Human Health Risk Assessment

Astoria Area-Wide Petroleum Site
Astoria, Oregon

Prepared for:

EnviroLogic Resources, Inc

Project No. 0116.01.01

Prepared by:

Maul Foster Alongi Inc.

Environmental & Engineering Consultants

Vancouver, WA | Portland, OR | www.MFAinc.org

June 11, 2008

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ASTORIA, OREGON
DEQ ECSI FILE NO. 2277

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Maul Foster & Alongi, Inc.
3121 SW Moody Avenue, Suite 200
Portland, Oregon 97239

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The material and data in this report were prepared under the supervision and direction of the undersigned.

Maul Foster & Alongi, Inc.

Jeffrey A. Peterson, PhD
Principal Environmental Scientist

Madi Novak
Project Environmental Scientist

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ACRONYMS AND ABBREVIATIONS

AOC	area of concern
API	American Petroleum Institute
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
BCE	British Columbia Ministry of Environment
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
cm	Centimeter
COI	chemical of interest
COPC	chemical of potential concern
CSM	conceptual site model
Delphia Oil	Delphia Oil Company
DEQ	Oregon Department of Environmental Quality
DRO	diesel-range organics
Ecology	Washington State Department of Ecology
FS	feasibility study
GRO	gasoline-range organics
Harris/Van West	Flying Dutchman and Harris Enterprises
HHRA	human health risk assessment
HQ	hazard quotient
IRIS	Integrated Risk Information System
LMS	linearized multistage model
LNAPL	light nonaqueous-phase liquid
McCall	McCall Oil and Chemical Company
MCL	maximum contaminant level
MFA	Maul Foster & Alongi, Inc.
mg/kg	milligrams per kilogram
mm	millimeter(s)
MRL	method reporting limit
$\mu g/m^3$	micrograms per cubic meter
Niemi Oil	Ed Niemi Oil Company
OAR	Oregon Administrative Rules
the Order	DEQ Unilateral Order No. ECSR-NWR-01-11
OWRD	Oregon Water Resources Department
PAH	polycyclic aromatic hydrocarbon

ACRONYMS AND ABBREVIATIONS (Continued)

PCB	polychlorinated biphenyl
the Port	Port of Astoria
ppbv	parts per billion by volume
ppmv	parts per million by volume
PRG	preliminary remediation goal
PRP	potentially responsible party
Qwest	Qwest Communications International
RBC	risk-based concentration
RBDM	Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
SF	slope factor
the Site	Astoria Area-Wide Petroleum Site
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbons
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

1 INTRODUCTION

Maul Foster & Alongi, Inc. (MFA) has been retained by EnviroLogic Resources, Inc. to complete the baseline human health risk assessment (HHRA) for the Astoria Area-Wide Petroleum Site (Site) in Astoria, Oregon. The purpose of the HHRA is to characterize potential risks that site-related chemicals in soil and groundwater may pose to human health. This HHRA is based on the results of site investigations documented in the Remedial Investigation (RI) Report (EnviroLogic Resources, 2008), and was performed consistent with methods outlined in the HHRA Work Plan (MFA, 2005) and in subsequent correspondence with the Oregon Department of Environmental Quality (DEQ) (DEQ, 2005, 2006; MFA, 2006).

The DEQ issued a unilateral order (DEQ Unilateral Order No. ECSR-NWR-01-11) (Order) requiring an RI/feasibility study (FS) and potential cleanup of properties in an area near the Port of Astoria (the Port) in Astoria, Oregon. The baseline HHRA has been completed as part of this RI. The Order was issued to several of the current and former facility operators, property owners, and leaseholders that have engaged in industrial and commercial activities. ChevronTexaco Products Company, Delphia Oil Company (Delphia Oil), McCall Oil and Chemical Company (McCall), Ed Niemi Oil Company (Niemi Oil), Flying Dutchman and Harris Enterprises (Harris/Van West), the Port, Qwest Communications International (Qwest), and Shell Oil Company, collectively hereinafter referred to as the potentially responsible parties (PRPs), are identified in the Order and have agreed to comply with its requirements. Qwest withdrew from participation in site investigations in 2004. ExxonMobil Corporation agreed to participate in investigations conducted by the PRP group in November 2003 because they are a former tenant of a property within the Site.

1.1 Assessment Approach

The baseline HHRA follows the assessment approach outlined in the DEQ (2003) *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites* (RBDM). The RBDM was designed to allow efficient evaluations of human-health risks associated with potential exposures to petroleum-related chemicals. Contaminant impacts to soil and groundwater at the Site are primarily the result of historical petroleum releases (MFA, 2005). To evaluate potential risk, the RBDM emphasizes comparisons of site-related chemical concentrations with relevant risk-based concentrations (RBCs). An RBC is an estimate of the concentration of a chemical in soil, groundwater, or air that would not pose unacceptable risks to humans with a reasonable maximum exposure (RME) to the impacted medium. The DEQ has developed generic RBCs for the most common pathways by which humans may contact petroleum-related chemicals at a site.

1.2 Report Organization

The rest of this HHRA report is organized into the following sections:

- Section 2 presents background information regarding the Site, such as site setting, geology and hydrogeology, chemicals of interest (COIs), and beneficial uses of land and water.

- Section 3 describes the data evaluation process and identifies chemicals of potential concern (COPCs).

- Section 4 describes the conceptual site model (CSM).

- Section 5 characterizes potential risks that COPCs may pose to human health.

- Section 6 describes important sources of uncertainty in risk estimates.

- Section 7 presents the primary findings of the risk assessment.

2 BACKGROUND

This section briefly describes background information regarding the Site, such as the setting, site history, geology and hydrogeology of the area, and current and reasonably likely future beneficial uses of land and water. More detailed descriptions of relevant background information are presented in the RI report (EnviroLogic Resources, 2008).

2.1 Site Setting

The Site comprises properties located at and near the Port in Astoria, Oregon (Figure 2-1). The Site is located in section 7, township 8 north, range 9 west, and section 12, township 8 north, range 10 west, Willamette Base and Meridian. The Site includes the former McCall bulk plant property and is bounded by the Burlington Northern Railroad tracks and Hamburg Street to the southwest, Marine Drive to the south, Portway to the east, and the Columbia River to the north.

West Marine Drive (U.S. Highways 26, 30, and 101) is located on a topographic bench approximately 15 feet above the level of the Port facilities. The Columbia River flows to the west on the north side of the Site. Young's Bay lies to the south.

2.2 Site History

The area around the Port has been used for petroleum storage and distribution since approximately the 1920s. Aboveground storage tanks (ASTs), underground storage tanks (USTs), and pipelines are present on several of the facilities on the Site. Historically, the Site was home to at least four bulk petroleum storage facilities and five vehicle-fueling or -service stations between West Marine Drive and the Columbia River. Pipelines from at least two of the bulk fuel storage facilities extend onto piers at the Port. Remedial actions have been conducted at several facilities on the Site.

2.3 Local Geology and Hydrogeology

The Site is underlain by dredge fill deposits, native alluvial deposits, and the Astoria Formation (EnviroLogic Resources, 2008). The dredge sand fill is characterized by grey and light-brown fine to medium sand with lenses of silt and clay. The nature of the sand is fairly consistent across the Site, although the amount of silt and clay varies within the dredge sand fill. In certain areas, the thin silt lenses are relatively extensive and contiguous. In other areas of the Site, these silt and clay lenses do not appear to be present. The dredge fill, native alluvial deposits, and Astoria Formation all appear to be hydraulically connected, although with differing abilities to transmit water.

The depth to groundwater is variable across the Site, ranging from approximately 5 feet in depth near the Columbia River to 25 feet in depth near West Marine Drive (EnviroLogic Resources, 2008). With the exception of the southeast portion of the Site near Val's Texaco, where the shallow water-bearing zone was encountered about 20 to 25 feet below ground surface (bgs), the shallow water-bearing zone is located within 5 to 15 feet bgs (Table 2-1). Variation in the groundwater elevation generally reflects the topography, as the properties along West Marine Drive are approximately 15 feet higher in elevation than those along Industry Street and near the Columbia River. A retaining wall is present along the north sides of several of the sites along West Marine Drive.

The direction of the hydraulic gradient in the shallow water-bearing zone is generally north or northwest throughout the year, and over most of the Site the horizontal hydraulic gradient ranges from 0.003 to 0.007 feet per foot (EnviroLogic Resources, 2008). However, along West Marine Drive the hydraulic gradient ranges from 0.025 to 0.05 feet per foot. The shallow groundwater system under the Site is influenced by tidal effects of Young's Bay and the Columbia River, especially in monitoring wells near the shoreline.

2.4 Chemicals of Interest

Contamination on the Site is primarily the result of unintentional releases of various petroleum products from storage or handling facilities. As a result, the primary COIs are petroleum-related compounds. However, the sampling program conducted as part of the RI evaluated a wide range of potential contaminants in soil and groundwater. Soil and groundwater samples were analyzed for total petroleum hydrocarbons (TPH); volatile organic compounds (VOCs); semivolatile organic compounds (SVOCs); polychlorinated biphenyls (PCBs); polycyclic aromatic hydrocarbons (PAHs); and various metals.

Petroleum products comprise numerous hydrocarbons. Environmental sampling efforts performed as part of the RI focused on the key petroleum-related chemicals identified in the DEQ's 1999 RBDM guidance (DEQ, 1999). The key constituents of a petroleum mixture differ, depending on the type of petroleum product. For example, benzene, toluene, ethylbenzene, and xylenes (BTEX) are key individual chemical constituents of gasoline, and PAHs are key constituents of diesel and heavy oil. Individual petroleum constituents that are considered COIs include the following:

- VOCs found in petroleum-based fuels, such as BTEX and trimethylbenzenes

- VOCs that have been used historically as amendments in fuels, such as 1,2-dibromoethane, 1,2-dichloroethane, and methyl-tert-butylether
- Certain PAHs that are found in fuels and lubricants
- Metals that may be found in waste oils

The DEQ's 2003 RBDM, issued after most of the soil data had been collected, revised the recommended approach for evaluating risks associated with exposure to petroleum compounds. In addition to an evaluation of key individual constituents of petroleum, the 2003 RBDM recommends an evaluation of whole petroleum mixtures such as gasoline and diesel. Using estimates of the composition of fresh product, the 2003 RBDM guidance provides default soil and groundwater RBCs for gasoline and diesel. The guidance also presents options for a responsible party to make site-specific adjustments to RBCs, based on characterization of the actual composition of the petroleum mixture present (e.g., fresh product is typically more toxic than weathered product). Although the RI sampling program was not specifically designed to characterize the composition of petroleum products that have been released at the Site, sufficient data regarding TPH in soil and groundwater have been collected to perform a risk evaluation consistent with the 2003 RBDM guidance.

Several soil and groundwater samples were analyzed for a variety of metals that are not typically associated with petroleum products. Many of the metals do not appear to be elevated above natural background concentrations. However, all metals evaluated as part of the RI are considered COIs for the purposes of the risk evaluation.

2.5 Beneficial Uses of Land and Water

The Site is currently used for commercial and industrial purposes (EnviroLogic Resources, 2003b). Most properties on the Site have been used for commercial or industrial purposes since the 1920s (EnviroLogic Resources, 2002b). All land on the Site is zoned for commercial and industrial uses (EnviroLogic Resources, 2003b), and parts of the Site are undergoing development to support commercial and industrial operations. Based on local land-use plans that emphasize commercial and industrial development at the Site, it is reasonably likely that future uses will be similar to current land uses. As a result, various workers are the human populations with the greatest potential to contact impacted environmental media at the Site.

When the HHRA Work Plan (MFA, 2005) was submitted, a four-unit apartment complex was located on West Marine Drive just west of the Harris/Van West property (Figure 2-2). The HHRA Work Plan identified urban residents as potential human receptors at this apartment complex. Recently, this apartment complex was demolished, and the property is likely to be redeveloped to support commercial activities.

Given current zoning, land-use plans, and development trends, it is not likely that single- or multi-family residences will be developed at the Site in the foreseeable future. Waterfront residential developments (condominiums and single-family residences) have occurred in Astoria east of the Site, but recent developments at the Site have been commercial. It is likely that future developments at the Site will continue to support commercial or industrial operations. Although current zoning does not preclude the construction of condominiums or similar types of residential structures in some portions of the Site, the lack of such prohibitions does not mean that future residential developments are reasonably likely. However, at the request of the DEQ, soil and groundwater data were compared with RBCs for the urban residential exposure scenario.

An inventory of borings and wells was developed using the Groundwater Resource Information Distribution database provided by the Oregon Water Resources Department (OWRD). Based on information obtained from this database search and from Port personnel, no water-supply wells appear to exist on or near the Site. The OWRD database was also searched for possible water rights related to properties on site. There are no places of use or points of diversion or appropriation located on or near the Site (EnviroLogic Resources, 2002b).

The City of Astoria supplies municipal water to facilities in and near the Site. Groundwater is not used for domestic, municipal, agricultural, or industrial purposes (EnviroLogic Resources, 2002b). Given the availability, reliability, and relatively low cost of the public water supply, municipal water will likely remain the primary water source for the Site in the foreseeable future; as a result, human receptors such as occupational workers are not likely to ingest or directly contact site-related chemicals in groundwater.

For a variety of reasons, shallow groundwater beneath the Site is unlikely to be used as a future source of industrial water. Yield from the shallow groundwater aquifer in many portions of the Site may be insufficient to meet large-scale industrial process water demands. Also, it is possible that sustained pumping of shallow groundwater in some portions of the Site could lead to intrusion of salt water into the shallow aquifer. Given these constraints, it is likely that hypothetical future industrial processes would use the relatively inexpensive municipal water supply that is already in place.

2.6 Areas of Concern

Based on the presence of potential or confirmed sources of hazardous substances, soil analytical results that characterize conditions near release locations, and groundwater analytical results that characterize the extent of contamination, five general areas of concern (AOCs) were identified in the RI report (EnviroLogic Resources, 2008). AOCs for the Site are shown in Figure 2-3.

3 DATA EVALUATION AND CHEMICALS OF POTENTIAL CONCERN

The quality of data used in risk assessment can affect the uncertainty in resulting risk estimates. Before data are used in a quantitative risk assessment, data quality is evaluated for appropriateness and usability. The data-evaluation process and selection of COPCs are described below.

3.1 Data Evaluation

Several environmental investigations were conducted within the boundaries of the Site dating back to the 1980s and before the RI was initiated (EnviroLogic Resources, 2002b). However, only data collected as part of the RI are used in this HHRA. Data collected during the RI are the most recent and better represent current conditions. The more recent data also are likely to be more accurate and reliable than historical results. For example, analytical methods have improved since the 1980s, and MFA could not confirm whether some historical data had undergone appropriate data-quality reviews. Historical data also may sometimes characterize chemical concentrations in soil and groundwater that have subsequently undergone a remedial action. The RI involved a comprehensive sampling program, and these data best characterize existing site conditions.

Soil and groundwater samples were analyzed for gasoline-range organics (GRO) by NWTPH-Gx; for diesel and heavy oil by NWTPH-Dx; for metals by U.S. Environmental Protection Agency (USEPA) Method series 200 or 6000/7000; for hexavalent chromium by USEPA Method 7195; for VOCs by USEPA Method 8260B; for BTEX by USEPA Method 8021B; for phenols by USEPA Method 8041; for formaldehyde by USEPA Method 8315A; and for PAHs by USEPA Method 8270M-SIM (selective ion monitoring). Analytical results were available for three xylene isomers: m-, p-, and o-xylenes. Concentrations of m-, p-, and o-xylenes were summed for comparison with screening levels.

MFA reviewed data-quality assurance reviews completed by EnviroLogic Resources and by each PRP of soil and groundwater samples collected as part of the RI (EnviroLogic Resources, 2003a, 2003c, 2004a, 2004b, 2004c, 2004d, 2004e). Data quality was evaluated using methods recommended by the USEPA (1989). For example, as part of data validation, some analytical results were assigned a standard letter code by the laboratory or validator to qualify the result (e.g., “J” to indicate that the value is an estimate). GRO and BTEX results for soil sample SB-813(Q)-0 were rejected during the validation process and are therefore not used in the risk assessment. No other data were rejected.

EnviroLogic Resources has developed a database (Access©) that includes analytical results from samples collected during historical investigations and results of samples collected as part of the RI. In June 2006, MFA transferred these data from the comprehensive database into spreadsheets. Data were queried to extract relevant information in a format usable for risk evaluation. The database included soil data collected from 1986 through 1997 and from 2002 through 2005. It also included groundwater data collected from 1986 through 1999 and from 2002 through 2004. The older data (1986 through 1999) frequently did not include method reporting limits (MRLs) for nondetections, and the origin and quality of many of these data could not be verified. Only the more recent data collected in 2002 through 2005 as part of the RI were used in the HHRA.

In some cases, multiple analyses for the same chemical were performed on a soil or groundwater sample. For example, the sample may have been analyzed for certain VOCs, using both USEPA Methods 8260B and 8021B. Results from both types of analyses were included in the HHRA.

Some remedial actions were completed after the RI soil sampling. A remedial action involving soil excavation was performed in the area where soil sample SB202(C) was collected at 2 feet bgs (EnviroLogic Resources, 2008). Because impacted soil was removed from this area, analytical data for this soil sample are not included in the risk assessment. As part of the groundwater investigation, several one-time reconnaissance groundwater samples were collected from borings. The purpose of the reconnaissance groundwater sampling was to determine the optimal location of monitoring wells for measuring water-quality conditions in a particular area (EnviroLogic Resources, 2008). Relative to data collected from reconnaissance groundwater samples, results from monitoring wells are more accurate and reliable indicators of groundwater conditions. Therefore, only analytical results from groundwater samples collected from monitoring wells are used in the HHRA.

Soil and groundwater data determined to be of sufficient quality for use in the risk assessment are presented in Appendix A. Soil GRO, diesel, and heavy-oil results are summarized in Table A-1; soil SVOC results are summarized in Table A-2; soil VOC results are summarized in Table A-3; soil metals results are summarized in Table A-4; and soil PCB results are summarized in Table A-5. Groundwater GRO, diesel, and heavy-oil results are summarized in Table A-6; groundwater SVOC results are summarized in Table A-7; groundwater VOC results are summarized in Table A-8; and groundwater metals results are summarized in Table A-9. Appendix A includes analytical results collected as part of the RI for analytes that were detected in at least one sample. Nondetections of a particular analyte are flagged with a "U" qualifier. The concentration value for a nondetection is set at half the MRL. Several statistics, such as the frequency of detection, maximum concentration, mean concentration, and median concentration, were calculated for each detected analyte. No attempt was made to average the results of primary and duplicate samples to characterize chemical concentrations for sample locations where multiple analyses were performed.

It should be noted that the data presented in Appendix A are a subset of the analytical data collected as part of the RI. Results for chemicals or entire classes of chemicals that were not detected in any soil or groundwater sample are not presented. For example, many VOCs and PCBs were not detected in soil or groundwater and are not included in Appendix A. Full sets of analytical results, including data for chemicals that have not been detected at the Site, are discussed in the RI report (EnviroLogic Resources, 2008).

Soil-vapor sampling was performed in 2004 at four locations outside the Port office building in an area where light nonaqueous-phase liquid (LNAPL) had been observed in monitoring wells (EnviroLogic Resources, 2005). Sampling was performed in this area because the Port office building was considered to be the most at-risk structure for vapor-intrusion impacts. Vapor samples were collected approximately 5 to 6 feet bgs, and samples were analyzed for BTEX and trimethylbenzenes, using USEPA Method TO-15, and for gasoline-range TPH (TPH-g), using USEPA Method TO-3 (EnviroLogic Resources, 2005). These data underwent a quality assurance review by GeoSyntec Consultants, Inc. The data are presented in Appendix A in Table A-10.

3.2 COPC Selection

To focus quantitative risk assessment on COIs with the potential to cause health risks to humans who may contact soil and groundwater, the list of chemicals detected at the Site was evaluated and reduced (MFA, 2005). Preliminary COPCs were selected using criteria recommended by the DEQ (2000), the USEPA (1989), and best scientific judgment. Chemicals were selected primarily on the basis of measured concentrations in soil or groundwater, inherent toxicity, and frequency of detection (MFA, 2005).

3.2.1 Soil

In general, COPCs were selected for soil by comparing the maximum concentration detected in soil with relevant USEPA Region 9 industrial soil preliminary remediation goals (PRGs). No PRGs are available for TPH mixtures such as GRO and diesel-range organics (DRO). Therefore, the maximum concentrations of GRO and DRO were compared with DEQ direct-contact soil RBCs for occupational workers (DEQ, 2003). The DEQ has not developed generic RBCs for heavy oil; the DEQ level 2 soil matrix value of 500 milligrams per kilogram (mg/kg) was used as the screening concentration for heavy-oil-range organics (MFA, 2005).

Industrial soil PRGs are calculated using conservative assumptions regarding intake rates, exposure durations, and other exposure factors for occupational workers (USEPA, 2004c). For example, the PRGs have been developed assuming that workers have chronic exposure to impacted soil over most of their careers (i.e., 250 days per year for 25 years). The target risk levels used by the USEPA when developing these PRGs are identical to the DEQ acceptable risk levels associated with exposure to single chemicals (USEPA, 2004c). The PRG for a carcinogen is the concentration associated with a one-in-a-million excess cancer risk over a lifetime. For a noncarcinogen, the PRG is the concentration associated with a hazard quotient (HQ) of one.

The selection process for COPCs in soil is outlined in Table 3-1. A chemical was not considered to be a COPC if it was detected in less than 5 percent of the soil samples that were tested for the chemical (DEQ, 2000). Chemicals that are infrequently detected in soil may be artifacts of sampling, analytical, or other types of errors.

Risk scores were calculated for each chemical that had been detected in at least one soil sample (Table 3-1). Chemical-specific risk scores were estimated as follows (DEQ, 2000):

$$R_i = \frac{MDC_i}{TSV_i} \qquad \text{(Equation 1)}$$

Where:

R_i = Risk score for chemical *i* (unitless)

MDC_i = Maximum detected concentration of chemical *i*

TSV_i = Toxicity screening value for chemical *i*

A chemical was considered a COPC if the chemical-specific risk score was greater than one (DEQ, 2000). If the risk score was less than one, it was inferred that exposure to the chemical is not likely to result in an unacceptable risk.

In some cases, an individual chemical was not detected at a concentration greater than the risk-based screening level, but the chemical could contribute to risk if multiple chemicals were present. To account for cumulative risks associated with potential exposure to multiple chemicals, the following method was used to determine COPCs, based on relative risk scores (DEQ, 2000):

$$\text{If } \Sigma R_i > 1 \text{ and } \frac{R_i}{\Sigma R_i} > \frac{1}{N_i}\text{, then chemical "i" is considered a COPC} \qquad \text{(Equation 2)}$$

Where:

ΣR_i = Sum of all chemical-specific risk scores.

N_i = Total number of chemicals included in the risk-based screen.

It should be noted that the DEQ COPC-selection process can result in a large number of COPCs that contribute little to overall risk estimates at sites where many analytes are evaluated. Using the DEQ COPC-selection process, the threshold risk score ($1/N_i$) for determining a COPC decreases as the total number of chemicals included in the risk-based screen increases. Fifty different chemicals were detected in at least one soil sample at the Site, several of which may not be related to past Site operations. As a result, chemicals with maximum concentrations 50 times lower than relevant screening levels were included as COPCs because they had risk scores above 0.02 (1/50). Risk assessors at USEPA Region 3 reviewed this type of COPC-selection process and concluded that it often leads to unnecessary work by requiring detailed evaluations of relatively unimportant risk drivers (USEPA, 1993). The USEPA Region 3 uses a chemical-specific target risk level of 0.1 for noncarcinogens and 10^{-6} for carcinogens. If the USEPA Region 3 approach had been used at this Site, the list of COPCs for soil would have been smaller, with little effect on overall risk estimates.

The maximum detected concentration was used to screen COPCs; this approach is conservative (health-protective) because it likely overestimates potential chemical exposures. Based on risk scores calculated using the maximum detected concentrations of chemicals in soil, the following are considered preliminary COPCs (Table 3-1):

<u>VOCs</u>

- Benzene
- n-Butylbenzene
- sec-Butylbenzene
- Ethylbenzene
- Naphthalene
- n-Propylbenzene
- 1,2,4-Trimethylbenzene

- 1,3,5-Trimethylbenzene
- Total xylenes

<u>SVOCs</u>

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Indeno(1,2,3-cd)pyrene

<u>TPH</u>

- GRO
- DRO
- Heavy-oil-range organics

<u>Metals</u>

- Arsenic
- Chromium
- Lead

As shown in Table 3-1, with the exception of Aroclor 1254, no chemical was eliminated as a COPC in soil based solely on a low site-wide frequency of detection. All other COPCs that were detected in fewer than 5 percent of site-wide soil samples had maximum detected concentrations below screening levels or had no screening value. Therefore, with the exception of Aroclor 1254, the list of COPCs for a particular property within the Site will not include chemicals that were not identified as COPCs for the Site as a whole.

Aroclor 1254 was detected in one of 58 soil samples collected on the former McCall bulk plant (Chevron) facility (Appendix A, Table A-5), and the property-specific frequency of detection is 2 percent. Because the property-specific frequency of detection in soil is less than 5 percent, Aroclor 1254 is not considered a COPC on this property. The single detection of Aroclor 1254 was from a soil sample collected at 4 feet bgs (SB-228) beneath a magnetic anomaly (pipeline). Aroclor 1254 was not detected in a nearby soil sample collected to better define PCB impacts (SB-256). As a result, the spatial distribution of Aroclor 1254 in subsurface soil appears to be very limited. Also, the concentration of Aroclor 1254 in subsurface soil is below the applicable construction worker RBC (see Appendix B). Because the spatial extent of Aroclor 1254 impacts are limited, the frequency of detection is low, and the detected concentration was below the applicable RBC, Aroclor 1254 is not considered a COPC.

Screening levels were not available for several chemicals. As shown in Table 3-1, chemicals for which no screening value was available were considered COPCs. However, these chemicals will not be carried through the quantitative risk assessment because insufficient toxicity data are available to make scientifically defensible risk estimates for these chemicals. Instead, potential risk associated with exposure to these chemicals will be discussed in the uncertainty-evaluation section of the HHRA. Chemicals that were considered COPCs because screening levels were not available are as follows:

- Benzo(g,h,i)perylene
- 4-Isopropyltoluene
- 2-Methylnaphthalene
- Phenanthrene

The results of COPC selection for soil indicate that, with the possible exception of the metals, all COPCs are related to petroleum products. These COPC-selection results support use of the RBDM (DEQ, 2003) to evaluate potential contaminant risks at the Site because contamination that is not related to historical petroleum releases appears to be insignificant. Also, please note that the concentrations of some of the metal COPCs in soil (e.g., arsenic) may not be elevated above natural background levels.

3.2.2 Groundwater

In general, COPCs were selected for groundwater by comparing the maximum concentration with the relevant USEPA Region 9 PRG for tap water (Table 3-2). Because no tap-water PRGs were available for GRO, DRO, and lead, DEQ generic groundwater RBCs for residents were used as screening values for these substances (MFA, 2005). If the maximum concentration was above the screening value, the chemical was considered a COPC.

No attempt was made to identify groundwater COPCs by considering the potential effects of exposure to multiple chemicals in drinking water. As stated previously, groundwater at the Site is not used as a drinking source and is unlikely to be used as a water-supply source in the foreseeable future. Relevant exposure scenarios include industrial workers who may inhale vapors that migrate from groundwater to indoor or outdoor air, and excavation workers who may contact chemicals in water of excavations that extend below the water table. Tap-water PRGs are often orders of magnitude lower than RBCs for the volatilization to indoor and outdoor air pathways and the direct-contact pathway for excavation workers (DEQ, 2003). Therefore, selection of groundwater COPCs based on multiple chemical risk scores where the threshold for selection is a fraction of the tap-water PRG would have led to the unnecessary inclusion of several COPCs that could have only a very small effect on groundwater risk estimates.

Based on chemical-specific risk scores calculated using the maximum detected concentrations of chemicals in groundwater, the following are considered preliminary COPCs (Table 3-2):

VOCs

- 1,2-Dichloroethane
- Benzene
- Ethylbenzene
- Naphthalene
- n-Propylbenzene
- Toluene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- Total xylenes

SVOCs

- Benzo(a)pyrene
- Dibenzo(a,h)anthracene

TPH

- GRO
- DRO

Metals

- Arsenic
- Lead

Screening levels were not available for several chemicals (Table 3-2). As indicated by DEQ (2006), iron, manganese, and magnesium are considered essential nutrients and are not considered COPCs. Similarly, calcium, potassium, and sodium are considered nutrients and are not included as COPCs in groundwater (USEPA, 1989). The chemicals that will be evaluated in the uncertainty section of the HHRA because they were selected as COPCs due to a lack of relevant screening levels are as follows (Table 3-2):

- 4-Isopropyltoluene
- Acenaphthylene
- Phenanthrene
- Heavy-oil-range organics
- Total chromium

Six chemicals not selected as COPCs had at least one MRL above their respective screening levels (Appendix A). MRLs for the PAHs benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded screening levels in four to 25 (depending on the analyte) of 159 groundwater samples. For VOCs, methyl-tert-butylether MRLs exceeded the screening level in 17 of 159 samples. With all six of these chemicals, the large majority of MRLs were below screening levels. These six chemicals do not appear to be important contaminants in groundwater because they were rarely detected even when MRLs were below conservative screening levels.

Again, with a few exceptions, the groundwater COPCs are petroleum-related compounds. Also, please note that some of the metal COPCs may not be elevated above natural background levels.

4 CONCEPTUAL SITE MODEL

The CSM describes potential chemical sources, release mechanisms, environmental transport processes, exposure routes, and receptors. The primary purpose of the CSM is to describe pathways by which human receptors may be exposed to COIs. According to the USEPA (1989), a complete exposure pathway consists of four necessary elements: (1) a source and mechanism of chemical release to the environment, (2) an environmental transport medium for a released chemical, (3) a point of potential contact with the impacted medium (referred to as the exposure point), and (4) an exposure route (e.g., soil ingestion) at the exposure point.

The human-health CSM, based on information that has been collected to date, is shown in Figure 4-1. Elements of potentially complete exposure scenarios are further discussed in Table 4-1. The areas on the Site where each exposure scenario is relevant are shown in Figure 4-2. Processes that could affect the fate and transport of petroleum in the environment and potential exposure scenarios are discussed below.

4.1 Primary Sources

Petroleum impacts to soil and groundwater at the Site have resulted from unintentional releases at a number of petroleum-storage and -handling facilities. Likely sources include USTs, ASTs, pipes, and dispensers. Releases may have occurred from leaks in tanks or pipes and during petroleum transfers (i.e., when products were being dispensed).

4.2 Fate and Transport

The primary mechanisms that affect fate and transport of released petroleum products include leaching from soil to groundwater, volatilization from soil or groundwater to air, advection and dispersion in groundwater, sorption to the soil matrix, and natural degradation processes. The relative importance of these processes in structuring the dynamics of contaminant fate and transport varies, depending on the chemical and physical properties of a released contaminant. The properties of soil and the dynamics of groundwater flow also shape contaminant fate and transport.

It appears that gasoline and diesel are the primary petroleum products that have been released at the Site. Whole gasoline and diesel are considered LNAPLs. LNAPL, or free-phase petroleum, has a density lower than that of water. As a result, LNAPL releases of a sufficient volume to result in significant gravity-driven downward migration through soil are typically constrained to the top of the groundwater zone. Because LNAPL and water are immiscible, there is little tendency for LNAPL to migrate deep into the groundwater zone. Once the released LNAPL encounters the capillary fringe above the water table (e.g., pore spaces completely or partially saturated with water), the weight of LNAPL will cause it to gradually displace pore water until equilibrium conditions are reached. The relatively high water content of the capillary fringe will result in low permeability to LNAPL, and at this point the downward gradient caused by gravitational forces will diminish. If there is a sufficient volume of released product, the driving hydraulic head will result in lateral migration of LNAPL until steady-state conditions are met (American Petroleum Institute [API], 2002).

Often, the lateral gradient for a product plume is radial because of free product mounding and the resistance presented by water-filled soil to freely transmit LNAPL. Once equilibrium conditions have developed and lateral migration of LNAPL has diminished, LNAPL plumes typically are stable. Unless new product is added to the system or other significant changes occur, there will be no further significant lateral movement of product.

Much of the Site is covered with permeable surfaces such as gravel, and it is likely that precipitation that falls in these areas can percolate through the vadose zone and interact with LNAPL or petroleum that is sorbed to soil. Chemicals with relatively high solubility may leach from soil to pore water, and dissolved chemicals may be transported downward to local groundwater. Also, when the water table rises and interacts with product or petroleum that is sorbed to soil, some constituents will partition into water.

Once in groundwater, dissolved contaminants may be transported by diffusion and advection in groundwater horizontally away from the original source. Horizontal migration with groundwater (advection) is expected to be significantly more extensive than vertical migration. It is most likely that the only significant mechanism that would allow for downward vertical migration of petroleum constituents is diffusion, and this process results in order-of-magnitude reductions in waterborne concentrations over relatively short distances (i.e., several feet) from the source (API, 2002). In general, the potential for a chemical to migrate in groundwater increases as a function of chemical solubility. Many petroleum constituents have relatively low solubility and a low likelihood of extensive migration in groundwater.

Dispersion, retardation, and biodegradation act to reduce dissolved concentrations of petroleum constituents in groundwater downgradient of the source area. A growing body of evidence suggests that in most systems, biodecay is a significant loss mechanism for many petroleum constituents such as benzene (API, 2002).

Some volatile contaminants that are either adsorbed to soil or dissolved in groundwater may volatilize to soil pore spaces. Chemical vapors in pore spaces may eventually migrate through the soil matrix and enter outdoor air. Once these have reached outdoor air, mixing with ambient air is expected to reduce airborne chemical concentrations rapidly and substantially. If buildings are located over groundwater impacted with volatile contaminants, it is possible that vapors may eventually enter indoor air by penetrating cracks in a building floor or foundation.

A seep with LNAPL has been observed in Slip 2 near the shoreline of the Columbia River. Petroleum constituents in the LNAPL at the seep may migrate to both sediment and surface water. Also, dissolved constituents in groundwater near the seep area may discharge to sediment and surface water of the Columbia River. Concentrations of petroleum constituents in surface water are expected to be low due to mixing with ambient water.

4.3 Exposure Scenarios

Properties at the Site are used for commercial and industrial purposes, and it is likely that they will continue to be used for commercial and industrial purposes for the foreseeable future. Various workers will have the greatest potential to contact contaminated soil or groundwater. Although visitors or trespassers could occasionally visit a property, they are expected to have far less potential to be exposed to soil or groundwater than on-site workers. The types of workers assumed to be present at the Site include occupational workers, occasional excavation workers, and construction workers. Relevant default DEQ (2003) potential exposure scenarios are presented in Table 4-1 and are briefly discussed below for both soil and groundwater.

4.3.1 Soil

Petroleum hydrocarbons have been observed in surface soil (<3 feet bgs) at several locations. In many cases, impacted surface soil is covered with asphalt, gravel, buildings, or other features that prevent workers (occupational, construction, and excavation) from directly contacting contamination. However, it is assumed that exposure barriers that may currently prevent workers from contacting chemicals in surface soil may be removed in the future. Direct-contact exposure routes for workers include incidental soil ingestion, inhalation of vapors or particulates, and dermal contact.

It is assumed that the reasonable maximum depth of future excavations that may be developed at the Site is 15 feet bgs (DEQ, 2003). In addition to contacting surface soil, excavation and construction workers may contact subsurface soil at depths above 15 feet bgs.

The vadose zone is the relatively unsaturated layer of soil that lies above the water table. In the northern section of the Site, near the Columbia River, the water table is located approximately 6 feet bgs (Table 2-1). The thickness of the vadose zone increases to the south. Near West Marine Drive, the water table is approximately 19 feet bgs. It is assumed that there are two pathways by which on-site occupational workers could have indirect exposure to petroleum hydrocarbons in subsurface vadose-zone soil. First, it is assumed that volatile petroleum hydrocarbons in the vadose zone could migrate through the soil matrix and enter outdoor air where they could then be inhaled by outdoor workers. Also, vapors from hydrocarbons in the vadose zone could migrate to the foundation of a building, penetrate the building through cracks in the foundation, and enter indoor air where they could then be inhaled by indoor workers.

Petroleum hydrocarbons have been observed in subsurface, saturated soil at several locations. In general, there is little potential for people to contact petroleum hydrocarbons trapped in soil below the water table. Indirect exposure to petroleum constituents in saturated soil is unlikely because soil that is saturated with water has little air-filled pore space, and this prevents volatile chemicals from partitioning into air and migrating to the soil surface. As mentioned previously, it is conservatively assumed that construction or excavation workers could directly contact soil within 15 feet of the ground surface, even in areas where the water table is typically above this depth.

It should be noted that the DEQ (2003) default exposure assumptions for construction workers assume exposure durations of one year. Many of the properties on the Site are too small to support construction projects that would entail a year of surface or subsurface work where workers could have direct-contact exposures to soil. Although the excavation-worker-exposure scenario is relevant for most of the Site, the construction-worker-exposure scenario is most applicable for large and undeveloped parcels of land that could potentially support large-scale construction projects. To be conservative, the construction-worker-exposure scenario will initially be used to evaluate all properties on the Site.

No residences are present at the Site, and given land-use plans for the area, it is not likely that residences will be developed in the foreseeable future. Although waterfront residential developments (condominiums and single-family residences) have occurred in Astoria east of the Site, all recent developments at the Site have been commercial. It is likely that future developments at the Site will continue to support commercial or industrial operations. However, at the request of DEQ, chemical concentrations in soil were compared with RBCs for urban residents. The pathways screened with urban resident RBCs included direct contact with surface soil (0 to 3 feet bgs), indirect exposure to volatile chemicals in vadose-zone soil that migrate to outdoor air, and indirect exposure to volatile chemicals in vadose-zone soil that migrate to indoor air.

Although chemicals in soil may leach to groundwater, soil-leaching models were not used to evaluate soil conditions in this HHRA. Soil RBCs for the leaching pathway are estimated using models that simulate partitioning of chemicals from soil to groundwater, and they are designed to protect groundwater that is used for drinking (DEQ, 2003). Groundwater at the Site is not used for drinking. Also, empirical data regarding groundwater quality are available to evaluate risks associated with exposure to impacted groundwater. As a result, model estimates of chemical concentrations in groundwater that may result from leaching are not necessary for the risk evaluation because actual groundwater-quality data can be used for this purpose.

4.3.2 Groundwater

As mentioned previously, the City of Astoria supplies municipal water to facilities in and near the Site. Groundwater at the Site is not used for drinking, and given the availability, reliability, and relatively low cost of the public water supply, it is unlikely that drinking water wells will be developed in the foreseeable future. As a result, human receptors such as occupational workers are not likely to ingest or directly contact site-related chemicals in groundwater.

It is assumed that occupational workers could be exposed to volatile hydrocarbons that migrate from groundwater to indoor or outdoor air. It is also assumed that excavation workers could have direct contact with chemicals in groundwater if an excavation were developed below the water table in the northern part of the Site. It should be noted that the Occupational Safety and Health Administration rules require that excavations be dewatered before worker entry. Therefore, it is unlikely that workers will have substantial direct contact with chemicals in groundwater.

As mentioned previously, urban residents are unlikely to occupy properties at the Site in the foreseeable future. However, at the request of DEQ, chemical concentrations in groundwater were compared with RBCs for urban residents. It was assumed that urban residents could be exposed to volatile hydrocarbons that migrate from groundwater to indoor or outdoor air.

4.3.3 Sediment and Surface Water

Petroleum constituents may have impacted sediment and surface water near a seep with LNAPL located in Slip 2, near the shoreline of the Columbia River. Potential risks associated with exposure to petroleum near the seep will be evaluated as part of the ecological risk assessment. For a variety of reasons, it is unlikely that potential human receptors would have significant exposure to petroleum constituents in sediment or surface water near the seep.

The human receptors who appear to have the greatest potential to contact sediment and surface water of the Columbia River are recreationists such as fishers or boaters. The seep area in Slip 2 is located in a part of the Site that is actively used for industrial purposes and that is likely to remain an industrial-use area for the foreseeable future. Recreational uses of the Columbia River near the seep are not compatible with site operations. Given the industrial nature of the Site, recreational fishing, clamming, or crabbing in Slip 2 would be unsafe. As a result, it is unlikely that people will have significant direct contact with impacted sediment.

Dissolved chemicals may migrate to surface water from groundwater or sediment near the seep. Given the small-scale and localized nature of the seep, the relatively small volume of LNAPL that discharges, and the substantial flow of ambient water over the seep area, chemical concentrations in surface water are expected to be low. Due to mixing with ambient water, it is likely that elevated chemical concentrations in surface water would be found only immediately adjacent to impacted sediment. It is unlikely that people would have significant exposure to elevated concentrations of petroleum constituents in surface water.

Several PAHs with relatively high molecular weights are present in impacted sediment. It is possible that some of these PAHs can accumulate in the tissues of some aquatic organisms. Vertebrates, including fish, can metabolize PAHs, and these hydrocarbons have little propensity to accumulate in tissues of vertebrates. As a result, it is not likely that people who catch and consume fish near the Site would have significant exposure to site-related chemicals. However, some invertebrates may accumulate some PAHs in tissues.

For several reasons, it is not likely that recreational fishers would have significant exposure to site-related chemicals in tissues of invertebrates. First, available evidence suggests that impacted sediment is restricted to a relatively small area (approximately 150 feet by 50 feet) of intertidal habitat. Given the small size of the impacted area and its periodic submergence, the population of invertebrate prey species with sufficient long-term exposure to accumulate site-related chemicals in tissues is expected to be small. As mentioned previously, it is not likely that recreational fishers would harvest invertebrates in or immediately adjacent to the impacted area. It is also not likely that recreational fishers would harvest and consume a sufficient number of local invertebrates that have migrated from the impacted area to have significant dietary exposure to site-related chemicals.

In summary, direct-contact exposures with impacted sediment and surface water are considered potentially complete, but insignificant, exposure pathways. Similarly, indirect exposure to site-related PAHs that may accumulate in tissues of invertebrates that are harvested and consumed by fishers is also considered an insignificant exposure pathway. Thus, these exposure pathways are not quantitatively evaluated in this HHRA.

5 RISK CHARACTERIZATION

Consistent with the risk evaluation framework for petroleum-contaminated sites outlined in the RBDM (DEQ, 2003), risk estimates were made by comparing concentrations of COPCs in soil and groundwater with applicable RBCs. As mentioned previously, an RBC is an estimate of the concentration of a chemical in the exposure unit that would not pose unacceptable risks to humans with an RME to impacted soil, groundwater, or air. If the concentration of a COPC is below an applicable RBC, it is inferred that exposure to the chemical will not result in unacceptable human health risks. Alternatively, if concentrations of a COPC are greater than an applicable RBC, either further evaluation of potential health risks may be warranted, or it can be concluded that the contamination may pose unacceptable health risks and requires some form of risk management.

Properties at the Site are used for commercial and industrial purposes, and it is likely that they will continue to be used for commercial and industrial purposes for the foreseeable future. Various workers will have the greatest potential to contact contaminated soil or groundwater. This evaluation focuses on characterizing risks that chemicals in soil and groundwater may pose to occupational workers, occasional excavation workers, and construction workers. However, at the request of DEQ, chemical concentrations in soil and groundwater are also compared with RBCs for urban residents. Comparisons to RBCs for urban residents are discussed in Section 5.5. The remainder of the risk evaluation presented below focuses on risks for potential workers at the Site.

5.1 Risk-Based Concentrations

The RBCs used to evaluate risks associated with potential exposure to soil and groundwater are discussed below. In general, generic DEQ RBCs were selected for most COPCs and most worker exposure scenarios. Site-specific groundwater RBCs were developed for volatile chemicals that may migrate from groundwater to indoor or outdoor air.

5.1.1 Soil RBCs

The DEQ has established generic soil RBCs for all of the soil COPCs, with the exception of heavy-oil-range organics and total chromium (DEQ, 2007). The screening process for total chromium, arsenic, and heavy-oil-range organics is discussed below.

5.1.1.1 Chromium

The DEQ has calculated soil RBCs for chromium III and chromium VI, but not total chromium (DEQ, 2007). Soil RBCs for chromium VI are lower than those for chromium III. It was conservatively assumed that all chromium in soil is chromium VI. The DEQ occupational worker RBC for chromium VI in soil is 180 mg/kg, which is higher than the maximum concentration of total chromium detected in soil. Chromium is not considered a volatile chemical and is not expected to migrate from subsurface soil to indoor or outdoor air.

5.1.1.2 Arsenic

Arsenic was selected as a COPC because concentrations in soil are above the industrial soil PRG that was used as a screening level in COPC selection. The DEQ occupational worker RBC for arsenic in shallow soil is 1.7 mg/kg (DEQ, 2007). Natural background concentrations of arsenic in soil of much of western Oregon are above the Region 9 PRG and the DEQ RBC. Based on the distribution of arsenic concentrations in soil, there is no compelling evidence of significant anthropogenic arsenic contamination. Instead, it appears that the arsenic in soil occurs naturally. For example, the 90th percentile arsenic concentrations for the State of Washington is 7 mg/kg (see Table A-4 in Appendix A), and the value for Clark County, Washington, is 6 mg/kg (Washington State Department of Ecology [Ecology], 1994). As shown in Table A-4 in Appendix A, the 90th percentile arsenic concentration in soil at the Site is 4.6 mg/kg. Similarly, the 95th percentile arsenic concentration in soil of British Columbia, Canada, ranges from 10 to 20 mg/kg, depending on region (British Columbia Ministry of Environment [BCE], 2005). At the Site, the 95th percentile arsenic concentration is 6.7 mg/kg (Table A-4, Appendix A). These results suggest that arsenic in soil at the Site is not elevated above natural background levels of the region.

Of the 77 soil samples analyzed for arsenic, only five had concentrations above the Clark County 90th percentile, two sample results were above the Washington State 90th percentile, and only a single sample result was above a 95th percentile for soil in British Columbia (Table A-4, Appendix A). Given that arsenic concentrations in soil at the Site are consistent with natural background levels and there are no significant known anthropogenic sources of arsenic, arsenic is not considered a site-related hazardous substance.

5.1.1.3 Heavy-Oil-Range Organics

At the time the RI sampling program was developed, the DEQ recommended evaluating risks associated with exposure to petroleum mixtures by focusing on key constituents that were relatively well studied and known to be particularly toxic components of petroleum (American Society for Testing and Materials [ASTM], 1995; DEQ, 1999). Current DEQ (2003) guidance recommends evaluations of individual constituents and of whole petroleum mixtures such as gasoline and diesel. Although the DEQ has developed generic RBCs for gasoline and diesel, RBCs have not been developed for heavy oil. Therefore, potential risks associated with exposure to heavy-oil-range organics will be evaluated using the 1999 RBDM framework by comparing concentrations of key constituents in heavy-oil-range organics (i.e., PAHs) to applicable constituent RBCs. The PRP group initially presented this assessment approach to the DEQ in late 2003, shortly after the most recent RBDM guidance was released.

5.1.2 Groundwater RBCs

There are three scenarios by which workers may have significant exposure to COPCs in groundwater: inhalation of volatile chemicals that migrate to outdoor air, inhalation of volatile chemicals that migrate from groundwater to indoor air, and direct contact with water in an excavation. With the exception of lead, DEQ groundwater RBCs are available for all of the groundwater COPCs. Lead is not considered a volatile hazardous substance (DEQ, 2000; USEPA, 2004c) and is not likely to migrate from groundwater to air in the vapor phase. A DEQ excavation worker RBC has not been developed for lead, and potential risks associated with exposure to lead in groundwater is evaluated in the uncertainty section (Section 6). The DEQ RBCs for excavation workers who may contact groundwater consider two potential exposure routes (DEQ, 2003): workers who have dermal contact with water in an excavation, and workers who inhale volatile chemicals that migrate from water to outdoor air of the excavation. The only significant pathway by which excavation workers may be exposed to lead is through dermal contact with groundwater in an excavation. This is expected to occur infrequently and for short exposure durations, and there do not appear to be any well-established methods for estimating lead risks associated with short-term exposure to water (USEPA, 2003). In general, dermal uptake of waterborne metals is a poorly understood process, and essential information for estimating dermal risks, such as permeability coefficients, are not available for most metals (USEPA, 2004b).

Two metal COPCs were selected for groundwater: arsenic and lead. However, based on the distribution of arsenic and lead concentrations in groundwater (Table A-9, Appendix A), there is no evidence of widespread metals contamination in groundwater. As mentioned previously, arsenic concentrations in soil do not appear to be elevated above natural background levels, and arsenic concentrations in groundwater may not be elevated above natural concentrations. Also, with the exception of monitoring well MW-28, concentrations of lead have not been consistently detected above the USEPA maximum contaminant level (MCL) of 0.015 milligrams per liter (mg/L) (the concentration limit for lead in municipal drinking-water supplies) in any monitoring well at the Site (Table A-9, Appendix A). The concentrations of lead at monitoring well MW-28 have been only slightly above the MCL. Groundwater at the Site is not used for drinking purposes. Given that arsenic may be a naturally occurring element in groundwater at the Site and lead concentrations are infrequently above drinking-water standards, it is unlikely that these metals could pose unacceptable risks to workers who have dermal contact with groundwater in an excavation.

5.1.2.1 Site-Specific Adjustment

The DEQ's RBDM guidance (2003) outlines a process for developing site-specific RBCs when conditions at a site may differ from the assumed DEQ default conditions. Because some soil conditions at the Site differ from DEQ default estimates, site-specific groundwater RBCs were developed for indirect exposure pathways (e.g., volatilization to outdoor air and vapor intrusion into buildings).

The DEQ spreadsheet model system for calculating RBCs was used to estimate site-specific RBCs (Appendix B). Specifically, a site-specific estimate of the thickness of the capillary fringe was used to better estimate RBCs associated with indirect exposure to VOCs in groundwater. The capillary fringe is a zone of partially saturated soil located immediately above the water table. Water enters this zone through the process of capillary attraction, which is an upward force caused, in part, by surface tension at the air-water interface. Because soil in the capillary fringe has a higher water-filled porosity than that of the overlying vadose zone, the thickness of the capillary fringe can have an important effect on vapor migration (i.e., a thicker capillary fringe results in less vapor migration).

The thickness of the capillary fringe (L_{cap}) is a function of soil type. The USEPA (Environmental Quality Management, 2004) presents the following equation to estimate L_{cap}, given groundwater conditions consistent with those found at the Site:

$$L_{cap} = \frac{0.15}{0.2 \times D} \qquad \text{(Equation 3)}$$

Where:

D = Mean soil particle diameter (centimeters [cm])

Sieve analyses were performed on seven soil samples as part of the Phase 1 investigation (EnviroLogic Resources, 2002a). Based on linear interpolation, the median particle diameter in millimeters (mm) for each of the seven soil samples is as follows: 0.21, 0.41, 2.36, 0.15, 0.17, 0.27, and 0.23. The mean of these particle diameter estimates is 0.55 mm or 0.055 cm. The site-specific mean particle diameter estimate is very similar to the USEPA default mean particle diameter of 0.044 cm for sandy soil (Environmental Quality Management, 2004). Using the mean particle diameter from the seven sieve analyses, the estimated capillary fringe thickness is 14 cm.

5.1.3 Soil-Gas RBCs

Soil-vapor sampling was performed outside of the Port office building to determine the potential for volatile COPCs to migrate from impacted media beneath the building into indoor air (EnviroLogic Resources, 2005). These vapor samples were analyzed for petroleum-related VOCs. To aid in interpretation of soil-vapor data, RBCs for soil gas were estimated as follows:

$$RBC_{sg} = \frac{RBC_{air}}{\alpha} \qquad \text{(Equation 4)}$$

Where:

RBC_{sg} = Soil gas RBC in micrograms per cubic meter ($\mu g/m^3$)

RBC_{air} = DEQ's generic occupational worker RBC for air ($\mu g/m^3$)

α = Attenuation factor relating concentrations of volatile chemicals in soil gas with estimated concentrations in indoor air (unitless).

The USEPA advanced soil-gas model (SG-ADV Version 2, 02/04) (USEPA, 2004a) was used to estimate infinite source attenuation factors for petroleum-related VOCs. The attenuation factor is the ratio of the estimated indoor-air concentration over the concentration in soil gas. The initial soil-gas concentration was set to 1 $\mu g/m^3$, and the model was run to estimate the resultant infinite source attenuation factor. The following modeling inputs were used to calculate volatilization factors:

- The average soil/groundwater temperature (T_s) was estimated at 13ºC. This temperature estimate was made by interpolating between isopleths on Figure 8 of the *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings* (Environmental Quality Management, 2004).

- The building construction is slab-on-grade, and the default value of 15 cm was used for the depth below grade to the bottom of the enclosed-space floor (L_F).

- Soil-gas samples were collected approximately 5 feet bgs, and the soil gas sampling depth below grade (L_s) was set to 152 cm.

- The thickness of soil stratum A (h_A) was set to 152 cm in this model, and soil strata B and C thicknesses were set to 0 cm. Soil stratum A was assumed to consist of sand.

- Building dimensions were set at estimates of the first floor length (L_B) of 100 feet (3,048 cm), width (W_B) of 53 feet (1,615 cm), and height (H_B) of 10.5 feet (320 cm), respectively.

- The building indoor air exchange rate was set at the DEQ (2003) default for an occupational setting of two exchanges per hour.

- The crack to building area ratio was set at the DEQ (2003) default value of 0.001 on the "intercalcs" tab of the soil-gas model. USEPA default values were used for other building characteristics such as enclosed-space floor thickness, and soil-building pressure differential.

- The USEPA default estimate of the average vapor flow rate into a building (Q_{soil}) of 5 liters per minute (L/min) is based on studies of residential structures and is not applicable to larger commercial or industrial buildings. Q_{soil} was estimated based on the building floor area, using the following approach that was discussed with the DEQ in a meeting held on May 17, 2006:

$$Q_{soil} = 5\, {}^{L}\!/_{\min} \times \frac{Area(m^2)}{100(m^2)} \qquad \text{(Equation 5)}$$

The resulting estimate of Q_{soil} was 24.6 L/min

Analytical results from soil gas samples were presented by the laboratory in units of parts per billion by volume (ppbv) for most chemicals (Appendix A). Soil gas RBC concentrations in units of µg/m^3 were converted to units of ppbv by using the molecular weight of a chemical.

GRO is a complex mixture of numerous hydrocarbons. The attenuation factor for benzene was used as a surrogate to estimate a conservative soil-vapor RBC for GRO because it is likely that most typical GRO hydrocarbons are less volatile than benzene. The GRO soil-vapor results were presented by the laboratory in units of parts per million by volume (ppmv). The GRO RBC was converted from units of µg/m^3 to ppmv, using a weighted-average GRO molecular weight of 103 grams per mole. This weighted average was calculated using the molecular weights and relative abundance (by mass) of GRO hydrocarbons (i.e., aliphatic and aromatic hydrocarbons with effective carbon numbers ranging from 5 through 12, n-hexane, BTEX, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and naphthalene) in fresh gasoline (DEQ, 2003). Attenuation factors calculated using the USEPA vapor-intrusion model (USEPA, 2004a) and a table with soil-vapor RBCs are presented as Appendix C.

5.2 Soil Risk Results

Tables summarizing analytical results and applicable worker RBCs are included in Appendix A. RBCs are included only for COPCs. Table 5-1 presents analytical results from soil samples where at least one COPC was detected at a concentration greater than an applicable RBC. These exceedances of RBCs are discussed in greater detail below.

5.2.1 Metals

Three metals were selected as COPCs for soil: arsenic, chromium, and lead. As mentioned above, arsenic is not considered a site-related contaminant because arsenic concentrations do not appear to be elevated above natural background levels.

As shown in Table 5-1 and Table A-4 in Appendix A, no soil sample collected at the Site had a concentration of chromium or lead that exceeded an RBC. In fact, very few soil samples had concentrations of chromium or lead that appeared to be elevated above natural background concentrations. As a result, chromium and lead in soil are unlikely to pose unacceptable risks to potential human receptors.

5.2.2 VOCs

Two petroleum-related VOCs were detected in at least one soil sample at a concentration greater than an applicable RBC (Table 5-1): benzene and 1,3,5-trimethylbenzene. These two VOCs were detected at concentrations that exceeded generic DEQ vapor-intrusion RBCs, but no other applicable RBCs.

In AOC 1, four soil samples had a concentration of benzene above the generic DEQ RBC for vapor intrusion into a commercial or industrial building (1.2 mg/kg): SB-602 (7.8 mg/kg), SB-605 (3.2 mg/kg), SB-820 (3.5 mg/kg), and SB-821 (1.3 mg/kg). Also, the concentration of 1,3,5-trimethylbenzene in a soil sample collected at SB-602 (189 mg/kg) was above the generic DEQ vapor-intrusion RBC (Table 5-1).

It appears that there are two separate areas within AOC 1 where concentrations of benzene in subsurface soil are above the generic DEQ vapor-intrusion RBC. One area is near the southern portion of the property boundary between the Niemi Oil cardlock and Qwest facilities, and includes sample locations SB-820 and SB-821 (Figure 5-1). The other area is the north central portion of the Niemi Oil cardlock facility, including sample locations SB-602 and SB-605 (Figure 5-1). No buildings that are commonly occupied by workers are within 50 feet of these locations, and benzene in soil will not pose an unacceptable risk to current workers. It is assumed that a building could be developed over portions of the benzene-impacted soil in the north central portion of the Niemi Oil cardlock facility. However, as explained further below, it is not likely that a building could be developed directly over benzene-impacted soil along the western boundary of the Niemi Oil cardlock facility.

A sewer line right-of-way is present immediately east of the Qwest and Niemi Oil cardlock property boundary and runs parallel to the property boundary. It appears that benzene impacts to subsurface soil in this area are limited to soil immediately adjacent to this utility corridor. Soil samples with benzene concentrations above the DEQ vapor-intrusion RBC (SB-820 and SB-821) were collected at least 5 feet bgs (Table 5-1) near backfill material in the utility corridor. Benzene was not detected in subsurface soil samples collected within approximately 30 feet of the utility corridor (SB-600, SB-632, and SB-407). Benzene impacts may be limited to soil in or very near the utility corridor because the relatively porous fill material in the corridor may have historically provided a preferential migration pathway for gasoline or gasoline-impacted groundwater. Buildings that may limit access to utilities are generally prohibited (Gift, 2006). If a future building is planned for this area, additional investigation may be required to determine if the building could be placed in an area where residual benzene in subsurface soil could pose unacceptable vapor-intrusion risks to indoor workers.

In AOC 2, one of the approximately 22 soil samples collected on or near the former Delphia Oil facilities had a concentration of benzene above the generic vapor-intrusion RBC (Table 5-1). The sample collected from SB-316 at 10 feet bgs at the former Val's Texaco facility had a concentration of benzene of 1.52 mg/kg, which is slightly higher than the generic DEQ RBC (Figure 5-1). No building commonly occupied by workers is within 50 feet of this sample location. The former Val's Texaco building is currently vacant. It appears that the areal extent of benzene-impacted soil is small relative to the footprint of most commercial or industrial buildings. For example, benzene concentrations in several surface and subsurface soil samples collected within approximately 50 feet of SB-316 were below the generic vapor-intrusion RBC. Because typical commercial or industrial buildings at the Site have footprints that are larger than the areal extent of impacted soil, even if a future building were placed directly over SB-316, it appears that only a portion of the building footprint would overlie soil with benzene concentrations above the generic DEQ vapor-intrusion RBC.

In AOC 4, concentrations of benzene in several soil samples collected in the subsurface near the zone with LNAPL were above the generic DEQ vapor-intrusion RBC protective of occupational workers (Table 5-1). Also, a soil sample collected at SB-612 had a concentration of 1,3,5-trimethylbenzene that was above the generic DEQ vapor-intrusion RBC (Figure 5-1). Based on data collected using cone penetration testing during the RI, it appears that most of these samples were collected in or near the smear zone (EnviroLogic Resources, 2008). Two soil samples collected north of the Port shop building (SB-507 and SB-006) and just outside of the inferred LNAPL plume also had benzene concentrations that were above the vapor-intrusion RBC for soil (Figure 5-1). Most of the soil samples with a VOC concentration above a vapor-intrusion RBC were collected in the southern third and the western half of the LNAPL plume (Figure 5-1). In general, this portion of the LNAPL plume comprises a relatively large proportion of gasoline-related hydrocarbons (EnviroLogic Resources, 2008).

5.2.3 PAHs

Three PAHs (benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene) were detected in at least one soil sample at a concentration greater than an applicable RBC

(Table 5-1). Only two soil samples had concentrations of a PAH that exceeded an applicable RBC (Table 5-1): SB-255, collected at 7 feet bgs, and SB-008, collected at 2 feet bgs.

On the former Chevron/McCall bulk plant facility in AOC 3, the concentration of benzo(a)pyrene in the sample collected from SB-255 at 7 feet bgs was above the DEQ construction-worker RBC (Figure 5-1). A shallower soil sample collected at 2.5 feet bgs at SB-255 had concentrations of PAHs that were well below applicable RBCs (Table A-7, Appendix A). As a result, it appears that soil with a concentration of benzo(a)pyrene above an RBC is limited to a discrete subsurface zone that underlies relatively uncontaminated soil.

For a variety of reasons, additional risk-management actions do not appear warranted for soil on the Chevron/McCall facility. First, the soil where benzo(a)pyrene was detected above a construction-worker RBC is located beneath a newly constructed parking lot, and it is unlikely that an excavation will be made in this area for the foreseeable future. Even if a future excavation was made in the area, it is unlikely that the average concentration of benzo(a)pyrene in soil that a construction worker may contact (e.g., exposure concentration) would be above the construction-worker RBC. As mentioned previously, shallow soil in this area (e.g., <3 feet bgs), soil that is more likely to be contacted by construction workers than deeper soil, had a concentration of benzo(a)pyrene that was below the applicable RBC. All other soil samples collected at the facility had concentrations of benzo(a)pyrene that were below the construction-worker RBC. As a result, the area of soil with a concentration of benzo(a)pyrene above a construction-worker RBC appears to be too small and is located too far below the ground surface to pose a significant risk to potential future construction workers.

A sample collected at 2 feet bgs from SB-008 near the Port maintenance building in AOC 4 had concentrations of benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene that were above occupational- and construction-worker RBCs (Figure 5-1). These PAHs were not detected in a sample collected at 7.5 feet bgs, indicating that impacts are restricted to shallow soil (Table 5-1).

5.2.4 DRO

In AOC 2, a soil sample collected at 12 feet bgs from SB-904 on the former Shell Oil Company facility had a concentration of DRO of 23,100 mg/kg that was slightly above the construction-worker RBC of 23,000 mg/kg (Table 5-1 and Figure 5-1). If this maximum detected concentration of DRO in soil at the facility is used to represent the average concentration a worker may contact, the chemical-specific HQ expressed with one significant unit (see DEQ, 2000) is one (i.e., HQ=23,100/23,000=1.004); this chemical-specific risk estimate meets, but does not exceed, the acceptable risk level. In fact, construction workers will not limit their potential exposure activities only to the area with the maximum detected concentration, and the average concentration of DRO a construction worker may contact will be lower than the maximum. For example, most construction work occurs at or near the ground surface, and most excavations extend only a few feet from the ground surface. The concentration of DRO in shallower soil at SB-904 (at 4 feet bgs), soil that is more likely to be encountered than deeper soil, was well below the RBC. Because the only soil with concentrations of DRO above the construction-worker RBC is below the depth of most excavations, and because the spatial extent of DRO impacts above the RBC is small relative to the construction-worker exposure unit, DRO in soil at the facility are not expected to pose unacceptable risks to potential construction workers. Also, as discussed in greater detail in Section 6, construction workers are expected to have acute or subchronic exposure durations, but RBCs for DRO are calculated using chronic toxicity data and overestimate potential risks.

In AOC 4, DRO concentrations in soil samples collected from SB-027, SB-021, and SB-510 were above the construction-worker RBC. All of these samples were collected approximately 10 to 12 feet bgs in what appears to the smear zone in the northeast portion of the inferred LNAPL plume (Figure 5-1).

5.2.5 Heavy-Oil-Range Organics

As mentioned previously, the DEQ has not developed generic RBCs for heavy-oil-range petroleum mixtures. A heavy-oil-range organics screening level of 500 mg/kg was used in COPC selection (see Section 3) because the Site would be classified as a Soil Matrix Level II facility if the Soil Matrix Scoresheet were used to determine cleanup levels for TPH. The Soil Matrix cleanup level is a conservative screening level that is not based on precise risk estimates.

Consistent with the 1999 RBDM approach that was in effect when the RI began, potential risks associated with exposure to heavy-oil-range organics are estimated by comparing concentrations of key petroleum constituents in the heavy-oil range (i.e., PAHs) to applicable chemical-specific RBCs. Specifically, a cumulative risk estimate was made by summing chemical-specific risk estimates for all PAH constituents in soil samples where heavy-oil-range organics concentrations were above 500 mg/kg and SVOC data were also available.

As shown in Table 5-2, a total of 21 soil samples had concentrations of heavy-oil-range organics above the screening level. In ten of these soil samples, analyses were performed for both TPH and PAHs, although PAH COPCs were detected in only eight of the soil samples (Table 5-3). All of the PAH COPCs that were detected in these samples were carcinogens (Table 5-3). One-half of the MRL was used as the concentration of a COPC when the chemical was not detected above the MRL. Chemical-specific lifetime potential excess cancer risks were estimated as follows:

$$LECR = \frac{C_{soil} \times TR}{RBC} \qquad \text{(Equation 6)}$$

Where:

LECR	=	Lifetime excess cancer risk (unitless).
C_{soil}	=	COPC concentration in the soil sample (mg/kg).
TR	=	Target cancer risk level used by the DEQ to calculate RBCs of 1 x 10^{-6}.
RBC	=	DEQ RBC (mg/kg). Occupational worker RBCs were used for soil samples collected 0 to 3 feet bgs, and construction worker RBCs were used for soil samples collected 3 to 15 feet bgs.

As shown in Table 5-3, total potential excess cancer-risk estimates were generally several orders of magnitude below the DEQ acceptable risk level associated with exposure to multiple carcinogens of 1 x 10^{-5}. These results indicate that most of the heavy-oil-range petroleum mixtures at the Site do not contain high concentrations of the relatively toxic key constituents of petroleum.

5.3 Groundwater Risk Results

Four COPCs were detected in groundwater at concentrations greater than an applicable RBC: benzene, 1,2,4-trimethylbenzene, naphthalene, and GRO (Table 5-4). Only generic DEQ RBCs protective of excavation workers who may have direct contact with groundwater were exceeded. As discussed in greater detail in Section 6, the excavation-worker RBCs are calculated using a number of unrealistic assumptions that likely overestimate excavation-worker risks, and risk estimates based on comparisons with these RBCs have considerable uncertainty.

Groundwater samples collected from four monitoring wells in AOC 1 had concentrations of 1,2,4-trimethylbenzene, naphthalene, or GRO above the construction-worker RBC: MW-26, MW-28, MW-29, and MW-30. Two of these monitoring wells are located on the Niemi Oil cardlock facility (MW-26 and MW-28), one is located in the Industry Street right-of-way (MW-29), and one (MW-30) is located on Port property north of the Burlington Northern railroad tracks (Table 5-4 and Figure 5-2).

GRO were detected at a concentration above the construction-worker RBC in a groundwater sample collected from monitoring well MW-13 on the Delphia Oil facility in AOC 3 (Appendix A, Table A-6), but the depth to groundwater at this location is below the depth of most excavations (Table 2-1). As a result, excavation workers are unlikely to contact groundwater at this location, and the exposure pathway is considered incomplete (Figure 4-2).

In AOC 4, groundwater samples collected from three monitoring wells had concentrations of benzene, 1,2,4-trimethylbenzene, naphthalene, or GRO that were above the construction-worker RBC: MW-40, MW-42, and MW-44 (Table 5-4). All three of these monitoring wells are located in the general area where LNAPL is present on groundwater (Figure 5-2).

5.4 Soil Gas Risk Results

Soil-vapor sampling was performed outside of the Port office building to determine the potential for volatile COPCs to migrate from impacted media beneath the building into indoor air (EnviroLogic Resources, 2005). Analytical results of soil-vapor samples are presented in Appendix A, Table A-10. In three soil-vapor sample locations (SVP-01, SVP-02, and SVP-03), concentrations of benzene were above the soil-vapor RBC (Figure 5-3). Concentrations of GRO were also above the soil-vapor RBC in soil-vapor sample SVP-01. No other VOCs were detected in soil vapor at concentrations that exceeded a soil-vapor RBC (Table 5-5).

Based in part on the exceedances of soil-vapor RBCs in some soil-vapor samples collected outside of the Port office building, a sub-slab vapor investigation was performed for the building. The purpose of the sub-slab vapor investigation was to better characterize potential vapor intrusion risks by measuring concentrations of volatile petroleum constituents in soil gas immediately beneath the Port office building. The sub-slab vapor investigation is presented as Appendix H of the RI report (EnviroLogic Resources, 2008), and findings of the investigation are briefly summarized below.

Sub-slab soil gas samples were collected at several locations throughout the Port office building during sampling events performed in July 2005 and September 2006. The highest concentrations of volatile petroleum hydrocarbons in sub-slab soil gas were detected in the southwestern portion of the building. Maximum concentrations of TPH-g and benzene in sub-slab soil gas were slightly above site-specific sub-slab soil gas RBCs, but maximum concentrations of all other constituents of concern were below RBCs. Area-weighted average exposure concentrations were calculated to better estimate soil gas concentrations beneath the entire Port building. Average exposure concentrations of TPH-g and benzene in sub-slab soil gas were below their respective RBCs. Results of the investigation found that sub-slab soil gas concentrations beneath the Port office building are unlikely to pose an unacceptable risk to occupational workers.

5.5 Urban Residents

At the time the HHRA Work Plan was submitted (MFA, 2005), a four-unit apartment complex was located on West Marine Drive just west of the Harris/Van West property (Figure 2-2). This apartment complex was recently demolished, and this property will likely be redeveloped for commercial uses. Given current zoning, land-use plans, and development trends, it is not likely that single- or multi-family residences will be developed at the Site in the foreseeable future. Although the urban resident scenario is not reasonably likely in the foreseeable future, at the request of DEQ, concentrations of chemicals in soil and groundwater were compared with RBCs for urban residents. Comparisons of soil and groundwater sample results with RBCs for urban residents are presented in Appendix D and briefly summarized below.

Concentrations of GRO and DRO in both surface and subsurface soil samples are compared to urban resident RBCs in Table D-1 of Appendix D. SVOC data for soil are presented in Table D-2, VOC data for soil in Table D-3 of Appendix D, and metals data for soil in Table D-4 of Appendix D. For groundwater, concentrations of GRO and DRO are presented in Table D-5 of Appendix D, and SVOC and VOC data are presented in Table D-6 and D-7, respectively.

Applying RBCs for urban residents to properties at the Site that are used for commercial and industrial purposes is unlikely to significantly change risk conclusions. With a few exceptions, the same areas where petroleum-related chemicals in soil and groundwater were above worker RBCs have concentrations above urban resident RBCs. Because RBCs for urban residents are generally lower than those for workers, the number of samples where concentrations were above an urban resident RBC is greater than the number of exceedances of worker RBCs. The general areas where chemical concentrations in soil and groundwater were above urban resident RBCs are described for each AOC below.

5.5.1 AOC 1

On the Niemi Oil cardlock facility in AOC 1, concentrations of petroleum-related VOCs and GRO in subsurface soil were above urban resident RBCs for vapor intrusion into a building (Table 5-6). As discussed in Section 5.2 above, concentrations of benzene in soil are also above the vapor intrusion RBC for occupational workers, and vapor intrusion into a future building has already been identified as an exposure pathway of concern on the property.

Concentrations of benzene in groundwater at monitoring wells MW-28, MW-29, MW-30, and MW-31 were above the urban resident RBC for vapor intrusion into a building (Table 5-7). As mentioned previously, concentrations of some petroleum-related chemicals were above excavation worker RBCs in groundwater samples from MW-30 (Section 5.3). However, applying urban resident RBCs to the commercial properties within AOC 1 would create a new exposure pathway of concern because VOC concentrations are below vapor intrusion RBCs for current and reasonably likely future occupational workers.

The concentration of benzo(a)pyrene in soil collected from sample SB-408 at 2.5 feet bgs was slightly above the urban resident soil RBC for direct contact. Applying urban resident soil RBCs to the commercial property where SB-408 was collected could create a new pathway of concern because PAH concentrations in surface soil are below direct contact RBCs for current and reasonably likely future occupational workers.

5.5.2 AOC 2

Concentrations of VOCs and GRO in soil on or near the former Delphia Oil facilities in AOC 2 were above urban resident RBCs for vapor intrusion into a future building (Table 5-6). Also, concentrations of benzene in groundwater at MW-13 were above the urban resident RBC for vapor intrusion into a future building (Table 5-7). As discussed in Section 5.2, vapor intrusion into a future building has already been identified as an exposure pathway of concern on the property.

Concentrations of GRO in three subsurface soil samples collected on the former Shell Oil Company facility in AOC 2 were above the urban resident RBCs for vapor intrusion into a building (Table 5-6). Applying urban resident RBCs to this commercial property would create a new exposure pathway of concern because GRO concentrations in soil are below vapor intrusion RBCs for current and reasonably likely future occupational workers.

5.5.3 AOC 3

On the former Chevron/McCall bulk plant facility in AOC 3, concentrations of benzo(a)pyrene and dibenzo(a,h)anthracene in the sample collected from SB-254 at 2 feet bgs, and benzo(a)pyrene at SB-255 at 2.5 feet bgs, were above urban resident direct contact RBCs (Table 5-6). Consistent with development trends at the Site, this area was redeveloped as a large commercial facility (Englund Marine and Industrial Supply, Inc.) after the above soil samples were collected. Given that a large new commercial facility was recently built, it is unlikely that the property will redeveloped to support residences in the foreseeable future.

5.5.4 AOC 4

Concentrations of petroleum-related VOCs and GRO were above urban resident vapor intrusion RBCs in several soil (Table 5-6) and groundwater (Table 5-7) samples collected in and near the zone with LNAPL in AOC 4. In addition, GRO and 1,2,4-trimethylbenzene concentrations were above urban resident volatilization to outdoor air RBCs in several soil samples. As discussed in Sections 5.2, 5.3, and 5.4, vapor intrusion into a future building has already been identified as an exposure pathway of concern for portion of AOC 4 with LNAPL in the subsurface. Concentrations of one or more PAHs were above the urban resident direct contact RBCs in samples collected from SB-008 at 2 feet bgs, SB-627 at 2 feet bgs, and SB-720 feet bgs. Applying urban resident RBCs to commercial and industrial properties in AOC 4 would create two new exposure pathways of concern because COI concentrations in soil are below volatilization to outdoor air and direct contact RBCs for current and reasonably likely future occupational workers.

5.6 Hot-Spot Evaluation

The DEQ's Environmental Cleanup Rules (Oregon Administrative Rules [OAR] 340-122) specify that the balancing factors used in remedy selection be weighted differently for areas considered hot spots of contamination compared to areas that are not hot spots. The criteria for determining groundwater hot spots differ from those for media other than water (DEQ, 1998).

Three conditions are used to determine hot spots of contamination in media other than water (OAR 340-122-115(31)(b)). These three conditions are termed "highly concentrated" material, "highly mobile" contamination, and contamination that is "not reliably containable" (DEQ, 1998). Highly concentrated soil hot spots are defined as areas where site-related chemicals are present at levels exceeding RBCs corresponding to 100 times the acceptable risk level for human exposure to each individual carcinogen, and ten times the acceptable risk level for human exposure to each individual noncarcinogen (DEQ, 1998). As shown in Table 5-1, no single carcinogen was detected in soil at a concentration greater than 100 times an applicable RBC, and no noncarcinogen was detected in soil at a concentration greater than ten times an applicable RBC. As a result, no highly concentrated hot spots were identified for soil.

The DEQ typically assumes that direct exposure to LNAPL represents an unacceptable risk (DEQ, 2003), and that zones with a significant volume of LNAPL represent "highly mobile" hot spots (DEQ, 1998). Three areas with LNAPL have been observed at the Site. As mentioned previously, a zone of LNAPL is present in AOC 4. LNAPL is also present in sediment near a seep in Slip 2 near the shoreline of the Columbia River, and a petroleum sheen has been observed on the water surface near the seep. Finally, LNAPL has been identified in monitoring well MW-15A at the former Delphia Oil facility. These three areas with LNAPL may be considered highly mobile hot spots.

For groundwater, a hot spot exists if a hazardous substance is having a significant adverse effect on the beneficial uses of that resource, and if restoration or protection of the beneficial use can occur within a reasonable amount of time. Because it must be feasible to treat areas of contaminated groundwater before they are considered hot spots, hot spots will be characterized as part of the FS. However, a preliminary evaluation of hot spots in groundwater is described below.

As mentioned previously, shallow groundwater at the Site is not used as a source of drinking water and is unlikely to be used as a water-supply source in the foreseeable future. Consistent with DEQ guidance (DEQ, 1998), preliminary hot spots in groundwater are defined as areas where COPC concentrations are above applicable RBCs (e.g., construction/excavation worker).

Groundwater samples collected from four monitoring wells (MW-26, MW-28, MW-29, and MW-30) in AOC 1, and from three monitoring wells (MW-40, MW-42, and MW-44) in AOC 4, had concentrations of at least one COPC that were above an applicable construction-worker RBC. These two zones of groundwater contamination are considered preliminary hot spots, and final hot spot determinations will be made in the FS.

5.7 Risk Summary

Based on risk estimates made using analytical results of soil, groundwater, and soil-gas samples, there are several discrete areas with chemical impacts that may pose unacceptable risks to workers. These relatively well-defined areas are discussed below.

5.7.1 AOC 1

In the north central portion of the Niemi Oil cardlock facility, the concentrations of benzene in subsurface soil are above the generic DEQ vapor-intrusion RBC. Although there currently are no buildings near this location, it is assumed that a building could be developed over benzene-impacted soil in this area at some time in the future. As a result, it is assumed that the benzene-impacted soil has the potential to pose unacceptable risks to indoor workers of a hypothetical building in the north central portion of the facility.

Benzene was also detected above the DEQ generic vapor-intrusion RBC in subsurface soil samples collected in the southern portion of the Niemi Oil cardlock facility near the property boundary with the Qwest facility. However, benzene-impacted soil in this area appears to be associated with the utility corridor, and it is unlikely that a building will be developed over this utility corridor in the foreseeable future. If a future building is planned for this area, additional investigation may be required to determine if the building could be placed in an area where residual benzene in subsurface soil could pose unacceptable vapor-intrusion risks to indoor workers.

Shallow groundwater beneath some portions of the Niemi Oil cardlock facility has concentrations of 1,2,4-trimethylbenzene, naphthalene, or GRO above excavation-worker RBCs. Also, groundwater from monitoring well MW-30 located on Port property north of the Burlington Northern railroad tracks had concentrations of naphthalene and GRO above excavation-worker RBCs.

5.7.2 AOC 2

One soil sample collected at the former Delphia Oil Val's Texaco facility had a concentration of benzene above the generic vapor-intrusion RBC (Figure 5-1). There are no buildings commonly occupied by workers within 50 feet of this sample location. It appears that the areal extent of benzene-impacted soil is small relative to the footprint of most commercial or industrial buildings, and only a portion of any future building would overlie soil with benzene concentrations above the generic DEQ vapor-intrusion RBC.

LNAPL has been identified on groundwater beneath the Delphia Oil bulk facility. The zone with LNAPL contamination may be considered a hot spot.

5.7.3 AOC 4

Petroleum-related chemicals in soil, groundwater, and soil gas of the portion of AOC 4 with LNAPL can pose unacceptable risks to workers. Concentrations of benzene in several subsurface soil samples collected in what appears to be the smear zone were above the generic DEQ vapor-intrusion RBC protective of occupational workers (Table 5-1). Similarly, concentrations of benzene in soil-gas samples collected over the LNAPL zone were above soil-gas RBCs protective of workers who may inhale benzene in the indoor air of a building (Table 5-1). At present, the Port office building is the only existing building overlying the LNAPL plume that routinely houses workers. Results of a subslab-vapor investigation for the Port office building indicate that potential vapor intrusion is unlikely to pose unacceptable risks to current occupational workers in the building. However, in the portion of AOC 4 with LNAPL, it is assumed that volatile chemicals in the subsurface can pose unacceptable risks to workers in a future building through the vapor intrusion pathway.

It should be noted that several risk-management actions have been implemented to limit current worker exposures to vapors that may migrate from the subsurface. For example, upgrades have been made to the building's air management system to create positive pressure within the building relative to without, and this pressure gradient is intended to limit vapor migration into the building.

New Port office buildings are planned on the former bulk plant property, some of which will be located over the LNAPL plume. DEQ-approved interim remedial measures will be implemented at the time of construction to mitigate risks that impacted soil or groundwater may pose to excavation workers or future building occupants. These remedial measures may include a Contaminant Media Management Plan and a sub-slab vapor barrier.

In addition to exceedances of vapor-intrusion RBCs, concentrations of DRO in soil samples collected from the smear zone in the northeast portion of the inferred LNAPL plume were above the construction-worker RBC. Also, groundwater samples collected from monitoring wells in the general area where LNAPL is present on groundwater had concentrations of benzene, 1,2,4-trimethylbenzene, naphthalene, or GRO that were above the construction-worker RBC. As a result, petroleum-related chemicals in the area with LNAPL may also pose unacceptable risks to potential construction workers, and the zone of LNAPL may be considered a hot spot.

A surface-soil sample collected near the Port maintenance building had concentrations of benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene that were above occupational- and construction-worker RBCs (Figure 5-1). The source of PAH impacts at this location is likely different from the source(s) of LNAPL in AOC 4.

6 UNCERTAINTY ANALYSIS

Uncertainty is inherent in many aspects of the risk-assessment process. A semi-quantitative approach for evaluating uncertainty is recommended by the USEPA (1989). The approach involves listing identifiable uncertainties associated with the parameters used to calculate risks, then gauging both the magnitude and direction of potential bias (i.e., over- or underestimation of actual risk) for each type of uncertainty.

Risk estimates are calculated by combining site data, assumptions about human exposures to impacted media, and toxicity data. The multitude of conservative assumptions used in this risk assessment means that the risk estimates are virtually assured to be overestimated. The uncertainties in a risk assessment can be grouped into the following main categories:

- Environmental sampling and analysis
- Environmental transport modeling
- Exposure assumptions
- Toxicity data and dose-response evaluations
- Combinations of sources of uncertainty

With few, if any, exceptions, when substantial uncertainty was associated with a variable used in modeling or risk estimation, health-protective approximations of this variable were employed in this HHRA. As a result, risks are likely to be overestimated. The uncertainties in each of the above categories are discussed in greater detail below.

6.1 Environmental Sampling and Analysis

The soil-sampling program focused on characterizing the nature and extent of contamination associated with features of potential concern. Soil sampling was focused in areas that were most likely to be contaminated as a result of historical operations. The sampling program was biased and includes a disproportionate number of samples from contaminated locations. If potential receptors move over an entire property and are equally likely to visit contaminated and uncontaminated areas, biased sampling is likely to result in overestimates of the concentrations of chemicals that workers are likely to contact.

Data quality can be compromised by errors that occur in the field during sampling, errors in laboratory analysis, or errors in data entry and analysis. Data-quality-assurance reviews lower the frequency of these types of errors. Also, the effects of these sorts of errors on risk estimates are likely to be low. In general, errors that occur during sampling and laboratory analysis are random and unbiased. As a result, these types of errors could lead to either an underestimate or an overestimate of risks.

6.2 Environmental Transport Modeling

Modeling was performed by the DEQ to estimate RBCs for the exposure scenarios involving indirect exposure to volatile chemicals that migrate from soil or groundwater to indoor and outdoor air (DEQ, 2003). The methods that were used to calculate the volatilization factors incorporate several assumptions that, on the whole, probably result in a significant overestimation of the loss of volatile COPCs from soil and groundwater to air. For example, the transport models do not account for biodegradation processes that are likely to reduce the amount of volatile petroleum constituents that migrate from soil to indoor or outdoor air.

The only groundwater COPCs detected above applicable RBCs are volatile petroleum constituents, and the only RBCs that were exceeded were those for excavation workers who may directly contact groundwater in an excavation. It is likely that only concentrations of volatile chemicals are above the excavation-worker RBC because of the unrealistic nature in which groundwater excavation-worker RBCs are calculated for these chemicals. For example, to estimate the concentrations of volatile chemicals that migrate from groundwater to outdoor air in an excavation, the DEQ uses a volatilization factor that represents the average emission of vapors into a home from typical domestic uses of water such as regular showering and dishwashing (DEQ, 2003). For a variety of reasons, the assumption that volatilization from tap water into indoor air of a home is similar to volatilization from groundwater into outdoor air of an excavation likely results in overestimation of inhalation exposures to volatile COPCs by excavation workers.

DEQ (2003) guidance for managing petroleum-contaminated sites outlines a process for developing site-specific RBCs when conditions at a site may differ from the assumed DEQ default conditions. Some soil conditions at the Site differ from DEQ default estimates. For example, the water content of soil at the Site appears to differ from that assumed by the DEQ to calculate generic RBCs (MFA, 2005). The DEQ uses the estimate of water-filled porosity of vadose-zone soil given in ASTM (1995) risk-based corrective-action guidance. The ASTM estimate of water-filled porosity is intended as a conservative value that is appropriate for developing screening values around the nation. Average annual precipitation in Astoria, Oregon, is high relative to most other parts of the country, and based on soil-moisture data, estimates of water-filled porosity of vadose-zone soil appears to be higher than the DEQ default estimate (MFA, 2005). At the request of the DEQ, available site-specific information regarding the water content in soil was not used to evaluate the vapor-intrusion exposure scenarios. It is likely that vapor-intrusion RBCs calculated using site-specific water-filled porosity estimates would be higher than generic DEQ RBCs, and the use of generic DEQ RBCs results in overestimates of vapor-intrusion risks.

6.3 Exposure Assessment

The exposure assessment is based on a number of assumptions with varying degrees of uncertainty. Uncertainties can arise from the types of exposures examined, intake assumptions, and the concentrations of COPCs at the points of human exposure.

6.3.1 Exposure Scenarios

The process of selecting exposure pathways that attempt to identify the most probable, potentially harmful exposure scenarios is often based on best professional judgment. In a risk assessment, risks sometimes are not calculated for all the exposure pathways that can occur, possibly causing some underestimation of risk. For example, risks are not estimated for occasional site visitors because it is likely that visitors would have lower exposures than on-site workers.

6.3.2 Intake Assumptions

DEQ RBCs were calculated using RME estimates. In general, the RME intake assumptions represent upper-bound exposure probabilities and make it likely that the calculated risks are overestimated.

Some of the exposure assumptions for the construction- and excavation-worker scenarios appear to be particularly conservative and likely result in significant overestimates of risks associated with contacting groundwater. For example, the Occupational Safety and Health Administration rules require that excavations be dewatered before worker entry. However, DEQ RBCs are calculated assuming that workers enter excavations with water and that the head, hands, forearms, and lower legs of a worker are wet for four hours each workday (DEQ, 2003). It is likely that the assumed skin-surface area that is wet, groundwater-exposure frequency, and the groundwater-exposure-event time result in significant overestimates of potential dermal exposures.

A groundwater RBCs was not developed for lead, which could result in underestimates of risks for construction and excavation workers who directly contact groundwater. The only significant pathway by which workers may be exposed to lead is through dermal contact with groundwater in an excavation. As mentioned previously, important information for estimating dermal risks, such as permeability coefficients, is not available for most metals (USEPA, 2004b). However, because there does not appear to be widespread metals contamination at the Site and dermal contact with groundwater in an excavation is expected to occur infrequently and for short exposure durations, it is unlikely that exposure to groundwater will result in unacceptable risks to workers.

6.4 Toxicity Data and Dose-Response Evaluation

The availability and quality of toxicological data used to calculate RBCs are another source of uncertainty in this HHRA. Uncertainties in animal and human studies are considered in establishing toxicity criteria. Extrapolation of toxicological data from animal studies to humans is one of the largest sources of uncertainty in a risk assessment. There may be important, but unidentified, differences in uptake, metabolism, and distribution of chemicals within the bodies of test species and humans. In establishing noncarcinogenic toxicity criteria, conservative multipliers, known as uncertainty factors, are used to account for these differences. For example, the chronic oral reference dose (RfD) established for ethylbenzene used an uncertainty factor of 1,000 (USEPA, 2006). This means that the lowest dose corresponding to an adverse effect was reduced even further by a factor of 1,000, effectively increasing the assumed toxicity 1,000 times over that which was actually measured.

Chronic RfDs for noncarcinogens are meant to represent a daily exposure level that is likely to be without an appreciable risk of deleterious effects during a lifetime. In the case of construction and excavation workers, chronic RfDs were used to estimate risks associated with subchronic exposures for most COPCs. The use of chronic RfDs to estimate risks for construction and excavation workers who have only acute or subchronic exposures to soil and groundwater results in overestimates of risks.

Uncertainty due to extrapolation of animal tests to humans is often more prominent for potentially carcinogenic chemicals than for noncarcinogenic ones. This is because the USEPA often uses the linearized multistage model (LMS) for evaluating animal test results. The LMS is used to extrapolate data from the high exposure levels typically used in animal studies to the lower levels corresponding to a one-in-one-million chance of developing cancer, and is based on the assumption that there is no threshold for carcinogenic effects. At high levels of exposure there may indeed be a risk of cancer, regardless of whether or not the effect occurs via a threshold mechanism. However, at the low levels of exposure evaluated in this assessment, physiological mechanisms in the human body are often present to reduce the risk of cancer. Therefore, use of the slope factor (SF) derived by the LMS provides a high level of confidence that the potential risk of developing cancer will not be underestimated.

Toxicity data in the Integrated Risk Information System (IRIS) were used by the DEQ to calculate RBCs when available. In several cases, no data from IRIS were available, but toxicity data from other sources such as the National Center for Environmental Assessment were available. It is unlikely that these alternative toxicity data have undergone the rigorous and open scientific review that data in IRIS undergo. Therefore, it can be reasonably inferred that risk estimates for these chemicals have greater uncertainty than estimates based on IRIS toxicity data.

As discussed in Section 3, no appropriate toxicity data were available to evaluate risks associated with exposures to 4-ispropyltoluene, benzo(g,h,i)perylene, 2-methylnaphthalene, phenanthrene, heavy-oil-range organics, and total chromium. The lack of appropriate toxicity data for these chemicals may lead to an underestimate of total risks.

6.5 Combinations of Sources of Uncertainty

Uncertainties from the sources discussed above are compounded in the derivation of a single value of risk. For example, if a person's daily intake rate for a chemical is compared with an SF to determine potential health risks, the uncertainties (typically all conservative) in the concentration measurements, exposure assumptions, and toxicity criteria are all expressed in the result. By combining conservative values for all of these parameters, the resulting risk estimate is likely to overestimate actual risk.

7 CONCLUSIONS

This HHRA evaluated potential risks that chemicals in soil and groundwater at the Site may pose to potential human receptors. Some of the important findings of the HHRA are discussed below.

Contaminants at the Site consist primarily of petroleum-related hydrocarbons. With the exception of a few metals, all of the COPCs in soil and groundwater were petroleum mixtures or petroleum-related constituents. Although some metals were identified as COPCs, there is no evidence of significant metals contamination in soil or groundwater.

Various workers are the human receptors with the greatest potential to contact COPCs in soil or groundwater. These workers include occupational workers, occasional excavation workers, and construction workers. Groundwater at the Site is not used as a source of drinking water and is not likely to be used as a water-supply source in the foreseeable future. The exposure scenarios evaluated include:

- Occupational workers who directly contact surface soil (less than 3 feet bgs).
- Occupational workers who may have indirect exposure to volatile chemicals that migrate from subsurface soil or groundwater to outdoor air.
- Occupational workers who may have indirect exposure to volatile chemicals that migrate from subsurface soil or groundwater to indoor air.
- Construction and excavation workers who directly contact soil or groundwater within 15 feet of the ground surface.

Risk estimates were made by comparing concentrations of COPCs in soil and groundwater with applicable RBCs. In general, generic DEQ RBCs were used for most COPCs and most exposure scenarios. Site-specific groundwater RBCs were developed for volatile chemicals that may migrate from groundwater to indoor or outdoor air. If the concentration of a COPC is below an applicable RBC, it is inferred that exposure to the chemical will not result in unacceptable human-health risks. Alternatively, if concentrations of a COPC are greater than an applicable RBC, either further evaluation of potential health risks is warranted or it can be concluded that the contamination may pose unacceptable health risks and may require some form of risk management.

The primary findings of the HHRA are as follows:

- Metal COPCs in soil and groundwater are not expected to pose unacceptable risks to various workers at the Site.

- In the portion of AOC 4 with LNAPL, petroleum-related chemicals in the subsurface may pose unacceptable risks to construction workers. Concentrations of DRO in soil samples collected from the smear zone in the northeast portion of the inferred LNAPL plume were above the construction-worker RBC. Groundwater samples collected from monitoring wells in the general area where LNAPL is present on groundwater also had concentrations of benzene, 1,2,4-trimethylbenzene, naphthalene, or GRO that were above the construction-worker RBC.

- Concentrations of benzene in both subsurface soil samples and soil-gas samples collected over the LNAPL zone in AOC 4 were above RBCs protective of workers who may inhale benzene in the indoor air of a building. At present, the Port office building is the only existing building overlying the LNAPL plume that routinely houses workers. Results of a subslab-vapor investigation for the Port office building indicate that potential vapor intrusion is unlikely to pose unacceptable risks to current occupational workers in the building. However, in the portion of AOC 4 with LNAPL, it is assumed that volatile chemicals in the subsurface can pose unacceptable risks to workers in a future building.

- A surface soil sample collected near the Port maintenance building had concentrations of benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene that were above occupational- and construction-worker RBCs.

- Concentrations of benzene in subsurface soil were above the generic DEQ vapor-intrusion RBC for occupational workers in the north central portion of the Niemi Oil cardlock facility, and near a utility corridor along the boundary between the Niemi Oil cardlock and Qwest properties. No building is currently located in these areas. It is assumed that the benzene-impacted soil in the north central portion of the Niemi Oil cardlock facility has the potential to pose unacceptable risks to workers of a hypothetical future building; however, it is not likely that a building would be developed over the utility corridor.

- Shallow groundwater beneath some portions of the Niemi Oil cardlock facility had concentrations of 1,2,4-trimethylbenzene, naphthalene, or GRO above construction-worker RBCs. Also, groundwater samples from monitoring well MW-30, located on Port property north of the Burlington Northern railroad tracks, had concentrations of naphthalene and GRO above construction-worker RBCs.

- One soil sample collected at the Delphia Oil facility had a concentration of benzene above the generic vapor-intrusion RBC for occupational workers. However, it appears that the areal extent of benzene-impacted soil is small relative to the footprint of most commercial or industrial buildings, and only a portion of any future building would overlie soil with benzene concentrations above the generic DEQ vapor-intrusion RBC.

- No highly-concentrated hot spots were identified for soil.

- Three zones of LNAPL may be considered highly mobile hots: LNAPL in AOC 4, LNAPL seep in Slip 2, and LNAPL at the Delphia Oil site.

- Groundwater samples collected from four monitoring wells (MW-26, MW-28, MW-29, and MW-30) in AOC 1, and from three monitoring wells (MW-40, MW-42, and MW-44) in AOC 4, had concentrations of at least one COPC that were above an applicable construction-worker RBC. These two zones of groundwater contamination are considered preliminary hot spots, and final hot spot determinations will be made in the FS.

- Given current zoning, land-use plans, and development trends, it is not likely that single- or multi-family residences will be developed at the Site in the foreseeable future. However, at the request of DEQ, concentrations of chemicals in soil and groundwater were compared with RBCs for urban residents. In general, applying RBCs for urban residents to properties at the Site that are used for commercial and industrial purposes is unlikely to significantly change risk conclusions. With a few exceptions, the same areas where petroleum-related chemicals in soil and groundwater were above worker RBCs have concentrations above urban resident RBCs. However, some new exposure pathways of concern are created if urban resident RBCs are applied to some of the commercial and industrial properties at the Site.

LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

REFERENCES

API. 2002. Evaluating hydrocarbon removal from source zones and its effect on dissolved plume longevity and magnitude. Publication No. 4715. American Petroleum Institute. September.

ASTM. 1995. Standard guide for risk-based corrective action applied at petroleum release sites. Designation E 1739-95. American Society for Testing and Materials.

BCE. 2005. Protocol for contaminated sites 4, determining background soil quality. British Columbia Ministry of Environment. http://wlapwww.gov.bc.ca/epd/epdpa/contam_sites/policy_procedure_protocol/protocols/background_soil.html (August).

DEQ. 1998. Guidance for identification of hot spots. Oregon Department of Environmental Quality, Waste Management and Cleanup Division. April 23.

DEQ. 1999. Risk-based decision making for the remediation of petroleum-contaminated sites. Oregon Department of Environmental Quality, Land Quality Division. September 29.

DEQ. 2000. Guidance for conduct of deterministic human health risk assessments. Final. Oregon Department of Environmental Quality. May.

DEQ. 2003. Risk-based decision making for the remediation of petroleum-contaminated sites. Oregon Department of Environmental Quality, Land Quality Division. September.

DEQ. 2005. Comments on RI/FS work plan addendum, human health risk assessment work plan, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon, DEQ ECSI File #2277. Oregon Department of Environmental Quality. December 8.

DEQ. 2006. Response to comments on RI/FS work plan addendum, human health risk assessment work plan, and sub-slab sampling results, Port of Astoria office building, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon, DEQ ECSI File #2277. Oregon Department of Environmental Quality. May 9.

DEQ. 2007. Risk-based concentration for individual chemicals spreadsheet. Oregon Department of Environmental Quality, Land Quality Division. March 20.

Ecology. 1994. Natural background soil metals concentrations in Washington State. Publication #94-115. Washington State Department of Ecology, Olympia, Washington. October.

EnviroLogic Resources 2002a. Technical memorandum, phase 1 source/soil characterization, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. January 30.

EnviroLogic Resources. 2002b. RI/FS and IRMA development work plan, phase 1, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. July 15.

EnviroLogic Resources. 2003a. Technical memorandum, phase 1 source/soil characterization, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. January.

EnviroLogic Resources. 2003b. Technical memorandum, beneficial land and water use surveys, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. February 21.

EnviroLogic Resources. 2003c. Memorandum, quality assurance/quality control review, June 19, 2003 water samples, Astoria area wide site. EnviroLogic Resources, Inc. June.

EnviroLogic Resources. 2004a. Technical memorandum, quarterly ground-water monitoring, fourth quarter 2003—1st round, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. March.

EnviroLogic Resources. 2004b. Technical memorandum, quarterly ground-water monitoring, first quarter 2004—2nd round, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. April.

EnviroLogic Resources. 2004c. Technical memorandum, quarterly ground-water monitoring, second quarter 2004—3rd round, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. August.

EnviroLogic Resources. 2004d. Technical memorandum, phase 2 source/soil characterization, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. November.

EnviroLogic Resources. 2004e. Technical memorandum, quarterly ground-water monitoring, third quarter 2004—4th round, remedial investigation/feasibility study, Astoria area-wide petroleum site, Astoria, Oregon. EnviroLogic Resources, Inc. November.

EnviroLogic Resources. 2005. Technical memorandum, vapor intrusion pathway assessment, Port of Astoria office building, Astoria area-wide petroleum site, Astoria, Oregon, DEQ ECSI File #2277. EnviroLogic Resources, Inc. April 29.

EnviroLogic Resources. 2008. Remedial investigation report, Astoria area-wide petroleum site, Astoria, Oregon, DEQ ECSI File #2277. EnviroLogic Resources, Inc.

Environmental Quality Management. 2004. User's guide for evaluating subsurface vapor intrusion into buildings. Prepared for U.S. Environmental Protection Agency. Environmental Quality Management, Cambridge, Massachusetts. February 22.

Gift, T. 2006. Telephone communication (re: building over utility corridors.) with M. Novak, Maul Foster & Alongi, Inc., Portland, Oregon. July 19.

MFA. 2005. Human health risk assessment work plan, Astoria area-wide petroleum site, Astoria, Oregon, DEQ ECSI File #2277. Prepared for EnviroLogic Resources, Inc. Maul Foster & Alongi, Inc., Portland, Oregon. October 6.

MFA. 2006. Letter (re: response to DEQ comments regarding human health risk assessment work plan for the Astoria area-wide petroleum site) to T. Calabrese, EnviroLogic Resources, Inc., Portland, Oregon, from J. Peterson, Maul Foster & Alongi, Inc., Portland, Oregon. February 14.

USEPA. 1989. Risk assessment guidance for Superfund. Vol. 1, human health evaluation manual (Part A). Interim final. EPA/540/1Ä89/002. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. December.

USEPA. 1993. Risk assessment: technical guidance manual, selecting exposure routes and contaminants of concern by risk-based screening. EPA/903/R-93-001. U.S. Environmental Protection Agency, Region 3. January.

USEPA. 2003. Assessing intermittent or variable exposures at lead sites. EPA-540-R-03-008. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. November.

USEPA. 2004a. Johnson and Ettinger model for subsurface vapor intrusion into buildings. U.S. Environmental Protection Agency. Waste and Cleanup Risk Assessment. http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm

USEPA. 2004b. 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, Office of Superfund Remediation and Technology Innovation, Washington, DC. July.

USEPA. 2004c. Region 9 preliminary remediation goals (PRGs) 2004. S. J. Smucker, Ph.D., regional toxicologist, technical support team, U.S. Environmental Protection Agency. October 1.

USEPA. 2006. Integrated risk information system. U.S. Environmental Protection Agency. http://www.epa.gov/iris. June 15.

TABLES

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-1(F)	10/13/2003	1142	1.5	31.71	np	23.44	0	8.27	
	10/22/2003	820	0.62	31.71	np	23.87	0	7.84	
	11/12/2003	1130	0.56	31.71	np	23.03	0	8.68	
	12/16/2003	1358	0.34	31.71	np	17.25	0	14.46	
	1/11/2004	1628	4.26	31.71	np	16.33	0	15.38	
	1/15/2004	800	3.86	31.71	np	16.21	0	15.50	
	2/12/2004	945	-2.53	31.71	np	15.61	0	16.10	
	3/18/2004	1355	1.23	31.71	np	17.82	0	13.89	
	4/12/2004	1105	-2.84	31.71	np	18.2	0	13.51	
	4/15/2004	730	1.78	31.71	np	18.36	0	13.35	
	5/19/2004	1307	1.86	31.71	np	19.98	0	11.73	
	6/16/2004	1246	1.78	31.71	np	20.76	0	10.95	
	7/19/2004	1042	-2.94	31.71	np	21.82	0	9.89	
	7/20/2004	1838	-0.48	31.71	np	21.9	0	9.81	
	8/17/2004	1330	2.69	31.71	np	22.92	0	8.79	
	9/16/2004	1320	3.67	31.71	np	23.18	0	8.53	
MW-1(M)	8/28/2002	1151	-1.99	14.53	9.61	10.08	0.47	4.86	18.27
	9/12/2002	1029	-2.84	14.53	9.34	9.88	0.54	5.12	
	9/13/2002	1536	1.12	14.53	9.13	9.34	0.21	5.37	
	10/11/2002	1141	-1.52	14.53	9.49	9.92	0.43	4.98	19.41
	11/15/2002	1118	3.51	14.53	7.11	7.19	0.08	7.41	
	12/13/2002	841	4.39	14.53	6.54	6.57	0.03	7.99	
	1/14/2003	1117	3.45	14.53	6.79	6.81	0.02	7.74	
	2/12/2003	1126	2.12	14.53	7.55	7.56	0.01	6.98	
	3/13/2003	1018	3.86	14.53	6.37	6.45	0.08	8.15	
	4/14/2003	1147	4.17	14.53	np	6.57	0	7.96	
	5/14/2003	1054	2.59	14.53	8.67	8.7	0.03	5.86	
	6/17/2003	1431	2.05	14.53	9.19	9.25	0.06	5.33	
	7/14/2003	1215	0.11	14.53	9.56	9.71	0.15	4.95	
	8/13/2003	1350	3	14.53	9.31	9.32	0.01	5.22	
	9/12/2003	1432	3.21	14.53	np	8.10	0	6.43	
	10/13/2003	846	-2.52	14.53	9.31	9.33	0.02	5.22	

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MW-1(M)	11/12/2003	1445	3.39	14.53	np	6.96	0	7.57	
cont.	12/16/2003	943	1.46	14.53	7.58	7.59	0.01	6.95	
	1/11/2004	1350	4.01	14.53	np	6.58	0	7.95	oduct globules in bail
	2/12/2004	1423	-2.19	14.53	8.64	8.65	0.01		
	3/18/2004	930	3.9	14.53	np	7.60	0	6.93	Strong odor
	4/12/2004	902	0.43	14.53	7.56	7.57	0.01	6.97	
	6/16/2004	1030	-0.35	14.53	9.39	9.41	0.01	5.13	
	7/19/2004	858	-5.63	14.53	9	9.03	0.01	5.51	
	8/17/2004	1020	-3.83	14.53	9.55	9.58	0.01	4.96	
	9/16/2004	932	-2.05	14.53	8.46	8.47	0.01	6.07	
MW-2(M)	8/28/2002	1122	-3.21	15.00	np	8.65	0	6.35	17.9
	9/12/2002	1015	-2.84	15.00	np	8.69	0	6.31	
	9/13/2002	1520	1.12	15.00	np	9.7	0	5.30	
	10/11/2002	1036	-2.45	15.00	np	8.95	0	6.05	19.03
	11/15/2002	930	2.73	15.00	np	8.55	0	6.45	
	12/13/2002	814	4.26	15.00	np	8.08	0	6.92	
	1/14/2003	1039	3.45	15.00	np	6.58	0	8.42	
	2/12/2003	1042	2.12	15.00	np	6.47	0	8.53	
	3/13/2003	940	3.86	15.00	np	5.91	0	9.09	
	4/14/2003	1103	4.35	15.00	np	6.02	0	8.98	
	5/14/2003	1008	1.15	15.00	np	6.91	0	8.09	
	6/17/2003	1354	0.45	15.00	np	7.51	0	7.49	
	7/14/2003	1132	0.11	15.00	np	8.02	0	6.98	
	8/13/2003	1324	1.76	15.00	np	8.34	0	6.66	
	9/12/2003	1318	2.26	15.00	np	8.58	0	6.42	
	10/13/2003	852	-2.52	15.00	np	8.62	0	6.38	
	10/15/2003	1300	2.26	15.00	np	8.62	0	6.38	
	11/12/2003	1432	3.39	15.00	np	8.29	0	6.71	
	12/16/2003	910	2.67	15.00	np	6.86	0	8.14	
	1/11/2004	1348	4.01	15.00	np	6.27	0	8.73	
	1/12/2004	1200	-0.09	15.00	np	6.39	0	8.61	
	2/12/2004	1418	-2.19	15.00	np	6.14	0	8.86	

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MW-2(M) cont.	3/18/2004	1023	3.9	15.00	np	6.66	0	8.34	
	4/12/2004	944	-1.26	15.00	np	6.98	0	8.02	
	4/14/2004	1730	-2.47	15.00	np	7.07	0	7.93	
	6/16/2004	1023	-1.94	15.00	np	7.77	0	7.23	
	7/19/2004	834	-5.63	15.00	np	8.12	0	6.88	
	7/22/2004	1757	2.45	15.00	np	8.18	0	6.82	
	8/17/2004	1015	-3.83	15.00	np	8.52	0	6.48	
	9/16/2004	928	-3.7	15.00	np	8.27	0	6.73	
MW-3(M)	8/28/2002	1345	1.05	15.42	9.45	10.17	0.72	5.87	17.51
	9/12/2002	1025	-2.84	15.42	9.42	10.12	0.7	5.90	
	9/13/2002	1547	2.52	15.42	9.51	9.88	0.37	5.86	
	10/11/2002	1155	-1.52	15.42	9.61	10.67	1.06	5.66	18.44
	11/15/2002	1134	3.51	15.42	9.07	9.7	0.63	6.26	
	12/13/2002	906	4.39	15.42	8.68	9.02	0.34	6.69	
	1/14/2003	1130	2.16	15.42	7.54	8.15	0.61	7.80	
	2/12/2003	1142	0.66	15.42	7.61	8.18	0.57	7.73	
	3/13/2003	1037	2.91	15.42	7.01	7.91	0.9	8.29	
	4/14/2003	1207	4.17	15.42	7.06	8.29	1.23	8.19	
	5/14/2003	1101	2.59	15.42	7.78	8.94	1.16	7.48	
	6/17/2003	1500	2.05	15.42	8.42	9.15	0.73	6.90	
	7/14/2003	1226	0.11	15.42	8.86	9.57	0.71	6.46	
	8/13/2003	1403	3	15.42	9.06	9.64	0.58	6.28	
	9/12/2003	1449	3.21	15.42	9.26	9.59	0.33	6.11	
	10/13/2003	921	-2.52	15.42	9.35	9.79	0.44	6.01	
	10/23/2003	939	2.62	15.42	9.15	9.6	0.45	6.21	
	11/12/2003	1438	3.39	15.42	8.99	9.16	0.17	6.41	
	12/16/2003	1003	1.46	15.42	7.76	8.21	0.45	7.60	
	1/11/2004	1359	4.01	15.42	7.19	8.09	0.9	8.11	
	2/12/2004	1437	-0.76	15.42	7.32	8.79	1.47	7.90	
	3/18/2004	925	2.49	15.42	7.77	8.51	0.74	7.55	
	4/12/2004	915	0.43	15.42	7.95	8.58	0.63	7.38	
	5/19/2004	1054	-1.19	15.42	8.55	9.35	0.8	6.76	

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MW-3(M) cont.	6/16/2004	1045	-0.35	15.42	8.7	9.52	0.82	6.61	
	7/19/2004	855	-5.63	15.42	8.94	9.53	0.59	6.40	
	8/17/2004	1033	-1.98	15.42	9.3	9.83	0.53	6.05	
	9/16/2004	944	-2.05	15.42	9.1	9.35	0.25	6.29	
MW-4(M)	8/28/2002	1302	-0.5	15.5	9.16	9.45	0.29	6.30	20.59
	9/12/2002	1042	-3.1	15.5	9.21	9.58	0.37	6.24	
	9/13/2002	1544	1.12	15.5	9.26	9.39	0.13	6.22	
	10/11/2002	1122	-2.45	15.5	9.46	9.77	0.31	6.00	21.11
	11/15/2002	1108	3.51	15.5	9.08	9.12	0.04	6.41	
	12/13/2002	850	4.39	15.5	np	8.66	0	6.84	
	1/14/2003	1106	3.45	15.5	np	7.18	0	8.32	
	2/12/2003	1112	2.12	15.5	6.95	7.92	0.97	8.42	
	3/13/2003	1007	3.86	15.5	6.46	7.49	1.03	8.91	
	4/14/2003	1137	4.17	15.5	6.28	8.89	2.61	8.88	
	5/14/2003	1126	2.59	15.5	7.18	9.48	2.3	8.02	
	6/17/2003	1452	2.05	15.5	7.98	8.78	0.8	7.42	
	7/14/2003	1232	1.8	15.5	8.53	8.79	0.26	6.94	
	8/13/2003	1303	1.76	15.5	8.87	9.14	0.27	6.59	
	9/12/2003	1445	3.21	15.5	9.07	9.28	0.21	6.40	
	10/13/2003	914	-2.52	15.5	9.17	9.32	0.15	6.31	
	10/23/2003	918	1.04	15.5	8.95	9.05	0.1	6.54	
	11/12/2003	1501	3.39	15.5	np	8.85	0	6.65	
	12/16/2003	918	2.67	15.5	np	7.45	0	8.05	
	1/11/2004	1344	4.01	15.5	np	6.86	0	8.64	
	2/12/2004	1408	-2.19	15.5	6.45	8.69	2.24	8.76	
	3/18/2004	1010	3.9	15.5	6.97	9.16	2.19	8.25	
	4/12/2004	919	0.43	15.5	7.34	8.81	1.47	7.97	
	5/19/2004	1055	-1.19	15.5	8.06	8.77	0.71	7.35	
	6/16/2004	1013	-1.94	15.5	8.27	8.9	0.63	7.15	
	7/19/2004	839	-5.63	15.5	8.66	8.78	0.12	6.82	
	8/17/2004	1008	-3.83	15.5	9.04	9.27	0.23	6.43	
	9/16/2004	922	-3.7	15.5	8.87	8.93	0.06	6.62	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-5(M)	8/28/2002						0		
MW-6(M)	8/28/2002	1140	-1.99	13.78	np	7.71	0	6.07	18.47
	9/12/2002	926	-1.83	13.78	np	8.25	0	5.53	
	9/13/2002	1515	1.12	13.78	np	7.71	0	6.07	
	10/11/2002	1012	-2.51	13.78	np	7.92	0	5.86	19.06
	11/15/2002	921	2.73	13.78	np	7.41	0	6.37	
	12/13/2002	802	4.26	13.78	np	8.85	0	4.93	
	1/14/2003	1028	3.99	13.78	np	7.01	0	6.77	
	2/12/2003	1031	2.12	13.78	np	6.61	0	7.17	
	3/13/2003	930	4.37	13.78	np	6.93	0	6.85	
	4/14/2003	1053	4.35	13.78	np	6.95	0	6.83	
	5/14/2003	956	1.15	13.78	np	7.14	0	6.64	
	6/17/2003	1402	0.45	13.78	np	7.12	0	6.66	
	7/14/2003	1050	-1.9	13.78	np	7.47	0	6.31	
	8/13/2003	1316	1.76	13.78	np	7.48	0	6.30	
	9/12/2003	1312	2.26	13.78	np	7.56	0	6.22	
	10/22/2003	1530	-2.21	13.78	np	7.00	0	6.78	
	11/12/2003	1348	3.65	13.78	np	8.27	0	5.51	
	12/16/2003	857	2.67	13.78	np	5.86	0	7.92	
	1/11/2004	1332	4.01	13.78	np	5.41	0	8.37	
	1/12/2004	814	0.52	13.78	np	5.58	0	8.20	
	2/12/2004	1328	-3.4	13.78	np	5.69	0	8.09	
	3/18/2004	941	3.9	13.78	np	6.41	0	7.37	
	4/12/2004	905	0.43	13.78	np	6.49	0	7.29	
	4/13/2004	1045	-0.52	13.78	np	6.45	0	7.33	
	5/19/2004	1135	0.49	13.78	np	6.95	0	6.83	
	6/16/2004	948	-1.94	13.78	np	7.69	0	6.09	
	7/19/2004	827	-5.2	13.78	np	7.45	0	6.33	
	7/19/2004	1505	2.72	13.78	np	7.29	0	6.49	
	8/17/2004	947	-3.83	13.78	np	7.82	0	5.96	
	9/16/2004	857	-3.7	13.78	np	7.56	0	6.22	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-7(M)	8/28/2002	1102	-3.21	14.86	np	8.31	0	6.55	18.64
	9/12/2002	900	-1.83	14.86	np	8.36	0	6.50	
	9/13/2002	1455	1.12	14.86	np	8.43	0	6.43	
	10/11/2002	957	-2.51	14.86	np	8.58	0	6.28	18.93
	11/15/2002	914	2.73	14.86	np	8.57	0	6.29	
	12/13/2002	754	4.26	14.86	np	7.7	0	7.16	
	1/14/2003	1017	3.99	14.86	np	6.01	0	8.85	
	2/12/2003	1021	3.06	14.86	np	5.96	0	8.90	
	3/13/2003	920	4.37	14.86	np	5.3	0	9.56	
	4/14/2003	1044	4.35	14.86	np	5.5	0	9.36	
	5/14/2003	947	1.15	14.86	np	6.42	0	8.44	
	6/17/2003	1347	0.45	14.86	np	7.13	0	7.73	
	7/14/2003	1124	-1.9	14.86	np	7.66	0	7.20	
	8/13/2003	1311	1.76	14.86	np	8.03	0	6.83	
	9/12/2003	1307	2.26	14.86	np	8.27	0	6.59	
	10/13/2003	852	-2.52	14.86	np	8.30	0	6.56	
	10/13/2003	1547	2.54	14.86	np	8.27	0	6.59	
	11/12/2003	1356	3.65	14.86	np	7.96	0	6.90	
	12/16/2003	903	2.67	14.86	np	6.41	0	8.45	
	1/11/2004	1335	4.01	14.86	np	5.77	0	9.09	
	1/12/2004	940	-1.27	14.86	np	5.81	0	9.05	
	2/12/2004	1333	-3.4	14.86	np	5.53	0	9.33	
	3/18/2004	946	3.9	14.86	np	6.23	0	8.63	
	4/12/2004	931	-1.26	14.86	np	6.51	0	8.35	
	4/12/2004	1725	-1.44	14.86	np	6.63	0	8.23	
	5/19/2004	1139	0.49	14.86	np	7.20	0	7.66	
	6/16/2004	957	-1.94	14.86	np	7.42	0	7.44	
	7/19/2004	829	-5.2	14.86	np	7.80	0	7.06	
	7/19/2004	1550	2.5	14.86	np	7.81	0	7.05	
	9/16/2004	903	-3.7	14.86	np	7.91	0	6.95	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-8(M)	8/28/2002	1326	-0.5	15.23	9.69	11.08	1.39	5.37	18.89
	9/12/2002	1036	-3.1	15.23	9.6	10.85	1.25	5.48	
	9/13/2002	1540	1.12	15.23	9.7	10.41	0.71	5.44	
	10/11/2002	1211	-1.52	15.23	9.89	10.91	1.02	5.22	18.74
	11/15/2002	1126	3.51	15.23	8.57	9.26	0.69	6.58	
	12/13/2002	859	4.39	15.23	8.04	8.81	0.77	7.10	
	1/14/2003	1123	3.45	15.23	8.2	8.53	0.33	6.99	
	2/12/2003	1133	0.66	15.23	8.27	8.75	0.48	6.90	
	3/13/2003	1029	3.86	15.23	np	8.22	0	7.01	
	4/14/2003	1158	4.17	15.23	np	7.72	0	7.51	
	5/14/2003	1042	2.59	15.23	8.71	9.45	0.74	6.43	
	6/17/2003	1440	2.05	15.23	8.91	9.77	0.86	6.22	
	7/14/2003	1221	0.11	15.23	9.32	9.79	0.47	5.85	
	8/13/2003	1357	3	15.23	9.36	9.63	0.27	5.84	
	9/12/2003	1437	3.21	15.23	9.19	9.41	0.22	6.01	
	10/13/2003	932	-1.55	15.23	9.57	9.92	0.35	5.62	
	10/23/2003	836	1.04	15.23	9.43	9.86	0.43	5.75	
	11/12/2003	1442	3.39	15.23	8.81	8.86	0.05	6.41	
	12/16/2003	954	1.46	15.23	np	8.71	0	6.52	
	1/11/2004	1355	4.01	15.23	np	7.55	0	7.68	
	2/12/2004	1430	-2.19	15.23	8.37	8.48	0.11	6.85	
	3/18/2004	913	2.49	15.23	8.44	8.53	0.09	6.78	
	4/12/2004	907	0.43	15.23	8.43	8.46	0.03	6.80	
	5/19/2004	1112	-1.19	15.23	9.04	9.2	0.16	6.17	
	6/16/2004	1037	-0.35	15.23	9.2	9.3	0.1	6.02	
	7/19/2004	859	-5.63	15.23	9.34	9.4	0.06	5.88	
	8/17/2004	1024	-3.83	15.23	9.64	9.9	0.26	5.56	
	9/16/2004	938	-2.05	15.23	9.41	9.43	0.02	5.82	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-9(M)	8/28/2002	1357	1.05	15.42	9.35	13.21	3.86	5.58	19.12
	9/12/2002	1049	-3.1	15.42	9.3	12.08	2.78	5.77	
	9/13/2002	1552	1.12	15.42	9.61	10.21	0.6	5.73	
	10/11/2002	1226	-1.52	15.42	9.75	10.92	1.17	5.52	19.47
	11/15/2002	1141	2.61	15.42	9.16	10.28	1.12	6.12	
	12/13/2002	915	4.39	15.42	8.78	9.79	1.01	6.51	
	1/14/2003	1137	2.16	15.42	7.76	8.55	0.79	7.56	
	2/12/2003	1150	0.66	15.42	7.85	8.85	1	7.44	
	3/13/2003	1045	2.91	15.42	7.35	8.21	0.86	7.96	
	4/14/2003	1217	4.17	15.42	7.33	8.9	1.57	7.89	
	5/15/2003	1116	2.59	15.42	8.11	10.3	2.19	7.03	
	6/17/2003	1508	2.05	15.42	8.44	10.65	2.21	6.70	
	7/14/2003	1241	1.8	15.42	9.00	9.94	0.94	6.30	
	8/13/2003	1409	3	15.42	9.20	9.8	0.6	6.14	
	9/12/2003	1456	3.21	15.42	9.38	9.9	0.52	5.97	
	10/13/2003	939	-1.55	15.42	9.46	10.18	0.72	5.87	
	10/23/2003	956	2.62	15.42	9.24	9.92	0.68	6.09	
	11/12/2003	1456	3.39	15.42	9.15	9.49	0.34	6.23	
	12/16/2003	1009	1.46	15.42	8.02	8.19	0.17	7.38	
	1/11/2004	1407	4.01	15.42	7.52	7.66	0.14	7.88	
	2/12/2004	1444	-0.76	15.42	7.76	8.69	0.93	7.54	
	3/18/2004	919	2.49	15.42	8.07	8.93	0.86	7.24	
	4/12/2004	912	0.43	15.42	8.21	8.83	0.62	7.13	
	5/19/2004	1108	-1.19	15.42	8.73	9.83	1.1	6.55	
	7/19/2004	905	-5.63	15.42	9.05	10.15	1.1	6.23	
	8/17/2004	1029	-3.83	15.42	9.41	10.44	1.03	5.88	
	9/16/2004	950	-2.05	15.42	9.22	9.88	0.66	6.12	
MW-10(M)	8/28/2002	1430	1.05	16.32	np	11.23	0	5.09	19.43
	9/12/2002	1005	-2.84	16.32	np	11.1	0	5.22	
	9/13/2002	1526	1.12	16.32	np	11.13	0	5.19	
	10/11/2002	1055	-2.45	16.32	np	11.22	0	5.10	19.83
	11/15/2002	942	3.5	16.32	np	10.63	0	5.69	

Table 2-1
Groundwater Measurements
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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-10(M)	12/13/2002	821	4.26	16.32	np	10.21	0	6.11	
cont.	1/14/2003	1048	3.45	16.32	np	9.62	0	6.70	
	2/12/2003	1051	2.12	16.32	np	9.91	0	6.41	
	3/13/2003	948	3.86	16.32	np	9.4	0	6.92	
	4/14/2003	1118	4.35	16.32	np	9.1	0	7.22	
	5/15/2003	1019	1.15	16.32	np	10.38	0	5.94	
	6/17/2003	1413	0.45	16.32	np	10.41	0	5.91	
	7/14/2003	1141	0.11	16.32	np	10.75	0	5.57	
	8/13/2003	1333	3	16.32	np	10.77	0	5.55	
	9/12/2003	1348	3.2	16.32	np	10.95	0	5.37	
	10/13/2003	950	-1.55	16.32	np	10.88	0	5.44	
	10/15/2003	1500	3.78	16.32	np	10.85	0	5.47	
	11/12/2003	1334	3.65	16.32	np	10.67	0	5.65	
	12/16/2003	1027	1.46	16.32	np	9.68	0	6.64	
	1/11/2004	1410	4.01	16.32	np	9.32	0	7.00	
	1/13/2004	1050	-1.76	16.32	np	9.55	0	6.77	
	2/12/2004	1305	-3.4	16.32	np	9.95	0	6.37	
	3/18/2004	856	2.49	16.32	np	10.17	0	6.15	
	4/12/2004	910	0.43	16.32	np	10.12	0	6.20	
	4/13/2004	820	2.99	16.32	np	10.19	0	6.13	
	5/19/2004	1124	-1.19	16.32	np	10.56	0	5.76	
	6/16/2004	1110	-0.35	16.32	np	10.69	0	5.63	
	7/19/2004	909	-5.63	16.32	np	10.68	0	5.64	
	7/19/2004	1715	1.56	16.32	np	10.65	0	5.67	
	8/17/2004	1048	-1.98	16.32	np	11.01	0	5.31	
	9/16/2004	1007	-2.05	16.32	np	10.72	0	5.60	
MW-11(M)	8/28/2002	1420	1.05	16.34	np	10.87	0	5.47	19.81
	9/12/2002	1000	-2.84	16.34	np	10.8	0	5.54	
	9/13/2002	1531	1.12	16.34	np	10.83	0	5.51	
	10/11/2002	1108	-2.45	16.34	np	11.01	0	5.33	19.83
	11/15/2002	949	3.5	16.34	np	10.37	0	5.97	
	12/13/2002	829	4.26	16.34	np	9.94	0	6.40	

Table 2-1
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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-11(M) cont.	1/14/2003	1057	3.45	16.34	np	9.08	0	7.26	
	2/12/2003	1058	2.12	16.34	np	9.25	0	7.09	
	3/13/2003	958	3.86	16.34	np	8.71	0	7.63	
	4/14/2003	1127	4.35	16.34	np	8.86	0	7.48	
	5/15/2003	1028	1.15	16.34	np	9.79	0	6.55	
	6/17/2003	1422	0.45	16.34	np	10.02	0	6.32	
	7/14/2003	1149	0.11	16.34	np	10.39	0	5.95	
	8/13/2003	1340	3	16.34	np	10.41	0	5.93	
	9/12/2003	1353	3.2	16.34	np	10.6	0	5.74	
	10/13/2003	956	-1.55	16.34	np	10.72	0	5.62	
	10/15/2003	1720	2.7	16.34	np	10.41	0	5.93	
	11/12/2003	1341	3.65	16.34	np	10.29	0	6.05	
	12/16/2003	1019	1.46	16.34	np	9.27	0	7.07	
	1/11/2004	1414	4.01	16.34	np	8.73	0	7.61	
	1/13/2004	1235	-0.61	16.34	np	9.21	0	7.13	
	2/12/2004	1311	-3.4	16.34	np	9.43	0	6.91	
	3/18/2004	903	2.49	16.34	np	9.48	0	6.86	
	4/12/2004	948	-1.26	16.34	np	9.6	0	6.74	
	4/13/2004	945	1.05	16.34	np	9.53	0	6.81	
	5/19/2004	1120	-1.19	16.34	np	10.2	0	6.14	
	6/16/2004	1124	-0.35	16.34	np	10.31	0	6.03	
	7/19/2004	907	-5.63	16.34	np	10.49	0	5.85	
	7/21/2004	1646	2.52	16.34	np	10.37	0	5.97	
	8/17/2004	1059	-1.98	16.34	np	10.77	0	5.57	
	9/16/2004	1000	-2.05	16.34	np	10.52	0	5.82	
MW-12(A)	10/13/2003	1152	1.5	30.58	np	20.00	0	10.58	25.38
	10/22/2003	955	3.54	30.58	np	19.61	0	10.97	
	11/12/2003	1116	0.56	30.58	np	18.87	0	11.71	
	12/16/2003	1345	0.34	30.58	np	15.44	0	15.14	
	1/11/2004	1616	4.26	30.58	np	14.76	0	15.82	
	1/15/2004	940	0.81	30.58	np	14.70	0	15.88	
	2/12/2004	932	-2.53	30.58	np	14.26	0	16.32	

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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-12(A) cont.	3/18/2004	1340	1.23	30.58	np	15.27	0	15.31	
	4/12/2004	1208	-4.16	30.58	np	15.85	0	14.73	
	4/16/2004	725	-1.63	30.58	np	16.00	0	14.58	
	5/19/2004	1253	1.86	30.58	np	17.04	0	13.54	
	6/16/2004	1233	1.78	30.58	np	17.61	0	12.97	
	7/19/2004	1122	-2.94	30.58	np	18.15	0	12.43	
	7/22/2004	655	-1.14	30.58	np	18.19	0	12.39	
	8/17/2004	1320	1.62	30.58	np	18.64	0	11.94	
	9/16/2004	1310	3.67	30.58	np	18.74	0	11.84	
MW-13(A)	10/13/2003	1157	1.5	31.36	np	22.68	0	8.68	26.42
	10/22/2003	1130	3.62	31.36	np	22.34	0	9.02	
	11/12/2003	1122	0.56	31.36	np	22.14	0	9.22	
	12/16/2003	1352	0.34	31.36	np	18.41	0	12.95	
	1/11/2004	1620	4.26	31.36	np	17.39	0	13.97	
	1/15/2004	1130	-1.98	31.36	np	17.28	0	14.08	
	2/12/2004	937	-2.53	31.86	np	16.71	0	15.15	
	3/18/2004	1345	1.23	31.86	np	17.83	0	14.03	
	4/12/2004	1210	-4.16	31.86	np	18.45	0	13.41	
	4/16/2004	927	1.51	31.86	np	18.82	0	13.04	
	5/19/2004	1255	1.86	31.86	np	19.85	0	12.01	
	6/16/2004	1238	1.78	31.86	np	20.53	0	11.33	
	7/19/2004	1124	-2.94	31.86	np	21.33	0	10.53	
	7/22/2004	818	-2.86	31.86	np	21.4	0	10.46	
	8/17/2004	1324	1.62	31.86	np	21.96	0	9.90	
	9/16/2004	1314	3.67	31.86	np	21.92	0	9.94	
MW-14(A)	10/13/2003	1203	1.5	23.39	np	15.06	0	8.33	18.81
	10/21/2003	1645	-1.5	23.39	np	14.7	0	8.69	
	11/12/2003	1056	0.56	23.39	np	14.55	0	8.84	
	12/16/2003	1336	0.34	23.39	np	12.01	0	11.38	
	1/11/2004	1624	4.26	23.39	np	11.47	0	11.92	
	1/15/2004	1250	-2.74	23.39	np	11.41	0	11.98	
	2/12/2004	1106	-3.59	23.39	np	11.07	0	12.32	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-14(A) cont.	3/18/2004	1226	4.37	23.39	np	11.57	0	11.82	
	4/12/2004	1205	-4.16	23.39	np	11.88	0	11.51	
	4/16/2004	815	-0.11	23.39	np	11.97	0	11.42	
	5/19/2004	1250	1.86	23.39	np	12.5	0	10.89	
	6/16/2004	1226	1.01	22.39	np	12.73	0	9.66	
	7/19/2004	1122	-2.94	22.39	np	13.28	0	9.11	
	7/23/2004	757	-1.63	22.39	np	13.34	0	9.05	
	8/17/2004	1317	1.62	22.39	np	14.21	0	8.18	
	9/16/2004	1304	3.67	22.39	np	13.83	0	8.56	
MW-15(A)	10/13/2003	1116	-0.1	16.95	np	9.08	0	7.87	14.81
	10/20/2003	1340	0.06	16.95	np	8.87	0	8.08	
	11/12/2003	1026	-0.65	16.95	np	8.58	0	8.37	
	12/16/2003	1239	-0.3	16.95	np	6.35	0	10.60	
	1/11/2004	1529	4.58	16.95	5.77	5.8	0.03	11.18	
	2/12/2004	1058	-3.59	16.95	5.41	5.9	0.49	11.47	
	3/18/2004	1230	4.37	16.95	6.1	8.04	1.94	10.56	
	4/12/2004	1153	-4.16	16.95	6.5	7.26	0.76	10.34	
	5/19/2004	1403	2.56	16.95	7.25	7.95	0.7	9.60	
	6/16/2004	1351	1.8	16.95	7.51	8.28	0.77	9.32	
	7/19/2004	1131	-1.08	16.95	8.04	8.84	0.8	8.79	
	8/17/2004	1305	1.62	16.95	8.46	9.27	0.81	8.37	
	9/16/2004	1255	3.67	16.95	8.4	8.89	0.49	8.48	
MW-16(A)	10/13/2003	1111	-0.1	16.48	np	8.59	0	7.89	15.21
	10/20/2003	1510	-0.31	16.48	np	8.39	0	8.09	
	11/12/2003	1035	0.56	16.48	np	8.18	0	8.30	
	12/16/2003	1224	-0.19	16.48	np	6.51	0	9.97	
	1/11/2004	1523	4.58	16.48	np	6.05	0	10.43	
	1/19/2004	930	5.44	16.48	np	6.04	0	10.44	
	2/12/2004	1110	-3.59	16.48	np	5.81	0	10.67	
	3/18/2004	1221	4.37	16.48	np	6.33	0	10.15	
	4/12/2004	1158	-4.16	16.48	np	6.63	0	9.85	
	4/15/2004	850	2.95	16.48	np	6.68	0	9.80	

Table 2-1
Groundwater Measurements
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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-16(A) cont.	5/19/2004	1357	2.56	16.48	np	7.2	0	9.28	
	6/16/2004	1400	1.8	16.48	np	7.37	0	9.11	
	7/19/2004	1021	-4.71	16.48	np	7.78	0	8.70	
	7/22/2004	1515	1.37	16.48	np	7.81	0	8.67	
	8/17/2004	1312	1.62	16.48	np	8.13	0	8.35	
	9/16/2004	1300	3.67	16.48	np	8.04	0	8.44	
MW-17(A)	10/13/2003	1125	-0.1	15.69	np	8.37	0	7.32	15.35
	10/17/2003	1240	1.23	15.69	np	8.31	0	7.38	
	11/12/2003	1020	-0.65	15.69	np	7.88	0	7.81	
	12/16/2003	1245	-0.3	15.69	np	5.7	0	9.99	
	1/11/2004	1540	4.26	15.69	np	5	0	10.69	
	1/19/2004	1130	4.2	15.69	np	5	0	10.69	
	2/12/2004	1047	-3.59	15.69	np	4.66	0	11.03	
	3/18/2004	1245	3.1	15.69	np	5.43	0	10.26	
	4/12/2004	1145	-4.16	15.69	np	5.88	0	9.81	
	4/15/2004	1055	3.34	15.69	np	6	0	9.69	
	5/19/2004	1351	2.56	15.69	np	6.66	0	9.03	
	6/16/2004	1338	1.8	15.69	np	6.95	0	8.74	
	7/19/2004	1026	-4.71	15.69	np	7.45	0	8.24	
	7/22/2004	1636	2.92	15.69	np	7.5	0	8.19	
	8/17/2004	1254	1.62	15.69	np	7.86	0	7.83	
	9/16/2004	1245	3.67	15.69	np	7.79	0	7.90	
MW-18(A)	10/13/2003	1117	-0.1	16.23	np	8.85	0	7.38	15.36
	10/21/2003	1300	0.89	16.23	np	8.58	0	7.65	
	11/12/2003	1042	0.56	16.23	np	8.39	0	7.84	
	12/16/2003	1234	-0.3	16.23	np	6.38	0	9.85	
	1/19/2004	1040	5.35	16.23	np	5.74	0	10.49	
	2/12/2004	1052	-3.59	16.23	np	5.42	0	10.81	
	3/18/2004	1240	3.1	16.23	np	6.1	0	10.13	
	4/12/2004	1148	-4.16	16.23	np	6.55	0	9.68	
	4/15/2004	1000	3.54	16.23	np	6.62	0	9.61	
	5/19/2004	1355	2.56	16.23	np	7.27	0	8.96	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-18(A) cont.	6/16/2004	1346	1.8	16.23	np	7.5	0	8.73	
	7/19/2004	1025	-4.71	16.23	np	7.98	0	8.25	
	7/21/2004	1535	2.65	16.23	np	8	0	8.23	
	8/17/2004	1258	1.62	16.23	np	8.36	0	7.87	
	9/16/2004	1251	3.67	16.23	np	8.29	0	7.94	
MW-19(A)	10/13/2003	1049	-0.1	17.98	np	10.59	0	7.39	15.3
	10/20/2003	1050	2.89	17.98	np	10.43	0	7.55	
	11/12/2003	1145	1.93	17.98	np	10.18	0	7.80	
	1/13/2004	1515	1.91	17.98	np	7.99	0	9.99	
	2/12/2004	1122	-3.59	17.9	np	7.66	0	10.24	
	3/18/2004	1210	4.37	17.9	np	8.26	0	9.64	
	4/12/2004	1133	-4.16	17.9	np	8.6	0	9.30	
	4/15/2004	1545	-3.71	17.9	np	8.67	0	9.23	
	5/19/2004	1243	1.86	17.9	np	9.18	0	8.72	
	7/19/2004	952	-4.71	17.9	np	9.8	0	8.10	
	7/20/2004	1343	1.28	17.9	np	9.85	0	8.05	
	8/17/2004	1152	-0.05	17.9	np	10.15	0	7.75	
	9/16/2004	1042	-0.04	17.9	np	10.07	0	7.83	
MW-20(A)	10/13/2003	1047	-0.1	17.04	np	10.03	0	7.01	15.39
	10/20/2003	1210	1.9	17.04	np	9.88	0	7.16	
	11/12/2003	1150	1.93	17.04	np	9.65	0	7.39	
	12/16/2003	1410	0.34	17.04	np	8.03	0	9.01	
	1/11/2004	1510	4.58	17.04	np	7.41	0	9.63	
	1/13/2004	1630	3.15	17.04	np	7.44	0	9.60	
	2/12/2004	1126	-3.59	17.04	np	7.11	0	9.93	
	3/18/2004	1215	4.37	17.04	np	7.7	0	9.34	
	4/12/2004	1128	-2.84	17.04	np	8.06	0	8.98	
	4/15/2004	1642	-4.14	17.04	np	8.13	0	8.91	
	5/19/2004	1246	1.86	17.04	np	8.63	0	8.41	
	6/16/2004	1415	1.8	17.04	np	8.86	0	8.18	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-20(A) cont.	7/19/2004	947	-4.71	17.04	np	9.27	0	7.77	
	7/20/2004	1444	2.36	17.04	np	9.3	0	7.74	
	8/17/2004	1156	-0.05	17.04	np	9.61	0	7.43	
	9/16/2004	1048	-0.04	17.04	np	9.82	0	7.22	
MW-21(A)	10/13/2003	1035	-0.1	15.90	np	9.22	0	6.68	15.35
	10/20/2003	940	3.26	15.90	np	9.11	0	6.79	
	11/12/2003	1156	1.93	15.90	np	8.91	0	6.99	
	12/16/2003	1216	-0.19	15.90	np	7.49	0	8.41	
	1/11/2004	1503	4.58	15.90	np	6.9	0	9.00	
	1/13/2004	1355	0.66	15.90	np	6.89	0	9.01	
	2/12/2004	1135	-3.92	15.90	np	6.66	0	9.24	
	3/18/2004	1202	4.37	15.90	np	7.17	0	8.73	
	4/12/2004	1138	-4.16	15.90	np	7.49	0	8.41	
	4/16/2004	1115	3.53	15.90	np	7.58	0	8.32	
	5/19/2004	1237	1.86	15.90	np	7.99	0	7.91	
	6/16/2004	1219	1.01	15.90	np	8.21	0	7.69	
	7/19/2004	942	-4.71	15.90	np	8.57	0	7.33	
	7/20/2004	1533	2.73	15.90	np	8.6	0	7.30	
	8/17/2004	1201	-0.05	15.90	np	8.9	0	7.00	
	9/16/2004	1037	-0.04	15.90	np	8.82	0	7.08	
MW-22(A)	10/13/2003	1037	-0.1	16.13	np	9.24	0	6.89	15.08
	10/16/2003	940	0.09	16.13	np	9.21	0	6.92	
	11/12/2003	1203	1.93	16.13	np	8.8	0	7.33	
	12/16/2003	1048	0.48	16.13	np	6.91	0	9.22	
	1/19/2004	815	3.22	16.13	np	6.15	0	9.98	
	3/18/2004	1157	4.37	16.13	np	6.55	0	9.58	
	4/12/2004	1120	-2.84	16.13	np	6.97	0	9.16	
	4/15/2004	1435	-2.62	16.13	np	7.07	0	9.06	
	5/19/2004	1233	1.86	16.13	np	7.66	0	8.47	
	6/16/2004	1210	1.01	16.13	np	7.93	0	8.20	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-22(A) cont.	7/19/2004	1008	-4.71	16.13	np	8.38	0	7.75	
	7/20/2004	1111	-3.82	16.13	np	8.4	0	7.73	
	8/17/2004	1147	-0.05	16.13	np	8.78	0	7.35	
	9/16/2004	1032	-0.04	16.13	np	8.74	0	7.39	
MW-23(A)	10/13/2003	1137	1.5	16.22	np	8.86	0	7.36	14.93
	10/20/2003	1630	0.49	16.22	np	8.71	0	7.51	
	11/12/2003	1013	-0.65	16.22	np	8.3	0	7.92	
	12/16/2003	1250	-0.3	16.22	np	5.36	0	10.86	
	1/11/2004	1543	4.26	16.22	np	4.57	0	11.65	
	1/15/2004	1745	1.31	16.22	np	4.47	0	11.75	
	2/12/2004	1041	-3.59	16.22	np	4.09	0	12.13	
	3/18/2004	1249	3.1	16.22	np	5.13	0	11.09	
	4/12/2004	1112	-2.84	16.22	np	5.69	0	10.53	
	4/15/2004	1201	2.17	16.22	np	5.8	0	10.42	
	5/19/2004	1349	2.56	16.22	np	6.78	0	9.44	
	6/16/2004	1331	1.8	16.22	np	7.18	0	9.04	
	7/19/2004	1032	-2.94	16.22	np	7.8	0	8.42	
	7/20/2004	1645	2.19	16.22	np	7.83	0	8.39	
	8/17/2004	1239	1.62	16.22	np	8.29	0	7.93	
	9/16/2004	1232	3.67	16.22	np	8.2	0	8.02	
MW-24(A)	10/13/2003	1154	1.5	16.56	np	9.15	0	7.41	14.87
	10/21/2003	1430	-1.43	16.56	np	8.52	0	8.04	
	11/12/2003	942	-0.65	16.56	np	8.17	0	8.39	
	12/16/2003	1304	-0.3	16.56	np	4.45	0	12.11	
	1/11/2004	1547	4.26	16.56	np	3.96	0	12.60	
	1/15/2004	1630	0.29	16.56	np	3.85	0	12.71	
	2/12/2004	1022	-2.53	16.56	np	4.05	0	12.51	
	3/18/2004	1301	3.1	16.56	np	4.96	0	11.60	
	4/12/2004	1103	-2.84	16.56	np	5.65	0	10.91	
	4/14/2004	1500	-3.92	16.56	np	5.78	0	10.78	
	5/19/2004	1338	2.56	16.56	np	6.94	0	9.62	
	6/16/2004	1312	1.78	16.56	np	7.08	0	9.48	

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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-24(A)	7/19/2004	1039	-2.94	16.56	np	7.97	0	8.59	
cont.	7/22/2004	1222	-3.63	16.56	np	8.03	0	8.53	
	8/17/2004	1230	1.62	16.56	np	8.49	0	8.07	
	9/16/2004	1221	2.05	16.56	np	8.02	0	8.54	
MW-26(A)	10/13/2003	1150	1.5	16.27	np	9.14	0	7.13	15.35
	10/17/2003	1600	3.29	16.27	np	9.09	0	7.18	
	11/12/2003	947	-0.65	16.27	np	8.46	0	7.81	
	12/16/2003	1259	-0.3	16.27	np	5.51	0	10.76	
	1/11/2004	1548	4.26	16.27	np	4.69	0	11.58	
	1/15/2004	1600	-0.91	16.27	np	4.65	0	11.62	
	2/12/2004	1026	-2.53	16.27	np	4.43	0	11.84	
	3/18/2004	1305	3.1	16.27	np	5.01	0	11.26	
	4/12/2004	1100	-2.84	16.27	np	5.91	0	10.36	
	4/14/2004	1414	-2.64	16.27	np	6	0	10.27	
	5/19/2004	1330	2.56	16.27	np	6.95	0	9.32	
	6/16/2004	1316	1.78	16.27	np	7.31	0	8.96	
	7/19/2004	1037	-2.94	16.27	np	7.98	0	8.29	
	7/22/2004	1140	-3.63	16.27	np	8.02	0	8.25	
	8/17/2004	1226	-0.05	16.27	np	8.5	0	7.77	
	9/16/2004	1217	2.05	16.27	np	8.43	0	7.84	
MW-27(A)	10/13/2003	1213	1.5	16.36	np	9.26	0	7.10	15.24
	10/21/2003	905	2.61	16.36	np	9.02	0	7.34	
	11/12/2003	1000	-0.65	16.36	np	8.54	0	7.82	
	12/16/2003	1329	-0.3	16.36	np	5.74	0	10.62	
	1/11/2004	1556	4.26	16.36	np	4.96	0	11.40	
	1/14/2004	1625	1.19	16.36	np	4.95	0	11.41	
	2/12/2004	1007	-2.53	16.36	np	4.72	0	11.64	
	4/12/2004	1049	-2.84	16.36	np	6.05	0	10.31	
	4/14/2004	1300	-1.18	16.36	np	6.15	0	10.21	
	5/19/2004	1323	1.86	16.36	np	7.05	0	9.31	
	7/19/2004	1048	-2.94	16.36	np	8.05	0	8.31	
	7/22/2004	1100	-4.85	16.36	np	8.11	0	8.25	

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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-28(A)	10/13/2003	1130	1.5	16.13	np	9.05	0	7.08	15.36
	10/17/2003	1415	1.92	16.13	np	9.01	0	7.12	
	11/12/2003	1007	-0.65	16.13	np	8.51	0	7.62	
	12/16/2003	1254	-0.3	16.13	np	6.12	0	10.01	
	1/11/2004	1550	4.26	16.13	np	5.31	0	10.82	
	1/19/2004	1450	-1.95	16.13	np	5.25	0	10.88	
	2/12/2004	1033	-3.59	16.13	np	4.91	0	11.22	
	3/18/2004	1255	3.1	16.13	np	5.77	0	10.36	
	4/12/2004	1110	-2.84	16.13	np	6.25	0	9.88	
	4/14/2004	1612	-4.32	16.13	np	6.31	0	9.82	
	5/19/2004	1346	2.56	16.13	np	7.12	0	9.01	
	6/16/2004	1326	1.78	16.13	np	7.46	0	8.67	
	7/19/2004	1029	-4.71	16.13	np	8.02	0	8.11	
	7/23/2004	905	-3.1	16.13	np	8.1	0	8.03	
	8/17/2004	1235	1.62	16.13	np	8.48	0	7.65	
	9/16/2004	1227	2.05	16.13	np	8.46	0	7.67	
MW-29(A)	10/13/2003	1202	1.5	15.84	np	9.88	0	5.96	15.37
	10/21/2003	1550	-1.89	15.84	np	8.69	0	7.15	
	11/12/2003	934	-0.65	15.84	np	8.33	0	7.51	
	12/16/2003	1309	-0.3	15.84	np	6.02	0	9.82	
	1/11/2004	1552	4.26	15.84	np	5.21	0	10.63	
	1/19/2004	1600	-3.67	15.84	np	5.13	0	10.71	
	2/12/2004	1014	-2.53	15.84	np	4.8	0	11.04	
	3/18/2004	1310	3.1	15.84	np	5.61	0	10.23	
	4/12/2004	1054	-2.84	15.84	np	6.13	0	9.71	
	4/16/2004	1222	3.28	15.84	np	6.25	0	9.59	
	5/19/2004	1330	2.56	15.84	np	6.98	0	8.86	
	6/16/2004	1307	1.78	15.84	np	7.3	0	8.54	
	7/19/2004	1035	-2.94	15.84	np	7.87	0	7.97	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-29(A) cont.	7/22/2004	1301	-2.04	15.84	np	7.91	0	7.93	
	8/17/2004	1220	-0.05	15.84	np	8.31	0	7.53	
	9/16/2004	1213	2.05	15.84	np	8.31	0	7.53	
MW-30(A)	10/13/2003	1000	-1.55	16.67	np	9.91	0	6.76	15.11
	10/16/2003	820	1.18	16.67	np	9.9	0	6.77	
	11/12/2003	1221	1.93	16.67	np	9.42	0	7.25	
	12/16/2003	1201	-0.19	16.67	np	7.49	0	9.18	
	1/11/2004	1452	4.58	16.67	np	6.72	0	9.95	
	1/16/2004	1400	-3.33	16.67	np	6.65	0	10.02	
	2/12/2004	1150	-3.92	16.67	np	6.34	0	10.33	
	4/12/2004	1008	-1.26	16.67	np	7.49	0	9.18	
	4/13/2004	1710	-2.75	16.67	np	7.52	0	9.15	
	5/19/2004	1223	0.49	16.67	np	8.22	0	8.45	
	6/16/2004	1156	1.01	16.67	np	8.55	0	8.12	
	7/19/2004	933	-4.71	16.67	np	9.03	0	7.64	
	7/20/2004	921	-5.4	16.67	np	9.04	0	7.63	
	8/17/2004	1139	-0.05	16.67	np	9.45	0	7.22	
	9/16/2004	1100	-0.04	16.67	np	9.45	0	7.22	
MW-31(A)	10/13/2003	950	-1.55	16.23	np	9.81	0	6.42	15.31
	10/16/2003	1350	2.65	16.23	np	9.77	0	6.46	
	11/12/2003	1210	1.93	16.23	np	9.48	0	6.75	
	12/16/2003	1207	-0.19	16.23	np	7.97	0	8.26	
	1/11/2004	1456	4.58	16.23	np	7.33	0	8.90	
	1/12/2004	1615	4	16.23	np	7.36	0	8.87	
	2/12/2004	1141	-3.92	16.23	np	7.12	0	9.11	
	3/18/2004	1152	4.37	16.23	np	7.64	0	8.59	
	4/12/2004	958	-1.26	16.23	np	7.98	0	8.25	
	4/13/2004	1425	-4.26	16.23	np	8	0	8.23	
	5/19/2004	1218	0.49	16.23	np	8.56	0	7.67	
	6/16/2004	1204	1.01	16.23	np	8.8	0	7.43	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-31(A)	7/19/2004	938	-4.71	16.23	np	9.14	0	7.09	
cont.	7/20/2004	1015	-5.25	16.23	np	9.15	0	7.08	
	8/17/2004	1144	-0.05	16.23	np	9.51	0	6.72	
	9/16/2004	1053	-0.04	16.23	np	9.42	0	6.81	
MW-32(A)	10/13/2003	944	-1.55	16.51	np	10.43	0	6.08	15.36
	10/14/2003	1350	3.21	16.51	np	10.41	0	6.10	
	11/12/2003	1316	3.06	16.51	np	10.07	0	6.44	
	12/16/2003	1039	0.48	16.51	np	8.84	0	7.67	
	1/11/2004	1419	4.01	16.51	np	8.21	0	8.30	
	1/12/2004	1525	3.66	16.51	np	8.3	0	8.21	
	2/12/2004	1241	-3.4	16.51	np	8.5	0	8.01	
	3/18/2004	1056	4.6	16.51	np	8.63	0	7.88	
	4/12/2004	955	-1.26	16.51	np	8.98	0	7.53	
	4/13/2004	1340	-4.26	16.51	np	9.12	0	7.39	
	5/19/2004	1212	0.49	16.51	np	9.56	0	6.95	
	6/16/2004	1130	1.01	16.51	np	9.76	0	6.75	
	7/19/2004	923	-5.63	16.51	np	9.98	0	6.53	
	7/19/2004	1400	2	16.51	np	10	0	6.51	
	8/17/2004	1103	-1.98	16.51	np	10.31	0	6.20	
	9/16/2004	1022	-2.05	16.51	np	10.15	0	6.36	
MW-33(A)	10/13/2003	937	-1.55	16.14	np	10.87	0	5.27	17.31
	10/14/2003	838	-2.15	16.14	np	10.7	0	5.44	
	11/12/2003	1328	3.06	16.14	np	10.33	0	5.81	
	12/16/2003	1034	0.48	16.14	np	9.47	0	6.67	
	1/11/2004	1416	4.01	16.14	np	8.92	0	7.22	
	1/12/2004	1425	2.64	16.14	np	9.23	0	6.91	
	4/12/2004	950	-1.26	16.14	np	9.88	0	6.26	
	4/13/2004	715	2.92	16.14	np	9.92	0	6.22	
	5/19/2004	1129	-1.19	16.14	np	10.58	0	5.56	
	6/16/2004	1117	-0.35	16.14	np	10.68	0	5.46	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-33(A) cont.	7/19/2004	919	-5.63	16.14	np	10.7	0	5.44	
	7/19/2004	1310	0.67	16.14	np	10.76	0	5.38	
	8/17/2004	1053	-1.98	16.14	np	11.02	0	5.12	
	9/16/2004	1017	-2.05	16.14	np	10.75	0	5.39	
MW-34(A)	10/13/2003	1003	-1.55	15.83	np	9.59	0	6.24	15.35
	10/15/2003	930	-0.99	15.83	np	9.57	0	6.26	
	11/12/2003	1308	3.06	15.83	np	9.3	0	6.53	
	12/16/2003	1054	0.48	15.83	np	7.91	0	7.92	
	1/11/2004	1429	4.01	15.83	np	7.28	0	8.55	
	1/13/2004	830	-0.07	15.83	np	7.31	0	8.52	
	2/12/2004	1236	-3.4	15.83	np	7.21	0	8.62	
	3/18/2004	1104	4.6	15.83	np	7.64	0	8.19	
	4/12/2004	1000	-1.26	15.83	np	7.96	0	7.87	
	4/14/2004	720	2.14	15.83	np	8.04	0	7.79	
	5/19/2004	1216	0.49	15.83	np	8.54	0	7.29	
	6/16/2004	1135	1.01	15.83	np	8.76	0	7.07	
	7/19/2004	926	-5.63	15.83	np	9.06	0	6.77	
	7/20/2004	710	-2.99	15.83	np	9.02	0	6.81	
	8/17/2004	1106	-1.98	15.83	np	9.42	0	6.41	
	9/16/2004	1112	-0.04	15.83	np	9.66	0	6.17	
MW-35(A)	10/13/2003	1007	-1.55	16.50	np	9.9	0	6.60	15.32
	10/16/2003	1115	0.27	16.50	np	9.86	0	6.64	
	11/12/2003	1228	1.93	16.50	np	9.47	0	7.03	
	12/16/2003	1154	-0.19	16.50	np	7.7	0	8.80	
	1/11/2004	1449	4.58	16.50	np	6.95	0	9.55	
	1/16/2004	1230	-2.45	16.50	np	6.87	0	9.63	
	2/12/2004	1236	-3.4	16.50	np	6.53	0	9.97	
	3/18/2004	1143	4.37	16.50	np	7.22	0	9.28	
	4/12/2004	1011	-1.26	16.50	np	7.63	0	8.87	
	4/13/2004	1550	-4	16.50	np	7.65	0	8.85	
	5/19/2004	1227	0.49	16.50	np	8.33	0	8.17	
	6/16/2004	1148	1.01	16.50	np	8.63	0	7.87	

Table 2-1
Groundwater Measurements
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Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-35(A)	7/19/2004	936	-4.71	16.50	np	9.08	0	7.42	
cont.	7/20/2004	832	-5.4	16.50	np	9.08	0	7.42	
	8/17/2004	1134	-0.05	16.50	np	9.51	0	6.99	
	9/16/2004	1104	-0.04	16.50	np	9.44	0	7.06	
MW-36(A)	10/13/2003	1124	-0.1	16.14	np	8.96	0	7.18	15.36
	10/21/2003	1130	2.25	16.14	np	8.78	0	7.36	
	11/12/2003	926	-1.42	16.14	np	8.41	0	7.73	
	12/16/2003	1322	-0.3	16.14	np	5.74	0	10.40	
	1/11/2004	1605	4.26	16.14	np	5.67	0	10.47	
	1/14/2004	1500	0.02	16.14	np	4.63	0	11.51	
	2/12/2004	1002	-2.53	16.14	np	4.19	0	11.95	
	3/18/2004	1328	3.1	16.14	np	4.83	0	11.31	
	4/12/2004	1043	-2.84	16.14	np	5.48	0	10.66	
	4/14/2004	1230	-1.18	16.14	np	5.55	0	10.59	
	5/19/2004	1320	1.86	16.14	np	6.48	0	9.66	
	6/16/2004	1259	1.78	16.14	np	6.87	0	9.27	
	7/19/2004	1046	-2.94	16.14	np	7.54	0	8.60	
	7/22/2004	1011	-5.09	16.14	np	7.6	0	8.54	
	8/17/2004	1215	-0.05	16.14	np	8.33	0	7.81	
	9/16/2004	1205	2.05	16.14	np	8.34	0	7.80	
MW-37(A)	10/13/2003	1011	-1.55	18.22	np	11.31	0	6.91	15.41
	10/17/2003	810	1.8	18.22	np	11.23	0	6.99	
	11/12/2003	1242	3.06	18.22	np	10.83	0	7.39	
	12/16/2003	1146	-0.19	18.22	8.39	8.4	0.01	9.83	
	1/11/2004	1447	4.58	18.22	7.32	7.33	0.01	10.90	
	2/12/2004	1159	-3.92	18.22	np	6.7	0	11.52	
	3/18/2004	1132	4.37	18.22	Trace	7.57	Trace	10.65	
	4/12/2004	1015	-1.26	18.22	8.05	8.08	0.03	10.17	

Table 2-1
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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-37(A) cont.	5/19/2004	1429	2.56	18.22	9.02	9.07	0.05	9.19	
	6/16/2004	1142	1.01	18.22	Trace	9.42	Trace	8.80	
	7/19/2004	1108	-2.94	18.22	10.12	10.13	0.01	8.09	
	8/17/2004	1130	-0.05	18.22	8.04	8.05	0.01	10.17	
	9/16/2004	1116	-0.04	18.22	10.77	10.81	0.04	7.41	
MW-38(A)	10/13/2003	1130	1.5	17.20	np	8.95	0	8.25	15.38
	10/21/2003	1040	3.15	17.20	np	8.53	0	8.67	
	11/12/2003	919	-1.42	17.20	np	8.33	0	8.87	
	12/16/2003	1314	-0.3	17.20	np	5.21	0	11.99	
	1/11/2004	1609	4.26	17.20	np	4.26	0	12.94	
	1/14/2004	810	2.72	17.20	np	4.4	0	12.80	
	2/12/2004	954	-2.53	17.20	np	3.72	0	13.48	
	3/18/2004	1322	3.1	17.20	np	4.74	0	12.46	
	4/12/2004	1037	-2.84	17.20	np	5.45	0	11.75	
	4/14/2004	1045	2.07	17.20	np	5.48	0	11.72	
	5/19/2004	1315	1.86	17.20	np	6.48	0	10.72	
	6/16/2004	1254	1.78	17.20	np	6.83	0	10.37	
	7/19/2004	1052	-2.94	17.20	np	7.67	0	9.53	
	7/22/2004	910	-4.31	17.20	np	7.72	0	9.48	
	8/17/2004	1209	-0.05	17.20	np	8.31	0	8.89	
	9/16/2004	1200	2.05	17.20	np	8.1	0	9.10	
MW-39(A)	10/13/2003	1025	-1.55	17.29	np	9.3	0	7.99	15.41
	10/16/2003	1540	3.64	17.29	np	9.22	0	8.07	
	12/16/2003	1104	0.48	17.29	np	5.79	0	11.50	
	1/11/2004	1435	4.01	17.29	np	4.71	0	12.58	
	1/16/2004	925	3.77	17.29	np	4.65	0	12.64	
	2/12/2004	1225	-3.92	17.29	np	4.21	0	13.08	
	3/18/2004	1114	4.6	17.29	np	5.12	0	12.17	
	4/12/2004	1032	-2.84	17.29	np	5.8	0	11.49	
	4/14/2004	920	3.58	17.29	np	5.89	0	11.40	
	5/19/2004	1531	1.47	17.29	np	6.85	0	10.44	
	6/16/2004	1433	1.13	17.29	np	7.24	0	10.05	

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Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-39(A)	7/19/2004	1100	-2.94	17.29	np	8	0	9.29	
cont.	7/21/2004	1333	0.54	17.29	np	8.05	0	9.24	
	8/17/2004	1116	-1.98	17.29	np	8.6	0	8.69	
	9/16/2004	1135	2.05	17.29	np	8.51	0	8.78	
MW-40(A)	10/13/2003	1025	-1.55	16.17	np	9.56	0	6.61	15.42
	10/17/2003	935	0.7	16.17	np	9.51	0	6.66	
	11/12/2003	1235	3.06	16.17	9.18	9.27	0.09	6.98	
	12/16/2003	1138	-0.19	16.17	np	7.45	0	8.72	
	1/11/2004	1444	4.58	16.17	np	6.68	0	9.49	
	1/20/2004	800	1.34	16.17	np	6.64	0	9.53	
	2/12/2004	1211	-3.92	16.17	np	6.24	0	9.93	
	3/18/2004	1125	4.6	16.17	np	6.96	0	9.21	
	4/12/2004	1018	-1.26	16.17	np	7.41	0	8.76	
	4/16/2004	1420	0.37	16.17	np	7.48	0	8.69	
	5/19/2004	1506	2.39	16.17	8.02	8.06	0.04	8.14	
	6/16/2004	1447	1.13	16.17	8.39	8.41	0.02	7.78	
	7/19/2004	1106	-2.94	16.17	8.88	8.95	0.07	7.28	
	8/17/2004	1126	-1.98	16.17	9.3	9.37	0.07	6.86	
	9/16/2004	1124	-0.04	16.17	np	9.14	0	7.03	
MW-41(A)	10/13/2003	907	-2.52	15.67	np	9.23	0	6.44	15.35
	10/14/2003	1540	2.91	15.67	np	9.25	0	6.42	
	11/12/2003	1417	3.65	15.67	np	8.91	0	6.76	
	12/16/2003	937	1.46	15.67	np	7.39	0	8.28	
	1/11/2004	1342	4.01	15.67	np	6.72	0	8.95	
	1/16/2004	1125	0.54	15.67	np	7.12	0	8.55	
	2/12/2004	1400	-2.19	15.67	6.41	6.71	0.3	9.22	
	3/18/2004	1004	3.9	15.67	6.95	7.92	0.97	8.59	
	4/12/2004	922	0.43	15.67	7.29	7.91	0.62	8.30	
	5/19/2004	1005	-2.92	15.67	8	8.25	0.25	7.64	
	7/19/2004	841	-4.71	15.67	8.64	8.66	0.02	7.03	
	8/17/2004	958	-3.83	15.67	Trace	9.04	Trace	6.63	
	9/16/2004	917	-3.7	15.67	np	8.87	0	6.80	

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Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-42(A)	10/13/2003	859	-2.52	15.91	np	9.39	0	6.52	15.37
	10/15/2003	1100	-0.18	15.91	np	9.38	0	6.53	
	11/12/2003	1408	3.65	15.91	np	9.06	0	6.85	
	12/16/2003	925	2.67	15.91	np	7.52	0	8.39	
	1/11/2004	1340	4.01	15.91	6.83	6.9	0.07	9.07	
	2/12/2004	1352	-2.19	15.91	6.41	7.47	1.06	9.36	
	3/18/2004	957	3.9	15.91	6.91	8.6	1.69	8.78	
	4/12/2004	926	0.43	15.91	7.29	8.89	1.6	8.41	
	5/19/2004	1029	-2.92	15.91	8	9.5	1.5	7.72	
	6/16/2004	1007	-1.94	15.91	8.35	8.87	0.52	7.49	
	7/19/2004	844	-5.63	15.91	8.78	9.15	0.37	7.08	
	8/17/2004	953	-3.83	15.91	9.2	9.57	0.37	6.66	
	9/16/2004	911	-3.7	15.91	8.89	8.91	0.02	7.02	
MW-43(A)	10/13/2003	857	-2.52	15.94	np	9.07	0	6.87	15.35
	10/13/2003	1645	0.78	15.94	np	9.01	0	6.93	
	11/12/2003	1403	3.65	15.94	np	8.74	0	7.20	
	12/16/2003	930	1.46	15.94	np	6.97	0	8.97	
	1/11/2004	1337	4.01	15.94	np	6.24	0	9.70	
	1/12/2004	1053	-1.03	15.94	np	6.33	0	9.61	
	2/12/2004	1347	-2.19	15.94	np	6	0	9.94	
	3/18/2004	953	3.9	15.94	np	6.62	0	9.32	
	4/12/2004	928	0.43	15.94	np	7.05	0	8.89	
	4/13/2004	1230	-3.33	15.94	np	7.1	0	8.84	
	5/19/2004	1050	-1.19	15.94	np	7.81	0	8.13	
	6/16/2004	1002	-1.94	15.94	np	8.02	0	7.92	
	7/19/2004	850	-5.63	15.94	np	8.52	0	7.42	
	7/21/2004	1133	-2.95	15.94	np	8.56	0	7.38	
	8/17/2004	950	-3.83	15.94	np	8.97	0	6.97	
	9/16/2004	908	-3.7	15.94	np	8.62	0	7.32	
MW-44(A)	10/13/2003	1010	-1.55	15.31	np	8.22	0	7.09	15.41
	10/17/2003	1135	0.72	15.31	np	8.17	0	7.14	
	11/12/2003	1302	3.06	15.31	np	7.95	0	7.36	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-44(A) cont.	12/16/2003	1132	-0.19	15.31	5.88	6.02	0.14	9.41	
	1/11/2004	1442	4.58	15.31	5.1	5.24	0.14	10.19	
	2/12/2004	1217	-3.92	15.31	4.15	4.34	0.19	11.13	
	3/18/2004	1119	4.6	15.31	4.82	4.99	0.17	10.46	
	4/12/2004	1020	-1.26	15.31	8.29	9.04	0.75		
	5/19/2004	1509	2.39	15.31	6.14	6.91	0.77	9.07	
	6/16/2004	1439	1.13	15.31	6.37	6.75	0.38	8.89	
	7/19/2004	1104	-2.94	15.31	7.12	7.57	0.45	8.13	
	8/17/2004	1121	-1.98	15.31	7.77	8.09	0.32	7.50	
	9/16/2004	1129	-0.04	15.31	6.68	6.8	0.12	8.61	
MW-45(A)	10/13/2003	1018	-1.55	17.32	np	9.92	0	7.40	17.16
	10/16/2003	1730	2.55	17.32	np	9.81	0	7.51	
	11/12/2003	1256	3.06	17.32	np	9.13	0	8.19	
	12/16/2003	1114	0.48	17.32	np	6.41	0	10.91	
	1/11/2004	1440	4.58	17.32	np	5.39	0	11.93	
	1/16/2004	1110	0.54	17.32	np	5.27	0	12.05	
	2/12/2004	1229	-3.92	17.32	np	4.44	0	12.88	
	3/18/2004	1109	4.6	17.32	np	5.69	0	11.63	
	4/12/2004	1029	-1.26	17.32	np	6.35	0	10.97	
	4/14/2004	820	3.11	17.32	np	6.42	0	10.90	
	5/19/2004	1532	1.47	17.32	np	7.41	0	9.91	
	6/16/2004	1425	1.8	17.32	np	7.71	0	9.61	
	7/19/2004	1057	-2.94	17.32	np	8.4	0	8.92	
	7/21/2004	1444	1.91	17.32	np	8.45	0	8.87	
	8/17/2004	1113	-1.98	17.32	np	8.97	0	8.35	
	9/16/2004	1139	2.05	17.32	np	8.8	0	8.52	
MW-46(A)	10/13/2003	919	-2.52	16.00	np	7.46	0	8.54	15.34
	10/14/2003	1015	-1.65	16.00	np	7.38	0	8.62	
	11/12/2003	857	-1.42	16.00	np	6.64	0	9.36	
	12/16/2003	837	2.67	16.00	np	3.2	0	12.80	
	1/11/2003	1318	2.89	16.00	np	2.47	0	13.53	
	1/14/2004	1020	-0.22	16.00	np	2.9	0	13.10	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-46(A) cont.	2/12/2004	901	-1.02	16.00	np	2.26	0	13.74	
	3/18/2004	1040	4.6	16.00	np	3.52	0	12.48	
	4/12/2004	850	0.43	16.00	np	4.2	0	11.80	
	4/12/2004	1555	-2.94	16.00	np	4.21	0	11.79	
	5/19/2004	1145	0.49	16.00	np	5.35	0	10.65	
	6/16/2004	912	-3.55	16.00	np	5.58	0	10.42	
	7/19/2004	818	-5.2	16.00	np	6.41	0	9.59	
	7/21/2004	1005	-5.45	16.00	np	6.45	0	9.55	
	8/17/2004	942	-3.83	16.00	np	7	0	9.00	
	9/16/2004	843	-3.7	16.00	np	6.55	0	9.45	
MW-47(A)	10/13/2003	907	-2.52	16.39	np	8.42	0	7.97	15.37
	10/13/2003	1745	-1.15	16.39	np	8.39	0	8.00	
	11/12/2003	911	-1.42	16.39	np	7.65	0	8.74	
	12/16/2003	851	2.67	16.39	np	4.81	0	11.58	
	1/11/2004	1328	2.89	16.39	np	4.03	0	12.36	
	1/14/2004	1230	-2.08	16.39	np	4.35	0	12.04	
	2/12/2004	923	-1.02	16.39	np	3.82	0	12.57	
	3/18/2004	1050	4.6	16.39	np	5.43	0	10.96	
	4/12/2004	846	0.43	16.39	np	5.42	0	10.97	
	4/12/2004	1440	-4.26	16.39	np	5.42	0	10.97	
	5/19/2004	1152	0.49	16.29	np	6.41	0	9.88	
	6/16/2004	929	-3.55	16.29	np	6.68	0	9.61	
	7/19/2004	822	-5.2	16.29	np	7.36	0	8.93	
	7/21/2004	755	-3.75	16.29	np	7.38	0	8.91	
	8/17/2004	932	-3.83	16.29	np	7.88	0	8.41	
	9/16/2004	852	-3.7	16.29	np	7.72	0	8.57	
MW-48(A)	10/13/2003	915	-2.52	16.21	np	8.51	0	7.70	15.88
	10/14/2003	1215	0.87	16.21	np	8.48	0	7.73	
	11/12/2003	905	-1.42	16.21	np	7.9	0	8.31	
	12/16/2003	844	2.67	16.21	np	5.65	0	10.56	
	1/11/2004	1325	2.89	16.21	np	4.97	0	11.24	
	1/14/2004	1130	-1.44	16.21	np	5.25	0	10.96	

Table 2-1
Groundwater Measurements
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Locator ID	Date	Time	Observed Tide Levels (Tongue Pt)	Top of Casing (feet MSL)	Depth to Product (feet)	Depth to Water (feet)	Product Thickness (feet)	Corrected Water Elevation (feet)	Depth to Bottom (feet)
MW-48(A) cont.	2/12/2004	910	-1.02	16.21	np	4.8	0	11.41	
	3/18/2004	1046	4.6	16.21	np	5.66	0	10.55	
	4/12/2004	853	0.43	16.21	np	6.12	0	10.09	
	4/12/2004	1345	-5.05	16.21	np	6.14	0	10.07	
	5/19/2004	1159	0.49	16.21	np	6.89	0	9.32	
	6/16/2004	922	-3.55	16.21	np	7.13	0	9.08	
	7/19/2004	815	-5.2	16.21	np	7.63	0	8.58	
	7/21/2004	901	-4.95	16.21	np	7.66	0	8.55	
	8/17/2004	936	-3.83	16.21	np	8.1	0	8.11	
	9/16/2004	848	-3.7	16.21	np	7.98	0	8.23	
R-1(M)	10/22/2003	1340	0.58	13.77	np	4.55	0	9.22	
	11/12/2003	1449	3.39	13.77	np	5.06	0	8.71	
	12/16/2003	948	1.46	13.77	np	3.51	0	10.26	
	1/11/2004	1352	4.01	13.77	np	2.87	0	10.90	
Pier2(A)	12/16/2003	1628	1.91	17.37	np	10.51	0	6.86	4.95
	1/11/2004	1425	4.01	17.37	np	8.33	0	9.04	5.03
	2/12/2004	1453	-0.76	17.37	np	13.37	0	4.00	4.76
	3/18/2004	850	2.49	17.37	np	10.5	0	6.87	4.38
	4/12/2004	937	-1.26	17.37	np	12.07	0	5.30	6.56
	5/19/2004	1130	0.49	17.37	np	14.37	0	3.00	2.51
	6/16/2004	1104	-0.35	17.37	np	14.2	0	3.17	3.52
	7/19/2004	914	-5.63	17.37	np	18.43	0	-1.06	4.57
	8/17/2004	1041	-1.98	17.37	np	16.75	0	0.62	2.60
	9/16/2004	1011	-2.05	17.37	np	15.71	0	1.66	3.71

NOTE:
Elevation datum from November 2003 survey.

Table 3-1
Identification of Chemicals of Potential Concern for Soil
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Chemicals of Interest	Sample Size	Detection Frequency (%)	Background Concentration[a] (mg/kg)	Maximum Detected Concentration (mg/kg)	Screening Value[b] (mg/kg)	Chemical Risk Score[c]		Comment
Volatile Organic Compounds								
1,2,4-Trimethylbenzene	234	46.2	NA	6.89E+02	1.70E+02	4.1E+00	**	COPC
1,2-Dichloroethane	236	0.8	NA	3.15E-04	6.00E-01	5.3E-04		IFD, BSL
1,3,5-Trimethylbenzene	236	41.9	NA	1.89E+02	7.00E+01	2.7E+00	**	COPC
1,4-Dichlorobenzene	98	1.0	NA	2.22E-04	7.90E+00	2.8E-05		IFD, BSL
2-Butanone	98	4.1	NA	1.45E-01	1.10E+05	1.3E-06		IFD, BSL
4-Isopropyltoluene	98	6.1	NA	4.34E+00	NV	NA		COPC(NTD)
Acetone	96	22.9	NA	1.00E-02	5.40E+04	1.9E-07		BSL
Benzene	470	13.6	NA	1.72E+01	1.40E+00	1.2E+01	**	COPC
Bromomethane	95	4.2	NA	4.28E-04	1.30E+01	3.3E-05		IFD, BSL
Carbon Disulfide	98	7.1	NA	3.89E-03	7.20E+02	5.4E-06		BSL
Chloromethane	98	2.0	NA	1.67E-02	1.60E+02	1.0E-04		IFD, BSL
Ethylbenzene	469	30.9	NA	2.04E+02	4.00E+02	5.1E-01	**	COPC(MC)
Formaldehyde	5	20.0	NA	2.80E+00	1.00E+05	2.8E-05		BSL
Isopropylbenzene	236	28.4	NA	2.26E+01	2.00E+03	1.1E-02		BSL
Methyl iodide	96	1.0	NA	4.99E-03	NV	NA		IFD
Methylene Chloride	97	7.2	NA	1.77E-02	2.10E+01	8.4E-04		BSL
Naphthalene	249	45.0	NA	1.32E+02	1.90E+02	6.9E-01	**	COPC(MC)
n-Butylbenzene	98	14.3	NA	1.50E+01	2.40E+02	6.3E-02	**	COPC(MC)
n-Propylbenzene	236	34.3	NA	9.13E+01	2.40E+02	3.8E-01	**	COPC(MC)
sec-Butylbenzene	98	5.1	NA	4.88E+00	2.20E+02	2.2E-02	**	COPC(MC)
tert-Butylbenzene	98	1.0	NA	9.61E-03	3.90E+02	2.5E-05		IFD, BSL
Tetrachloroethene	98	13.3	NA	5.98E-03	1.30E+00	4.6E-03		BSL
Toluene	468	14.5	NA	1.69E+02	5.20E+02	3.3E-01		BSL
Xylenes	470	32.3	NA	1.16E+03	4.20E+02	2.8E+00	**	COPC
Semivolatile Organic Compounds								
2-Methylnaphthalene	2	100.0	NA	8.05E+01	NV	NA		COPC(NTD)
Acenaphthene	187	20.9	NA	8.70E+00	2.90E+04	3.0E-04		BSL
Acenaphthylene	187	3.7	NA	1.65E+00	NV	NA		IFD
Anthracene	187	18.7	NA	3.72E+00	1.00E+05	3.7E-05		BSL

Table 3-1
Identification of Chemicals of Potential Concern for Soil
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Chemicals of Interest	Sample Size	Detection Frequency (%)	Background Concentration[a] (mg/kg)	Maximum Detected Concentration (mg/kg)	Screening Value[b] (mg/kg)	Chemical Risk Score[c]		Comment
Semivolatile Organic Compounds, cont.								
Benzo(a)anthracene	187	11.8	NA	4.43E+00	2.10E+00	2.1E+00	**	COPC
Benzo(a)pyrene	187	13.4	NA	5.84E+00	2.10E-01	2.8E+01	**	COPC
Benzo(b)fluoranthene	187	11.8	NA	3.48E+00	2.10E+00	1.7E+00	**	COPC
Benzo(g,h,i)perylene	187	16.6	NA	6.39E+00	NV	NA		COPC(NTD)
Benzo(k)fluoranthene	187	9.6	NA	3.54E+00	2.10E+01	1.7E-01	**	COPC(MC)
Chrysene	187	22.5	NA	5.39E+00	2.10E+02	2.6E-02	**	COPC(MC)
Dibenzo(a,h)anthracene	187	7.0	NA	6.94E-01	2.10E-01	3.3E+00	**	COPC
Fluoranthene	187	21.4	NA	2.45E+01	2.20E+04	1.1E-03		BSL
Fluorene	187	23.0	NA	2.54E+01	2.60E+04	9.8E-04		BSL
Indeno(1,2,3-cd)pyrene	187	12.8	NA	4.23E+00	2.10E+00	2.0E+00	**	COPC
Naphthalene	187	28.3	NA	7.11E+01	1.90E+02	3.7E-01	**	COPC(MC)
Phenanthrene	187	36.4	NA	6.01E+01	NV	NA		COPC(NTD)
Pyrene	187	35.8	NA	2.44E+01	2.90E+04	8.4E-04		BSL
Hydrocarbons								
Gasoline Range Organics	341	43	NA	7.62E+03	2.20E+04	3.5E-01	**	COPC(MC)
Diesel Range Organics	336	38	NA	5.14E+04	7.00E+04	7.3E-01	**	COPC(MC)
Heavy Oil Range Organics	336	28	NA	1.92E+04	5.00E+02	3.8E+01	**	COPC
Metals								
Arsenic	77	100.0	6	1.28E+01	1.60E+00	8.0E+00	**	COPC
Barium	77	100.0	NV	1.61E+02	6.70E+04	2.4E-03		BSL
Cadmium	100	1.0	1	6.68E-01	4.50E+02	1.5E-03		IFD, BSL
Chromium	103	100.0	27	9.22E+01	4.50E+02	2.0E-01	**	COPC(MC)
Lead	178	97.2	17	2.00E+02	8.00E+02	2.5E-01	**	COPC(MC)
Mercury	77	3.9	0.04	5.51E-01	3.10E+02	1.8E-03		IFD, BSL
Selenium	77	26.0	NV	2.45E+01	5.10E+03	4.8E-03		BSL
Polychlorianted Biphenyls								
Aroclor 1254	0	0.0	NV	0.00E+00	7.40E-01	0.0E+00		IFD
Cumulative Risk Score						1.09E+02		
Total Number of Chemicals						50		

Table 3-2
Identification of Chemicals of Potential Concern for Groundwater
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Chemicals of Interest	Sample Size	Detection Frequency (%)	Maximum Detected Concentration	Screening Value[d]	Chemical Risk Score[c]	Comment
Volatile Organic Compounds (µg/L)						
1,2,4-Trimethylbenzene	159	49.7	3.47E+03	1.20E+01	2.9E+02	COPC
1,2-Dichloroethane	159	1.3	6.80E+00	1.20E-01	5.7E+01	COPC
1,3,5-Trimethylbenzene	159	39.6	8.98E+02	1.20E+01	7.5E+01	COPC
Benzene	159	56.6	3.02E+03	3.50E-01	8.6E+03	COPC
Ethylbenzene	159	67.9	2.89E+03	1.30E+03	2.2E+00	COPC
Isopropylbenzene	159	55.3	2.33E+02	6.60E+02	3.5E-01	BSL
Methyl-t-butyl ether	159	3.1	9.80E-01	1.10E+01	8.9E-02	BSL
Naphthalene	159	56.0	1.50E+03	6.20E+00	2.4E+02	COPC
n-Propylbenzene	159	61.6	6.76E+02	2.40E+02	2.8E+00	COPC
Toluene	159	45.9	8.17E+03	7.20E+02	1.1E+01	COPC
Xylenes	159	54.1	1.49E+04	2.10E+02	7.1E+01	COPC
Semivolatile Organic Compounds (µg/L)						
Acenaphthene	159	37.7	2.45E+00	3.70E+02	6.6E-03	BSL
Acenaphthylene	159	1.3	9.98E-02	NV	NA	COPC(NTD)
Anthracene	159	3.8	1.56E-01	1.80E+03	8.7E-05	BSL
Benzo(a)anthracene	159	5.7	4.75E-02	9.20E-02	5.2E-01	BSL
Benzo(a)pyrene	159	3.1	6.90E-02	9.20E-03	7.5E+00	COPC
Benzo(b)fluoranthene	159	4.4	6.25E-02	9.20E-02	6.8E-01	BSL
Benzo(k)fluoranthene	159	3.1	5.48E-02	9.20E-01	6.0E-02	BSL
Chrysene	159	8.2	5.54E-02	9.20E+00	6.0E-03	BSL
Dibenzo(a,h)anthracene	159	1.3	1.11E-02	9.20E-03	1.2E+00	COPC
Fluoranthene	159	3.1	1.23E-01	1.50E+03	8.2E-05	BSL
Fluorene	159	30.8	4.97E+00	2.40E+02	2.1E-02	BSL
Indeno(1,2,3-cd)pyrene	159	1.9	1.40E-02	9.20E-02	1.5E-01	BSL
Naphthalene	159	60.4	1.64E+03	6.20E+00	2.6E+02	COPC
Phenanthrene	159	19.5	6.93E+00	NV	NA	COPC(NTD)
Pyrene	159	3.8	2.00E-01	1.80E+02	1.1E-03	BSL

Table 3-2
Identification of Chemicals of Potential Concern for Groundwater
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Chemicals of Interest	Sample Size	Detection Frequency (%)	Maximum Detected Concentration	Screening Value[d]	Chemical Risk Score[c]	Comment
Hydrocarbons (mg/L)						
Gasoline Range Organics	159	61.0	6.77E+01	1.00E-01	6.8E+02	COPC
Diesel Range Organics	159	45.3	9.38E+00	8.80E-02	1.1E+02	COPC
Heavy Oil Range Organics	159	13.8	2.18E+00	NV	NA	COPC(NTD)
Metals (mg/L)						
Arsenic	80	76.3	3.72E-02	4.50E-05	8.3E+02	COPC
Barium	80	100.0	2.54E-01	2.60E+00	9.8E-02	BSL
Cadmium	80	5.0	7.00E-04	1.80E-02	3.9E-02	BSL
Calcium	40	100.0	1.36E+02	NV	NA	COPC(NTD)
Chromium	97	71.1	7.09E-02	NV	NA	COPC(NTD)
Chromium, Hexavalent	15	20.0	1.86E-02	1.10E-01	1.7E-01	BSL
Iron	60	100.0	6.83E+01	1.10E+01	6.2E+00	COPC
Lead	155	87.1	6.83E+01	1.50E-02	4.6E+03	COPC
Magnesium	40	100.0	4.68E+01	NV	NA	COPC(NTD)
Manganese	40	100.0	1.05E+01	8.80E-01	1.2E+01	COPC
Mercury	80	12.5	3.30E-04	1.10E-02	3.0E-02	BSL
Potassium	40	100.0	1.24E+01	NV	NA	COPC(NTD)
Selenium	80	31.3	4.41E-03	1.80E-01	2.5E-02	BSL
Silver	80	3.8	1.80E-04	1.80E-01	1.0E-03	BSL
Sodium	40	100.0	9.63E+01	NV	NA	COPC(NTD)

Table 4-1
Human-Exposure Scenarios
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Medium	Exposure Pathway	Receptors	Selected Pathway	Reason for Selection or Exclusion
Soil (0 to 3 feet bgs)	Ingestion Inhalation Dermal absorption	Urban Residents Occupational Workers	No Yes	Commercial and industrial workers may be present over most of the site. A single property located along West Marine Drive formerly supported an appartment complex with urban residents, but the apartment complex has been demolished. Urban residential developments are unlikely to occur at the Site in the foreseeable future.
Soil (0 to 15 feet bgs)	Ingestion Inhalation Dermal absorption	Construction Workers Excavation Workers	Yes	Excavations may be developed over most of the site. Future construction workers may visit large parcels of land that could support large-scale construction projects.
Vadose-Zone Soil (bottom depth ranges from approximately 6 to 19 feet bgs)	Volatilization to outdoor air	Occupational Workers	Yes	Volatile chemicals in vadose-zone soil may migrate to the surface and enter outdoor air.
Vadose-Zone Soil (bottom depth ranges from approximately 6 to 19 feet bgs)	Volatilization to indoor air	Occupational Workers	Yes	Volatile chemicals in vadose-zone soil may migrate to the surface and enter indoor air.
Soil	Leaching to groundwater	Occupational Workers	No	Leaching to groundwater RBCs are designed to protect water that is used for drinking. Groundwater is not used for drinking, groundwater quality is monitored, and leaching models are not necessary to predict groundwater quality.
Groundwater	Ingestion Inhalation Dermal absorption	Occupational Workers	No	Groundwater in the estimated LOF is not used for drinking. The site and neighboring facilities are supplied with municipal water and will continue to be so supplied in the future.

Table 4-1
Human-Exposure Scenarios
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Medium	Exposure Pathway	Receptors	Selected Pathway	Reason for Selection or Exclusion
Groundwater	Dermal absorption	Excavation Workers	Yes	Shallow groundwater is located within 15 feet of the ground surface (reasonable maximum bottom depth of excavations) in the northern portion of the site.
Groundwater	Volatilization to outdoor air	Occupational Workers	Yes	Volatile chemicals in groundwater may migrate to the surface and enter outdoor air.
Groundwater	Volatilization to indoor air	Occupational Workers	Yes	Volatile chemicals in groundwater may migrate to the surface and enter indoor air.
Sediment	Ingestion Dermal absorption	Recreationists	No	Impacted sediment is located in Slip 2 and it is unlikely that this area will be used for recreational fishing or boating.
Surface Water	Ingestion Dermal absorption	Recreationists	No	Waterborne concentrations of site-related chemicals are expected to be very low. It is unlikely that recreationists would have significant exposure to chemicals in surface water.
Sediment and Surface Water	Fish/shellfish ingestion	Recreationists	No	Dietary exposure to site-related chemicals that bioaccumulate from water or sediment into tissues of fish and shellfish is expected to be insignificant.

Table 5-1
Exceedance of Screening Levels in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
SB-602(N)-7	9/13/2002	7	1,3,5-Trimethylbenzene	189	140	RBC Soil Vapor Intrusion—Occupational
SB-612 (N)-7	9/12/2002	7	1,3,5-Trimethylbenzene	148	140	RBC Soil Vapor Intrusion—Occupational
SB-006(A)-7	3/31/2004	7	Benzene	4.39	1.2	RBC Soil Vapor Intrusion—Occupational
SB-316-D-10.0	8/20/2002	10	Benzene	1.52	1.2	RBC Soil Vapor Intrusion—Occupational
SB-501 (M) 8-12	8/29/2002	10	Benzene	6.11	1.2	RBC Soil Vapor Intrusion—Occupational
SB-506 (M) 8-12	8/29/2002	10	Benzene	2.14	1.2	RBC Soil Vapor Intrusion—Occupational
SB-507 (M) 8-12	8/29/2002	10	Benzene	2.61	1.2	RBC Soil Vapor Intrusion—Occupational
SB-508 (M) 8-12	8/29/2002	10	Benzene	3.12	1.2	RBC Soil Vapor Intrusion—Occupational
SB-510 (M) 8-12	8/29/2002	10	Benzene	1.43	1.2	RBC Soil Vapor Intrusion—Occupational
SB-602(N)-7	9/13/2002	7	Benzene	7.84	1.2	RBC Soil Vapor Intrusion—Occupational
SB-605(N)-7	9/13/2002	7	Benzene	3.22	1.2	RBC Soil Vapor Intrusion—Occupational
SB-612 (N)-7	9/12/2002	7	Benzene	17.2 / 5.35	1.2	RBC Soil Vapor Intrusion—Occupational
SB-720(P)-8.5	8/23/2002	8.5	Benzene	5.86	1.2	RBC Soil Vapor Intrusion—Occupational
SB-820 (Q)-9C	8/29/2002	9	Benzene	3.54	1.2	RBC Soil Vapor Intrusion—Occupational
SB-821 (Q)-5	8/29/2002	5	Benzene	1.29	1.2	RBC Soil Vapor Intrusion—Occupational
SB-008(A)-2	8/26/2003	2	Benzo(a)pyrene	2.59	0.27	DEQ RBC Occupational—Direct Contact
SB-008(A)-2	8/26/2003	2	Benzo(a)pyrene	2.59	2.1	RBC Soil Ingestion/Contact—Construction Worker
SB-255(C)-7	9/4/2003	7	Benzo(a)pyrene	5.84	2.1	RBC Soil Ingestion/Contact—Construction Worker
SB-008(A)-2	8/26/2003	2	Benzo(b)fluoranthene	3.14	2.7	RBC Direct Contact—Occupational
SB-008(A)-2	8/26/2003	2	Dibenzo(a,h)anthracene	0.661	0.27	RBC Direct Contact—Occupational
SB-510 (M) 8-12	8/29/2002	10	Diesel-Range Organics	35,500	23,000	RBC Soil Ingestion/Contact—Construction Worker
SB-904 (S)-12	8/26/2002	12	Diesel-Range Organics	23,100	23,000	RBC Soil Ingestion/Contact—Construction Worker
SB-027 (A)-11	9/14/2005	11	Diesel-Range Organics	31,900	23,000	RBC Soil Ingestion/Contact—Construction Worker
SB-021(A)-11.5	9/14/2005	11.5	Diesel-Range Organics	51,400	23,000	RBC Soil Ingestion/Contact—Construction Worker

Table 5-2
Exceedance of Screening Levels for Heavy-Oil-Range Organics in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
EX-3/S-1	3/31/2004	1	Heavy-Oil-Range Organics	760	500	DEQ Soil Matrix Level 2
SB-022 (A)-10.5	9/14/2005	10.5	Heavy-Oil-Range Organics	720	500	DEQ Soil Matrix Level 2
SB254(C)-2	9/4/2003	2	Heavy-Oil-Range Organics	1,010	500	DEQ Soil Matrix Level 2
SB-321(D)-2	9/9/2003	2	Heavy-Oil-Range Organics	3,560	500	DEQ Soil Matrix Level 2
SB-321(D)-5	9/9/2003	5	Heavy-Oil-Range Organics	19,200	500	DEQ Soil Matrix Level 2
SB-710(P)-3	8/21/2002	3	Heavy-Oil-Range Organics	2,450	500	DEQ Soil Matrix Level 2
SB-712(P)-10	8/21/2002	10	Heavy-Oil-Range Organics	1,630	500	DEQ Soil Matrix Level 2
SB-712(P)-2	8/21/2002	2	Heavy-Oil-Range Organics	2,110	500	DEQ Soil Matrix Level 2
SB-804(Q)-2	8/26/2002	2	Heavy-Oil-Range Organics	953	500	DEQ Soil Matrix Level 2
SB815(Q)-4.5	8/27/2002	4.5	Heavy-Oil-Range Organics	571	500	DEQ Soil Matrix Level 2
SB-829(Q)-9	8/28/2002	9	Heavy-Oil-Range Organics	926	500	DEQ Soil Matrix Level 2
SB-833 (Q)-0	8/28/2002	0	Heavy-Oil-Range Organics	563	500	DEQ Soil Matrix Level 2
SB-904(S)-4	8/26/2002	4	Heavy-Oil-Range Organics	3,070	500	DEQ Soil Matrix Level 2
SB-905(S)-4	8/26/2002	4	Heavy-Oil-Range Organics	7,500	500	DEQ Soil Matrix Level 2
SB-906(S)-4	8/27/2002	4	Heavy-Oil-Range Organics	1,100	500	DEQ Soil Matrix Level 2
SB-908(S)-4	8/27/2002	4	Heavy-Oil-Range Organics	12,300	500	DEQ Soil Matrix Level 2
SB-909(S)-10	8/27/2002	10	Heavy-Oil-Range Organics	894	500	DEQ Soil Matrix Level 2
SB-909(S)-4	8/27/2002	4	Heavy-Oil-Range Organics	5,500	500	DEQ Soil Matrix Level 2
SB-913(S)-2	9/3/2003	2	Heavy-Oil-Range Organics	6,390	500	DEQ Soil Matrix Level 2
SB-913(S)-7	9/3/2003	7	Heavy-Oil-Range Organics	1,250	500	DEQ Soil Matrix Level 2

Table 5-3
Cancer Risk Estimates for PAHs in Soil with Elevated Heavy-Oil-Range Organics Concentrations (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Sample Date	Feet bgs	Benzo(a) Anthracene	Cancer Risk	Benzo(a) Pyrene	Cancer Risk	Benzo(b) Fluoranthene	Cancer Risk	Benzo(k) Fluoranthene	Cancer Risk
DEQ RBC—Occupational Direct Contact			2.7		0.27		2.7		27	
DEQ RBC—Construction Worker Direct Contact			21		2.1		21		210	
Ex-3/S-1	3/31/2004	1	0.0967	3.6E-08	0.102	3.8E-07	0.0941	3.5E-08	0.0592	2.2E-09
SB-254(C)-2	9/4/2003	2	0.117	4.3E-08	0.167	6.2E-07	0.249	9.2E-08	0.0335 U	1.2E-09
SB-913(S)-2	9/3/2003	2	0.335 U	1.2E-07	0.335 U	1.2E-06	0.335 U	1.2E-07	0.335 U	1.2E-08
SB-710(P)-3	8/21/2002	3	0.0134 U	5.0E-09	0.0117	4.3E-08	0.0268 U	9.9E-09	0.0134 U	5.0E-10
SB-906 (S)-4	8/27/2002	4	0.0067 U	3.2E-10	0.0067 U	3.2E-09	0.0067 U	3.2E-10	0.0067 U	3.2E-11
SB-908 (S)-4	8/27/2002	4	0.254	1.2E-08	0.148	7.0E-08	0.0868	4.1E-09	0.148	7.0E-10
SB-909 (S)-4	8/27/2002	4	0.067 U	3.2E-09	0.067 U	3.2E-08	0.067 U	3.2E-09	0.067 U	3.2E-10
SB-913(S)-7	9/3/2003	7	0.1675 U	8.0E-09	0.1675 U	8.0E-08	0.1675 U	8.0E-09	0.1675 U	8.0E-10
SB-712(P)-10	8/21/2002	10	0.326	1.6E-08	0.151	7.2E-08	0.324	1.5E-08	0.268	1.3E-09

Table 5-3
Cancer Risk Estimates for PAHs in Soil with Elevated Heavy-Oil-Range Organics Concentrations (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Sample Date	Feet bgs	Chrysene		Cancer Risk	Dibenzo(a,h) Anthracene		Cancer Risk	Indeno(1,2,3-cd) Pyrene		Cancer Risk	Total Excess Cancer Risk
DEQ RBC—Occupational Direct Contact			270			0.27			2.7			
DEQ RBC—Construction Worker Direct Contact			2,100			2.1			21			
Ex-3/S-1	3/31/2004	1	0.106		3.9E-10	0.0233		8.6E-08	0.0629		2.3E-08	5.6E-07
SB-254(C)-2	9/4/2003	2	0.199		7.4E-10	0.0439		1.6E-07	0.1		3.7E-08	9.6E-07
SB-913(S)-2	9/3/2003	2	0.335	U	1.2E-09	0.335	U	1.2E-06	0.335	U	1.2E-07	NC
SB-710(P)-3	8/21/2002	3	0.0368		1.4E-10	0.0134	U	5.0E-08	0.00864		3.2E-09	1.1E-07
SB-906 (S)-4	8/27/2002	4	0.00707		3.4E-12	0.0067	U	3.2E-09	0.00516		2.5E-10	7.3E-09
SB-908 (S)-4	8/27/2002	4	0.585		2.8E-10	0.134	U	6.4E-08	0.134	U	6.4E-09	1.6E-07
SB-909 (S)-4	8/27/2002	4	0.0389		1.9E-11	0.067	U	3.2E-08	0.067	U	3.2E-09	7.4E-08
SB-913(S)-7	9/3/2003	7	0.1675	U	8.0E-11	0.1675	U	8.0E-08	0.1675	U	8.0E-09	NC
SB-712(P)-10	8/21/2002	10	0.698		3.3E-10	0.0475		2.3E-08	0.116		5.5E-09	1.3E-07

Table 5-4
Exceedance of Screening Levels in Groundwater
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Analyte	Units	Detected Concentration	Screening Level	Screening Level Exceeded
MW-26 (A)	1/15/2004	1,2,4-Trimethylbenzene	µg/L	3,120	1,300	RBC for Direct Contact—Excavation Workers
	4/14/2004	1,2,4-Trimethylbenzene	µg/L	2,580	1,300	RBC for Direct Contact—Excavation Workers
	7/22/2004	1,2,4-Trimethylbenzene	µg/L	3,300	1,300	RBC for Direct Contact—Excavation Workers
MW-29 (A)	10/21/2003	1,2,4-Trimethylbenzene	µg/L	1,980	1,300	RBC for Direct Contact—Excavation Workers
	1/19/2004	1,2,4-Trimethylbenzene	µg/L	2,630	1,300	RBC for Direct Contact—Excavation Workers
	4/16/2004	1,2,4-Trimethylbenzene	µg/L	1,770	1,300	RBC for Direct Contact—Excavation Workers
	7/22/2004	1,2,4-Trimethylbenzene	µg/L	2,260	1,300	RBC for Direct Contact—Excavation Workers
MW-40(A)	1/20/2004	1,2,4-Trimethylbenzene	µg/L	3,170	1,300	RBC for Direct Contact—Excavation Workers
	4/16/2004	1,2,4-Trimethylbenzene	µg/L	3,170	1,300	RBC for Direct Contact—Excavation Workers
MW-44 (A)	10/17/2003	1,2,4-Trimethylbenzene	µg/L	3,470	1,300	RBC for Direct Contact—Excavation Workers
MW-42 (A)	10/15/2003	Benzene	µg/L	3,020	1,700	RBC for Direct Contact—Excavation Workers
MW-26 (A)	1/15/2004	Gasoline-Range Organics	mg/L	24.8	12	RBC for Direct Contact—Excavation Workers
	4/14/2004	Gasoline-Range Organics	mg/L	18.5	12	RBC for Direct Contact—Excavation Workers
	7/22/2004	Gasoline-Range Organics	mg/L	26	12	RBC for Direct Contact—Excavation Workers
MW-28(A)	1/19/2004	Gasoline-Range Organics	mg/L	13.8	12	RBC for Direct Contact—Excavation Workers
MW-29 (A)	10/21/2003	Gasoline-Range Organics	mg/L	60.2	12	RBC for Direct Contact—Excavation Workers
	1/19/2004	Gasoline-Range Organics	mg/L	62	12	RBC for Direct Contact—Excavation Workers
	4/16/2004	Gasoline-Range Organics	mg/L	34.2	12	RBC for Direct Contact—Excavation Workers
	7/22/2004	Gasoline-Range Organics	mg/L	39.8	12	RBC for Direct Contact—Excavation Workers
MW-30 (A)	10/16/2003	Gasoline-Range Organics	mg/L	14.7	12	RBC for Direct Contact—Excavation Workers
	7/20/2004	Gasoline-Range Organics	mg/L	12.6	12	RBC for Direct Contact—Excavation Workers
MW-40(A)	1/20/2004	Gasoline-Range Organics	mg/L	31.4	12	RBC for Direct Contact—Excavation Workers
	4/16/2004	Gasoline-Range Organics	mg/L	41.6	12	RBC for Direct Contact—Excavation Workers
MW-42 (A)	10/15/2003	Gasoline-Range Organics	mg/L	18.9	12	RBC for Direct Contact—Excavation Workers
MW-44 (A)	10/17/2003	Gasoline-Range Organics	mg/L	67.7	12	RBC for Direct Contact—Excavation Workers
MW-26 (A)	1/15/2004	Naphthalene	µg/L	1,030	680	RBC for Direct Contact—Excavation Workers
	4/14/2004	Naphthalene	µg/L	801	680	RBC for Direct Contact—Excavation Workers
	7/22/2004	Naphthalene	µg/L	869	680	RBC for Direct Contact—Excavation Workers

Table 5-4
Exceedance of Screening Levels in Groundwater
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Analyte	Units	Detected Concentration	Screening Level	Screening Level Exceeded
MW-29 (A)	10/21/2003	Naphthalene	µg/L	1,340	680	RBC for Direct Contact—Excavation Workers
	10/21/2003	Naphthalene	µg/L	1,640	680	RBC for Direct Contact—Excavation Workers
	1/19/2004	Naphthalene	µg/L	1,310	680	RBC for Direct Contact—Excavation Workers
	1/19/2004	Naphthalene	µg/L	867	680	RBC for Direct Contact—Excavation Workers
	4/16/2004	Naphthalene	µg/L	1,000	680	RBC for Direct Contact—Excavation Workers
	4/16/2004	Naphthalene	µg/L	806	680	RBC for Direct Contact—Excavation Workers
	7/22/2004	Naphthalene	µg/L	1,360	680	RBC for Direct Contact—Excavation Workers
	7/22/2004	Naphthalene	µg/L	1,040	680	RBC for Direct Contact—Excavation Workers
MW-30 (A)	10/16/2003	Naphthalene	µg/L	1,130	680	RBC for Direct Contact—Excavation Workers
	1/16/2004	Naphthalene	µg/L	1,200	680	RBC for Direct Contact—Excavation Workers
	1/16/2004	Naphthalene	µg/L	696	680	RBC for Direct Contact—Excavation Workers
	4/13/2004	Naphthalene	µg/L	1,030	680	RBC for Direct Contact—Excavation Workers
	7/20/2004	Naphthalene	µg/L	1,240	680	RBC for Direct Contact—Excavation Workers
	7/20/2004	Naphthalene	µg/L	1,130	680	RBC for Direct Contact—Excavation Workers
MW-40 (A)	1/20/2004	Naphthalene	µg/L	682	680	RBC for Direct Contact—Excavation Workers
	1/20/2004	Naphthalene	µg/L	1,220	680	RBC for Direct Contact—Excavation Workers
	4/16/2004	Naphthalene	µg/L	1,500	680	RBC for Direct Contact—Excavation Workers
	4/16/2004	Naphthalene	µg/L	850	680	RBC for Direct Contact—Excavation Workers
MW-44 (A)	10/17/2003	Naphthalene	µg/L	1,050	680	RBC for Direct Contact—Excavation Workers
	10/17/2003	Naphthalene	µg/L	696	680	RBC for Direct Contact—Excavation Workers

Table 5-5
Exceedance of Screening Levels in Soil Vapor
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Analyte	Units	Detected Concentration	Screening Level	Screening Level Exceeded
SVP-01	10/8/2004	Benzene	µg/m3	98,900	8,523	Soil Gas RBC for Occupational Workers
SVP-01	12/29/2004	Benzene	µg/m3	60,700	8,523	Soil Gas RBC for Occupational Workers
SVP-02	10/8/2004	Benzene	µg/m3	57,400	8,523	Soil Gas RBC for Occupational Workers
SVP-02	12/29/2004	Benzene	µg/m3	41,500	8,523	Soil Gas RBC for Occupational Workers
SVP-03	10/8/2004	Benzene	µg/m3	12,800	8,523	Soil Gas RBC for Occupational Workers
SVP-01	10/8/2004	Gasoline-Range Organics	ppmv	7,570	3,479	Soil Gas RBC for Occupational Workers
SVP-01	12/29/2004	Gasoline-Range Organics	ppmv	6,650	3,479	Soil Gas RBC for Occupational Workers

Table 5-6
Exceedance of Urban Residential Screening Levels in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
Ex-3/S	3/31/2004	1	Benzo(a)pyrene	0.102	0.031	DEQ RBC—Urban Residential Direct Contact
SB-006(A)	3/31/2004	7	Gasoline-Range Organics	2190	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	186	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	31.1	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	4.39	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-007(A)	8/26/2003	7.5	Gasoline-Range Organics	2520	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	247	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	58	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	1.19	0.15	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	120	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-008(A)	8/26/2003	2	Benzo(a)anthracene	2.53	0.31	DEQ RBC—Urban Residential Direct Contact
			Benzo(a)pyrene	2.59	0.031	DEQ RBC—Urban Residential Direct Contact
			Benzo(b)fluoranthene	3.14	0.31	DEQ RBC—Urban Residential Direct Contact
			Dibenzo(a,h)anthracene	0.661	0.031	DEQ RBC—Urban Residential Direct Contact
			Indeno(1,2,3-cd)pyrene	1.64	0.31	DEQ RBC—Urban Residential Direct Contact
SB-009(A)	8/27/2003	7.5	Gasoline-Range Organics	1670	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.309	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-015(A)	9/10/2003	7	Gasoline-Range Organics	695	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-019(A)	8/27/2003	7.5	Gasoline-Range Organics	5960	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	288	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	46.3	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	134	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-021 (A)	9/14/2005	11.5	Gasoline-Range Organics	1550	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.926	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-027 (A)	9/14/2005	11	Gasoline-Range Organics	2450	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	16.9	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.477	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-254(C)	9/4/2003	2	Benzo(a)pyrene	0.167	0.031	DEQ RBC—Urban Residential Direct Contact
			Dibenzo(a,h)anthracene	0.0439	0.031	DEQ RBC—Urban Residential Direct Contact
SB-255(C)	9/4/2003	2.5	Benzo(a)pyrene	0.118	0.031	DEQ RBC—Urban Residential Direct Contact
SB-306-D	8/19/2002	2	1,3,5-Trimethylbenzene	17	12	DEQ RBC—Urban Residential Vapor Intrusion
		4.5	Benzene	0.265	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-310-D	8/19/2002	5	1,3,5-Trimethylbenzene	49.6	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.226	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-316-D	8/20/2002	5	1,2,4-Trimethylbenzene	95.2	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	31.6	12	DEQ RBC—Urban Residential Vapor Intrusion
		10	1,2,4-Trimethylbenzene	174	70	DEQ RBC—Urban Residential Vapor Intrusion

Table 5-6
Exceedance of Urban Residential Screening Levels in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
			1,3,5-Trimethylbenzene	55.1	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	1.52	0.15	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	304	110	DEQ RBC—Urban Residential Vapor Intrusion
		14.5	1,2,4-Trimethylbenzene	115	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	36.4	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.37	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-318-D	8/20/2002	10	1,2,4-Trimethylbenzene	80.2	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	25	12	DEQ RBC—Urban Residential Vapor Intrusion
		15	1,3,5-Trimethylbenzene	18.6	12	DEQ RBC—Urban Residential Vapor Intrusion
SB-321(D)	9/9/2003	2	Gasoline-Range Organics	392	140	DEQ RBC—Urban Residential Vapor Intrusion
		5	Gasoline-Range Organics	1530	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	22.2	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.563	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-324(D)	9/10/2003	10	Gasoline-Range Organics	586	140	DEQ RBC—Urban Residential Vapor Intrusion
		15	Gasoline-Range Organics	162	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-324(D)-DUP			Benzene	0.156	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-326(D)	9/9/2003	5	Gasoline-Range Organics	870	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.599	0.15	DEQ RBC—Urban Residential Vapor Intrusion
		10	Gasoline-Range Organics	1920	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.639	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-327(D)	9/10/2003	10	Gasoline-Range Organics	758	140	DEQ RBC—Urban Residential Vapor Intrusion
		15	Gasoline-Range Organics	390	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-328(D)	9/10/2003	10	Gasoline-Range Organics	1360	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	77	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	13.1	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.472	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-407(F)	8/22/2002	7.5	Gasoline-Range Organics	1570	140	DEQ RBC—Urban Residential Vapor Intrusion
SB407/S-2	8/22/2002	7	Gasoline-Range Organics	1470	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-408(F)	8/22/2002	2.5	Benzo(a)pyrene	0.0582	0.031	DEQ RBC—Urban Residential Direct Contact
SB-501 (M)	8/29/2002	10	Gasoline-Range Organics	1300	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	6.11	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-502 (M)	8/29/2002	10	Gasoline-Range Organics	217	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-503 (M)	8/29/2002	10	Gasoline-Range Organics	490	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-505 (M)	8/29/2002	10	Gasoline-Range Organics	186	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-506 (M)	8/29/2002	10	Gasoline-Range Organics	890	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	2.14	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-507 (M)	8/29/2002	10	Gasoline-Range Organics	532	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	2.61	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-508 (M)	8/29/2002	10	Gasoline-Range Organics	1380	140	DEQ RBC—Urban Residential Vapor Intrusion

Table 5-6
Exceedance of Urban Residential Screening Levels in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
			Benzene	3.12	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-510 (M)	8/29/2002	10	Gasoline-Range Organics	2040	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	1.43	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-600(N)	9/13/2002	7	Gasoline-Range Organics	2510	140	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	171	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-601(N)	9/13/2002	7	Gasoline-Range Organics	3750	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	252	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	65.9	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	482	110	DEQ RBC—Urban Residential Vapor Intrusion
				426	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-602(N)	9/13/2002	7	Gasoline-Range Organics	337	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	689	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	189	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	7.84	0.15	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	1160	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-603(N)	9/13/2002	7	Gasoline-Range Organics	3750	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	151	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	40.3	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	393	110	DEQ RBC—Urban Residential Vapor Intrusion
				253	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-604(N)	9/13/2002	7	1,2,4-Trimethylbenzene	392	70	DEQ RBC—Urban Residential Vapor Intrusion
					200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
			1,3,5-Trimethylbenzene	118	12	DEQ RBC—Urban Residential Vapor Intrusion
			Gasoline-Range Organics	601	140	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	172	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-605(N)	9/13/2002	3	Benzene	0.157	0.15	DEQ RBC—Urban Residential Vapor Intrusion
		7	Gasoline-Range Organics	3000	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	567	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	137	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	3.22	0.15	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	333	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-612 (N)	9/12/2002	7	Gasoline-Range Organics	4100	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	480	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	148	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	17.2	0.15	DEQ RBC—Urban Residential Vapor Intrusion

Table 5-6
Exceedance of Urban Residential Screening Levels in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
				5.35	0.15	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	478	110	DEQ RBC—Urban Residential Vapor Intrusion
				931	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-613 (N)	9/12/2002	5.5	Gasoline-Range Organics	2110	140	DEQ RBC—Urban Residential Vapor Intrusion
	9/12/2002	5.5	Xylenes	181	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-614 (N)	9/12/2002	7	Gasoline-Range Organics	1370	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-615 (N)	9/12/2002	7	Gasoline-Range Organics	1340	140	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	156	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-616 (N)	9/12/2002	7	Gasoline-Range Organics	4000	140	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	207	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-618 (N)	9/12/2002	7	Gasoline-Range Organics	1780	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	150	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	47.3	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	137	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-619 (N)	9/12/2002	11	1,2,4-Trimethylbenzene	284	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	58.3	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	287	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-620 (N)	9/12/2002	7	Gasoline-Range Organics	2130	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	121	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	39.3	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	121	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-623 (N)	9/12/2002	7	Gasoline-Range Organics	1460	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	102	70	DEQ RBC—Urban Residential Vapor Intrusion
SB-624 (N)	9/12/2002	7	Gasoline-Range Organics	753	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-626 (N)	9/12/2002	7	Gasoline-Range Organics	4560	4500	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	221	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	66.4	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	195	110	DEQ RBC—Urban Residential Vapor Intrusion
				295	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-627(N)-2	8/28/2003	2	Benzo(a)pyrene	0.0577	0.031	DEQ RBC—Urban Residential Direct Contact
SB-629(N)	8/28/2003	7.5	Gasoline-Range Organics	1650	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-632(N)	9/8/2003	7.5	Gasoline-Range Organics	1690	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	152	70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	36.8	12	DEQ RBC—Urban Residential Vapor Intrusion
SB-700(P)	8/21/2002	10.5	Gasoline-Range Organics	2920	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-714(P)	8/21/2002	7.5	Gasoline-Range Organics	1150	140	DEQ RBC—Urban Residential Vapor Intrusion

Table 5-6
Exceedance of Urban Residential Screening Levels in Soil (mg/kg)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Feet bgs	Analyte	Detected Concentration	Screening Level	Screening Level(s) Exceeded
		10	Gasoline-Range Organics	3460	140	DEQ RBC—Urban Residential Vapor Intrusion
			1,2,4-Trimethylbenzene	262	200	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					70	DEQ RBC—Urban Residential Vapor Intrusion
			1,3,5-Trimethylbenzene	83.5	12	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	344	110	DEQ RBC—Urban Residential Vapor Intrusion
				259	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-720(P)	8/23/2002	2	Benzo(a)pyrene	0.238	0.031	DEQ RBC—Urban Residential Direct Contact
			Dibenzo(a,h)anthracene	0.052	0.031	DEQ RBC—Urban Residential Direct Contact
		8.5	Gasoline-Range Organics	3420	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	5.86	0.15	DEQ RBC—Urban Residential Vapor Intrusion
		11.5	Gasoline-Range Organics	2590	140	DEQ RBC—Urban Residential Vapor Intrusion
			Xylenes	125	110	DEQ RBC—Urban Residential Vapor Intrusion
SB-807 (Q)-7	8/28/2002	7	Gasoline-Range Organics	2300	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-820 (Q)	8/29/2002	9	Gasoline-Range Organics	537	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	3.54	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-821 (Q)	8/29/2002	5	Gasoline-Range Organics	1950	140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	1.29	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-821 (Q)	8/29/2002	5	Gasoline-Range Organics	459	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-822 (Q)	8/29/2002	8	Gasoline-Range Organics	7620	4500	DEQ RBC—Urban Residential Volatilization to Outdoor Air
					140	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.307	0.15	DEQ RBC—Urban Residential Vapor Intrusion
SB-900(S)	8/26/2002	12	Gasoline-Range Organics	2160	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-903 (S)	8/26/2002	10	Gasoline-Range Organics	396	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-904 (S)	8/26/2002	12	Gasoline-Range Organics	647	140	DEQ RBC—Urban Residential Vapor Intrusion
SB-D-DUP-3	8/20/2002	3	1,3,5-Trimethylbenzene	13.5	12	DEQ RBC—Urban Residential Vapor Intrusion
			Benzene	0.168	0.15	DEQ RBC—Urban Residential Vapor Intrusion

Table 5-7
Exceedance of Urban Residential Screening Levels in Groundwater (µg/l)
Astoria Area-Wide Petroleum Site
Astoria, Oregon

Sample ID	Date	Analyte	Detected Concentration	Screening Level	Screening Level Exceeded
MW-13 (A)	1/15/2004	Benzene	750	340	DEQ RBC—Vapor Intrusion—Urban Residential
	4/16/2004	Benzene	564	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-28 (A)	1/19/2004	Benzene	702	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-29 (A)	7/22/2004	Benzene	380	340	DEQ RBC—Vapor Intrusion—Urban Residential
	10/21/2003	Benzene	482	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-30 (A)	1/16/2004	Benzene	341	340	DEQ RBC—Vapor Intrusion—Urban Residential
	4/13/2004	Benzene	533	340	DEQ RBC—Vapor Intrusion—Urban Residential
	7/20/2004	Benzene	407	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-31 (A)	10/16/2003	Benzene	1170	340	DEQ RBC—Vapor Intrusion—Urban Residential
	1/12/2004	Benzene	1390	340	DEQ RBC—Vapor Intrusion—Urban Residential
	4/13/2004	Benzene	574	340	DEQ RBC—Vapor Intrusion—Urban Residential
	7/20/2004	Benzene	1020	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-41(A)	10/14/2003	Benzene	355	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-42 (A)	10/15/2003	Benzene	3020	340	DEQ RBC—Vapor Intrusion—Urban Residential
MW-44 (A)	10/17/2003	Benzene	898	340	DEQ RBC—Vapor Intrusion—Urban Residential

FIGURES

Figure 4-1
Conceptual Site Model of
Potential Human Exposure Pathways
Astoria Area-Wide Petroleum Site
Astoria, Oregon