates potential future risk from inhalation of indoor vapor but is dependent on future buildings and uses at the Site. Figure 6-1 summarizes the VI screen. Naphthalene in all four sub-slab soil samples exceeded the residential VISL. Exterior soil gas benzene, ethylbenzene, and naphthalene had the highest exceedance ratios of 3000, 300, and 100, respectively. In addition, 1,2,4-trimethylbenzene, bromodichloromethane, carbon tetrachloride, chloroform, m,p-xylene, and o-xylene also exceeded the residential VISL. Exterior soil gas from ESG-7 had the most VI-COPC exceeding residential VISL and the highest exceedance ratios. VI risk to potential future residents may be further evaluated based on future land use.

#### Cumulative Exposure from All Pathways

The combined cumulative cancer risk and noncancer hazards from exposure to Site soil and groundwater are summarized in Table 6-22. Adult, child, and adult/child RME cancer risks are above EPA’s acceptable risk range. The estimated RME HIs are greater than the threshold of 1 for the adult and child. While both exposure to both soil and groundwater contribute to cumulative cancer risks above EPA’s acceptable range and HIs greater than 1, Site-wide groundwater exposure is the greatest contributor to cancer risks and noncancer hazards. The cumulative results are summarized as follows:

RME soil and Site-wide groundwater cancer risks: adult (2 x 10-2), child (8 x 10-3), and adult/child (2 x 10-2)

RME soil and Site-wide groundwater noncancer HIs: adult (400) and child (400)

The estimated RME noncancer hazards by target organ (shown in Table 6-23) indicate that HIs are greater than the threshold of 1 for all organs except adult adrenal, gastrointestinal, liver, and reproductive and child adrenal, gastrointestinal, and liver.

### Tribal Shellfish Consumers

Tribal shellfish consumers were quantitatively evaluated for exposure to ISA surface sediment (0 to 3 feet) and surface water while collecting clams, and for consumption of clams collected within the ISA, consistent with the exposure pathway CSM for this receptor. Exposures to adults and children were evaluated. Risks and noncancer hazards from exposure to each medium and the cumulative exposure are summarized in this section.

#### Exposure to Sediment

As shown in Tables 6-24 and 6-25, the total cumulative RME cancer risks from exposure to sediment are above 1 x 10-6 but within EPA’s acceptable risk range for adults, and are equal to or above EPA’s acceptable risk range for the child and combined adult/child, respectively. The estimated RME HIs are less than and equal to the threshold of 1 for the adult and child, respectively. These results are summarized as follows:

RME sediment cancer risks: adult (9 x 10-5), child (1 x 10-4), and adult/child (2 x‑10‑4)

RME sediment noncancer HIs: adult (0.2) and child (1)

For the adult, child, and combined adult/child, several COPCs are above 1 x 10-6 but within EPA’s acceptable risk range, including arsenic and the cPAHs benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3‑c,d)pyrene. Adult and child benzo(a)pyrene estimate cancer risk is within the acceptable risk range, and the combined adult/child cancer risk is equal to the upper end of the acceptable risk range. When added together, the child cumulative cancer risk is equal to the upper end of the acceptable range, and the combined adult/child cumulative risks are above EPA’s acceptable range. For RME noncancer HIs, adult and child individual COPC HQs are less than and equal to 1, respectively.

The sediment arsenic EPC is below the marine sediment natural background concentrations established by Ecology (Ecology 2019). This indicates that ISA arsenic cancer risks are comparable to background arsenic cancer risks.

#### Exposure to Surface Water

As shown in Tables 6-26 and 6-27, combined adult/child total cumulative RME cancer risks from exposure to surface water are above 1 x 10-6 but within EPA’s acceptable risk range. The adult and child cumulative cancer risks are equal to and less than 1 x 10-6, respectively. The estimated RME HIs are well below the threshold of 1 for the adult and child. These results are summarized as follows:

RME surface water cancer risks: adult (1 x 10-6), child (4 x 10-7), and adult/child (2 x 10-6)

RME surface water noncancer HIs: adult (0.003) and child (0.009)

For the combined adult/child, arsenic is the COPC with estimated cancer risk above 1 x 10-6. The surface water arsenic EPC (1.2 µg/L) is below the Puget Sound median concentration (1.41 µg/L; Ecology 2011b).

#### Clam Consumption

Tribal shellfish (clam) consumption was evaluated for the ISA and from non-urban clams for comparison. The non-urban clam dataset is described in Section 3.1.3.

##### ISA Exposure

As shown in Tables 6-28 and 6-29, the adult, child, and combined adult/child total cumulative RME cancer risks from consuming ISA clams are above 1 x 10-6 but within EPA’s acceptable risk range. The estimated RME HIs are less than the threshold of 1 for the adult and child. These results are summarized as follows:

RME clam consumption cancer risks: adult (6 x 10-5), child (2 x 10-5), and adult/child (8 x 10-5)

RME clam consumption noncancer HIs: adult (0.1) and child (0.09)

For the adult and combined adult/child, several cPAHs are above 1 x 10-6 but within EPA’s acceptable risk range, including benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene. Child benzo(a)pyrene and dibenzo(a,h)anthracene are above 1 x 10-6 but within the acceptable risk range.

##### Non-urban Comparison

The objective of this risk assessment is to evaluate potential risks due to exposure from COPCs that originate from the ISA and, therefore, to support remedial decision-making. To evaluate the significance of regional levels of COPCs in clam tissue, cancer risks and noncancer hazards for COPCs were calculated using non-urban clam data for comparison to ISA cancer risks and noncancer hazards.

Risk calculations for non-urban clam consumption were completed using EPCs estimated using the non-urban clam tissue data for the same set of COPCs that were identified for the ISA. The EPCs that were estimated based on the non-urban tissue dataset are presented in Attachment G. These EPCs were then used with the RME Tribal shellfish (clam) consumption rates and associated exposure parameters to calculate cancer risks and noncancer hazards based on consumption of clams collected from the non-urban areas. The risk characterization results are presented in Attachment G. Total cumulative non-urban clam consumption RME cancer risks and noncancer hazards are compared to those of the ISA in Table 6-30.

The estimated cancer risks and noncancer hazards for the consumption of clams are presented in the following bullets for both the non-urban areas and ISA to allow for comparisons. The EPCs and daily intakes used for the calculation of the non-urban cancer risks and noncancer hazards are presented in Tables G1-1, G2-1, and G2-2.

**Non-Urban**

RME clam consumption cancer risks: adult (1 x 10-6), child (2 x 10-7), and adult/child (1 x 10-6)

RME clam consumption noncancer HIs: adult (0.0009) and child (0.0007)

**Marine ISA**

RME clam consumption cancer risks: adult (6 x 10-5), child (2 x 10-5), and adult/child (8 x 10-5)

RME clam consumption noncancer HIs: adult (0.1) and child (0.09)

For the non-urban clams, the total RME cancer risks for adult and combined adult/child are equal to 1 x 10-6 and HIs are well below the threshold of 1 for adult and child. For the non-urban clam RME scenario, all COPCs had cancer risks less than 1 x 10-6. The non-urban clam RME scenario represents one estimate of cancer risks and noncancer hazards that could be expected in the absence of Site-related contamination.

#### Cumulative Exposure from All Pathways

The combined cumulative cancer risk and noncancer hazards from exposure to sediment, surface water, and clam consumption are summarized in Table 6-31. Adult, child, and adult/child RME cancer risks are above EPA’s acceptable risk range. The estimated RME HIs are less than and equal to the threshold of 1 for the adult and child, respectively. Exposure to sediment drives the cumulative cancer risks above EPA’s acceptable range. The cumulative results are summarized as follows:

RME sediment, surface water, and clam consumption cancer risks: adult (2 x 10-4), child (1 x 10-4), and adult/child (3 x 10-4)

RME sediment, surface water, and clam consumption noncancer HIs: adult (0.4) and child (1)

The estimated RME noncancer hazards by target organ (shown in Table 6-32) indicate that HIs are less than the threshold of 1 for all organs.

## Summary of Risk Characterization

The RME total cancer risks and total noncancer HIs for the receptors evaluated in this BHHRA are summarized in Table 6-33. The RME target organ total noncancer HIs are summarized in Table 6-34.

The receptors for which the estimated RME cumulative cancer risks are above EPA’s acceptable risk range are the occupational worker, future resident, and Tribal shellfish consumers. The construction/excavation worker (upland areas) and recreational beach user have RME cancer risks above 1 x 10-6 but within EPA’s acceptable risk range (1 x 10-6 to 1 x 10-4). The construction/excavation worker (beach areas) has RME cancer risk below 1 x 10-6.

The receptors where the estimated HIs are above 1 are the construction/excavation worker (upland areas), occupational worker, and adult and child resident. The child Tribal shellfish (clam) consumer has an HI equal to 1.

The Site and ISA receptor cancer risk and noncancer hazard are summarized below. The COPCs with cancer risk or noncancer HQ for each receptor are summarized in Table 6‑35 for the Site, and Table 6-36 for the marine ISA.

**Upland Site**

**Current/Future Construction/Excavation Worker (Upland Areas):** Construction/excavation worker (upland areas) were evaluated for subchronic exposure to Site surface and subsurface soil (0 to 10 feet bgs). RME cumulative cancer risk is above 1 x 10-6 but within EPA’s acceptable risk range. The noncancer hazards are above the HI threshold of 1. Arsenic, benzo(a)pyrene, and naphthalene are the COPCs with HQs greater than the threshold of 1.

**Current/Future Occupational Worker:** Occupational workers were evaluated for chronic exposure to Site surface soil (0 to 0.5 feet bgs) and current and potential future VI. Soil RME cumulative cancer risk is above EPA’s acceptable risk range, and the noncancer HI is above the threshold of 1. The arsenic cancer risk is above the upper end of the EPA acceptable range, and the arsenic HQ exceeds the threshold of 1. There is not a current VI risk to occupational workers using existing buildings on the Site. Exterior soil gas VI-COPCs exceed the commercial VISL. The potential future VI risk to occupational workers may be further evaluated based on future land use, as applicable.

**Future Resident:** Future residents were evaluated for chronic exposure to Site surface soil (0 to 3 ft bgs), groundwater for use as tap water, and potential future VI consistent with the exposure pathway CSM for this receptor. Combined soil and groundwater RME cumulative cancer risk is above EPA’s acceptable risk range, and the noncancer HI is above the threshold of 1. Groundwater exposure is the greatest contributor to cancer risk and noncancer HI.

COPCs with estimated cancer risk above the upper end of EPA’s acceptable risk range include soil arsenic and the cPAHs benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene, and Site-wide groundwater benzene, ethylbenzene, naphthalene, benzo(a)pyrene, and benzo(a)anthracene.

COPCs with noncancer HQ exceeding the threshold of 1 include soil antimony, D/F TEQ, arsenic, and benzo(a)pyrene, and Site-wide groundwater cyanide (WAD), manganese, benzene, m,p-xylene, 2-methylnaphthalene, and naphthalene.

Groundwater from individual wells was also evaluated. Total cancer ranged from within EPA’s acceptable risk range to 1 x 10-1 in MW-09 and MW-11. Total HI ranged from less than 1 to 2000 in MW-09 and MW-11. Wells MW-09 and MW-11 are located in an area of source material.

Soil lead exposure may result in child blood lead levels above the 5 µg/dL threshold.

Sub-slab and exterior soil gas VI-COPC exceed residential VISL. Potential future VI risk to residents may be further evaluated based on future land use, as applicable.

**Marine ISA**

**Recreational Beach User:** Recreational beach users were evaluated for chronic exposure to ISA surface sediment (0 to 4 inches below mudline) and surface water consistent with the exposure pathway CSM for this receptor. RME cumulative cancer risks are above 1 x 10-6 but within EPA’s acceptable risk range. The noncancer hazards are below the HI threshold of 1.

**Construction/Excavation Worker (Beach Areas):** Construction/excavation workers (beach areas) were evaluated for subchronic exposure to ISA surface sediment (0 to 3 feet below mudline) and surface water consistent with the exposure pathway CSM for this receptor. RME cumulative cancer risk is below 1 x 10-6 and the noncancer hazard is below the HI threshold of 1.

**Tribal Shellfish Consumer:** Tribal shellfish consumers were evaluated for chronic exposure to ISA surface sediment (0 to 3 feet bgs) and surface water while collecting shellfish, and for consumption of shellfish (clams) collected from the ISA. RME cumulative cancer risk is above EPA’s acceptable risk range. The child noncancer HI is equal to the threshold of 1. Sediment exposure contributes the most to cumulative cancer risk. Sediment combined adult/child cancer risk is above the upper end of EPA’s acceptable cancer risk range. No individual COPCs in any media have estimated cancer risk above the upper end of the acceptable risk range. Shellfish consumption cumulative cancer risk is above 1 x 10-6 but within EPA’s acceptable risk range. Consumption of shellfish (clams) collected from the ISA results in higher cancer risk than consumption of non-urban shellfish (clams).

# Uncertainty Analysis

Uncertainty is associated with each of the following four steps of a risk assessment: 1) data collection and evaluation, 2) exposure assessment, 3) toxicity assessment, and 4) risk characterization.

This risk assessment was conducted consistent with EPA guidance, which promotes consistency and, where possible, reduces uncertainty. Although risk assessments are generally conducted with conservative assumptions, it is important to specify the assumptions and uncertainties inherent in each step of the risk assessment to provide context for the risk estimates.

This section addresses the sources of uncertainty in the risk assessment and provides an evaluation of the potential impacts on the risk estimates. An understanding of the strengths and potential uncertainties associated with the risk assessment provides important information to support risk management decisions.

## Data Evaluation

Environmental investigations intrinsically include some uncertainty associated with the data collection and evaluation methods. This section provides a summary of the uncertainties associated with the use and evaluation of the data in this BHHRA.

### Data Quality

Environmental data uncertainties may be introduced through sample collection and analytical methods. If the samples do not adequately represent media at the Site, hazard/risk estimates could be overestimated or underestimated. The RI Data Acquisition programs data were collected under EPA-approved QAPPs. The laboratory data were validated prior to being used in this BHHRA. Time Critical Removal Evaluation analytical data collected outside of the RI/FS process met the usability requirements prior to being used in this BHHRA. Therefore, the data used in this BHHRA are considered to adequately represent the Site and do not introduce bias in the estimated cancer risks and noncancer hazards.

The non-urban clam tissue were used as presented in Ecology’s Environmental Information Management database. While the quality of these data is unknown, these data have been used in other EPA and Ecology managed projects.

### COPC Screening

There is uncertainty associated with the COPC screening process due to the lack of human health-based sediment screening levels. The sediment COPC screening level hierarchy was composed of ecologically based screening levels, as described in Section 3.3.1.1. All ISA surface sediment (0 to 3 feet) samples were conservatively used in the screening, including subtidal samples located outside the intertidal exposure area. Some COPCs were identified based on maximum concentrations in subtidal samples but were nondetect in intertidal samples (e.g., 3-methylphenol and 4-methylphenol). The use of these ecologically based screening levels for sediment, and the use of intertidal and subtidal sediment samples in the screen, may result in including COPCs with small contributions to overall risk estimates. However, this was intended to ensure that no contaminants were overlooked in the identification of COPCs.

### Uncertain COPCs

Chemicals were identified as uncertain if the maximum MDL/EDL was greater than the screening level. Chemicals without screening levels, but with an FoD of greater than 5%, were also identified as uncertain COPCs. Uncertain COPCs were identified in soil, groundwater, sediment, and surface water.

Uncertain chemicals are unlikely to add to overall potential risk or hazards when compared with the chemicals that are the primary risk drivers, which have comparatively large excess cancer risk or HQs. Uncertain COPCs are discussed in the remainder of this section.

#### Soil

Thirty chemicals were identified as uncertain COPCs in soil because the MDL/EDL exceeded the COPC screening level. All 30 chemicals had an FoD less than 5%. Seven chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there was no screening level for the chemical (see Table 3-13).

#### Groundwater

Forty-five chemicals were identified as uncertain COPCs in groundwater because the MDL/EDL exceeded the COPC screening level. All 45 chemicals had an FoD less than 5%. Eight chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there are no screening levels for these chemicals (see Table 3-14).

#### Sediment

Eighteen chemicals were identified as uncertain COPCs in sediment because the MDL/EDL exceeded the COPC screening level. Of the 18 chemicals, 3 chemicals had an FoD greater than 5%. Forty-seven chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there are no screening levels for these chemicals (see Table 3-17).

#### Surface Water

Twenty-two chemicals were identified as uncertain COPCs because the MDL/EDL exceeded the COPC screening level. All 22 chemicals had an FoD less than 5%. Two chemicals were identified as uncertain COPCs because the FoD was greater than 5% but there was no screening level for the chemical (see Table 3-18).

### Exposure Point Concentrations

Soil, groundwater, sediment, surface water, and shellfish (clam) tissue EPCs were based on the 95% UCL of the mean where sufficient data were available. The use of this conservative estimate of exposure provides a buffer against uncertainties associated with EPC estimation. Furthermore, the use of the 95% UCL as the EPC can reduce uncertainty associated with the use of datasets with nondetect concentrations and outliers, as well as spatial variability in chemical concentrations.

EPC for some COPCs are based on limited samples (e.g., soil D/F) or are influenced by a subset of samples with elevated concentrations compared to other Site or ISA samples. The EPC for these COPCs may not be representative of Site/ISA-wide exposures. Noted examples of this for each exposure medium are discussed in this section.

#### Soil

D/F were tested in one soil sample from the Bluff Area, as described in the RI Data Report (Aspect and Anchor QEA 2020). The soil D/F TEQ EPC used for the construction/excavation worker (upland area), occupational worker, and resident is based on the results of this single sample. It is unknown if the D/F TEQ concentrations in the single Bluff Area sample are representative of D/F TEQ across the Site.

The resident soil lead value used as input for the IEUBK was the mean of the Site surface soil (0 to 3 feet bgs) samples. The lead evaluation indicated potential risk to future resident children from exposure to soil lead. Site soil lead concentrations were notably elevated in Bluff Area sample locations BLUFF-5, BLUFF-4, and BLUFF-10, compared to the other Site samples. The lead concentration in samples from these locations exceeded the soil residential RSL (400 mg/kg). All other Site surface soil samples are well below the residential RSL (2.98 to 107 mg/kg), indicating that potential lead risk to future child residents is attributed to soil lead concentrations at specific Site locations along the Bluff Area.

BLUFF-4 and BLUFF-5 samples also have elevated arsenic concentrations compared to other Site samples in the resident dataset. BLUFF-4 and BLUFF-5 sample arsenic concentrations (884 to 2,240 mg/kg) are over an order of magnitude higher than other samples for the resident soil dataset. All other sample arsenic concentrations are well below the arsenic EPC (410 mg/kg), and the majority of samples are below the Puget Sound 90th percentile soil natural background (7.3 mg/kg; Ecology 1994), indicating that the arsenic risks and hazards are likely overestimated for most areas of the Site.

#### Groundwater

The resident groundwater evaluation assumes all wells are potable. A potability evaluation is planned (Aspect 2020). Depending on the outcome of this evaluation, the Site-wide groundwater dataset may be refined to exclude non-potable wells. In this BHHRA, Site-wide groundwater was evaluated in addition to individual wells. Individual well EPCs were predominantly based on maximum concentrations. MW-09, MW-11, and MW-14 had the highest combined child/adult cancer risks (7 x 10-2 to 1 x 10-1) and noncancer HIs (1,000 to 2,000). These wells are located in areas of source material.

#### Sediment

Intertidal sediment exposures were evaluated using EPCs calculated from all applicable ISA samples. Individual cPAHs were identified as a major contributor to Tribal shellfish (clam) consumer sediment RME cumulative cancer risk, exceeding the upper end of EPA’s acceptable cancer risk range. The cPAHs are not evenly distributed throughout the ISA. As shown in Figure 7-1, cPAH concentrations are highest in surface sediments adjacent to the Former Gas Works Property and are significantly less in the eastern intertidal portion of the ISA. Using ISA-wide cPAH EPCs to calculate risk may not accurately characterize risk to Tribal shellfish (clam) consumers who preferentially collect clams in the area adjacent to Former Gas Works Property or those who avoid this area and preferentially clam in the eastern portion of the Site.

#### Clam

Tribal shellfish (clam) consumption exposure to COPCs accumulated in clam tissue was evaluated with EPCs calculated from clams collected in Area 1, adjacent to the Former Gas Works Property, and Area 2 in the eastern portion of the ISA (Figure 3-10). Clams from Area 1 were collected from an area with significantly higher sediment cPAH concentrations than those collected from Area 2. Tribal shellfish (clam) consumption risk was characterized for Areas 1 and 2 separately to evaluate if the risk characterization of ISA-wide clam consumption is representative of Tribal shellfish (clam) consumers who may preferentially collect clams from Area 1 or Area 2. The clam EPCs from Areas 1 and 2 are based on the maximum concentrations.

The Tribal shellfish (clam) consumption RME cancer risks and noncancer hazards for Areas 1 and 2 individually are included in Tables 7-1 through 7-4. As shown below, the ISA-wide EPC may underestimate cumulative cancer risk from consuming clams from Area 1 adjacent to the Former Gas Works Property, and may overestimate cumulative cancer risk from consuming clams from Area 2 in the eastern portion of the ISA. This evaluation also indicates that Tribal shellfish (clam) consumption cancer risk of clams from both Area 1 and Area 2 is higher than consumption of non-urban clams.

**Area 1: Adjacent to the Former Gas Works Property**

RME clam consumption cancer risks: adult (1 x 10-4), child (3 x 10-5), and adult/child (1 x 10-4)

RME clam consumption noncancer HIs: adult (0.2) and child (0.2)

**Area 2: Eastern portion of the ISA**

RME clam consumption cancer risks: adult (1 x 10-5), child (3 x 10-6), and adult/child (2 x 10-5)

RME clam consumption noncancer HIs: adult (0.03) and child (0.02)

**ISA-wide: Areas 1 and 2 Combined**

RME clam consumption cancer risks: adult (6 x 10-5), child (2 x 10-5), and adult/child (8 x 10-5)

RME clam consumption noncancer HIs: adult (0.1) and child (0.09)

**Non-Urban**

RME clam consumption cancer risks: adult (1 x 10-6), child (2 x 10-7), and adult/child (1 x 10-6)

RME clam consumption noncancer HIs: adult (0.0009) and child (0.0007)

## Exposure Assessment

This section provides a summary of the uncertainties associated with exposure pathways and parameters, EPCs, clam consumption rate, and exposure areas.

### Exposure Pathways and Parameters

Uncertainty is inherent in the selection of exposure pathways and the values selected for exposure parameters. For the Site, no quantifiable information is available for beach users, construction workers, occupational workers, and potential future resident receptor parameter values. For the exposure frequency and exposure duration parameters for all exposure scenarios, the values selected were based on EPA guidance and professional judgment; conservative upper-bound values were selected. Because the exposure factors include upper-bound assumptions, the resulting risks are conservative and more likely to overestimate than underestimate risk at the Site.

In particular, there are uncertainties associated with the sediment ingestion and dermal contact exposure parameters that are based on default soil ingestion and dermal exposure parameters. There are no EPA default exposure parameters for sediment ingestion or dermal contact. The use of conservative exposure parameters for soil to quantify risks associated with sediment exposures overestimates risks associated with this exposure pathway.

#### Exposure Parameters and Assumptions for Sediment Exposures

This BHHRA uses conservative assumptions regarding exposure parameters selected for evaluating sediment exposures. EPA does not currently have default exposure parameters for sediment exposures, and soil exposure parameters were used to evaluate sediment dermal and ingestion parameters. The uncertainty in the use of these parameters is further discussed in this section.

In this BHHRA, soil dermal exposure parameters were used to estimate sediment dermal exposures. Exposures to sediment will differ from exposures to soil due to differences in the chemical and physical properties between the two media and the differing conditions under which exposures occur. The ABS is used to estimate the amount of the chemical absorbed from sediment. EPA guidance (EPA 2004a; EPA 2020b) provides the available soil ABS values that were used in this BHHRA. These ABS values were derived from studies of contaminated soil. The difference in chemical and physical properties between soil and sediment, soil/sediment loading rates to skin based on upland conditions compared to aquatic conditions, and other variables that influence the absorption of chemicals from sediment, are not accounted for in these values. Because of the multiple differences between sediment and soil exposure conditions, the use of soil ABS values adds uncertainty to the sediment dermal risk estimates quantified in this BHHRA.

A significant additional uncertainty in the sediment dermal intake equations that use the ABS term is that EPA guidance (EPA 2004) does not allow for any explicit effect of exposure time, and the default assumption for exposure time is 24 hours per event. None of the receptors that have complete exposure pathways for sediment dermal exposures are exposed for this numbers of hours per day. The longest daily exposures to sediment are the construction/excavation worker (beach areas) (8 hours a day each). The use of a calculated dermal intake value based on 24 hours of exposure likely overestimates the actual dermal exposures and subsequent calculated risks for these receptors.

For the construction/excavation worker (beach areas), recreational beach user, and Tribal shellfish consumer sediment adherence factor (AF), the geometric meal value for adult reed gatherer (EPA 2004) is used for the adults. The geometric mean value for children in wet soil (EPA 2004) is used for the recreational beach user and Tribal shellfish consumer child receptors. Skin adherence may be affected by grain size. EPA (2011) Section 7.4.2.3, “Driver et al. (1989)—Soil Adherence to Human Skin,” and Section 7.4.2.6, “Kissel et al. (1996a)—Factors Affecting Soil Adherence to Skin in Hand-Press Trials: Investigation of Soil Contact and Skin Coverage,” describe several studies on particle size and skin adherence. Key findings include the following:

Soil adherence is directly related to particle size. Increases in soil adherence occur with decreasing particle size.

For particle sizes <250 microns (µm) (i.e., fine sand and smaller), adherence is similar.

Particles of soil >250 µm have the lowest adherence, ranging from 0.06 to 0.3 mg/cm2.

The ISA sediment particle sizes of the intertidal beach are a coarse mix of gravely sand and sandy gravel with very low fines (see RI Data Report Table 4-8; Aspect and Anchor QEA 2020). This is a function of the slope of the beach and fast current. PAHs associated with briquette fragments mixed into the substrate have a range of particle sizes that are consistent with the mineral fractions. As such, PAHs associated with lampblack briquettes and other sources are heterogeneously distributed at the scale of exposure, sediment adhered to the skin, and transferred to the mouth. Given the large grain size of the beach sediment and briquette fragments, the adherence is likely to be overestimated by the adult default value of 0.3 mg/cm2  and actual dermal exposure is likely overestimated. For example, if an ABS of 0.06 was used for the adult sediment dermal exposure instead of 0.3, cancer risks and noncancer hazards from this pathway would be 20% of the current estimates.

In this BHHRA, default daily soil ingestion rates are used as estimates of sediment ingestion rates because EPA does not have any recommended sediment ingestion rates for use as exposure assumptions. The default soil ingestion rates are used in this BHHRA for the following exposure scenarios: construction/excavation workers (beach areas), recreational beach users, and Tribal shellfish (clam) consumers. Similar to the uncertainties associated with the sediment dermal evaluations, ingestion of sediment will differ from ingestion of soil due to differences in the chemical and physical properties between the two media and the differing conditions under which exposures occur.

There are a limited number of studies available that provide estimates of soil ingestion rates. The soil ingestion rates recommended by EPA have components and associated assumptions regarding hand-to-mouth contact, associated dermal adherence of the chemical, and the inhalation of fugitive dust generated by soil. There is considerable uncertainty in applying these types of assumptions to the conditions where sediment contact and ingestion likely occur. If sediment exposures are occurring in shallow sediment under water, it is likely that sediment adhering to skin will be rinsed off before hand-to-mouth contact can occur. For exposed shallow sediment (e.g., under low tide conditions), the coarse grain size of sediment may result in lower dermal adhesion than for soil. The assumption in the soil ingestion rates that include a component of fugitive dust is likely to overestimate sediment ingestion because the characteristics of the beach environment do not favor the generation of dust.

Another significant source of uncertainty in applying default daily soil ingestion rates to sediment ingestion assumptions is that the duration of exposure to sediment is much less than 24 hours, as discussed for the sediment dermal parameters. The assumption that default daily soil ingestion rates represent sediment ingestion rates that are based on limited hours of sediment exposures per day likely overestimates the sediment ingestion rate and associated risk estimates for the BHHRA receptors.

##### PAH Relative Bioavailability

A potentially significant additional uncertainty is the oral RBA of PAH in sediment, which is related to lampblack briquettes being the primary source of PAHs at the Site. For the BHHRA exposure calculations, the EPA RAGS assumes that the absolute oral bioavailability of PAHs is 100%. This assumes that the form of PAHs applied in food or by gavage in animal toxicity tests to derive SF and RfD is equivalent to the form of PAHs in the environment and will be equally bioavailable.

EPA (2007b) describes why the relative bioavailability is important in risk assessment. The extent to which the absolute bioavailability increases or decreases is in context with the exposure matrix (e.g., food vs. water vs. soil), or with the physical or chemical form(s) of the compound to which humans are exposed. PAHs in lampblack have been demonstrated to be very strongly or irreversibly bound to the carbon matrix. This type of pyrogenic carbon matrix is expected to result in limited bioavailability (Ruby et al. 2016).

The ISA sediment particle sizes of the intertidal beach are coarse (gravely sand or sandy gravel), and briquette fragments mixed into the substrate range in size from cobble to coarse sand. As such, natural carbon and lampblack briquettes are heterogeneously distributed at the scale of exposure, in sediment adhered to the skin and transferred to the mouth. Given the large grain size of the briquette fragments, the surface-to-volume ratios are relatively low compared to fine-grained particles. Therefore, the surface area available for desorption in the stomach and intestines would be expected to be lower compared to the amount incorporated in animal soil ingestion sample treatments or doses from food or water.

Given the ISA sediment and source characteristics, the PAH RBA is likely to be lower than 100%. The assumption of 100% PAH RBA for ISA sediments is conservative and may overestimate PAH cancer risk and noncancer hazards for the sediment ingestion pathway. Although this was recognized by EPA in their comments regarding the July 14, 2020 Anchor QEA memorandum “Bremerton Gas Works PAH Bioaccessibility Evaluation,” the burden of proof to confirm this hypothesis is Site-specific data from small-mammal tests, which are currently unavailable.

#### Tribal Shellfish Consumption Rates

This BHHRA used the 95% percentile daily Suquamish Tribal shellfish consumption rates from information provided in the *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region* (Suquamish Tribe 2000) as presented in the *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia* (EPA 2007a). For adults and children, the consumption rates are 498.4 g/day and 79.5 g/day, respectively.

This BHHRA assumes that all clams are collected from the ISA and that the clams are consumed 365 days a year. Clams in the ISA are most abundant in a relatively narrow elevation band, between 4 and 8 feet MLLW (Aspect and Anchor QEA 2020). It is unknown if collection of 577.9 grams (tissue weight) of clams per day from the ISA is a sustainable harvest.

### Dermal Contact Exposure to Groundwater and Surface Water

The quantification of cancer risks and noncancer hazards associated with dermal contact with surface waters and groundwater includes a key chemical-specific parameter, Kp. As stated in EPA RAGS Part E Guidance (EPA 2004), predicting Kp values is uncertain for highly lipophilic and halogenated chemicals with log octanol/water partition coefficient (Kow) and molecular weight values that are very high or low. Consistent with EPA guidance, this BHHRA did not quantify cancer risks and noncancer hazards for surface water or groundwater dermal exposures for organic chemicals for which the Kp values were identified as being outside the effective predictive domain of the EPA model (Exhibit B-3; EPA 2004). These organic COPCs included the seven cPAHs, fluoranthene, and bis(2-ethylhexylphthalate). However, as required by RAGS Part E Guidance, the risk and hazard estimates for dermal contact with surface water and Site-wide groundwater for all COPCs are presented in Tables D2-1 through D2-7 in Attachment D2.

The estimated cancer risks and noncancer hazards for organic chemicals for which the estimated Kp values were outside the effective predictive domain were calculated for the two human health receptor categories that include the highest predicted dermal contact with surface water—recreational boater and swimmer/bather. As shown in Tables D2-1 through D2-7, the estimated cancer risks and noncancer hazards for dermal contact with surface water are higher when all organic COPCs are included.

The surface water cancer risks for the adult and combined adult/child recreational beach user and adult, child and combined adult/child Tribal shellfish consumer are within EPA’s acceptable cancer risk range. Noncancer HIs are below 1. Construction/ excavation workers (beach areas) surface water total cancer risk is below 1 x 10-6 and noncancer HI is below 1. The adult, child, and combined adult/child resident groundwater cancer risks are above the upper end of EPA’s acceptable risk range, and the child and adult HIs are 400.

However, the cancer risks and noncancer hazards presented in Attachment D2 tables should not be considered plausible upper-bound risk and hazard estimates for this exposure pathway. For highly lipophilic chemicals or chemicals with high log Kow values, a viable epidermis is a significant barrier for chemical transfer to systemic circulation. There are significant uncertainties associated with the use of estimated Kp values that are outside the effective predictive domain of EPA models (EPA 2004). Because this BHHRA did not quantify risks for the organic chemicals for the estimated Kp values that are outside the effective predictive domain, the potential for overestimating dermal risks from dermal exposures to surface water and groundwater was reduced.

## Toxicity Assessment

The toxicity values used in this risk assessment have been peer-reviewed and are the most current values recommended by EPA in IRIS and other toxicity sources identified in the “Toxicity Hierarchy Human Health Toxicity Values in Superfund Risk Assessments Memorandum” (EPA 2003a). Nonetheless, the potential exists that the risks may be underestimated or overestimated (EPA 1989, 2005c). For noncancer effects, EPA applies several uncertainty factors to extrapolate doses from animal studies to humans, which range from 1 to 3,000. These are designed to provide a conservative buffer to account for the uncertainty in toxicity values.

Similarly, EPA estimates cancer SFs with conservatism to account for uncertainty. The SFs developed by EPA represent plausible upper-bound estimates, which means that EPA is reasonably confident that the actual cancer risk will not exceed the estimated risk calculated using the SF (EPA 2005c).

EPA introduces conservatism in developing toxicity values in order to make risk assessments protective, in spite of this uncertainty. Thus, the risk estimates in this BHHRA are likely to overestimate risk due to the conservative nature of the toxicity values.

### COPCs with Surrogate Toxicity Values

There were a few COPCs, as discussed in Section 5, for which a toxicity value (RfD or SF) was not available, and therefore, a structurally similar chemical was identified as a surrogate. Based on the results of the risk characterization, the chemicals that exceeded the EPA acceptable risk range or had an HQ greater than 1, except for WAD cyanide, did not rely on surrogate toxicity values.

The hydrogen cyanide RfD and RfC were used to evaluate WAD cyanide. Free cyanide is the most toxic form of cyanide. WAD cyanide exposure in Site-wide groundwater has HQs of 9 and 8 for the future resident child and adult, respectively. The inhalation exposure pathway HQ contributes 90% of the total HQ from dermal, ingestion, and inhalation exposures for both the child and adult. The use of the hydrogen cyanide RfC to evaluate WAD cyanide is conservative because metal cyanide complexes included in WAD cyanide, such as copper cyanide and zinc cyanide, are not considered volatile. The use of WAD cyanide as an estimate for free cyanide exposure through inhalation overestimates the cyanide hazard.

For the other chemicals in which surrogates were used, the use of surrogate toxicity values is not expected to impact the conclusions of the risk assessment.

### Lead Target Blood Level

This BHHRA uses the threshold of 5% probability of the population exceeding a blood lead concentration of 5 µg/dL to evaluate adult worker and child resident risk from Site soil lead exposure. The 5 µg/dL blood level target is from the CDC (2012) and is more conservative than the 10 µg/dL target blood level supported by EPA Superfund guidance and used to develop soil lead RSLs (EPA 2020d, 2020e). The 5 µg/dL target was conservatively selected based on recent EPA guidance summarizing findings of adverse effects in children with less than 10 µg/dL blood lead level and noting that this level may not be adequately protective (EPA 2016, EPA 2017).

The IEUBK results from this BHHRA identified a 7.4% probability of the population exceeding a blood lead concentration of 5 µg/dL. This exceeds the 5% probability target and indicates that future resident children have an unacceptably high probability of blood lead levels being elevated above the target level and may be at risk from lead exposure. The mean (165 mg/kg) of the resident soil dataset (0 to 3 feet bgs) was used as the input for the IEUBK model, consistent with EPA guidance (2020c). This mean concentration is less than half of the current residential soil lead RSL (400 mg/kg). This comparison emphasizes the conservativism in selecting the lower target blood lead level.

## Risk Characterization

As summarized in Section 6, the primary cancer risks and noncancer hazards in the Site are due to upland soil and groundwater exposure, and to Tribal shellfish consumers from combined exposure to Site sediment and clam consumption. The primary uncertainties with the EPC and exposure assumptions used to calculate and characterize risk have been discussed in the preceding sections.

### Background Comparison

The available background datasets described in Section 3.1.3 include soil, groundwater, non-urban clam tissue, and sediment. The non-urban clam data were used in this BHHRA to understand incremental risk from consuming shellfish (clams) harvested from the ISA. The other background datasets are relevant for characterizing anthropogenic background conditions for the other media. In particular, the urban background soil and anthropogenic sediment background datasets could be used to develop soil and sediment EPC to evaluate incremental risk from exposure to these media at the Site and in the marine ISA.

## Overall Assessment of Uncertainty

The key uncertainties in this BHHRA are the conservative nature of the exposure assumptions and the EPC for some COPCs used in this BHHRA. These uncertainties may lead to an overestimation of risks to human receptors evaluated in this BHHRA, and are summarized below:

This BHHRA uses the Site-wide and ISA-wide datasets to estimate EPC. Some COPCs have skewed concentration distributions or, in the instance of soil D/F, were only tested for in a single sample. Samples with notably elevated COPC concentrations likely bias high 95% UCL based EPC and may lead to cancer and noncancer hazards being overestimated for some areas of the Site and ISA. It is unknown if the single D/F soil sample is representative of concentrations throughout the Site. Child resident lead risk is attributable to specific Bluff Area locations, and soil lead concentrations are not elevated Site-wide. Arsenic concentrations are also notably elevated in specific Bluff Area locations, and the arsenic EPC overestimates exposure in other areas of the Site. For the marine area, the proposed anthropogenic study may provide an alternative boundary to the ISA.

The planned potability evaluation may identify wells that are non-potable. The data for these wells should be removed from the BHHRA Site-wide groundwater dataset and EPC calculation.

This BHHRA uses conservative exposure parameters for sediment dermal contact and ingestion. These exposure parameters include dermal absorption, ingestion rates, and PAH RBA. ISA sediments are coarse grained; the bioaccessibility evaluation information suggests that a primary contributor to sediment PAH is briquet fragments. Sediment PAHs are expected to have RBA less than the RBA of 1 used in this BHHRA. The conservative sediment exposure parameters likely overestimate risk for sediment exposures.

This BHHRA uses conservative exposure assumptions for Tribal shellfish collection and consumption. It is unknown if the consumption rates used in this BHHRA are related to a sustainable harvest within the ISA. For this reason, risk may be overestimated for Tribal shellfish collection and consumption.

# Summary

This BHHRA presents an evaluation of potential risks to human health in the Site and ISA as part of the RI/FS. This BHHRA is intended to evaluate potential adverse health effects caused by exposure to CERCLA hazardous substances at the Site. This BHHRA fulfills one of the four objectives established in the RI/FS Work Plan (Aspect and Anchor QEA 2017), which is to evaluate potential current and future human health risks posed by the COPCs present at the Site.

This BHHRA is based on the human health exposure pathway CSM presented in the approved RATM (Anchor QEA and Aspect 2020). It incorporates decisions made during the RATM working groups between the Suquamish Tribe, EPA, and Cascade (see Attachment A). Based on the current and future uses of the Site and ISA, three categories of receptors exposed to the upland portion of the Site and three categories of receptors exposed to the marine ISA were identified for quantification of risks for this BHHRA. These categories are as follows:

**Upland Site**

Current/future construction/excavation worker (upland areas)

Current/future occupational worker

Future resident

**Marine ISA**

Current/future construction/excavation worker (beach areas)

Current/future recreational beach user

Future Tribal shellfish consumer

The estimated RME total cancer risks and total noncancer HIs for the receptors evaluated are summarized in Table 6-33. The COPCs contributing the most to cancer risk and noncancer hazards are summarized in Table 6-35 for the upland Site and Table 6-36 for the marine ISA.

**Upland Site Findings.** For the upland portion of the Site, occupational workers and future residents have cumulative cancer risk above EPA’s acceptable cancer risk level. Construction/excavation worker (upland areas), occupational workers, and future residents have noncancer HI above 1.

For the future resident, exposure to groundwater contributes the most to cumulative risk and noncancer HI. Site soil COPCs contributing most to cumulative risk and noncancer HI include arsenic and cPAHs. Groundwater COPCs contributing most to future resident cumulative cancer risk and noncancer hazard include benzene, ethylbenzene, cPAHs, and naphthalene.

There is uncertainty regarding the potability of all wells currently included in the Site-wide dataset. The groundwater evaluation may be refined in the future based on the planned potability determination.

The resident arsenic EPC is influenced by two Bluff Area sample locations with notably elevated concentrations and is likely not representative of arsenic exposure in other areas of the Site. Soil lead exposure may present a risk to future child residents. However, elevated lead concentrations were limited to the Bluff Area of the Site and lead concentrations in other areas of the Site are below current EPA residential RSL.

VI may present a risk to future occupational workers or residents based on a qualitative evaluation and may be further evaluated in the future based on future land use.

**Marine ISA Findings.** For the marine ISA, Tribal shellfish consumers had cumulative cancer risk above EPA’s acceptable cancer risk range and noncancer HI equal to 1. Recreational beach user cumulative cancer risk was above 1 x 10-6 but within EPA’s acceptable risk range and the noncancer HI was below 1. Both cumulative cancer risk and noncancer HI were below the acceptable levels for the construction/excavation worker (beach areas).

Sediment exposure contributed the most to Tribal shellfish consumer cumulative cancer risk. Sediment COPCs contributing most to cumulative risk include arsenic and cPAHs. The surface sediment (0 to 3 feet) arsenic EPC is below the natural background level, indicating sediment arsenic exposure in the ISA is comparable to background. The sediment cPAH concentrations are notably higher in the area adjacent to the Former Gasworks Property. The current method of evaluating sediment exposure on an ISA-wide basis may not be representative of exposures across the ISA. Conservative exposure factors were used in the sediment evaluations that may bias high cPAH sediment exposure risk.

Tribal consumption of shellfish (clam) cumulative risk is above 1 x 10-6, but within EPA’s acceptable cancer risk range. Consumption of clams from only Area 1, adjacent to the Former Gas Works Property, would result in higher cPAH risk estimates than consuming clams from the eastern portion (Area 2) of the ISA, indicating that tissue cPAH concentrations are not evenly distributed throughout the ISA. This BHHRA assumes all shellfish consumed from Puget Sound are sourced from the ISA. It is unknown if this is a sustainable harvest.

# References

* AECOM and Windward Environmental, LLC, 2012. Appendix B, Updated Beach Play Risk Estimates, Species-specific RBTC Calculations, and the Puget Sound Tissue Dataset. For Submittal to: The U.S. Environmental Protection Agency, Region 10, Seattle, WA, and The Washington State Department of Ecology, Northwest Regional Office, Bellevue, WA. October 31, 2012.
* Anchor QEA, LLC, and Aspect Consulting, LLC (Anchor QEA and Aspect), 2013. Removal Evaluation Work Plan. June 2013.
* Anchor QEA, LLC, and Aspect Consulting, LLC (Anchor QEA and Aspect), 2020. Risk Assessment Technical Memorandum. Bremerton Gas Works Superfund Site. Prepared for Cascade Natural Gas Corporation, Aspect Project No. 080239-005, Anchor QEA Project No. 131014 01. May 2020.
* Aspect Consulting, LLC, and Anchor QEA, LLC (Aspect and Anchor QEA), 2017. Final Remedial Investigation/Feasibility Study Work Plan. Bremerton Gas Works Superfund Site. Prepared for Cascade Natural Gas Corporation Project No. 123456-789. May 31, 2017.
* Aspect Consulting, LLC, and Anchor QEA, LLC (Aspect and Anchor QEA), 2019. RI/FS Work Plan Addendum, Bremerton Gas Works Superfund Site. Prepared for Cascade Natural Gas Corporation, Aspect Project No. 080239-005, Anchor QEA Project No. 131014 01. October 28, 2019.
* Aspect Consulting, LLC, and Anchor QEA, LLC (Aspect and Anchor QEA)), 2020. Draft Remedial Investigation Data Report. Bremerton Gas Works Superfund Site. Prepared for Cascade Natural Gas Corporation, Aspect Project No. 080239-005, Anchor QEA Project No. 131014-01.01. July 2020.
* Aspect Consulting, LLC, 2020. Draft Memorandum Bremerton Gas Works – Groundwater Potability Evaluation Approach, Project No. 080239-5.12.
* Campbell, W.W. 1996. Procedures to determine intertidal populations of Protothaca staminea, Tapes philippinarum, and Crassostrea gigas in Hood Canal and Puget Sound, Washington. Washington Department of Fish and Wildlife, Procedures Manual MRD96-01.
* CDC (Centers for Disease Control and Prevention), 1991. Preventing Lead Poisoning in Young Children. A Statement by the Centers for Disease Control. October 1991.
* CDC (Centers for Disease Control and Prevention), 2012. Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention. Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention. January 4, 2012.
* Parametrix, 2003. Results of a Human Use Survey for Shoreline Areas of Lake Union, Lake Washington, and Lake Sammamish. Sammamish - Washington Analysis and Modeling Program (SWAMP). Submitted to King County Department of Natural Resources.
* Replinger et al. (Replinger, S., S. Katka, J. Toll, B. Church, and L. Saban), 2017. Recommendations for the derivation and use of biota-sediment bioaccumulation models for carcinogenic polycyclic aromatic hydrocarbons. Integrated Environmental Assessment and Management, 13(6):1060-1071.
* Ruby et al. (Ruby, M.V., Y. W. Lowney, A. L Bunge, S.M. Roberts, J. L Gomez-Eyles, U Ghosh, J. C. Kissel, P Tomlinson, and C. Menzie), 2016. Oral Bioavailability, Bioaccessibility, and Dermal Absorption of PAHs from Soil - State of the Science. Environ. Sci. Technol., 50 (5): 2151–2164.
* Rust et al. (Rust, A. J., R. M. Burgess, B.J. Brownawell, and A. E. McElroy), 2004. Relationship between metabolism and bioaccumulation of Benzo(a)pyrene in benthic invertebrates. Environmental Toxicology and Chemistry, 23(11):2587-2593.
* The Suquamish Tribe, 2000. Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation Puget Sound Region. The Suquamish Tribe, 15838 Sandy Hook Road, Post Office Box 498, Suquamish, Washington 98392.
* The Suquamish Tribe, 2011. Letter providing additional information on the Bremerton Gasworks Site, Bremerton Washington. July 27, 2011.
* The Suquamish Tribe, 2014. Comments on August 1, 2014, Draft Scoping Memorandum. Bremerton Gasworks Site, Suquamish Tribe. September 12, 2014.
* U.S. Army Corps of Engineers (USACE), 2009. OSV Bold Summer 2008 Survey Data Report, Final. Prepared by: The Dredged Material Management Program U.S. Army Corps of Engineers, Seattle District U.S. EPA Region 10, WA State Department of Natural Resources, and WA State Department of Ecology. June 25, 2009.
* U.S. Environmental Protection Agency (EPA), 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/G-89/004.
* U.S. Environmental Protection Agency (EPA), 1989. Risk Assessment Guidance for Superfund (RAGS) Volume 1. Human Health Evaluation Manual, Part A. Office of Emergency and Remedial Response. EPA/540/1-9/002.
* U.S. Environmental Protection Agency (EPA), 1990. National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule, Codified as amended at 40 C.F.R. Part 300.
* U.S. Environmental Protection Agency (EPA), 1991a. Risk Assessment Guidance for Superfund (RAGS) Volume 1. Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors. Interim Final. Office of Emergency and Remedial Response, Toxics Integration Branch. OSWER Directive No. 9285.6-03. March 25, 1991.
* U.S. Environmental Protection Agency (EPA), 1991b. Role of the Baseline Risk Assessment in Superfund Remedy Selection, Office of Solid Waste and Emergency Response. OSWER Directive 9355.0-30. April 22, 1991.
* U.S. Environmental Protection Agency (EPA), 1993a. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons, Office of Research and Development. EPA/600/R-93/089. July 1993.
* U.S. Environmental Protection Agency (EPA), 1993b. Selecting Exposure Routes and Contaminants of Concern by Risk-based Screening. Hazardous Waste Management Division. EPA/903/R-93-001. January 1993.
* U.S. Environmental Protection Agency (EPA), 1994a. Memorandum: OSWER Directive: Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. Office of Solid Waste and Emergency Response. OSWER Directive No. 9355.4-12. August 1994.
* U.S. Environmental Protection Agency (EPA), 1994b. Guidance Manual for the IEUBK Model for Lead in Children. Office of Solid Waste and Emergency Response. OSWER No. 8284.7-15-1. February 1994.
* U.S. Environmental Protection Agency (EPA), 1998. Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive #9200.4-27P. EPA/540/F-98/030. August 1998.
* U.S. Environmental Protection Agency (EPA), 2001. Risk Assessment Guidance for Superfund (RAGS) Volume 1, Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments, Final. Office of Emergency and Remedial Response. Publication 9285.7-47, December 2001.
* U.S. Environmental Protection Agency (EPA), 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, OSWER 9355.4-24. December 2002.
* U.S. Environmental Protection Agency (EPA), 2003a. Memorandum – Human Health Toxicity Values in Superfund Risk Assessments. Office of Superfund Remediation and Technology Innovation. December 5, 2003.
* U.S. Environmental Protection Agency (EPA), 2003b. Assessing Intermittent or Variable Exposures at Lead Sites. OSWER #9285.7-76. EPA-540-R-03-008.
* U.S. Environmental Protection Agency (EPA), 2004. Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual (Part E, Supplemental guidance for Dermal Risk Assessment) Final. EPA/540/R/99/005.
* U.S. Environmental Protection Agency (EPA), 2005a. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. Office of Solid Waste and Emergency Response. EPA 540-R-05-012. December 2005.
* U.S. Environmental Protection Agency (EPA), 2005b. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens, Risk Assessment Forum. EPA/630/R-03/003F. March 2005.
* U.S. Environmental Protection Agency (EPA), 2005c. Guidelines for Carcinogen Risk Assessment. Risk Assessment Forum. EPA/630/P-03/001F, March 2005.
* U.S. Environmental Protection Agency (EPA), 2007a. Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia, Working Document.
* U.S. Environmental Protection Agency (EPA), 2007b. Guidance for Evaluating the Oral Bioavailability of Metals in Soils for Use in Human Health Risk Assessment. OSWER 9285.7-80. May 2007.
* U.S. Environmental Protection Agency (EPA), 2009a. Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual (Part F - Supplemental guidance for Inhalation Risk Assessment) Final. EPA/540/R/070/002.
* U.S. Environmental Protection Agency (EPA), 2009b. Update of the Adult Lead Methodology’s Default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters. Prepared by the Technical Review Workgroup for Metals and Asbestos (TRW). OSWER 9200.2-82. June 2009.
* U.S. Environmental Protection Agency (EPA), 2010. Integrated Exposure Update Biokinetic Model for Lead in Children. Windows Version (IEUBKwin V1.1 build 11); 32-bit version. February, 2010.
* U.S. Environmental Protection Agency (EPA), 2011. Exposure Factors Handbook. EPA/600/R-09/052F. September 2011.
* U.S. Environmental Protection Agency (EPA), 2012. Recommendations for Default Value for Relative Bioavailability of Arsenic in Soil. OSWER 9200.1-113. December 2012.
* U.S. Environmental Protection Agency (EPA), 2014a. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120.
* U.S. Environmental Protection Agency (EPA), 2014b. Record of Decision, Lower Duwamish Waterway Site. U.S. Environmental Protection Agency, Region 10. November 2014.
* U.S. Environmental Protection Agency (EPA), 2015. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER Publication 9200.2-154. June 2015.
* U.S. Environmental Protection Agency (EPA), 2016. Updated Scientific Considerations for Lead in Soil Cleanups. OLEM Directive 9200.2-167. December 22, 2016.
* U.S. Environmental Protection Agency (EPA), 2017. Transmittal of Update to the Adult Lead Methodology's Default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters. OLEM Directive 9285.6-56. May 2017.
* U.S. Environmental Protection Agency (EPA), 2020a. Email from Eva DeMaria Approval of RATM. June 3, 2020.
* U.S. Environmental Protection Agency (EPA), 2020b. Regional Screening Levels (RSLs) Generic Tables. May 2020. Available at: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.
* U.S. Environmental Protection Agency (EPA), 2020c. Regional Screening Levels (RSLs) - User's Guide. May 2020. Available at: <https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide>.
* U.S. Environmental Protection Agency (EPA), 2020d. Lead at Superfund Sites. Available at: https://www.epa.gov/superfund/lead-superfund-sites.
* U.S. Environmental Protection Agency (EPA), 2020e. Frequent Questions from Risk Assessors on the Integrated Exposure Uptake Biokinetic (IEUBK) Model. Available at: https://www.epa.gov/superfund/lead-superfund-sites-frequent-questions-risk-assessors-integrated-exposure-uptake.
* Van den Berg et al. (Van den Berg, M., L.S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson), 2006. The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. Toxicological Sciences 93(2):223-241.
* Washington State Department of Ecology (Ecology), 1994. Natural Background Soil Metals Concentrations in Washington State. Publication No. 94-115. October 1994.
* Washington State Department of Ecology (Ecology), 2011a. Urban Seattle Area Dioxin and PAH Concentrations: Initial Summary Report. Publication 11-09-049.
* Washington State Department of Ecology (Ecology), 2011b. Control of Toxic Chemicals in Puget Sound, Characterization of Toxic Chemicals in Puget Sound and Major Tributaries, 2009 - 2010. Prepared by Tom Gries and David Osterberg, Toxics Studies Unit, Environmental Assessment Program. Publication No. 11-03-008.
* Washington State Department of Ecology (Ecology), 2019. Sediment Cleanup User’s Manual (SCUM) Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards. Chapter 173-204 WAC Toxics Cleanup Program, Washington State Department of Ecology Olympia, Washington Publication No. 12-09-057. Final Revised December 2019.

Tables

Figures

1. Subsurface vapor sources include NAPL and contaminated soil in the source areas, and contaminated groundwater in/downgradient of the source areas. [↑](#footnote-ref-2)
2. Exterior soil gas samples were collected outside the footprints of existing buildings, from deeper in the vadose zone (5 to 10 feet bgs), to evaluate near-source soil gas quality. [↑](#footnote-ref-3)
3. Per the OSWER *Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (EPA, 2015). [↑](#footnote-ref-4)
4. Aroclor 1260 was reported to be present in two surface soil samples, collected between the ground surface and 1.5 feet bgs from a single RI exploration on the shoreline bluff. Aroclor 1260 was not reported to be present above the laboratory reporting limits in 105 subsurface soil samples or 46 of the 48 total surface soil samples. Based on the limited presence of Aroclor 1260 at the Site and its location in surface soil on the shoreline bluff, it does not pose a risk to human health through the VI pathway and was not identified as a VI-COPC for the Site. [↑](#footnote-ref-5)
5. -4 feet MLLW is the approximate water elevation during the lowest astronomical predicted tide (https://tidesandcurrents.noaa.gov/datums.html?id=9447130). [↑](#footnote-ref-6)
6. Per the *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from*

   *Subsurface Vapor Sources to Indoor Air* (EPA 2015). [↑](#footnote-ref-7)
7. Not including helium, for which data were collected and reported for QA/QC purposes, but helium is not a VI-COPC. [↑](#footnote-ref-8)
8. As described in the RI Data Report, clam surveys were conducted on foot on April 22, 2017, during low tide following modified Washington Department of Fish and Wildlife methods (Campbell 1996). A total of 69 clams belonging to five species were recovered from eight transects. Manila littleneck (*Venerupis philippinarum*) clams were the most abundant species and accounted for half of all clams recovered. Native littlenecks (*Leukoma staminea*) and *Macoma* species were relatively abundant, while less than five butter clams (*Saxidomus gigantean*) and eastern softshells (*Mya arenaria*) were recovered. [↑](#footnote-ref-9)
9. The CTE is defined as a more typical (or average) estimate of exposure. Mean or 50th percentile values are used to quantify exposures under the CTE scenario. If mean or 50th percentile values are not available, 50% of the RME is typically used to represent the CTE scenario. CTE exposure estimates will not be used in the risk characterization. [↑](#footnote-ref-10)
10. The fraction of shellfish (64.8%) is based on the total average children’s fish consumption rate, excluding Group F, which is over 90% canned tuna. The total includes Puget Sound salmon (Group A; 0.271 g/kg/day), pelagic fish (Group B; 0.004 g/kg/day and Group C; 0.131 g/kg/day), bottom fish (Group D; 0.030 g/kg/day), and all shellfish (Groups E and G combined; 0.801) (Table T-14 in Suquamish Tribe 2000). [↑](#footnote-ref-11)