DRAFT FINAL

RISK ASSESSMENT/FEASIBILITY STUDY

PORT QUENDALL TERMINALS SITE

Prepared for

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1 INTRODUCTION

The Quendall Terminals Site (Site) is a 23-acre property located on the southeast shore of Lake Washington. Shortly after the lowering of Lake Washington in 1916 to construct the Lake Washington Ship Canal, the Site, including newly exposed portions of the former May Creek delta, was developed into a creosote manufacturing facility. Up until 1969, creosote was manufactured on Site by refining and processing coal tar and oil-gas tar residues. From 1969 to approximately 1977, some of the above-ground tanks at the Site were used intermittently for crude oil, waste oil, and diesel storage. Since 1977, the Site has been used primarily for log sorting and storage. Aquatic lands adjacent to the facility and managed by the Washington Department of Natural Resources (DNR) have been leased for log rafting and vessel storage uses since approximately 1936.

The physical and chemical characteristics of the Site have been explored through more than 150 soil/sediment borings and test pits excavated for environmental and geotechnical investigations over the past 30 years. These data support a relatively detailed description of the nature and extent of hazardous substances present at the Site, including identification of cleanup requirements under the Washington State Model Toxics Control Act (MTCA; Chapter 173-340 Washington Administrative Code [WAC]; Chapter 70.105D RCW). The considerable validated site characterization data collected to date at the Site (e.g., Hart Crowser 1997, Retec 1997, Retec and Papadopoulos 1998, Exponent 1999, and others) have previously been submitted to the Washington Department of Ecology (Ecology), and have been incorporated into the existing administrative record for the Site. The principal findings and conceptual site model developed from these investigations were summarized in the Data Gap Memo (Anchor and Aspect 2002) and the Risk Assessment/ Feasibility Study Work Plan (Work Plan; Anchor and Aspect 2003). Based on a review of these data, polynuclear aromatic hydrocarbons (PAHs) and other organic chemicals such as benzene and wood waste have previously been detected at the Site at concentrations that trigger actions under MTCA. The Site has been listed by Ecology as a hazardous substance cleanup site.

1.1 Purpose of the Risk Assessment

Sections 2 through 5 of this report detail the derivation of cleanup levels and proposed site-specific points of compliance (incorporating the results of the site-specific risk assessment [RA]) for use in the feasibility study (FS), including the identification of chemicals of

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potential concern (COPC). An update of the site conceptual model is also provided, which was informed by prior site characterization efforts, also incorporating data recently collected as part of the RA/FS.

Under MTCA, cleanup standards consist of cleanup levels (numeric concentrations at which risks are not expected to occur under a reasonable maximum exposure condition) and points of compliance (the location at which the cleanup level must be met). Cleanup standards are developed for those media that are affected by site contaminants such as soil, groundwater, sediment, and surface water. Consistent with MTCA requirements, cleanup levels were developed assuming the site will continue to be used for industrial storage. In addition, cleanup levels were developed for potential future alternative land uses. The final determination of site-specific cleanup levels and points of compliance will be made by Ecology following public review of the RA/FS and subsequent Cleanup Action Plan.

1.2 Purpose of the Feasibility Study

The FS, presented in Sections 6 through 11 of this RA/FS report, builds upon the risk-based cleanup standards developed from the RA. Site-wide remedial alternatives are developed from an initial screening of technologies. The identification and assembly of cleanup technologies into site-wide alternatives was performed in accordance with the MTCA regulations and associated guidance (e.g., Sediment Management Standards User Manual), along with additional direction provided by Ecology. Each alternative was developed to achieve cleanup standards at the Site, though the alternatives use different remedial technologies to accomplish this objective. Each alternative is evaluated relative to the applicable criteria. The overall FS evaluation is intended to provide sufficient data and engineering analysis to enable Ecology to select a cleanup action that is protective of human health and the environment.

1.3 Document Organization

The remainder of this report is presented as follows:

- Section 2 presents the methodology used to develop cleanup levels, and details the use of relevant MTCA Method B procedures, including consideration of applicable and relevant and appropriate requirements (ARARs), interim guidelines available

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from Ecology and the U.S. Environmental Protection Agency (EPA), and previously-derived site-specific levels.

- Section 3 presents the steps to identify COPCs, based on screening the substantial site-specific database against the most stringent cleanup levels that may be developed using Method B procedures. The site-specific list of COPCs is identified.
- Section 4 discusses recent refinements of the site conceptual model developed to date, including summaries of further assessments of surface soil quality conditions, groundwater to surface water fate and transport pathways, and sediment natural recovery processes, incorporating the results of recent data collection efforts.
- Section 5 presents cleanup levels and points of compliance (including conditional points of compliance) for soil, groundwater, sediment, and surface water/porewater media, given the implementation of institutional controls anticipated at the site addressing a range of Site use scenarios. The cleanup standards also inform FS evaluations of the protectiveness of potential remedial action scenarios, such as on-site management of site contaminants.
- Section 6 provides an overview of the FS.
- Section 7 presents a summary of applicable federal, state, and local laws.
- Section 8 presents an initial screening of cleanup technologies.
- Section 9 presents a description of the site-wide cleanup alternatives retained for detailed evaluation.
- Section 10 evaluates the alternatives against MTCA criteria for cleanup actions.
- Section 11 presents the recommended site-wide cleanup alternative, based on the results of the MTCA evaluation.
- Section 12 presents the references cited in the RA/FS Report.

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2 CLEANUP LEVEL DEVELOPMENT METHODOLOGY

This section presents the methodology used to develop cleanup levels to be used for screening purposes. These initial cleanup levels were developed using the most stringent assumptions in the MTCA Method B equations or ARARs, also accounting for potential cross-media transport. For sediments, site-specific values or proposed freshwater sediment quality values (SQVs; Ecology 2003), were applied as the cleanup levels. Chemicals at the Quendall Site that have been detected at concentrations exceeding these potential cleanup levels are identified in Section 3 of this memorandum as COPCs, which were carried forward in later sections of this memorandum to derive cleanup standards for all media. Proposed cleanup levels and points of compliance based on site-specific considerations are discussed in Section 5.

2.1 Methodology

Cleanup levels were developed following procedures described in the MTCA regulations. The sections below describe the methodology used to develop initial cleanup levels based on MTCA Method B procedures[1], ARARs and risk-based calculations.

2.1.1 MTCA Method B Procedure

The MTCA Cleanup Regulations (Sections 173-340-720, -730, and -740 WAC) establish procedures to develop cleanup levels for groundwater, surface water, and soil. MTCA Method B procedures employ a risk-based evaluation of potential human health and environmental exposures to site COPCs. The development of sediment cleanup levels under MTCA is established in Chapter 173-340-760 WAC through reference to the SMS (Chapter 173-204 WAC). Procedures used to develop sediment cleanup levels are discussed in Section 2.2.

As defined in the MTCA regulation, for a given chemical detected in soil, groundwater, and/or surface water media, Method B cleanup levels must be at least as stringent as established state or federal standards or other laws (i.e., ARARs) developed for human health and environmental protection. Not all chemicals have state or federal standards. If a state or federal standard was available, that ARAR was evaluated to ensure that it

[1] Modified Method B procedures for were used to develop cleanup levels for potentially carcinogenic PAHs (cPAHs) based on the approved MTCA toxicity equivalency factor (TEF) procedure. The TEF procedure was applied to address potential human health risks associated with exposure to surface water, groundwater, and soil media. No other modification to the Method B procedures was used to derive cleanup levels.

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was protective under MTCA. If the ARAR was not protective, the cleanup level was adjusted to a lower value to ensure its protectiveness. MTCA Method B risk-based calculations and any deviations from ARAR values are discussed below in Section 2.1.3.

The Method B cleanup level for one media must also be protective of the beneficial uses of other affected media. For example, since Site groundwater eventually discharges into Lake Washington, site-specific groundwater cleanup levels need to consider surface water protection requirements. The procedures for developing cleanup levels for Site groundwater, surface water, and soil are outlined in the MTCA Cleanup Regulation Sections 173-340-720, -730, and -740 WAC, respectively. Included in these sections are the specific rules for evaluating cross-media protectiveness. Where relevant to this Site, cross-media protectiveness of cleanup levels is discussed below. The development of groundwater cleanup levels using site-specific contaminant transport and risk assessment to ensure surface water protection is discussed in greater detail in Section 4.

2.1.2 ARARs

The potentially applicable federal laws that were considered for potential numeric levels include:

- Clean Water Act (including the National Toxics Rule and National Pollutant Discharge Elimination System requirements)
- Safe Drinking Water Act (including Drinking Water Standards and Health Advisories)
- Clean Air Act
- Resource Conservation and Recovery Act
- Toxic Substances Control Act

Potentially applicable state laws include:

- Water Pollution Control Act (including Surface Water Quality Standards, Groundwater Quality Standards, and SMS)
- Water Resources Act of 1971
- Drinking Water Act (including Drinking Water Regulations)
- Air Pollution Control Act
- Hazardous Waste Management Act (including Dangerous Waste Regulations)

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Table 2-1 summarizes the ARARs, and relevant MTCA citations used to develop cleanup levels for surface water, groundwater, soil, and sediment. All ARARs were evaluated for protectiveness under MTCA using risk equations described in Section 2.1.3. Where not protective, cleanup levels were adjusted downward so that the MTCA-required risk levels were achieved.

2.1.3 Risk Calculations

Baseline risk evaluations to develop potential surface water, groundwater, and soil cleanup levels were performed using standard MTCA Method B risk equations. Method B default assumptions for unrestricted site uses were used in the equations, as follows:

- For surface water, the initial risk evaluation was based on protection of human health from consumption of both shoreline drinking water and fish/shellfish potentially in contact with groundwater/porewater releases (e.g., benthic shellfish as may be present in surface sediment), conservatively assuming that a sufficiently large population of such organisms may potentially be available on-site to support such a harvest (MTCA Equations 730-1 [noncarcinogens] and 730-2 [carcinogens]). Potential drinking water uses of surface water were also addressed through an evaluation of ARARs, as discussed in Section 2.3 below.
- For groundwater, the initial risk evaluation was based on protection of human health from drinking water consumption, conservatively assuming withdrawal from hypothetical on-site supply wells (Equations 720-1 [noncarcinogens] and 720-2 [carcinogens]) (note: as discussed in the Upland Remedial Investigation Report [Hart Crowser 1997], there is no existing or identified potential future use of groundwater or shoreline surface water at this Site for drinking water consumption purposes).
- For soil, the initial risk evaluation was based on protection of human health from direct contact with soil, conservatively assuming for COPC screening purposes an unrestricted upland site use (Equations 740-1 [noncarcinogens] and 740-2 [carcinogens]).

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Table 2-1
Sources of ARARs
Evaluated for Determining Cleanup Levels

MTCA Rule Citation	Basis	Presentation in Screening Tables
Surface Water		
730(3)(b)(i)(A)	Ch. 173-201A WAC (ECO, chronic)	173-201A WAC
730(3)(b)(i)(B)	Clean Water Act (ECO, chronic)	Clean Water Act Freshwater Chronic (2002 Update)
730(3)(b)(i)(B)	Clean Water Act (HH)	Clean Water Act Freshwater Water + Organism (2002 Update)
730(3)(b)(i)(C)	40 CFR 131, NTR (ECO, chronic)	National Toxics Rule Freshwater Chronic
730(3)(b)(i)(C)	40 CFR 131, NTR (HH)	National Toxics Rule Freshwater Water + Organism
730(3)(b)(iii)(A)	Fish Consumption, non-carcinogens	MTCA Method B - Surface Water (1)
730(3)(b)(iii)(B)	Fish Consumption, carcinogens	MTCA Method B - Surface Water (1)
730(3)(b)(iv)	Ingestion → 720(4) Method B	MTCA Method B Most Restrictive Groundwater
Ground Water		
720(4)(b)(i)	SDWA, MCL (40 CFR 141)	SDWA, MCL
720(4)(b)(i)	SDWA, MCLG (40 CFR 141)	SDWA, MCLG
720(4)(b)(i)	Ch. 246-290 WAC, MCL	246-290 WAC, MCL
720(4)(b)(iii)(A)	Ingestion, non-carcinogens	MTCA Method B - Groundwater (1)
720(4)(b)(iii)(B)	Ingestion, carcinogens	MTCA Method B - Groundwater (1)
720(4)(b)(ii)	→ 730(3) Method B	MTCA Method B Most Restrictive Surface Water
Soil		
740(3)b)(i)	ARARs	Presented
740(3)b)(iii)(B)(I)	Direct Contact, non-carcinogens	MTCA Method B - Soil (1)
740(3)b)(iii)(B)II)	Direct Contact, carcinogens	MTCA Method B - Soil (1)
740(3)b)(iii)(A)	→ 720(4) Method B	na - Empirical groundwater data being used instead of soil-to-groundwater model
Sediment		
760	Sediment Mgmt. Standards Ch. 173-204 WAC	Freshwater Sediment Quality Values (Ecology 2003)
760	Site-specific	Site Specific Cleanup Values and for Pentachlorophenol and Total PAH

Note:

(1) Most restrictive endpoint is either carcinogen or noncarcinogen

For non-carcinogenic chemicals, cleanup levels were developed to be at least as stringent as all ARARs, and to achieve a hazard index of 1. For known or suspected carcinogens, cleanup levels were established using a two-fold process, consistent with MTCA regulations: 1) if an ARAR was available but was not sufficiently protective, the cleanup level was adjusted to achieve the MTCA-required 1×10^{-5} excess cancer risk, also including initial evaluations of potential cumulative cancer risks from multiple carcinogens; and 2) if an ARAR was not available, the cleanup level for an individual carcinogen was established to achieve an excess cancer risk of 1×10^{-6}. Cleanup levels for cPAHs, one of the primary COPCs identified at the Site, were evaluated using TEF per MTCA regulations.

2.2 Sediment Cleanup Levels

MTCA addresses sediment cleanup levels by reference to the SMS. Under the SMS, the primary endpoint for sediment quality evaluations is protection of the environment, specifically the benthic community, from adverse effects associated with COPCs. Numeric freshwater SQVs for a range of chemicals are still under development by Ecology, though interim guidelines have been released based on probable or apparent effects thresholds (AETs) calculated using the available regional database of synoptic chemistry and toxicity test information. While SMS cleanup levels have been promulgated for sediments in the marine environment, freshwater sediment quality criteria are currently determined on a case-by-case basis (Chapter 173-204-340 WAC).

Sediment cleanup levels for the Site were developed using information from several sources, including site-specific studies and other information available from Ecology and EPA. No sediment ARARs are currently available. However, site-specific sediment cleanup levels have previously been developed by Ecology for total PAHs, pentachlorophenol (PCP), and total organic carbon (TOC) based on correlations with site-specific confirmatory biological data, and were used as available. Interim Ecology (2003) freshwater SQVs were used for those chemicals for which site-specific cleanup levels were not available.

EPA's Tier I PAH final chronic values (FCVs) for the protection of aquatic life, which formed the basis for EPA's (2002a) total PAH sediment criterion, were not utilized in developing sediment cleanup levels for the Quendall Site, since site-specific correlations

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with biological data are available for this purpose. However, EPA's values were incorporated into the development of porewater cleanup levels[2]. Use of the Tier I FCVs for PAHs is discussed in Section 2.3. Initial sediment cleanup levels are summarized in Table 2-2.

2.3 Surface Water/Porewater Cleanup Levels

There is no current or identified future use of surface waters within the boundaries of the Site for drinking water. The lake was closed to further water appropriation in 1979 (Chapter 173-508 WAC). In addition, the presence of listed species (salmonids) in Lake Washington has led to a determination by Ecology and other resource agencies that additional appropriation of Lake Washington water for potable or any other use will not occur in the foreseeable future. These limitations effectively preclude any potential surface water/porewater exposure pathway at the Quendall Site. Nevertheless, the State Surface Water Quality Standards (Chapter 173-201A WAC) list potential drinking water consumption of Lake Washington as one of a number of possible characteristic uses of this water body. Thus, in accordance with the Work Plan (Anchor and Aspect 2003) and Section 173-340-730(2)(b)(ii) WAC, potential drinking water consumption of surface waters at the Site was considered in the development of cleanup levels. Surface water at the Site is also current habitat for freshwater aquatic life, which was similarly also considered in the development of cleanup levels.

[2] The FCVs for PAHs were obtained from EPA's equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organisms for PAH mixtures (EPA 2002a). In developing the "baseline" ESBs, EPA used as sediment toxicity benchmarks the most recent updates of final Tier I chronic values for each PAH from the National Water Quality Criteria database, such that the derived baseline ESBs are protective of the presence of any form of aquatic life, even those which may not reside in or near sediments or shoreline habitats. (Note: EPA defines Tier I FCVs as those that meet minimum data requirements to verify their accuracy; Tier II FCVs do not meet all of these requirements and are therefore associated with more uncertainty.) EPA recommends that the site-specific "Resident Species Deletion/ Substitution Procedure" be used as appropriate to adjust for those species or life stages that may not be reasonably associated with Site conditions. However, for the purpose of developing screening levels, the FCVs were used as they have been published by EPA (2002a), and thus likely represent values that are conservatively overprotective of actual exposures to aquatic life at the Site.

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Table 2-2
Initial Sediment Screening Levels

Sediment	Ecology (2003) Freshwater Sediment Quality Screening Values - Lowest Apparent Effects Threshold	Site-Specific Screening Level	Most Restrictive Endpoint
Metals (mg/kg dw)			
Antimony	0.60	na	Freshwater LAET (Ecology 2003)
Arsenic	31.4	na	Freshwater LAET (Ecology 2003)
Beryllium	0.46	na	na
Cadmium	2.39	na	Freshwater LAET (Ecology 2003)
Chromium	95	na	Freshwater LAET (Ecology 2003)
Copper	619	na	Freshwater LAET (Ecology 2003)
Lead	335	na	Freshwater LAET (Ecology 2003)
Mercury	0.80	na	Freshwater LAET (Ecology 2003)
Nickel	53.1	na	Freshwater LAET (Ecology 2003)
Selenium	na	na	na
Silver	0.55	na	Freshwater LAET (Ecology 2003)
Thallium	na	na	na
Tin as Tributyltin	na	na	na
Zinc	683	na	Freshwater LAET (Ecology 2003)
Conventionals			
Sulfides (mg/kg dw)	702	na	Freshwater LAET (Ecology 2003)
TOC (percent)	9.82	13.5	Site Specific Criterion
Semivolatile (ug/kg dw)			
Benzidine	na	na	na
Benzoic Acid	2,910	na	Freshwater LAET (Ecology 2003)
Benzyl Alcohol	na	na	na
Carbazole	923	na	Freshwater LAET (Ecology 2003)
Dibenzofuran	399	na	Freshwater LAET (Ecology 2003)
1,2-Diphenylhydrazine	na	na	na
Semivolatile, Organochlorine (ug/kg dw)			
Aldrin	na	na	na
Chlordane	na	na	na
2-Chloronaphthalene	na	na	na
DDD	96	na	Freshwater LAET (Ecology 2003)
DDE	21	na	Freshwater LAET (Ecology 2003)
DDT	19	na	Freshwater LAET (Ecology 2003)
DDT Total	na	na	na
Dieldrin	na	na	na
Endosulfan	na	na	na
Endrin	na	na	na
Endrin Aldehyde	na	na	na
Heptachlor	na	na	na
Heptachlor Epoxide	na	na	na
Hexachlorobenzene	na	na	na
Hexachlorobutadiene	na	na	na
Hexachlorocyclohexane (BHC)	na	na	na
alpha-BHC	na	na	na
beta-BHC	na	na	na
delta-BHC	na	na	na
gamma-BHC (Lindane)	na	na	na

Table 2-2
Initial Sediment Screening Levels

Sediment	Ecology (2003) Freshwater Sediment Quality Screening Values - Lowest Apparent Effects Threshold	Site-Specific Screening Level	Most Restrictive Endpoint
Hexachlorocyclopentadiene	na	na	na
Hexachloroethane	na	na	na
Methoxychlor	na	na	na
Mirex	na	na	na
Pentachlorobenzene	na	na	na
1,2,4,5-Tetrachlorobenzene	na	na	na
Toxaphene	na	na	na
Semivolatile, Phenolic (ug/kg dw)			
Biphenyl	na	na	na
2-Chlorophenol	na	na	na
2,4-Dichlorophenol	na	na	na
2,4-Dimethylphenol	na	na	na
2-Methyl-4,6-Dinitrophenol	na	na	na
2,4-Dinitrophenol	na	na	na
2-Methylphenol	na	na	na
4-Methylphenol	760	na	Freshwater LAET (Ecology 2003)
4-Nitrophenol	na	na	na
3-Methyl-4-Chlorophenol	na	na	na
Pentachlorophenol	na	500	Site Specific SQV
Phenol	na	na	na
2,3,4,6-Tetrachlorophenol	na	na	na
2,4,5-Trichlorophenol	na	na	na
2,4,6-Trichlorophenol	na	na	na
Semivolatile, Phthalate (ug/kg dw)			
Butyl Benzyl Phthalate	260	na	Freshwater LAET (Ecology 2003)
Bis (2-Ethylhexyl) Phthalate	2,520	na	Freshwater LAET (Ecology 2003)
Di-2-Ethylhexyl Phthalate	na	na	na
Diethyl Phthalate	na	na	na
Dimethyl Phthalate	311	na	Freshwater LAET (Ecology 2003)
Di-N-Octyl Phthalate	11	na	Freshwater LAET (Ecology 2003)
Di-N-Butyl Phthalate	103	na	Freshwater LAET (Ecology 2003)
Semivolatile, Polycyclic Aromatic Hydrocarbons			
Total PAH (mg/kg dw)	na	100	Site Specific SQV
PCBs (ug/kg dw)			
Total PCBs	62	na	Freshwater LAET (Ecology 2003)
Dioxin (ug/kg dw)			
2,3,7,8-TCDD	na	na	na

Most Stringent Screening Level

na - Not Available

The ARARs for surface water in this case include Chapter 173-201A WAC requirements, as well as federal Clean Water Act ecological and human health criteria, and National Toxics Rule ecological and human health criteria. In addition, the more stringent of the groundwater and surface water cleanup levels were applied for the purpose of COPC screening, which also incorporated federal Drinking Water Standards and Health Advisories (EPA 2002b) and the State Primary Drinking Water Regulations (Chapter 246-290 WAC).

Human health risk calculations for reasonable maximum surface water exposures were performed using the standard MTCA Method B risk equations described in Section 2.1.3. Acute and chronic aquatic life criteria, addressing interim EPA (2002a) Tier I water quality benchmarks as appropriate, were also considered in the initial development of cleanup levels. Initial surface water/porewater cleanup levels are summarized in Table 2-3.

2.4 Groundwater Cleanup Levels

As discussed in the Upland Remedial Investigation Report (Hart Crowser 1997), there is no current or identified future use of groundwater within the boundaries of the Site for drinking water, and existing water supply regulations effectively preclude this potential site exposure pathway at the Quendall Site. However, consistent with the discussion above and with MTCA regulations, potential drinking water use and surface water protection were both considered in the initial development of groundwater cleanup levels.

The ARARs for groundwater in this case include the federal Drinking Water Standards and Health Advisories (EPA 2002b) and the State Primary Drinking Water Regulations (Chapter 246-290 WAC). Human health risk calculations for reasonable maximum groundwater (i.e., drinking water) exposures were performed using the standard MTCA Method B risk equations described in Section 2.1.3.

Because Site groundwater eventually discharges to Lake Washington, the more stringent of groundwater and surface water cleanup levels (see Section 2.3) were used for the purpose of COPC screening. Initial groundwater cleanup levels derived in this manner are summarized in Table 2-4.

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Table 2-3
Initial Surface Water/Porewater Screening Levels

Surface Water (ug/L)	Ecological			Human Health				Most Restrictive Groundwater Screening Value	Most Restrictive Groundwater Criterion	Most Restrictive Criterion (3)
						MTCA Method B Screening				
	WAC 173-201A Freshwater Chronic Value ARAR	Clean Water Act: Freshwater Chronic Value ARAR (EPA 2002 Update)	National Toxic Rule: Freshwater Chronic Value ARAR (40 CFR 131)	Clean Water Act: Water + Organism ARAR (EPA 2002 Update)	National Toxic Rule: Water + Organism ARAR (40 CFR 131)	Screening Value	Most Restrictive Method B Endpoint			
Metals (1)										
Antimony	na	na	na	5.6	14	1,037	Noncarcinogen	6	ARAR (246-290 WAC), MCL	ARAR - CWA - Human Health
Arsenic	190	150	190	0.018 (2)	0.018	5	Carcinogen	5	Natural Background-Method A	Natural Background Method A (2)
Barium	na	na	na	na	na	na	na	560	ARAR SWDS Noncancer Risk Adjustment	ARAR SWDS Noncancer Risk Adjustment
Beryllium	na	na	na	4 (MCL)	na	273	Noncarcinogen	4	ARAR (246-290 WAC), MCL	ARAR (246-290 WAC), MCL
Cadmium	0.71	0.178	0.71	5 (MCL)	na	20.3	Noncarcinogen	5	ARAR (246-290 WAC), MCL	ARAR - WAC 173-201A
Chromium	10 (Cr^{+6})	11 (Cr^{+6})	10 (Cr^{+6})	100 (MCL)	na	486	Noncarcinogen	48	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment	ARAR - WAC 173-201A
Copper	6.28	4.95	6.28	1,300 (MCL)	na	2,665	Noncarcinogen	592	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment	ARAR - CWA - Ecological
Lead	1.04	1.17	1.04	1,300	na	na	na	15	ARAR (246-290 WAC), MCL	ARAR - WAC 173-201A
Mercury	0.012	0.77	0.012	na	0.14	na	Noncarcinogen	2	ARAR (246-290 WAC), MCL	ARAR - WAC 173-201A
Nickel	88	24.96	88	610	610	na	Noncarcinogen	100	ARAR (246-290 WAC)	ARAR - CWA - Ecological
Selenium	5	5	5	170	na	na	Noncarcinogen	50	ARAR (246-290 WAC), MCL	ARAR - WAC 173-201A
Silver	1.05 (acute value)	0.98 (acute value)	1.05 (acute value)	na	na	25,926	Noncarcinogen	80	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment	ARAR - CWA - Ecological
Thallium	na	na	na	1.7	1.7	na	Noncarcinogen	1.2	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment
Tin	na	na	na	na	na	na	na	9,600	Method B - Groundwater	Method B - Groundwater
Zinc	58.1	42.01	58.1	7,400	na	16,548	Noncarcinogen	4,800	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment	ARAR - CWA - Ecological
Cyanide	5.2	5.2	5.2	700	700	51,852	Noncarcinogen	200	ARAR (246-290 WAC), MCL	ARAR - WAC 173-201A
Semivolatile										
Benzidine	na	na	na	0.000086	0.00012	0.000322	Carcinogen	0.00038	Method B - Groundwater	ARAR - CWA - Human Health
Benzoic Acid	na	na	na	na	na	na	na	64,000	Method B - Groundwater	Method B - Groundwater
Benzyl Alcohol	na	na	na	na	na	na	na	4,800	Method B - Groundwater	Method B - Groundwater
Carbazole	na	na	na	na	na	na	na	4.38	Method B - Groundwater	Method B - Groundwater
Dibenzofuran	na	na	na	na	na	na	na	na	na	na
1,2-Diphenylhydrazine	na	na	na	0.036	na	0.33	Carcinogen	0.109	ARAR - CWA - Human Health	ARAR - CWA - Human Health
Semivolatile, Nitroaromatic										
2,4-Dinitrotoluene	na	na	na	0.11	0.11	1,365	Carcinogen	32	Method B - Groundwater	ARAR - CWA - Human Health
2,6-Dinitrotoluene	na	na	na	na	na	na	na	16	Method B - Groundwater	
N-Nitrosodimethylamine	na	na	na	0.00069	0.00069	4.89	Carcinogen	0.031	Method B - Groundwater	ARAR - CWA - Human Health
N-Nitroso-di-n-Propylamine	na	na	na	0.005	na	0.82	Carcinogen	0.013	Method B - Groundwater	ARAR - CWA - Human Health
N-Nitrosodiphenylamine	na	na	na	3.3	5	9.73	Carcinogen	17.9	Method B - Groundwater	ARAR - CWA - Human Health
Semivolatile, Organochlorine										
Aldrin	0.0019	3 (acute value)	3 (acute value)	0.000049	0.00013	0.000082	Carcinogen	0.005	Method B - Groundwater	ARAR - CWA - Human Health
Chlordane	0.0043	0.0043	0.0043	0.00022	0.00057	0.0013	Carcinogen	2.0	ARAR SDWA	ARAR - CWA - Human Health
2-Chloronaphthalene	na	na	na	1,000	na	na	na	na	na	ARAR - CWA - Human Health
DDD	na	na	na	0.00031	0.00083	0.00050	Carcinogen	0.365	Method B - Groundwater	ARAR - CWA - Human Health
DDE	na	na	na	0.00022	0.00059	0.00036	Carcinogen	0.257	Method B - Groundwater	ARAR - CWA - Human Health
DDT	0.0010	0.0010	0.0010	0.00022	0.00059	0.00036	Carcinogen	0.257	Method B - Groundwater	ARAR - CWA - Human Health
DDT Total	na	na	na	na	na	na	na	na	na	na
Dieldrin	0.0019	0.056	0.0019	0.000052	0.00014	0.000087	Carcinogen	0.005	Method B - Groundwater	ARAR - CWA - Human Health
Endosulfan	0.056	0.056	0.056	62	0.93	57.6	Noncarcinogen	96.0	Method B - Groundwater	ARAR - WAC 173-201A

Table 2-3
Initial Surface Water/Porewater Screening Levels

Surface Water (ug/L)	Ecological			Human Health				Most Restrictive Groundwater Screening Value	Most Restrictive Groundwater Criterion	Most Restrictive Criterion (3)
						MTCA Method B Screening				
	WAC 173-201A Freshwater Chronic Value ARAR	Clean Water Act: Freshwater Chronic Value ARAR (EPA 2002 Update)	National Toxic Rule: Freshwater Chronic Value ARAR (40 CFR 131)	Clean Water Act: Water + Organism ARAR (EPA 2002 Update)	National Toxic Rule: Water + Organism ARAR (40 CFR 131)	Screening Value	Most Restrictive Method B Endpoint			
Endrin	0.0023	0.036	0.0023	0.76	0.76	0.196	Noncarcinogen	2.0	ARAR SDWA	ARAR - WAC 173-201A
Endrin Aldehyde	na	na	na	0.29	0.76	na	na	na	na	ARAR - CWA - Human Health
Heptachlor	0.0038	0.0038	0.0038	0.000079	0.00021	0.00013	Carcinogen	0.194	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
Heptachlor Epoxide	0.0038	0.0038	0.0038	0.000039	0.0001	0.000064	Carcinogen	0.096	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
Hexachlorobenzene	na	na	na	0.00028	0.0075	0.00047	Carcinogen	0.547	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
Hexachlorobutadiene	na	na	na	0.44	0.44	29.9	Carcinogen	0.561	Method B - Groundwater	ARAR - CWA - Human Health
Hexachlorocyclohexane (BHC)	na	na	na	0.0123	na	na	na	0.049	Method B - Groundwater	ARAR - CWA - Human Health
alpha-BHC	na	na	na	0.0026	0.0039	0.0079	Carcinogen	0.014	Method B - Groundwater	ARAR - CWA - Human Health
beta-BHC	na	na	na	0.0091	0.014	0.028	Carcinogen	0.049	Method B - Groundwater	ARAR - CWA - Human Health
delta-BHC	na	na	na	na	na	na	na	0.2	ARAR SDWA	na
gamma-BHC (Lindane)	0.08	0.95 (acute value)	0.08	0.019	0.019	0.038	Carcinogen	na	na	ARAR - CWA - Human Health
Hexachlorocyclopentadiene	na	na	na	240	240	3,584	Noncarcinogen	50	ARAR SDWA Noncancer Risk Adjustment	ARAR - CWA - Human Health
Hexachloroethane	na	na	na	1.4	1.9 (2)	5.33	Carcinogen	6.250	Method B - Groundwater	ARAR - CWA - Human Health
Methoxychlor	na	0.03	na	na	na	8.4	Noncarcinogen	40	ARAR SDWA	ARAR - CWA - Ecological
Mirex	na	0.001	na	na	na	na	na	0.049	Method B - Groundwater	ARAR - CWA - Ecological
Pentachlorobenzene	na	na	na	na	na	na	na	12.8	Method B - Groundwater	na
1,2,4,5-Tetrachlorobenzene	na	na	na	0.97	na	na	na	4.8	Method B - Groundwater	ARAR - CWA - Human Health
Toxaphene	0.0002	0.0002	0.0002	0.00028	0.00073 (2)	0.00045	Carcinogen	0.795	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
Semivolatile, Organophosphate										
Chlorpyrifos	0.041	0.083 (acute value)	na	na	na	na	na	48	Method B - Groundwater	ARAR - WAC 173-201A
Malathion	na	0.1	na	na	na	na	na	320	Method B - Groundwater	ARAR - CWA - Ecological
Parathion	0.013	na	na	na	na	na	na	96	Method B - Groundwater	ARAR - WAC 173-201A
Semivolatile, Phenolic						na				
2-Chlorophenol	na	na	na	81 / 0.1 (6)	na	97	Noncarcinogen	na	na	ARAR - CWA - Human Health
2,4-Dichlorophenol	na	na	na	77	93	191	Noncarcinogen	48	Method B - Groundwater	Method B - Groundwater
2,4-Dimethylphenol	na	na	na	380	na	553	Noncarcinogen	320	Method B - Groundwater	Method B - Groundwater
2-Methyl-4,6-Dinitrophenol	na	na	na	13	13.4	na	Noncarcinogen	na	na	ARAR - CWA - Human Health
2,4-Dinitrophenol	na	na	na	69	70	3,457	Noncarcinogen	32	Method B - Groundwater	Method B - Groundwater
2-Methylphenol	na	na	na	na	na	na	na	na	na	na
4-Methylphenol	na	na	na	na	na	na	na	na	na	na
4-Nitrophenol	na	na	na	na	na	na	na	na	na	na
3-Methyl-4-Chlorophenol	na	na	na	3000 (6)	na	na		na	na	ARAR - CWA - Human Health
Pentachlorophenol	13	15	13	0.27	0.28	4.91	Carcinogen	1	ARAR SDWA	ARAR - CWA - Human Health
Phenol	na	na	na	21000 / 300 (6)	21,000	1,111,111	Noncarcinogen	9,600	Method B - Groundwater	ARAR - CWA - Human Health
2,3,4,6-Tetrachlorophenol	na	na	na	1 (6)	na	na	na	480	Method B - Groundwater	ARAR - CWA - Human Health
2,4,5-Trichlorophenol	na	na	na	1 (6)	na	na	na	1,600	Method B - Groundwater	ARAR - CWA - Human Health
2,4,6-Trichlorophenol	na	na	na	1.4	2.1	3.93	na	7.95	Method B - Groundwater	ARAR - CWA - Human Health
Semivolatile, Phthalate										
Butyl Benzyl Phthalate	na	na	na	1,500	na	1252 (4)	Noncarcinogen	3,200	Method B - Groundwater	ARAR - CWA - Human Health - Noncancer Risk Adjustment
Bis (2-Ethylhexyl) Phthalate	na	na	na	1.2	1.8	3.56	Carcinogen	6	ARAR SDWA	ARAR - CWA - Human Health

Table 2-3
Initial Surface Water/Porewater Screening Levels

	Ecological			Human Health						
						MTCA Method B Screening				
Surface Water (ug/L)	**WAC 173-201A Freshwater Chronic Value ARAR**	**Clean Water Act: Freshwater Chronic Value ARAR (EPA 2002 Update)**	**National Toxic Rule: Freshwater Chronic Value ARAR (40 CFR 131)**	**Clean Water Act: Water + Organism ARAR (EPA 2002 Update)**	**National Toxic Rule: Water + Organism ARAR (40 CFR 131)**	**Screening Value**	**Most Restrictive Method B Endpoint**	**Most Restrictive Groundwater Screening Value**	**Most Restrictive Groundwater Criterion**	**Most Restrictive Criterion (3)**
Diethyl Phthalate	na	na	na	17,000	23,000	28,412	Noncarcinogen	12,800	Method B - Groundwater	Method B - Groundwater
Dimethyl Phthalate	na	na	na	270,000	313,000	72,016 (4)	Noncarcinogen	16,000	Method B - Groundwater	Method B - Groundwater
Di-N-Octyl Phthalate	na	na	na	na	na	na	na	320	Method B - Groundwater	Method B - Groundwater
Di-N-Butyl Phthalate	na	na	na	2,000	2,700	na	Noncarcinogen	na	na	ARAR - CWA - Human Health
Semivolatile, Polycyclic Aromatic Hydrocarbons										
Acenaphthene	na	na	na	670 / 20 (6)	na	643	Noncarcinogen	960	Method B - Groundwater	ARAR - CWA - Human Health
Acenaphthylene	na	na	na	na	na	na	na	na	na	na
Anthracene	na	na	na	8,300	9,600	25,926	Noncarcinogen	na	na	ARAR - CWA - Human Health
Benzo(a)anthracene	na	na	na	0.038 (5)	0.028 (5)	0.3 (5)	Carcinogen	1.2	ARAR SDWA Cancer Risk Adjustment	ARAR - NTR - Human Health
Benzo(a)pyrene	na	na	na	0.0038	0.0028	0.030	Carcinogen	0.12	ARAR SDWA Cancer Risk Adjustment	ARAR - NTR - Human Health
Benzo(b)fluoranthene	na	na	na	0.038 (5)	0.028 (5)	0.3 (5)	Carcinogen	1.2	ARAR SDWA Cancer Risk Adjustment	ARAR - NTR - Human Health
Benzo(k)fluoranthene	na	na	na	0.038 (5)	0.028 (5)	0.3 (5)	Carcinogen	1.2	ARAR SDWA Cancer Risk Adjustment	ARAR - NTR - Human Health
Benzo(g,h,i)perylene	na	na	na	na	na	na	na	na	na	na
Chrysene	na	na	na	0.38 (5)	0.28 (5)	3 (5)	Carcinogen	12.0	ARAR SDWA Cancer Risk Adjustment	ARAR - NTR - Human Health
Dibenzo(a,h)anthracene	na	na	na	0.0095 (5)	0.007 (5)	0.075 (5)	Carcinogen	0.30	ARAR SDWA Cancer Risk Adjustment	ARAR - NTR - Human Health
Fluoranthene	na	na	na	130	300	na	na	640	Method B - Groundwater	ARAR - CWA - Human Health
Fluorene	na	na	na	1,100	1,300	3,457	Noncarcinogen	640	Method B - Groundwater	Method B - Groundwater
Indeno(1,2,3-cd)pyrene	na	na	na	0.038 (5)	0.028 (5)	0.3 (5)	Carcinogen	1.2	ARAR Cancer Risk Adjustment	ARAR - NTR - Human Health
2-Methylnaphthalene	na	na	na	na	na	na	na	na	na	na
Naphthalene	na	na	na	na	na	4,938	Noncarcinogen	160	Method B - Groundwater	Method B - Groundwater
Phenanthrene	na	na	na	na	na	na	na	na	na	na
Pyrene	na	na	na	830	960	2,593	Noncarcinogen	480	Method B - Groundwater	Method B - Groundwater
Total PAH	na	(8)	na	na	na	na	na	na	na	na
PCBs										
Total PCBs	0.014	0.014	0.014	6.40E-05	1.70E-04	na	Carcinogen	0.5	ARAR SDWA	ARAR - CWA - Human Health
Dioxin										
2,3,7,8-TCDD	na	na	na	5.00E-09	1.30E-08	8.64E-09	Carcinogen	5.80E-06	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
Volatile, Aromatic and Halogenated										
Acetone		na	na	na	na	na	Noncarcinogen	800	Method B - Groundwater	
Benzene	na	na	na	2.2	1.2	22.7	Carcinogen	5.0	ARAR SDWA	ARAR - CWA - Human Health
Bromoform	na	na	na	4.3	4.3	219	Carcinogen	5.538	Method B - Groundwater	ARAR - CWA - Human Health
Bromomethane	na	na	na	na	na	na	na	11.2	Method B - Groundwater	Method B - Groundwater
2-Butanone	na	na	na	na	na	na	na	4,800	Method B - Groundwater	Method B - Groundwater
Carbon Tetrachloride	na	na	na	0.23	0.25	2.66	Carcinogen	3.37	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
Chlorobenzene	na	na	na	680 / 20 (6)	680	5,034	Noncarcinogen	100	ARAR SDWA	ARAR - CWA - Human Health
Chlorodibromomethane	na	na	na	0.4	0.41	na	Carcinogen	na	na	ARAR - CWA - Human Health
Chloroform	na	na	na	5.7	5.7	283	Carcinogen	71.7	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health

Table 2-3
Initial Surface Water/Porewater Screening Levels

	Ecological			Human Health						
						MTCA Method B Screening				
Surface Water (ug/L)	WAC 173-201A Freshwater Chronic Value ARAR	Clean Water Act: Freshwater Chronic Value ARAR (EPA 2002 Update)	National Toxic Rule: Freshwater Chronic Value ARAR (40 CFR 131)	Clean Water Act: Water + Organism ARAR (EPA 2002 Update)	National Toxic Rule: Water + Organism ARAR (40 CFR 131)	Screening Value	Most Restrictive Method B Endpoint	Most Restrictive Groundwater Screening Value	Most Restrictive Groundwater Criterion	Most Restrictive Criterion (3)
Dibromomethane	na	na	na	na	na	na	na	na	na	na
1,2-Dibromo-3-chloropropane	na	na	na	na	na	na	na	0.031	Method B - Groundwater	Method B - Groundwater
1,2-Dichlorobenzene	na	na	na	2,700	2,700	4,197	Noncarcinogen	720	Method B - Groundwater	Method B - Groundwater
1,3-Dichlorobenzene	na	na	na	320	400	na	Noncarcinogen	1.82	Method B - Groundwater	Method B - Groundwater
1,4-Dichlorobenzene	na	na	na	400	400	48.6 (4)	Carcinogen	na		ARAR - CWA - Human Health - Noncancer Risk Adjustment
3,3-Dichlorobenzidine	na	na	na	na	na	0.046	Carcinogen	na	na	Method B
Dichlorobromomethane	na	na	na	0.55	0.27	na	Carcinogen	1,600	Method B - Groundwater	ARAR - CWA - Human Health
Dichlorodifluoromethane	na	na	na	na	na	na	Noncarcinogen	800	Method B - Groundwater	Method B - Groundwater
1,2-Dichloroethane	na	na	na	0.38	0.38	59.4	Carcinogen	4.81	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
1,1-Dichloroethylene	na	na	na	0.057	0.057	1.93	Carcinogen	0.729	ARAR SDWA Cancer Risk Adjustment	ARAR - CWA - Human Health
1,2-cis Dichloroethylene	na	na	na	na	na	na	na	70	ARAR SDWA	ARAR SDWA
1,2-trans Dichloroethylene	na	na	na	na	na	32,818	Noncarcinogen	100	ARAR SDWA	ARAR SDWA
1,2-Dichloropropane	na	na	na	0.5	na	23.2	Carcinogen	5.00	ARAR SDWA	ARAR - CWA - Human Health
1,3-Dichloropropene	na	na	na	10	10	18.9	Carcinogen	0.243	Method B - Groundwater	Method B - Groundwater
Ethylbenzene	na	na	na	3,100	3,100	6,914	Noncarcinogen	700	na	ARAR SDWA
2-Hexanone	na	na	na	na	na	na	Noncarcinogen	528	Method B - Groundwater	Method B - Groundwater
Methyl Bromide	na	na	na	47	48	na	na	na	na	ARAR - CWA - Human Health
Methyl Chloride	na	na	na	na	na	na	na	na	na	na
Methylene Chloride	na	na	na	4.6	4.7	960	Carcinogen	5.0	ARAR SDWA	ARAR - CWA - Human Health
4-Methyl-2-pentanone	na	na	na	na	na	na	Noncarcinogen	640	Method B - Groundwater	Method B - Groundwater
Pentachloroethane	na	na	na	na	na	na	na	na	na	na
Propylene Dichloride	na	na	na	na	na	na	na	na	na	na
Styrene	na	na	na	na	na	na	Carcinogen	14.6	ARAR SDWA Cancer Risk Adjustment	ARAR SDWA Cancer Risk Adjustment
Tetrachloroethane	na	na	na	na	na	na	na	na	na	na
1,1,2,2-Tetrachloroethane	na	na	na	0.17	0.17	6.48	Carcinogen	0.219	Method B - Groundwater	ARAR - CWA - Human Health
Tetrachloroethylene	na	na	na	0.69	0.8	4.15	Carcinogen	5.0	Method B - Groundwater	ARAR - CWA - Human Health
Toluene	na	na	na	6,800	6,800	48,460	Noncarcinogen	1,000	ARAR SDWA	ARAR - CWA - Human Health
1,2,4-Trichlorobenzene	na	na	na	na	na	227	Noncarcinogen	70	ARAR SDWA	ARAR SDWA
1,1,1-Trichloroethane	na	na	na	na	na	416,667	Noncarcinogen	200	ARAR SDWA	ARAR SDWA
1,1,2-Trichloroethane	na	na	na	0.59	0.6	25	Carcinogen	5.00	ARAR SDWA	ARAR - CWA - Human Health
Trichlorethylene	na	na	na	2.50	2.7	3.93	Carcinogen	5.00	ARAR SDWA	ARAR - CWA - Human Health
Trichlorofluoromethane	na	na	na	na	na	na	na	2,400	Method B - Groundwater	Method B - Groundwater
1,3,5-Trimethylbenzene	na	na	na	na	na	na	na	na	na	
Vinyl Chloride	na	na	na	2	2	3.69	Carcinogen	0.29	ARAR SDWA Cancer Risk Adjustment	ARAR SDWA Cancer Risk Adjustment
m,p-Xylene	na	na	na	na	na	na	na	na	na	na
o-Xylene	na	na	na	na	na	na	na	16,000	Method B - Groundwater	Method B - Groundwater
Total Xylene	na	na	na	na	na	na	na	10,000	ARAR SDWA	ARAR SDWA

Table 2-3
Initial Surface Water/Porewater Screening Levels

Surface Water (ug/L)	Ecological			Human Health				Most Restrictive Groundwater Screening Value	Most Restrictive Groundwater Criterion	Most Restrictive Criterion (3)
						MTCA Method B Screening				
	WAC 173-201A Freshwater Chronic Value ARAR	Clean Water Act: Freshwater Chronic Value ARAR (EPA 2002 Update)	National Toxic Rule: Freshwater Chronic Value ARAR (40 CFR 131)	Clean Water Act: Water + Organism ARAR (EPA 2002 Update)	National Toxic Rule: Water + Organism ARAR (40 CFR 131)	Screening Value	Most Restrictive Method B Endpoint			
Volatile, Nitrile										
Acrolein	na	na	na	190	320	na	Noncarcinogen	160	Method B - Groundwater	Method B - Groundwater
Acrylonitrile	na	na	na	0.051	0.059	0.40	Carcinogen	na	na	ARAR - CWA - Human Health
Aniline	na	na	na	na	na	na	na	7.68	Method B - Groundwater	Method B - Groundwater
4-Chloroaniline	na	na	na	na	na	na	na	64.0	Method B - Groundwater	Method B - Groundwater

Notes:

ARAR - Applicable or Relevant and Appropriate Requirement

MCL - Maximum contaminant level.

NTR - National Toxics Rule

173-201A WAC - Water quality standards for surface waters of the State of Washington

na - Not Available

(1) Aquatic life criterion hardness adjusted values calculated at 50 mg/L as $CaCO_3$.

(2) Method B fish consumption pathway. For carcinogenic chemicals, a 1E-6 cancer risk was applied.

(3) The most restrictive endpoint for surface water or is listed. Where a non-carcinogenic ARAR was available, the hazard qotient was evaluated based on MTCA Equation 730-1 and adjusted to a hazard quotient of 1, if necessary. Where a non-carcinogenic ARAR was adjusted downward to a hazard quotient of 1, the value was equivalent to the MTCA Method B value, which is highlighted. Where a carcinogenic ARAR was available, the cancer risk, calculated using MTCA Equation 730-2, was evaluated and is presented. If necessary the ARAR value was adjusted downward to achieve a cancer risk of 1E-5. Where human health values are the same under NTR and CWA columns, the CWA column is highlighted because it reflects the most recent update by EPA (2002).

(4) Value adjusted to noncancer risk of 1 OR value adjusted to cancer risk of 1E-5

(5) Based on Benzo(a)pyrene using Toxicity Equivalency Factors (173-340-708 WAC)

(6) Organoleptic Effect Criteria. If Aquatic Life Criteria was Available and was Less than Human Health Values, the Organoleptic Value was Not Presented

(7) ARAR protective at cancer risk of 1E-5

(8) Total PAH surface water final chronic value is based on the additive narcosis model proposed by EPA and pending release. The Total PAH values is calculated as a molar sum of individual PAHs as described in the Work Plan (Anchor 2003).

Most Stringent Screening Level

Table 2-4
Initial Groundwater Screening Levels

Groundwater (ug/L)	Ch. 246-290 WAC, MCL	SDWA, MCL	SDWA, MCLG	MTCA Method B Screening Level (1)	Most Restrictive Method B Endpoint	Most Restricive Surface Water Criterion	Most Restrictive Groundwater Criterion (2)
Metals							
Antimony	6	6	6	6.40	Noncarcinogen	5.6	ARAR - CWA - Human Health
Arsenic	50	10	zero	5	Carcinogen	5	Natural Background (3)
Barium	2,000	2,000	2,000	560	Noncarcinogen	na	ARAR SDWA Noncancer Risk Adjustment
Beryllium	4	4	4	32	Noncarcinogen	4	ARAR (246-290 WAC), MCL
Cadmium	5	5	5	8	Noncarcinogen	0.71	ARAR - WAC 173-201A
Chromium (Cr^{+6})	100	100	100	48	Noncarcinogen	10 (Cr^{+6})	ARAR - WAC 173-201A
Copper	1,300	1,300	1,300	592	Noncarcinogen	4.95	ARAR - CWA - Ecological
Lead	15	15	zero	na	Noncarcinogen	1.04	ARAR - WAC 173-201A
Mercury	2	2	2	4.8	Noncarcinogen	0.012	ARAR - WAC 173-201A
Nickel	100	na	na	320	Noncarcinogen	25	ARAR - CWA - Ecological
Selenium	50	50	50	80	Noncarcinogen	5	ARAR - WAC 173-201A
Silver	100	na	na	80	Noncarcinogen	0.98	ARAR - CWA - Ecological
Thallium	2	2	0.5	1.2	Noncarcinogen	1.7	ARAR (246-290 WAC), MCL Noncancer Risk Adjustment
Tin	na	na	na	9,600	Noncarcinogen	na	Method B - Groundwater
Zinc	5,000	na	na	4,800		42	ARAR - CWA - Ecological
Cyanide	200	200	200	320	Noncarcinogen	5.2	ARAR - WAC 173-201A
Semivolatile							
Benzidine	na	na	na	0.00038	Carcinogen	0.000086	ARAR - CWA - Human Health
Benzoic Acid	na	na	na	64,000	Noncarcinogen	na	Method B - Groundwater
Benzyl Alcohol	na	na	na	4,800	Noncarcinogen	na	Method B - Groundwater
Carbazole	na	na	na	4.38	Carcinogen	na	Method B - Groundwater
Dibenzofuran	na	na	na	na	na	na	na
1,2-Diphenylhydrazine	na	na	na	0.109	Carcinogen	0.036	ARAR - CWA - Human Health
Semivolatile, Nitroaromatic							
2,4-Dinitrotoluene	na	na	na	32	Noncarcinogen	0.11	ARAR - CWA - Human Health
2,6-Dinitrotoluene	na	na	na	16	Carcinogen	na	Method B - Groundwater
N-Nitrosodimetnylamine	na	na	na	0.031	Carcinogen	0.00069	ARAR - CWA - Human Health
N-Nitroso-di-n-Propylamine	na	na	na	0.013	Carcinogen	0.005	ARAR - CWA - Human Health
N-Nitrosodiphenylamine	na	na	na	17.9	Carcinogen	3.3	ARAR - CWA - Human Health
Semivolatile, Organochlorine							
Aldrin	na	na	na	0.005	Carcinogen	0.000049	ARAR - CWA - Human Health
Chlordane	na	2.0	zero	0.250	Carcinogen (8E-6)	0.00022	ARAR - CWA - Human Health
2-Chloronaphthalene	na	na	na	na	na	1,000	ARAR - CWA - Human Health
DDD	na	na	na	0.365	Carcinogen	0.00031	ARAR - CWA - Human Health
DDE	na	na	na	0.257	Carcinogen	0.00022	ARAR - CWA - Human Health
DDT	na	na	na	0.257	Carcinogen	0.00022	ARAR - CWA - Human Health
DDT Total	na	na	na	na	na	na	na
Dieldrin	na	na	na	0.005	Carcinogen	0.000052	ARAR - CWA - Human Health

Table 2-4
Initial Groundwater Screening Levels

Groundwater (ug/L)	Ch. 246-290 WAC, MCL	SDWA, MCL	SDWA, MCLG	MTCA Method B Screening Level (1)	Most Restrictive Method B Endpoint	Most Restricive Surface Water Criterion	Most Restrictive Groundwater Criterion (2)
Endosulfan	na	na	na	96.0	Noncarcinogen	0.056	ARAR - CWA - Human Health
Endrin	na	2.0	2	4.800	Noncarcinogen	0.0023	ARAR - CWA - Human Health
Endrin Aldehyde	na	na	na	na	na	0.29	na
Heptachlor	na	0.194 (4)	zero	0.019	Carcinogen (2E-5)	0.000079	ARAR - CWA - Human Health
Heptachlor Epoxide	na	0.096 (4)	zero	0.010	Carcinogen (2E-5)	0.000039	ARAR - CWA - Human Health
Hexachlorobenzene	na	0.547 (4)	zero	0.055	Carcinogen (2E-5)	0.00028	ARAR - CWA - Human Health
Hexachlorobutadiene	na	na	na	0.561	Carcinogen	0.44	ARAR - CWA - Human Health
Hexachlorocyclohexane (BHC) Technical	na	na	na	0.049	Carcinogen	0.0123	ARAR - CWA - Human Health
alpha-BHC	na	na	na	0.014	Carcinogen	0.0026	ARAR - CWA - Human Health
beta-BHC	na	na	na	0.049	Carcinogen	0.0091	ARAR - CWA - Human Health
gamma-BHC (Lindane)	na	0.2	0.2	0.067	Carcinogen (3E-6)	na	ARAR SDWA
delta-BHC	na	na	na	na	na	0.019	ARAR - CWA - Human Health
Hexachlorocyclopentadiene	na	50	50	96	Noncarcinogen	240	ARAR - CWA - Human Health
Hexachloroethane	na	na	na	6.25	Carcinogen	1.4	ARAR - CWA - Human Health
Methoxychlor	na	40	40	80	Noncarcinogen	0.03	ARAR - CWA - Ecological
Mirex	na	na	na	0.049	Carcinogen	0.001	ARAR - CWA - Ecological
Pentachloroenzene	na	na	na	12.8	Noncarcinogen	na	Method B - Groundwater
1,2,4,5-Tetrachlorobenzene	na	na	na	4.8	Noncarcinogen	0.97	ARAR - CWA - Human Health
Toxaphene	na	0.795 (4)	zero	0.08	Carcinogen (4E-5)	0.00028	ARAR - CWA - Human Health
Semivolatile, Organophosphate							
Chlorpyrifos	na	na	na	48	Noncarcinogen	0.041	ARAR - WAC 173-201A
Malathion	na	na	na	320	Noncarcinogen	0.1	ARAR - CWA - Ecological
Parathion	na	na	na	96	Noncarcinogen	0.013	ARAR - WAC 173-201A
Semivolatile, Phenolic							
2-Chlorophenol	na	na	na	na	na	0.1	ARAR - CWA - Organoleptic
2,4-Dichlorophenol	na	na	na	48	Noncarcinogen	77	Method B - Groundwater
2,4-Dimethylphenol	na	na	na	320	Noncarcinogen	380	Method B - Groundwater
2-Methyl-4,6-Dinitrophenol	na	na	na	na	na	13	ARAR - CWA - Human Health
2,4-Dinitrophenol	na	na	na	32	Noncarcinogen	69	Method B - Groundwater
2-Methylphenol	na	na	na	na	na	na	na
4-Methylphenol	na	na	na	na	na	na	na
4-Nitrophenol	na	na	na	na	na	na	na
3-Methyl-4-Chlorophenol	na	na	na	na	na	3,000	ARAR - CWA - Organoleptic
Pentachlorophenol	na	1	zero	0.729	Carcinogen (1.4E-6)	0.27	ARAR - CWA - Human Health
Phenol	na	na	na	9,600	Noncarcinogen	300	ARAR - CWA - Organoleptic
2,3,4,6-Tetrachlorophenol	na	na	na	480	Noncarcinogen	1	ARAR - CWA - Organoleptic
2,3,4-Trichlorophenol	na	na	na	na	na	na	na
2,4,5-Trichlorophenol	na	na	na	1,600	Noncarcinogen	1	ARAR - CWA - Organoleptic
2,4,6-Trichlorophenol	na	na	na	7.955	Carcinogen	1.4	ARAR - CWA - Human Health
Semivolatile, Phthalate							
Butyl Benzyl Phthalate	na	na	na	3,200	Noncarcinogen	1,252	ARAR - CWA - Human Health
Bis (2-Ethylhexyl) Phthalate	na	6	zero	6.250	Carcinogen	1.2	ARAR - CWA - Human Health

Table 2-4
Initial Groundwater Screening Levels

Groundwater (ug/L)	Ch. 246-290 WAC, MCL	SDWA, MCL	SDWA, MCLG	MTCA Method B Screening Level (1)	Most Restrictive Method B Endpoint	Most Restricive Surface Water Criterion	Most Restrictive Groundwater Criterion (2)
Diethyl Phthalate	na	na	na	12,800	Noncarcinogen	17,000	Method B - Groundwater
Dimethyl Phthalate	na	na	na	16,000	Noncarcinogen	72,016	Method B - Groundwater
Di-N-Octyl Phthalate	na	na	na	320	Noncarcinogen	na	Method B - Groundwater
Di-N-Butyl Phthalate	na	na	na	na	na	2,000	ARAR - CWA - Human Health
Semivolatile, Polycyclic Aromatic Hydrocarbons							
Acenaphthene	na	na	na	960	Noncarcinogen	20	Method B - Groundwater
Acenaphthylene	na	na	na	na	na	na	na
Anthracene	na	na	na	na	Noncarcinogen	8,300	ARAR - CWA - Human Health
Benzo(a)anthracene	na	1.2 (5)	na	0.12 (5)	Carcinogen	0.028	ARAR - NTR - Human Health - TEF adjusted
Benzo(a)pyrene	na	0.12 (4)	zero	0.012 (5)	Carcinogen (2E-5)	0.0028	ARAR - NTR - Human Health
Benzo(b)fluoranthene	na	1.2 (5)	na	0.12 (5)	Carcinogen	0.028	ARAR - NTR - Human Health - TEF adjusted
Benzo(k)fluoranthene	na	1.2 (5)	na	0.12 (5)	Carcinogen	0.028	ARAR - NTR - Human Health - TEF adjusted
Benzo(g,h,i)perylene	na	na	na	na	na	na	na
Chrysene	na	12 (5)	na	1.2 (5)	Carcinogen	0.280	ARAR - NTR - Human Health - TEF adjusted
Dibenzo(a,h)anthracene	na	0.3 (5)	na	0.03 (5)	Carcinogen	0.0070	ARAR - NTR - Human Health - TEF adjusted
Fluoranthene	na	na	na	640	Noncarcinogen	130	ARAR - CWA - Human Health
Fluorene	na	na	na	640	Noncarcinogen	1,100	Method B - Groundwater
Indeno(1,2,3-cd)pyrene	na	1.2 (5)	na	0.12 (5)	Carcinogen	0.028	ARAR - NTR - Human Health - TEF adjusted
2-Methylnaphthalene	na	na	na	na	na	na	na
Naphthalene	na	na	na	160	Noncarcinogen	4,938	Method B - Groundwater
Phenanthrene	na	na	na	na	na	na	na
Pyrene	na	na	na	480	Noncarcinogen	830	Method B - Groundwater
Total PAH	na	na	na	na	na	na	na
PCBs							
Total PCBs	na	0.5	zero	na	Noncarcinogen	6.40E-05	ARAR - CWA - Human Health
Dioxin							
2,3,7,8-TCDD		5.8E-06 (4)	na	5.83E-07	Carcinogen (5E-6)	5.00E-09	ARAR - CWA - Human Health
Volatile, Aromatic and Halogenated							
Acetone	na	na	na	800	Noncarcinogen	na	Method B - Groundwater
Benzene	na	5.0	zero	0.795	Carcinogen (3E-6)	1.2	ARAR - NTR - Human Health
Bromoform	na	na	na	5.538	Carcinogen	4.3	ARAR - CWA - Human Health
Bromomethane	na	na	zero	11.2	Noncarcinogen	na	Method B - Groundwater
2-Butanone	na	na	na	4,800	Noncarcinogen	na	Method B - Groundwater
Carbon Tetrachloride	na	3.37 (4)	zero	0.337	Carcinogen (1.5E-5)	2	ARAR - CWA - Human Health
Chlorobenzene	na	100	100	na	Noncarcinogen	4.3	ARAR - CWA - Organoleptic
Chlorodibromomethane	na	na	na	na	na	2	ARAR - CWA - Human Health
Chloroform	na	71.7 (4)	zero	7.17	Carcinogen (1.1E-5)	4.3	ARAR - CWA - Human Health

Table 2-4
Initial Groundwater Screening Levels

Groundwater (ug/L)	Ch. 246-290 WAC, MCL	SDWA, MCL	SDWA, MCLG	MTCA Method B Screening Level (1)	Most Restrictive Method B Endpoint	Most Restricive Surface Water Criterion	Most Restrictive Groundwater Criterion (2)
Dibromomethane	na	na	na	na	na	na	na
1,2-Dibromo-3-chloropropane	na	na	na	0.031	Carcinogen	2,700	Method B - Groundwater
1,2-Dichlorobenzene	na	na	na	720	Noncarcinogen	320	ARAR - CWA - Human Health
1,4-Dichlorobenzene	na	na	na	1.82	Carcinogen	4.86	ARAR - CWA - Human Health - Noncancer risk adjustment
Dichlorobromomethane	na	na	na	na	na	0.046	Method B - Surface Water
Dichlorodifluoromethane	na	na	na	1,600	Noncarcinogen	0.55	ARAR - CWA - Human Health
1,1-Dichloroethane	na	na	na	800	Noncarcinogen	na	Method B - Groundwater
1,2-Dichloroethane	na	4.81 (4)	zero	0.481	Carcinogen (1.04E-5)	0.38	ARAR - CWA - Human Health
1,1-Dichloroethylene	na	0.729 (4)	7	0.0792	Carcinogen (1E-4)	0.057	ARAR - CWA - Human Health
1,2-cis Dichloroethylene	na	70	70	80	Noncarcinogen	na	ARAR SDWA
1,2-trans Dichloroethylene	na	100	100	160	Noncarcinogen	32,818	ARAR SDWA
1,2-Dichloropropane	na	5.00	zero	0.643	Carcinogen (8E-6)	0.5	ARAR - CWA - Human Health
1,3-Dichloropropene	na	na	na	0.243	Carcinogen	10	Method B - Groundwater
Ethylbenzene	na	700	700	800	Noncarcinogen	3,100	ARAR SDWA
2-Hexanone	na	na	na	528	Noncarcinogen	na	Method B - Groundwater
Methyl Bromide	na	na	na	na	na	47	ARAR - CWA - Human Health
Methyl Chloride	na	na	na	na	na	na	na
Methylene Chloride	na	5.0	na	5.8	Carcinogen (9E-6)	4.6	ARAR - CWA - Human Health
4-Methyl-2-pentanone	na	na	na	640	Noncarcinogen	na	Method B - Groundwater
Pentachloroethane	na	na	na	na	na	na	na
Propylene Dichloride	na	na	na	na	na	na	na
Styrene	na	14.6 (4)	100	1.46	Carcinogen (7E-5)	na	ARAR SDWA Cancer Risk Adjustment
Tetrachloroethane	na	na	na	na	Noncarcinogen	na	na
1,1,2,2-Tetrachloroethane	na	na	na	0.219	Carcinogen	0.17	ARAR - CWA - Human Health
Tetrachloroethylene	na	na	zero	5.0	Carcinogen	0.69	ARAR - CWA - Human Health
Toluene	na	1,000	1,000	1,600.000	Noncarcinogen	6,800	ARAR SDWA
1,2,4-Trichlorobenzene	na	70	70	80.000	Noncarcinogen	227	ARAR SDWA
1,1,1-Trichloroethane	na	200	200	7,200.000	Noncarcinogen	416,667	ARAR SDWA
1,1,2-Trichloroethane	na	5.00	3	0.768	Carcinogen (6E-6)	0.59	ARAR - CWA - Human Health
Trichlorethylene	na	5.00	zero	3.977	Carcinogen (1E-6)	2.50	ARAR - CWA - Human Health
Trichlorofluoromethane	na	na	na	2,400	Noncarcinogen	na	Method B - Groundwater
Vinyl Chloride	na	0.29 (4)	zero	0.029	Carcinogen (7E-5)	2	ARAR SDWA Cancer Risk Adjustment
m,p-Xylene	na	na	na	na	na	na	na
o-Xylene	na	na	na	16,000.000	Noncarcinogen	na	Method B - Groundwater
Total Xylene	na	10,000	10,000	na	Noncarcinogen	na	ARAR SDWA

Table 2-4
Initial Groundwater Screening Levels

Groundwater (ug/L)	Ch. 246-290 WAC, MCL	SDWA, MCL	SDWA, MCLG	MTCA Method B Screening Level (1)	Most Restrictive Method B Endpoint	Most Restricive Surface Water Criterion	Most Restrictive Groundwater Criterion (2)
Volatile, Nitrile							
Acrolein	na	na	na	160	Noncarcinogen	190	Method B - Groundwater
Acrylonitrile	na	na	na	na	na	0.051	ARAR - CWA - Human Health
Aniline	na	na	na	7.68	Carcinogen	na	Method B - Groundwater
4-Chloroaniline	na	na	na	64.0	Noncarcinogen	na	Method B - Groundwater

Notes:

ARAR - Applicable or Relevant and Appropriate Requirement

Ch. 246-290 WAC - Public Water Supply Maximum Contaminant Levels for the State of Washington

MCL - Maximum Contaminant Level

na - Not Available

(1) Method B water ingestion pathway value. For carcinogenic chemicals, a 1E-6 cancer risk was applied

(2) The most restrictive endpoint for either groundwater or surface water is listed. Where a non-carcinogenic ARAR was available, the hazard qotient was evaluated based on MTCA Equation 720-1 and adjusted to a hazard quotient of 1, if necessary. Where a non-carcinogenic ARAR was adjusted downward to a hazard quotient of 1, the value was equivalent to the MTCA Method B value, which is highlighted. Where a carcinogenic ARAR was available, the cancer risk, calculated using MTCA Equation 720-2, was evaluated and is presented. If necessary the ARAR value was adjusted downward to achieve a cancer risk of 1E-5.

(3) Method B Carcinogenic Value is 0.058 ug/L

(4) Value adjusted to cancer risk of 1E-5

(5) Based on Benzo(a)pyrene using Toxicity Equivalency Factors (173-340-708 WAC)

(6) ARAR protective at cancer risk of 1E-5

Most Stringent Screening Level

2.5 Soil Cleanup Levels

The Quendall Site is currently used for industrial storage operations, and meets the requirement of a "traditional industrial use" under the MTCA regulations (Section 173-340--745 WAC). Thus, industrial use is the appropriate basis for development of site-specific soil cleanup levels, as described in Section 5. However, for the purpose of identifying site COPCs, more conservative soil cleanup levels were also developed assuming an unrestricted upland site use condition.

Soil cleanup levels were developed by considering the following potential exposure/risk pathways:

- Human Health Protection from Direct Soil Contact – evaluated through MTCA risk screening calculations
- Terrestrial Ecological Protection – evaluated by comparing site data with the simplified terrestrial ecological evaluation (see below)
- Human Health Protection from Soil-to-Groundwater Pathway Exposure – evaluated initially through direct evaluation of groundwater data (see Section 2.4; also see Section 4)
- Human Health Protection from Soil-to-Air Pathway Exposure – Ecology and EPA screening-level comparisons suggest that this pathway is nearly always protected by attaining direct soil contact, terrestrial ecological protection, and groundwater protection criteria (this was also confirmed through site-specific evaluation of the soil-to-air pathway discussed in Section 5.5.2)

The only ARAR available for soils is the criterion for polychlorinated biphenyls (PCBs) set forth in the Toxic Substances Control Act (40 CFR 761.61). Method B direct contact risk calculations were used to derive the remainder of the soil cleanup levels.

Because of the size of the Site, existing upland habitat quality, and the potential to attract wildlife, the Quendall Site does not qualify for an exclusion from a terrestrial ecological evaluation, and may also not qualify for a simplified terrestrial ecological evaluation because of potential use by threatened or endangered species, such as the bald eagle. Although the Site can be evaluated using the more detailed site-specific terrestrial ecological risk evaluation, MTCA also provides that such an evaluation may be conducted by

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comparing site characterization data with the simplified terrestrial ecological evaluation criteria (MTCA Table 749-2). Thus, soil criteria listed in MTCA Table 749-2 were used for the purpose of developing soil cleanup levels at the Site that are protective of potential ecological exposures. Initial soil cleanup levels are summarized in Table 2-5.

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Table 2-5
Initial Soil Screening Levels

Soil (mg/kg)	ARAR	ARAR Source	MTCA Method B Screening Level (1)	Most Restrictive Risk Endpoint (1)	Simplified Terrestrial Ecological - Industrial or Commercial Site	Most Restrictive Criterion
Metals						
Antimony	na	na	32	Noncarcinogen	na	Method B
Arsenic	na	na	20	Carcinogen	20 (As III)	Method A - Natural Background
Barium	na	na	na	na	1,320	Ecological
Beryllium	na	na	160	Noncarcinogen	25	Ecological
Cadmium	na	na	80	Noncarcinogen	36	Ecological
Chromium (Cr^{+6})	na	na	240	Noncarcinogen	135	Ecological
Copper	na	na	2,960	Noncarcinogen	550	Ecological
Lead	na	na	250	Noncarcinogen	220	Ecological
Mercury	na	na	24	Noncarcinogen	0.7 (organic)	Ecological
Nickel	na	na	1,600	Noncarcinogen	1,850	Method B
Selenium	na	na	400	Noncarcinogen	0.8	Ecological
Silver	na	na	400	Noncarcinogen	na	Method B
Thallium	na	na	5.6	Noncarcinogen	na	Method B
Tin	na	na	48,000	Noncarcinogen	na	Method B
Zinc	na	na	24,000	Noncarcinogen	570	Ecological
Cyanide	na	na	1,600	Noncarcinogen	na	Method B
Semivolatile						
Benzidine	na	na	0.00435	Carcinogen	na	Method B
Benzoic Acid	na	na	320,000	Noncarcinogen	na	Method B
Benzyl Alcohol	na	na	24,000	Noncarcinogen	na	Method B
Dibenzofuran	na	na	na	Noncarcinogen	na	Ecological
1,2-Diphenylhydrazine	na	na	1.25	Carcinogen	na	Method B
Semivolatile, Nitroaromatic						
2,4-Dinitrotoluene	na	na	160	Noncarcinogen	na	Method B
N-Nitrosodimethylamine	na	na	0.0196	Carcinogen	na	Method B
N-Nitroso-di-n-Propylamine	na	na	0.143	Carcinogen	na	Method B
N-Nitrosodiphenylamine	na	na	204	Carcinogen	na	Method B
Semivolatile, Organochlorine						
Aldrin	na	na	0.0588	Carcinogen	0.17	Method B
Chlordane	na	na	2.86	Carcinogen	7	Method B
2-Chloronaphthalene	na	na	na	na	na	na
DDD	na	na	4.17	Carcinogen	na	Method B

Table 2-5
Initial Soil Screening Levels

Soil (mg/kg)	ARAR	ARAR Source	MTCA Method B Screening Level (1)	Most Restrictive Risk Endpoint (1)	Simplified Terrestrial Ecological - Industrial or Commercial Site	Most Restrictive Criterion
DDE	na	na	2.94	Carcinogen	na	Method B
DDT	na	na	2.94	Carcinogen	na	Method B
DDT Total	na	na	na	na	1	Ecological
Dieldrin	na	na	0.0625	Carcinogen	0.17	Method B
Endosulfan	na	na	480	Noncarcinogen	na	Method B
Endrin	na	na	24	Noncarcinogen	0.4	Method B
Endrin Aldehyde	na	na	na	na	na	na
Heptachlor	na	na	0.222	Carcinogen	0.6 (total Heptachlor)	Method B
Heptachlor Epoxide	na	na	0.110	Carcinogen	na	Method B
Hexachlorobenzene	na	na	0.625	Carcinogen	31	Method B
Hexachlorobutadiene	na	na	12.82	Carcinogen	na	Method B
Hexachlorocyclohexane (BHC)	na	na	0.556	Carcinogen	10 (total BHC including Lindane)	Method B
alpha-BHC	na	na	0.159	Carcinogen	na	Method B
beta-BHC	na	na	0.556	Carcinogen	na	Method B
gamma-BHC (Lindane)	na	na	0.769	Carcinogen	na	Method B
delta-BHC	na	na	na	na	na	na
hexachlorocyclopentadiene	na	na	480	Noncarcinogen	na	Method B
Hexachloroethane	na	na	71.43	Carcinogen	na	Method B
Methoxychlor	na	na	400	Noncarcinogen	na	Method B
Mirex	na	na	0.556	Carcinogen	na	Method B
Pentachlorobenzene	na	na	64	Noncarcinogen	na	Method B
1,2,4,5-Tetrachlorobenzene	na	na	24	Noncarcinogen	na	Method B
Toxaphene	na	na	0.909	Carcinogen	na	Method B
Semivolatile, Organophosphate						
Chlorpyrifos	na	na	240	Noncarcinogen	na	Method B
Malathion	na	na	1,600	Noncarcinogen	na	Method B
Parathion	na	na	480	Noncarcinogen	na	Method B
Semivolatile, Phenolic						
2-Chlorophenol	na	na	400	Noncarcinogen	na	Method B
2,4-Dichlorophenol	na	na	240	Noncarcinogen	na	Method B
2,4-Dimethylphenol	na	na	1,600	Noncarcinogen	na	Method B
2-Methyl-4,6-Dinitrophenol	na	na	na	na	na	na
2,4-Dinitrophenol	na	na	160	Noncarcinogen	na	Method B

Table 2-5
Initial Soil Screening Levels

Soil (mg/kg)	ARAR	ARAR Source	MTCA Method B Screening Level (1)	Most Restrictive Risk Endpoint (1)	Simplified Terrestrial Ecological - Industrial or Commercial Site	Most Restrictive Criterion
2-Methylphenol	na	na	na	na	na	na
4-Methylphenol	na	na	na	na	na	na
4-Nitrophenol	na	na	na	na	na	na
3-Methyl-4-Chlorophenol	na	na	na	na	na	na
Pentachlorophenol	na	na	8.33	Carcinogen	11	Method B
Phenol	na	na	48,000	Noncarcinogen	na	Method B
2,3,4,6-Tetrachlorophenol	na	na	2,400	Noncarcinogen	na	Method B
2,4,5-Trichlorophenol	na	na	8,000	Noncarcinogen	na	Method B
2,4,6-Trichlorophenol	na	na	90.9	Carcinogen	na	Method B
Semivolatile, Phthalate						
Butyl Benzyl Phthalate	na	na	16,000	Noncarcinogen	na	Method B
Bis (2-Ethylhexyl) Phthalate	na	na	71.4	Carcinogen	na	Method B
Diethyl Phthalate	na	na	64,000	Noncarcinogen	na	Method B
Dimethyl Phthalate	na	na	80,000	Noncarcinogen	na	Method B
Di-N-Octyl Phthalate	na	na	1,600	Noncarcinogen	na	Method B
Di-N-Butyl Phthalate	na	na	na	na	na	na
Semivolatile, Polycyclic Aromatic Hydrocarbons						
Acenaphthene	na	na	4,800	Noncarcinogen	na	Method B
Acenaphthylene	na	na	na	na	na	na
Anthracene	na	na	24,000	Noncarcinogen	na	Method B
Benzo(a)anthracene	na	na	1.37 (3)	Carcinogen	na	Method B
Benzo(a)pyrene	na	na	0.137	Carcinogen	300	Method B
Benzo(b)fluoranthene	na	na	1.37 (3)	na	na	Method B
Benzo(k)fluoranthene	na	na	1.37 (3)	Carcinogen	na	Method B
Benzo(g,h,i)perylene	na	na	na	Carcinogen	na	na
Chrysene	na	na	13.7 (3)	Carcinogen	na	Method B
Dibenzo(a,h)anthracene	na	na	.342 (3)	Carcinogen	na	Method B
Fluoranthene	na	na	3,200	Noncarcinogen	na	Method B
Fluorene	na	na	3,200	Noncarcinogen	na	Method B
Indeno(1,2,3-cd)pyrene	na	na	1.37 (3)	Carcinogen	na	Method B
2-Methylnaphthalene	na	na	na	na	na	na
Naphthalene	na	na	1,600	Noncarcinogen	na	Method B
Phenanthrene	na	na	na	na	na	na
Pyrene	na	na	2,400	Noncarcinogen	na	Method B

Table 2-5
Initial Soil Screening Levels

Soil (mg/kg)	ARAR	ARAR Source	MTCA Method B Screening Level (1)	Most Restrictive Risk Endpoint (1)	Simplified Terrestrial Ecological - Industrial or Commercial Site	Most Restrictive Criterion
HPAH	na	na	na	na	na	na
LPAH	na	na	na	na	na	na
Total PAH	na	na	na	na	na	na
PCBs						
Total PCBs	1	40 CFR Part 761.61 (2)	na	ARAR	2	ARAR
Dioxin						
2,3,7,8-TCDD	na	na	6.67E-06	Carcinogen	5.0E-06	Ecological
Volatile, Aromatic and Halogenated						
Benzene	na	na	18.2	Carcinogen	na	Method B
Bromoform	na	na	127	Carcinogen	na	Method B
Carbon Tetrachloride	na	na	7.69	Carcinogen	na	Method B
Chlorobenzene	na	na	7.69	Carcinogen	na	Method B
Chlorodibromomethane	na	na	na	na	na	na
Chloroform	na	na	164	Carcinogen	na	Method B
Dibromomethane	na	na	na	na	na	na
1,2-Dichlorobenzene	na	na	7,200	Noncarcinogen	na	Method B
1,4-Dichlorobenzene	na	na	41.7	Carcinogen	na	Method B
Dichlorobromomethane	na	na	na	na	na	na
Dichlorodifluoromethane	na	na	16,000	Noncarcinogen	na	Method B
1,2-Dichloroethane	na	na	11.0	Carcinogen	na	Method B
1,1-Dichloroethylene	na	na	1.67	Carcinogen	na	Method B
1,2-cis Dichloroethylene	na	na	800	Noncarcinogen	na	Method B
1,2-trans Dichloroethylene	na	na	1,600	Noncarcinogen	na	Method B
1,2-Dichloropropane	na	na	14.7	Carcinogen	na	Method B
1,3-Dichloropropene	na	na	5.56	Carcinogen	na	Method B
Ethylbenzene	na	na	8,000	Noncarcinogen	na	Method B
Ethylene Dichloride	na	na	na	na	na	na
Methyl Bromide	na	na	na	na	na	na
Methyl Chloride	na	na	na	na	na	na
Methylene Chloride	na	na	133	Carcinogen	na	Method B
Pentachloroethane	na	na	na	na	na	na
Propylene Dichloride	na	na	na	na	na	na
Styrene	na	na	33.3	Carcinogen	na	Method B

Table 2-5
Initial Soil Screening Levels

Soil (mg/kg)	ARAR	ARAR Source	MTCA Method B Screening Level (1)	Most Restrictive Risk Endpoint (1)	Simplified Terrestrial Ecological - Industrial or Commercial Site	Most Restrictive Criterion
1,1,2,2-Tetrachloroethane	na	na	5	Carcinogen	na	Method B
Tetrachloroethylene	na	na	19.6	Carcinogen	na	Method B
Toluene	na	na	16,000	Noncarcinogen	na	Method B
1,2,4-Trichlorobenzene	na	na	800	Noncarcinogen	na	Method B
1,1,1-Trichloroethane	na	na	72,000	Noncarcinogen	na	Method B
1,1,2-Trichloroethane	na	na	17.5	Carcinogen	na	Method B
Trichlorethylene	na	na	90.9	Carcinogen	na	Method B
Trichlorofluoromethane	na	na	24,000	Noncarcinogen	na	Method B
Vinyl Chloride	na	na	0.667	Carcinogen	na	Method B
m,p-Xylene	na	na	160,000	Noncarcinogen	na	Method B
o-Xylene	na	na	160,000	Noncarcinogen	na	Method B
Total Xylene	na	na	160,000	Noncarcinogen	na	Method B
Volatile, Nitrile						
Acrolein	na	na	1,600	Noncarcinogen	na	Method B
Acrylonitrile	na	na	na	na	na	na

Notes:

ARAR - Applicable or Relevant and Appropriate Requirement

Method B - MTCA Direct Contact Pathway

na - not available

(1) Method B direct contact pathway. For carcinogenic chemicals, a 1E-6 cancer risk was applied

(2) ARAR is for high occupancy areas with no cap, from 40 CFR Part 761.61 (EPA rule governing disposal and cleanup of PCB contaminated facilities under TSCA).

(3) Based on Benzo(a)pyrene using Toxicity Equivalency Factors (173-340-708 WAC)

Most Stringent Screening Level

3 CHEMICALS OF POTENTIAL CONCERN

As discussed above, COPCs were identified by screening the available site characterization database against the most stringent MTCA Method B cleanup levels. The purpose of identifying COPCs was to focus subsequent RA/FS evaluations towards those chemicals that pose a potential exposure concern at the Site, eliminating from further consideration those chemicals that are unlikely to pose even a minor risk.

3.1 Remedial Investigation Database

The database of validated historical sampling data for soil, groundwater, surface water, porewater, and sediment was compiled from previous Site investigations available in the administrative record for the Site (Anchor and Aspect 2003). Anchor and Aspect converted this database to an Equis™ platform to facilitate its use in conducting the RA/FS. Data collected as part of the Work Plan tasks, including sediment natural recovery assessments, confirmatory sediment bioassays, and supplemental surface soil sampling data, were also added to the database prior to screening, ensuring that the most up-to-date information was considered in the screening.

3.2 Points of Compliance

Standard (default) points of compliance were used in the initial screening to identify COPCs, as follows:

- Soil
  - Direct contact – soils present from the ground surface to the maximum depth of potential future soil excavations, which can extend to 15 feet below ground surface (bgs).
  - Ecological – soils present from the ground surface to the maximum depth of potential future soil excavations, which can extend to 15 feet bgs.
  - Protection of ground water – soils present throughout the Site.
  - Protection of soil vapor – soils present from the ground surface to the water table (top of the saturated zone).
- Groundwater
  - Protection of drinking water – groundwater extending from the uppermost level of the saturated zone extending vertically to the lowest depth that could be potentially affected by Site releases.

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- Surface Water
  - Protection of human health and the environment – surface waters potentially affected by Site releases, including at the point of porewater release into the biologically active surface water habitat zone, defined for this RA/FS at a depth of 10 centimeters (cm; approximately 0.3 feet) below the mudline, prior to discharge into surface sediments.
- Sediment
  - Protection of the environment – surface sediments within the biologically active surface water habitat zone, represented by samples collected across the top 10 cm (0 to 0.3 feet) below the mudline.

As discussed in more detail in Section 5, proposed site-specific conditional points of compliance have been developed for the Quendall Site based on an initial consideration of the impracticability of achieving groundwater cleanup levels throughout the Site. Conditional points of compliance, which are subject to Ecology review based on the results of the accompanying FS, also assumed site-wide implementation of a deed restriction to further ensure that water supply withdrawal is precluded at the site, consistent with MTCA requirements.

3.3 Screening-Level Comparisons

The methodology used in the COPC screening, summarized in Table 3-1, is presented below.

3.3.1 Screening Decision Criteria

Conservative screening decision criteria were applied to identify COPCs at the Site using a 4-stage process. First, all validated historical and recent site characterization data available for the Site were compiled into the Equis™ database. Second, only those chemicals that were detected in at least one sample collected from the Site were retained for further screening (verification that sample detection limits were frequently below screening levels or practical quantitation limits was also performed at this stage). Third, the MTCA three-fold statistical criteria were applied to screen out infrequent, low-level detections of chemicals that do not constitute a potential concern from the standpoint of

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Table 3-1
Summary of Chemicals of Potential Concern Screening Results

Chemicals of Potential Concern for Risk Assessment	Validated Sample Size and Maximum Exceedance Factor (relative to screening level)			
	Soil	Groundwater	Surface Water/Porewater	Sediment
Conventionals				
Total Organic Carbon	No Screening Value	No Screening Value	No Screening Value	n = 162; Max EF = 3.4
Trace Element				
Antimony	n = 19; No Direct Contact Exceedances	No Data	No Data	n = 24; No Exceedances
Arsenic	n = 23; No Method A Exceedances	n = 24; Max EF = 30	No Data	n = 24; No Exceedances
Barium	n = 4; No Direct Contact Exceedances	No Data	No Data	No Data
Beryllium	n = 22; No Direct Contact Exceedances	n = 9; No Exceedances	No Data	n = 24; No Exceedances
Cadmium	n = 31; No Direct Contact Exceedances	n = 10; No Exceedances	No Data	n = 24; Max EF = 1.1
Chromium	n = 39; No Direct Contact Exceedances	n = 10; Max Surface Water ER =18	No Data	n = 24; No Exceedances
Copper	n = 34; No Direct Contact Exceedances	n = 80 Max Surface Water EF = 10.5	No Data	n = 24; No Exceedances
Lead	n = 31; No Direct Contact Exceedances	n = 59; Max EF = 2.9	No Data	n = 24; No Exceedances
Mercury	n = 30; No Direct Contact Exceedances	n = 9; No Exceedances	No Data	n = 24; No Exceedances
Nickel	n = 39; No Direct Contact Exceedances	n = 33; Max Surface Water EF = 1.2	No Data	n = 24; No Exceedances
Selenium	n = 26; No Direct Contact Exceedances	No Data	No Data	n = 24; No Screening Value
Silver	n = 26; No Direct Contact Exceedances	n = 10; No Exceedances	No Data	n = 24; No Exceedances
Thallium	n = 22; No Direct Contact Exceedances	n = 9; No Exceedances	No Data	n = 24; No Screening Value
Tin	No Data	No Data	No Data	No Data
Zinc	n = 39; No Direct Contact Exceedances	n = 80 Max Surface Water EF = 34	No Data	n = 24; Max EF = 2.3
Cyanide	No Data	No Data	No Data	No Data
Carcinogenic Polycyclic Aromatic Hydrocarbons (CPAHs)				
Benzo(a)anthracene	n = 99; Max Direct Contact EF = 1,400	n = 123Max Surface Water EF = 39,000	n = 16; Max EF = 790	Screening Based on Total PAH
Benzo(a)pyrene	n = 99; Max Direct Contact EF = 15,000	n = 123; Max Surface Wate EF = 607,000	n = 16; Max EF = 10,700	Screening Based on Total PAH
Benzo(b)fluoranthene	n = 60; Max Direct Contact EF = 1,200	n = 123; Max Surface Water EF = 8,200	n = 16; Max EF = 1,140	Screening Based on Total PAH
Benzo(k)fluoranthene	n = 58; Max Direct Contact EF = 1,600	n = 94; Max Surface Water EF = 9,100	n = 16; Max EF = 1,040	Screening Based on Total PAH
Chrysene	n =99; Max Direct Contact EF = 180	n = 124; Max Surface Water EF = 6,100	n = 16; Max EF = 60	Screening Based on Total PAH
Dibenzo(a,h)anthracene	n = 99; Max Direct Contact EF = 580	n = 123 Max Surface Water EF = 60,000	n = 16; Max EF = 1.1	Screening Based on Total PAH
Indeno(1,2,3-cd)pyrene	n = 99; Max Direct Contact EF = 1,100	n = 123 Max Surface Water EF = 3,000	n = 16; Max EF = 50	Screening Based on Total PAH
Total cPAH (1)	n = 99; Max Direct Contact EF = 20,000	n = 124; Max EF = 730,000	n = 16; Max EF = 13,700	Screening Based on Total PAH
Other Polycyclic Aromatic Hydrocarbons				
Acenaphthene	n = 99; No Direct Contact Exceedances	n = 123; Max EF = 2.1	n = 16; Max EF = 9	Screening Based on Total PAH
Acenaphthylene	n = 99; No Direct Contact Exceedances	n = 123; No Exceedances	n = 16; No Exceedances	Screening Based on Total PAH
Anthracene	n = 99; No Direct Contact Exceedances	n = 123; No Exceedances	n = 16; No Exceedances	Screening Based on Total PAH
Benzo(g,h,i)perylene	No Screening Value	No Screening Value	No Screening Value	Screening Based on Total PAH
Fluoranthene	n = 99; Max EF = 1.4	n = 123; Max Surface Wate EF = 21	n = 16; No Exceedances	Screening Based on Total PAH
Fluorene	n = 99; No Direct Contact Exceedances	n = 123; Max EF = 3.4	n = 16; No Exceedances	Screening Based on Total PAH
Naphthalene	n = 99; Max Direct Contact EF = 6.9	n = 123; Max EF = 270	n = 16; Max EF = 34	Screening Based on Total PAH
Phenanthrene	n = 99; No Direct Contact Exceedances	n = 18; No Exceedances	n = 16; No Exceedances	Screening Based on Total PAH
Pyrene	n = 99; Max Direct Contact EF = 2.2	n = 123; Max EF = 5.0	n = 16; No Exceedances	Screening Based on Total PAH
Total PAH (2)	No Screening Value	No Screening Value	No Screening Value	n = 303; Max EF = 460
Semivolatile, Miscellaneous				

Table 3-1
Summary of Chemicals of Potential Concern Screening Results

Chemicals of Potential Concern for Risk Assessment	Validated Sample Size and Maximum Exceedance Factor (relative to screening level)			
	Soil	Groundwater	Surface Water/Porewater	Sediment
Benzoic acid	n = 39; No Direct Contact Exceedances	n = 109; No Exceedances	No Data	n = 17; No Exceedances
Benzyl alcohol	n = 39; No Direct Contact Exceedances	n = 67; No Exceedances	No Data	n = 17; No Screening Value
Dibenzofuran	n = 96; No Screening Value	n = 147; No Exceedances	No Data	n = 182; Max EF = 5,500
Semivolatile, Nitroaromatic				
2,4-Dinitrotoluene	n = 37; No Direct Contact Exceedances	n = 45; No Exceedances	No Data	n = 17; No Screening Value
2,6-Dinitrotoluene	n = 37; No Direct Contact Exceedances	n = 45; No Exceedances	No Data	n = 17; No Screening Value
n-Nitroso-di-methylamine	n = 16; No Direct Contact Exceedances	n = 6; No Exceedances	No Data	No Data
n-Nitroso-di-n-propylamine	n = 39; No Direct Contact Exceedances	n = 46; No Exceedances	No Data	n = 17; No Exceedances
n-Nitroso-di-phenylamine	n = 39; No Direct Contact Exceedances	n = 47; Max EF = 13	No Data	n = 18; No Exceedances
Semivolatile, Organochlorine				
Aldrin	n = 6; Max Direct Contact EF = 2.2	n = 31; No Exceedances	No Data	No Data
Chlordane (total)	n = 2; No Direct Contact Exceedances	No Data	No Data	No Data
2-Chloronaphthalene	n = 81; No Direct Contact Exceedances	n = 47; No Screening Value	No Data	No Data
4,4'-DDD	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
4,4'-DDE	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
4,4'-DDT	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Total DDT	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Dieldrin	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Endosulfan	n = 6; No Direct Contact Exceedances	n = 31; No Screening Value	No Data	No Data
Endrin	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Endrin ketone	n = 4; No Screening Value	n = 31; No Screening Value	No Data	No Data
Heptachlor	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Heptachlor epoxide	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Hexachlorobenzene	n = 39; No Direct Contact Exceedances	n = 46; No Exceedances	No Data	n = 17; No Screening Value
Hexachlorobutadiene	n = 39; No Direct Contact Exceedances	n = 5; No Exceedances	No Data	n = 40; No Screening Value
alpha-BHC	n = 6; No Direct Contact Exceedances	n = 31; No Screening Value	No Data	No Data
beta-BHC	n = 6; No Direct Contact Exceedances	n = 31; No Screening Value	No Data	No Data
delta-BHC	n = 6; No Direct Contact Exceedances	n = 31; No Screening Value	No Data	No Data
gamma-BHC (Lindane)	n = 6; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
Hexachlorocyclopentadiene	n = 39; No Direct Contact Exceedances	n = 46; No Exceedances	No Data	n = 17; No Screening Value
Hexachloroethane	n = 39; No Direct Contact Exceedances	n = 46; No Exceedances	No Data	n = 17; No Screening Value
Methoxychlor	n = 4; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	No Data
PCBs				
Total PCBs	n = 22; No Direct Contact Exceedances	n = 31; No Exceedances	No Data	n = 10; No Exceedances
Dioxin				
Total TCDD-Equivalents	n = 6; No Direct Contact Exceedances	No Data	No Data	No Data
Semivolatile, Phenolic				
2,-Chlorophenol	n = 39; No Direct Contact Exceedances	n = 61; No Exceedances	No Data	n = 17; No Screening Value
2,4-Dichlorophenol	n = 39; No Direct Contact Exceedances	n = 61; No Exceedances	No Data	n = 17; No Screening Value
2,4-Dimethylphenol	n = 77; No Direct Contact Exceedances	n = 61; Max EF = 3.8	No Data	n = 17; No Exceedances

Table 3-1
Summary of Chemicals of Potential Concern Screening Results

Chemicals of Potential Concern for Risk Assessment	Validated Sample Size and Maximum Exceedance Factor (relative to screening level)			
	Soil	Groundwater	Surface Water/Porewater	Sediment
2,4-Dinitrophenol	n = 39; No Direct Contact Exceedances	n = 61; No Exceedances	No Data	n = 17; No Screening Value
4,6-Dinitro-2-methylphenol	n = 39; No Screening Value	n = 67; No Screening Value	No Data	n = 17; No Screening Value
2-Methylphenol	n = 59; No Screening Value	n = 67; No Screening Value	No Data	n = 17; No Screening Value
4-Methylphenol	n = 39; No Screening Value	n = 109; No Screening Value	No Data	n = 17; No Exceedances
2-Nitrophenol	n = 39; No Screening Value	n = 66; No Screening Value	No Data	n = 17; No Screening Value
4-Nitrophenol	n = 39; No Screening Value	n = 67; No Screening Value	No Data	n = 17; No Screening Value
4-Chloro-3-methylphenol	n = 39; No Screening Value	n = 67; No Screening Value	No Data	n = 17; No Screening Value
Pentachlorophenol	n = 79 Max Direct Contact EF = 5.1	n = 61; Max Surface Water EF = 2,300	No Data	n = 105; No Exceedances
Phenol	n = 39; No Direct Contact Exceedances	n = 65; Max Surface Water EF = 3.1	No Data	n = 17; Max EF = 6.5
2,3,4,5-Tetrachlorophenol	n = 16; No Screening Value	n = 5; No Screening Value	No Data	No Data
2,3,4-Trichlorophenol	n = 16; No Screening Value	n = 5; No Screening Value	No Data	No Data
2,3,5,6-Tetrachlorophenol	n = 16; No Screening Value	n = 5; No Screening Value	No Data	No Data
2,3,6-Trichlorophenol	n = 16; No Screening Value	n = 5; No Screening Value	No Data	No Data
2,4,5-Trichlorophenol	n = 73; No Direct Contact Exceedances	n = 67; No Screening Value	No Data	n = 17; No Screening Value
2,4,6-Trichlorophenol	n = 55; No Direct Contact Exceedances	n = 67; No Screening Value	No Data	n = 17; No Screening Value
Phthalates				
Butylbenzylphthalate	n = 39; No Direct Contact Exceedances	n = 47; No Exceedances	No Data	n = 17; No Exceedances
bis(2-Ethylhexyl)phthalate	n = 77; No Direct Contact Exceedances	n = 60; Max Surface Water EF = 158	No Data	n = 17; No Exceedances
Diethylphthalate	n = 39; No Direct Contact Exceedances	n = 47; No Exceedances	No Data	n = 17; No Exceedances
Dimethylphthalate	n = 39; No Direct Contact Exceedances	n = 46; No Exceedances	No Data	n = 17; No Exceedances
Di-n-octylphthalate	n = 57; No Direct Contact Exceedances	n = 48; No Exceedances	No Data	n = 17; Max EF = 36
Di-n-butylphthalate	n = 84; No Screening Value	n = 89; No Screening Value	No Data	n = 17; No Exceedances
Volatile, Aromatic and Halogenated				
Benzene	n = 65; No Direct Contact Exceedances	n = 67; Max Surface Water EF = 6,400	n = 16; Max EF = 350	n = 37; No Exceedance
Bromoform	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	n = 23; No Screening Value
Carbon tetrachloride	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	No Data
Chlorobenzene	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	n = 23; No Screening Value
Chloroform	n = 2; No Direct Contact Exceedances	n = 50; Max Surface Water EF = 4.7	No Data	n = 23; No Screening Value
1,2-Dichlorobenzene	n = 57; No Direct Contact Exceedances	n = 46; No Exceedances	No Data	n = 40; No Screening Value
1,3-Dichlorobenzene	n = 57; No Screening Value	n = 51; No Screening Value	No Data	n = 40; No Screening Value
1,4-Dichlorobenzene	n = 57; No Direct Contact Exceedances	n = 47; No Exceedances	No Data	n = 40; No Screening Value
Dichlorodifluoromethane	n = 2; No Direct Contact Exceedances	No Data	No Data	No Data
1,1-Dichloroethane	n = 2; No Screening Value	n = 47; No Exceedances	No Data	n = 23; No Screening Value
1,2-Dichloroethane	n = 2; No Direct Contact Exceedances	n = 47; No Exceedances	No Data	n = 23; No Screening Value
1,1-Dichloroethene	n = 2; No Direct Contact Exceedances	n = 47; No Exceedances	No Data	n = 23; No Screening Value
Methylene chloride	n = 2; No Direct Contact Exceedances	n = 50 Max EF = 22	No Data	n = 20; No Exceedances
1,2-Dichloropropane	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	n = 23; No Screening Value
1,3-Dichloropropene	n = 2; No Direct Contact Exceedances	No Data	No Data	No Data
Ethylbenzene	n = 59; No Direct Contact Exceedances	n = 121; Max EF = 6	n = 16; No Exceedances	n = 37; No Exceedance
Styrene	No Soil Data	n = 47; Max EF = 75	No Data	n = 23; No Exceedance

Table 3-1
Summary of Chemicals of Potential Concern Screening Results

Chemicals of Potential Concern for Risk Assessment	Validated Sample Size and Maximum Exceedance Factor (relative to screening level)			
	Soil	Groundwater	Surface Water/Porewater	Sediment
1,1,2,2-Tetrachloroethane	No Soil Data	n = 5; No Screening Value	No Data	n = 23; No Exceedance
1,1,2,2-Tetrachloroethane	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	n = 23; No Exceedance
Tetrachloroethene	n = 2; No Direct Contact Exceedances	n = 94; Max Surface Water EF = 1.4	No Data	n = 23; No Exceedance
Toluene	n = 65; No Direct Contact Exceedances	n = 121; Max EF = 3.4	n = 16; No Exceedances	n = 37; No Exceedance
1,2,4-Trichlorobenzene	n = 39; No Direct Contact Exceedances	n = 53; No Exceedances	No Data	n = 40; No Screening Value
1,1,1-Trichloroethane	n = 2; No Direct Contact Exceedances	n = 94; No Exceedances	No Data	n = 23; No Exceedance
1,1,2-Trichloroethane	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	n = 23; No Exceedance
Trichloroethene	n = 2; No Direct Contact Exceedances	n = 52; No Exceedances	No Data	n = 23; No Exceedance
Xylenes (total)	n = 29; No Direct Contact Exceedances	n = 112; No Exceedances	n = 16; No Exceedances	n = 37; No Exceedance

Notes:

(1) Carcinogenic PAHs will be evaluated using the toxicity equivalancy factor method to normalize concentrations to Benzo(a)pyrene

(2) Total PAHs in sediment will be evaluated using the site-specific criterion.

Exceedance Factor Less Than or Equal to 2. Statistical analyses will be conducted to confirm whether the chemical is of concern under MTCA.
Exceedance Factor Greater Than 2. Additional analyses will be conducted to confirm that chemical is represented by the selected indicator hazardous substances.

MTCA compliance monitoring[3]. Finally, any chemical that exceeded the most stringent cleanup level (the "screening" level) for one media was retained as a COPC for all media.

3.3.2 Identification of COPCs

Table 3-1 provides a summary of the COPC screening results including the analyte sample size and the maximum exceedance factor when compared to the most stringent cleanup level. Those COPCs that were retained for further evaluation in the RA/FS, including development of proposed site-specific cleanup levels, are listed in Table 3-2.

Table 3-2
Site-Specific Chemicals of Potential Concern

Metals	**Total Organic Carbon** (wood waste)
Arsenic	**Semivolatile, Miscellaneous**
Chromium (III)[4]	Dibenzofuran
Copper	n-Nitroso-di-phenylamine
Lead	**Organochlorine Pesticides**
Zinc	Aldrin
Polycyclic Aromatic Hydrocarbons	**Semivolatile, Phenolic**
Acenaphthene	2,4-Dimethylphenol
Benzo(a)anthracene (cPAH)	Pentachlorophenol (PCP)
Benzo(a)pyrene (cPAH)	Phenol
Benzo(b)fluoranthene (cPAH)	**Phthalates**
Benzo(k)fluoranthene (cPAH)	bis(2-Ethylhexyl)phthalate
Chrysene (cPAH)	Di-n-octylphthalate
Dibenzo(a,h)anthracene (cPAH)	**Volatile, Aromatic and Halogenated**
Indeno(1,2,3-cd)pyrene (cPAH)	Benzene
Fluoranthene	Chloroform
Fluorene	Methylene Chloride
Naphthalene	Ethylbenzene
Pyrene	Styrene
	Toluene

[3] MTCA three-fold criteria are as follows: 1) the maximum concentration must be less than or equal to 2 times the site-specific cleanup level; 2) the 95 percent upper confidence level (UCL), calculated using MTCASTAT statistical software, must be less than the cleanup level; and 3) less than 10 percent of the individual concentrations shall exceed the cleanup level.

[4] Soil conditions at the site are characterized by high organic content, supporting a reducing environment, and neutral pH. Because the oxidizing environment required to maintain Cr (VI) is not present at the site, Cr (VI) was not retained as a COPC.

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As discussed in the Upland Remedial Investigation Report (Hart Crowser 1997), the presence of the identified COPCs listed in Table 3-2 including PAHs, volatiles, metals, TOC, and phenolic compounds is consistent with historic uses of the Site for creosote manufacturing (coal tar and oil-gas tar processing), petroleum storage, and log sorting/storage.

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4 SITE CONCEPTUAL MODEL UPDATE

A detailed conceptual model of the Site was previously presented in the Upland Remedial Investigation Report (Hart Crowser 1997). The conceptual model has subsequently been refined by incorporating newer data, as presented in the Data Gap Memo (Anchor and Aspect 2002) and Work Plan (Anchor and Aspect 2003). All of these documents are incorporated by reference into this RA/FS Report. Focused refinements of the site model, as envisioned in the Work Plan, are provided below.

4.1 Groundwater to Surface Water Fate and Transport

Groundwater enters the subsurface of the Site from the east and from infiltration of on-site precipitation. Both shallow and deep aquifer systems have been defined. Groundwater moves downward through the shallow aquifer to the deep aquifer in the east and east-central portions of the Site, horizontally through the middle site area, and vertically upward along the west of the shoreline, discharging into Lake Washington (Figures 4-1 and 4-2). This pathway defines the point of discharge into the lake environment. This conceptual groundwater flow system has been simulated using a calibrated three-dimensional numerical groundwater flow model (Retec and Papadopoulos 1998). The geologic units and water quality conditions define the flowpath travel times and the potential for attenuation during transport.

Groundwater flow has been identified as a pathway for contaminant migration from contaminated upland soils and dense non-aqueous phase liquid (DNAPL) sources. Understanding the specific areas of discharge of groundwater from the shallow and deep aquifers is important to targeting areas of concern for the FS. As groundwater flows contact these contaminant sources, the more mobile COPCs (e.g., benzene and naphthalene) partition into the groundwater and are transported to downgradient receptor environments in Lake Washington. As discussed in various site characterization reports prepared for the Site, groundwater chemical concentrations have been observed to decline downgradient of identified DNAPL source areas. These observations are consistent with modeling predictions (Hart Crowser 1997, Retec and Papadopoulos 1998) suggesting that significant attenuation (primarily biodegradation) of COPCs is likely along groundwater migration pathways from the upland source areas, prior to discharge into Lake Washington. Substantial site data are available that allow the biodegradation process to be characterized

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for the purpose of this RA/FS. As discussed in later sections of this report, additional data on specific biodegradation mechanisms may be collected during the forthcoming remedial design phase to optimize cleanup designs.

To further evaluate and verify predicted attenuation of COPCs along the groundwater to surface water pathway, a series of wellpoints were previously installed along the lakebed sediment at a depth of approximately 4 to 6 feet below mudline, along generalized groundwater flowpath transects (Figure 4-1; also see Anchor and Aspect 2002). Validated wellpoint sampling data collected over a range of hydrologic conditions (sampling in January 2001, September 2002, and February 2003), along with concurrent bulk sediment and porewater sample data collected within the biologically active habitat zone (0 to 10 cm) at these same locations, have been previously provided to Ecology under separate cover.

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Insert Figure 4-2. Representative Site Cross Section through Northwest Area (A-A′ cross section)¶
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The wellpoint/porewater data, summarized in Table 4-1, confirm earlier modeling analyses indicating that, outside of identified DNAPL areas, contaminant concentrations decrease rapidly along the groundwater to surface water flow pathway. The considerable attenuation of mobile COPCs such as benzene and naphthalene over the last 5 feet of groundwater transport is clearly evident in the Table 4-1 data summary.

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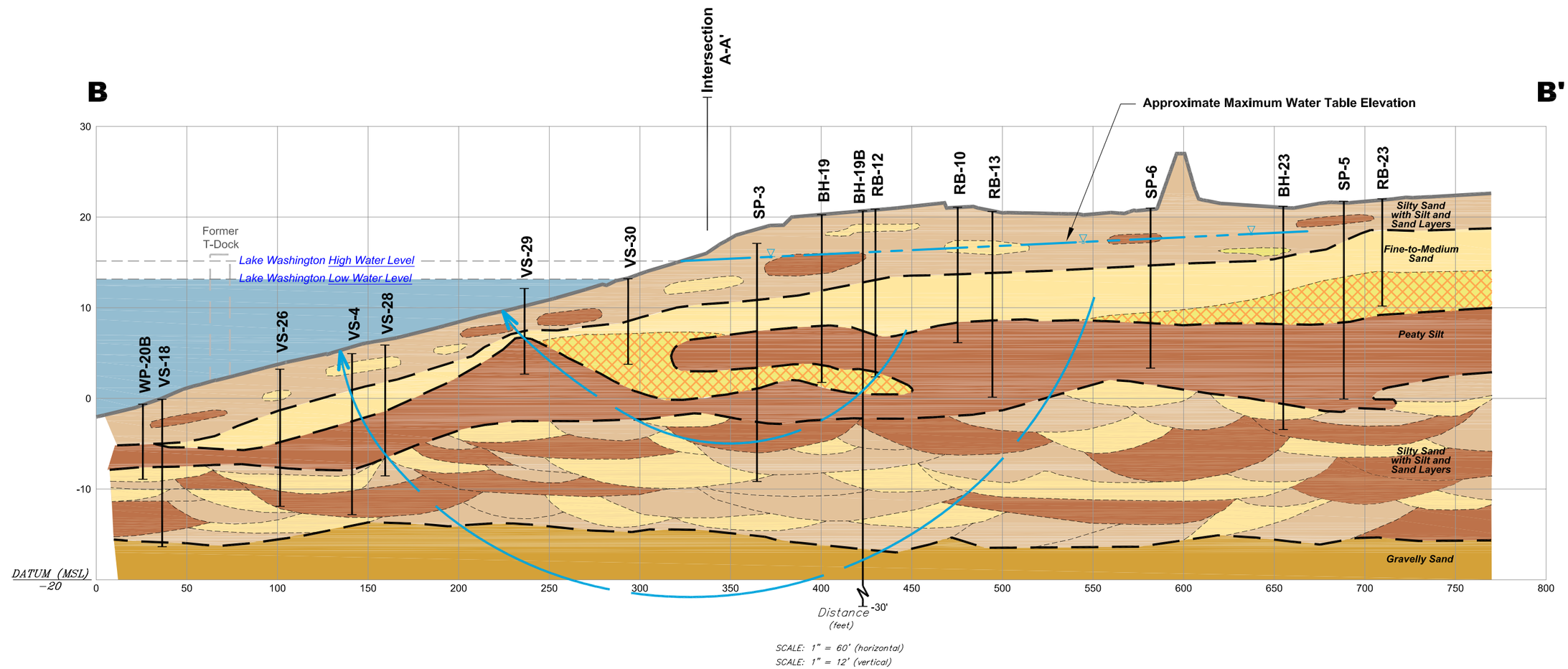


LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Silt and Sand Layers
- Gravelly Sand
- Generalized Ground Water Flow Path [Based on Ground Water Modeling (Retec 1998)]

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

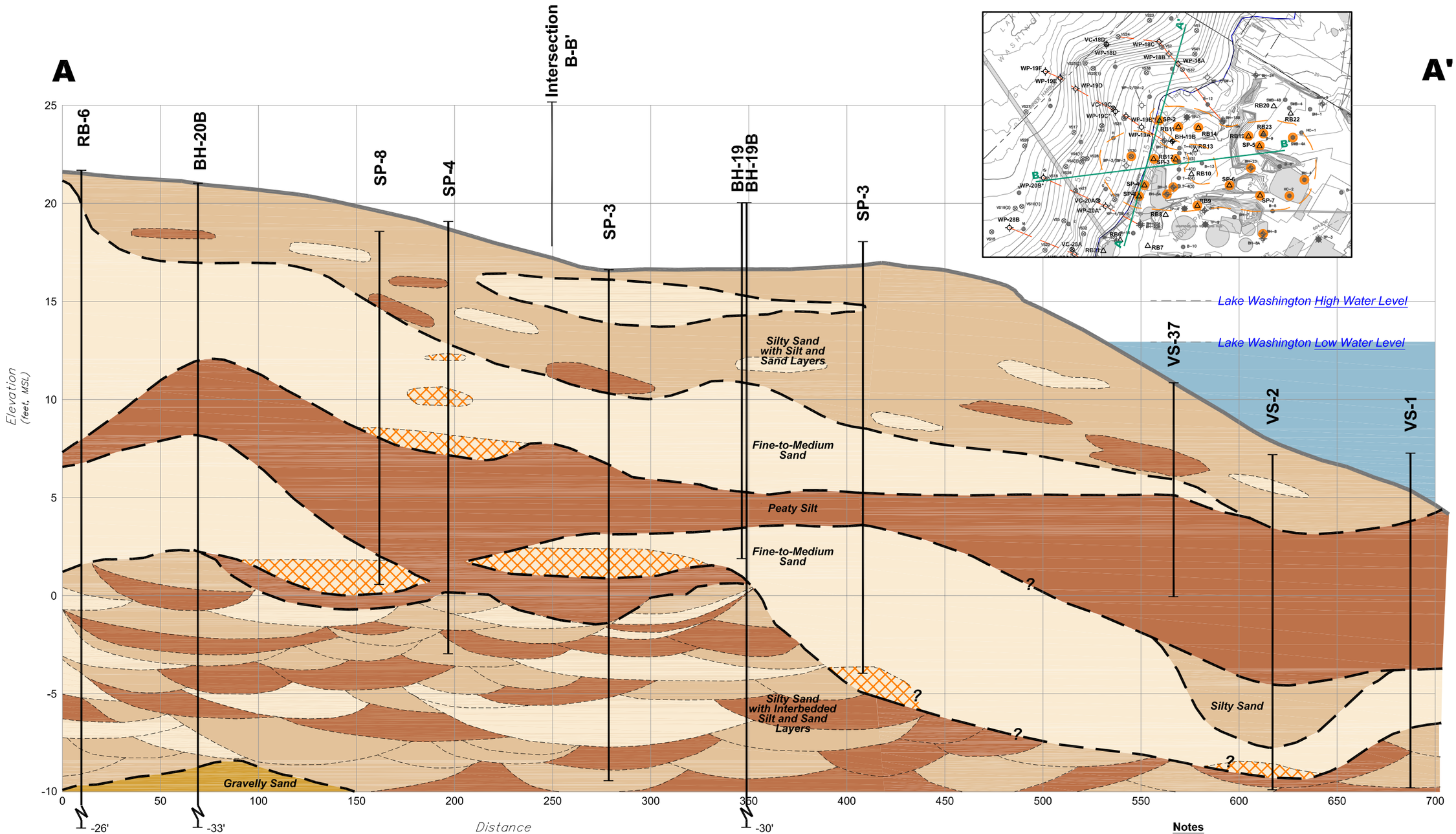
Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

May 28, 2004 11:11am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-18.dwg FIG 4-1

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 4-1
Representative Cross Sections
Through Northwest Area
Quendall Terminals



LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Interbedded Silt and Sand Layers
- Gravelly Sand

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

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Aspect consulting IN-DEPTH PERSPECTIVE

Figure 4-2
Representative Cross Sections
Through Northwest Area
Quendall Terminals

May 28, 2004 11:10am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-17.dwg FIG 4-2

Intermittent, localized discharge of hydrocarbon sheen has been observed during the winter months along the exposed lake shoreline adjacent to the Quendall Pond – located approximately 30 feet from the lake. The occurrence of these intermittent discharges corresponds to seasonal mounding of perched groundwater around Quendall Pond caused by two factors, First, observed sheen during the winter corresponds to the annual lowering of the lake level (approximately 2 feet by the Corps. of Engineers), which seasonally increases the gradient between the lake and the pond. Second, a rapid rise in the surface water level (hydraulic head) in Quendall Pond can result from heavy precipitation events and stormwater inflow from the surrounding site. Field inspection of the pond area identified preferential drainage into the pond from the south and east off the present log yard operation. Given the pond's relatively small surface area and steep sidewalls, the pond level rises rapidly in response to inflow. Recent soil probe explorations conducted to delineate DNAPL occurrence at the site – including the area between Quendall Pond and the shoreline (i.e., SP-4 and SP-8 as shown on Figures 4-1 and 4-2) – identified hydrocarbon product staining but did not detect any discernible accumulation of DNAPL at shallow depths of 6 to 10 feet below grade. This indicates a limited source area contributing to intermittent sheen discharge.

The presence of hydrocarbon sheen along the shoreline appears to be directly related to pond water seepage into the lake, under seasonally high flow gradients caused by mounding in the pond and seasonally lowered lake level. Seepage occurs through the permeable soils that form the narrow north-south embankment between the pond and the lake. Review of previous water level monitoring data (i.e., pond staff gage and shallow monitoring wells) collected in the Quendall Pond area indicate localized mounding of perched groundwater immediately around the pond corresponding to a rise in the pond water level. It is anticipated that this shallow seepage during the seasonally steep hydraulic gradient – created by the combined lowering of the lake level and elevated water level in the Quendall Pond – mobilizes hydrocarbon sheen as it discharges toward the lake. Because the hydraulic gradient between the pond and the lake during the wet season (greater than 0.2 ft/ft) is much greater than groundwater gradients measured in other areas of the site, biodegradation processes may not be sufficient in this case to adequately attenuate contaminants before discharge to surface water without controlling the effects of this hydraulic mounding.

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As identified by previous investigations (Retec 1997), a deep PAH area is located northwest of the Quendall Pond areas that is likely associated with DNAPL migration either northwest from the North Sump area or north from the nearshore Quendall Pond area. A thin (6-inch) layer of DNAPL-stained soil was identified at one sediment boring (VS-2) at a depth of approximately 16 feet below the mudline, well below the sediment point of compliance (Figure 4-2, A-A' cross section) and below the peaty silt layer. Additional sediment borings subsequently advanced in this area did not identify any DNAPL occurrences. Surface sediment samples in this area indicate that the deep PAH is not impacting sediment quality. Groundwater quality samples from well points installed in this area (WP-18 series) indicate that groundwater flow through the deep PAH area does not result in exceedences in pore water quality at the point of compliance

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The available data indicate that DNAPL occurrences in offshore sediments are contained by stratigraphic traps formed by interbedded peaty silt layers extending from the upland area out beneath Lake Washington, as indicated on the Figures 4-1 and 4-2. Results of subsurface sampling of the off-shore area indicate that DNAPL occurrences in the deep sediments below the peaty silt are limited and not impacting surface water quality.

4.1.1 Supplemental Seepage Characterization

In order to provide further characterization of the groundwater to surface water transport pathway, direct field measurements of vertical hydraulic gradients, and hydraulic conductivities of the lakebed were performed in fall 2003, consistent with an Ecology-approved addendum to the Work Plan (Aspect 2003). The results of these measurements are summarized in Table 4-2. The data reveal that groundwater seepage velocities through the nearshore lakebed ranged from approximately 1.6 to 30 meters per year (Table 4-1), with highest velocities measured in the more permeable sand materials, and lower seepage velocities in the less permeable peat deposits. These results are consistent with other regional seepage measurements, and are also consistent with previous modeling-based evaluations of the Site (Hart Crowser 1997, Retec and Papadopoulos 1998).

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Table 4-1
Wellpoint and Porewater Data Pairs Used in Attunuation Modeling

	WP-19A			WP-19B			WP-19C			WP-20A			WP-20B (historic spill influence)		
	Groundwater at Wellpoint	Sediment Porewater	Bulk Sediment	Groundwater at Wellpoint	Sediment Porewater	Bulk Sediment	Groundwater at Wellpoint	Sediment Porewater	Bulk Sediment	Groundwater at Wellpoint	Sediment Porewater	Bulk Sediment	Groundwater at Wellpoint	Sediment Porewater	Bulk Sediment
MEASURED PARAMETERS															
Depth below Mudline (cm; avg.)	147	0 - 10	0 - 10	150	0 - 10	0 - 10	147	0 - 10	0 - 10	168	0 - 10	0 - 10	153	0 - 10	0 - 10
Hydraulic Parameters:															
Vertical Gradient (unitless)	0.0074	-	-	0.0697	-	-	0.1167	-	-	0.0126	-	-	-	-	-
Hydraulic Conductivity (m/year)	815	-	-	7	-	-	7	-	-	711	-	-	-	-	-
Effective Seepage Porosity (unitless)	20%	51%	-	20%	41%	-	20%	39%	-	20%	69%	-	20%	86%	-
Calculated Seepage Velocity (m/year)	20			1.6			2.6			30			-		
Conventional Parameters:															
Total Solids (% wet wt)	-	-	63%	-	-	71%	-	-	73%	-	-	46%	-	-	23%
Calculated Porosity (unitless)	-	-	61%	-	-	51%	-	-	49%	-	-	76%	-	-	89%
Sediment TOC (% dry wt)	-	-	2.50%	-	-	0.53%	-	-	0.32%	-	-	3.70%	-	-	6.10%
Porewater TOC (mg/L)	-	-	-	-	-	-	-	-	-	-	19.2	-	-	8.1	-
Volatile Organics (ug/L or ug/kg dry wt):															
Benzene	10,250	545	-	10,450	6.0	-	120	1 U	-	165	1 U	-	*905*	*39*	-
Ethylbenzene	3,350	120	-	3,800	10	-	*4.2*	*1 U*	-	655	1 U	-	*880*	*98*	-
Toluene	702	6.0	-	285	1 U	-	*3.8*	*1 U*	-	16	1 U	-	*9.4*	*11*	-
Low Molecular Weight PAHs (ug/L or ug/kg dry wt):															
Acenaphthene	108	2.7	79	82	1.5	7	*1 U*	*1 U*	*7*	*1 U*	*1.2*	*2,800*	*26*	*137*	*60,000*
Fluorene	15	2.6	38	8.3	1 U	7	*1 U*	*1 U*	*7*	*1 U*	*1 U*	*3,400*	*1 U*	*52*	*43,000*
Naphthalene	6,650	370	12,000	7,100	40	19	*9.1*	*1 U*	*7*	*2.1*	*1 U*	*2,600*	*3,750*	*3,180*	*150,000*
High Molecular Weight PAHs (ug/L or ug/kg dry wt):															
Benzo(a)anthracene	*1 U*	*2.6*	*330*	*1 U*	*1 U*	*100*	*1 U*	*1 U*	*22*	*1 U*	*1.1*	*8,200*	*1 U*	*14*	*75,000*
Benzo(a)pyrene	*1 U*	*2.6*	*1,000*	*1 U*	*1 U*	*520*	*1 U*	*1 U*	*21*	*1 U*	*1.6*	*16,000*	*1 U*	*19*	*140,000*
Benzo(b)fluoranthene	*1 U*	*2.6*	*960*	*1 U*	*1 U*	*540*	*1 U*	*1 U*	*33*	*1 U*	*1.7*	*19,000*	*1 U*	*20*	*130,000*
Benzo(k)fluoranthene	*1 U*	*2.6*	*870*	*1 U*	*1 U*	*320*	*1 U*	*1 U*	*18*	*1 U*	*1.6*	*17,000*	*1 U*	*18*	*130,000*
Chrysene	*1 U*	*2.6*	*740*	*1 U*	*1 U*	*330*	*1 U*	*1 U*	*28*	*1 U*	*1.1*	*19,000*	*1 U*	*10*	*140,000*
Dibenzo(a,h)anthracene	*1 U*	*2.6*	*290*	*1 U*	*1 U*	*120*	*1 U*	*1 U*	*7*	*1 U*	*1 U*	*2,500*	*1 U*	*3.0*	*9,600*
Fluoranthene	*1 U*	*2.6*	*200*	*1 U*	*1 U*	*34*	*1 U*	*1 U*	*24*	*1 U*	*1.1*	*38,000*	*1 U*	*26*	*98,000*
Indeno(1,2,3-cd)pyrene	*1 U*	*2.6*	*620*	*1 U*	*1 U*	*270*	*1 U*	*1 U*	*9*	*1 U*	*1 U*	*6,200*	*1 U*	*8.2*	*19,000*
Pyrene	*1 U*	*2.6*	*280*	*1 U*	*1 U*	*45*	*1 U*	*1 U*	*20*	*1 U*	*1.3*	*38,000*	*1 U*	*34*	*100,000*
LITERATURE-BASED PARAMETERS															
Equilibrium Partitioning Coefficient (L/kg OC; from MTCA regulation):															
Benzene	62														
Ethylbenzene	204														
Toluene	140														
Acenaphthene	4,898														
Fluorene	7,707														
Naphthalene	1,191														

Notes:

Surface Mass Transfer Coefficient - from DiToro et al. (2001)

Molecular Diffusion Coefficient below Bioturbation Depth - from DiToro et al. (1981)

Effective Bioturbation Mixing Depth - 10 cm (SMS default)

Bioturbation Mixing Rate Coefficient - from Boudreau (1997)

Yellow highlighted data were used in model-based evaluations of attenuation processes; see text.

Table 4-2
Quendall Site Lakebed Seepage Measurements

Location	Sediment	Depth Inches	Gradient cm/cm	K_v cm/s	K_v ft/day	Effective Porosity at Wellpoint	Source of K_v If not collected at same location
WP-21A	Sand	0 to 60	0.0023	0.028	79	0.2	Sand from WP-20A No.3
WP-21B	Sand	0 to 60	0.0042	0.028	79	0.2	Sand from WP-20A No.3
WP-19A No. 1	Silty Sand	0 to 10	0.0074	0.0076	22	0.2	
WP-19A No. 2	Silty Sand	0 to 10	0.0074	0.0026	7.3	0.2	
WP-19A No. 3	Sand	0 to 10	0.0074	0.0114	32.3	0.2	
WP-20A No. 2	Silty Sand	0 to 12	0.0126	0.0023	6.4	0.2	
WP-20A No. 3	Sand	0 to 12	0.0048	0.0277	79	0.2	
WP-19C	Peaty Silt	14 to 18, 44 to 56	0.117	0.000021	0.06	0.2	Retec modeling
WP-19B	Sandy Silt	18 to 48	0.070	0.000021	0.06	0.2	Retec modeling

4.2 Wellpoint-Porewater Biodegradation Analysis

In order to understand the relative importance of biodegradation and/or dispersion processes in contributing to the observed attenuation of porewater concentrations along the groundwater to surface water transport pathway (Table 4-1), a one-dimensional analytical model evaluation of the wellpoint and porewater data was performed, as described below.

4.2.1 Analytical Model Framework

For the purpose of this analysis, and in order to maximize the accuracy and transparency of the model-based evaluations, readily available one-dimensional contaminant transport equations – the Boudreau (1997) model – were used to identify attenuation mechanisms at the Quendall Site. The Boudreau model was used in the present application to evaluate groundwater/porewater transport through the soil/sediment system at each of the four locations summarized in Table 4-1 for which detailed site characterization data are available. The numerical Boudreau model represents the primary physical, chemical, and biological processes that control the flux of chemicals within the groundwater/sediment system through a vertically-segmented

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one-dimensional model structure. Primary chemical transport processes represented by the modeling described herein included:

- Chemical partitioning between groundwater/porewater and soil/sediment
- Upward advective flow of groundwater
- Chemical diffusion along porewater concentration gradients
- Bioturbation within the upper mixed sediment layer
- Physical, chemical, and biologically-mediated exchange across the sediment/surface water interface (mudline)
- Biodegradation

In order to simplify the Boudreau model evaluation, it was assumed that no sedimentation or resuspension occurs within the project area. This simplifying assumption is supported by sediment trap and radioisotope core dating data collected at the Site, which suggest that sedimentation rates in the nearshore area are relatively low, on the order of 0.2 to 0.7 cm/year (Table 4-3), and not likely to substantively affect fate and transport processes given the advective flow velocities measured at the Site (see below).

Table 4-3
T-Dock Area Sedimentation Rates

Station	Measured Accumulation Rate (traps) (gms/cm^2-yr)	Percent Solids (0 - 10 cm) (% wet wt)	Porosity (unitless)	In Situ Sediment Density (gms/cm^3)	Gross Sedimentation Rate (cm/yr)
WP-20B	0.18	23%	0.90	1.16	0.69
QB-04	0.12	19%	0.92	1.13	0.53
SO-52	0.06	25%	0.89	1.18	0.21

Boudreau (1997) has written several numerical models to evaluate contaminant transport through the soil/sediment/surface water system in both the dissolved and sorbed (mixing of sediments) phases. The Boudreau model used herein was based on the differential equation shown in his Example 8-2. The theory underlying the model and the equations used in implementation of the model are described in detail by Boudreau (1997). It is a finite difference model that uses the Method of Lines solution technique. The temporal differential equations were solved using spatial finite

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differences as specified in the example. The model was run on an Excel platform using Excel formulas with supporting Visual Basic code.

In addition, the constitutive equations of the Boudreau model were applied to obtain an analytical solution of the steady-state case (i.e., assuming groundwater and porewater concentrations are in equilibrium with source inputs, as suggested by Retec and Papadopoulos (1998). This steady-state version of the model calculates the endpoint or equilibrium concentration of the time-dependent Boudreau model.

A key element of the evaluation described herein was the selection of appropriate parameters for input into the model, and the use of measured site-specific parameters wherever possible. In fact, all of the key input values used in the model were based on site-specific measurements at individual wellpoint/porewater stations, including porewater chemical concentrations, porosity, bulk sediment properties (e.g., TOC content), equilibrium partition coefficients (which agreed with literature values), and vertical hydraulic gradient and hydraulic conductivity. Model inputs are summarized in Table 4-1.

Several deterministic parameters are typically used in the Boudreau model, as follows (default deterministic parameter values were obtained from DiToro et al., 1981 and DiToro 2001 unless noted otherwise):

- Molecular diffusion coefficients
- Chemical solubility in water
- Surface bioturbation mixing rate coefficient
- Effective bioturbation and interface exchange depths

Diffusion coefficients were calculated based on the molecular weight of the chemical using equations from DiToro et al. (1981). This coefficient is entered into the Boudreau model, which then incorporates effective diffusion through porous media in surface layers resulting from bioturbation. Bioturbation rates and mixing depths were developed from evaluations of radioisotope core profiles collected at the Quendall Site, and were consistent with rates reported from other similar sites, as summarized by Boudreau, DiToro, and others. A typical value of 0.1 cm was used for the

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sediment/surface water interface exchange depth. A porosity exponent for tortuosity value of 1.14 was used based on data presented in Boudreau (1997).

4.2.2 Biodegradation Rate Calculations

The only major fate and transport parameter that was not measured along the groundwater to surface water flow path was the biodegradation rate. This value was calculated as the dependent variable in the Boudreau model applied to each of the wellpoint/porewater data pairs. That is, the biodegradation rate that explained the observed reduction in concentration along the wellpoint to porewater flow path was calculated by the model at each wellpoint location (Table 4-1). The steady-state Boudreau model was used to essentially back-calculate the biodegradation rate that would explain the observed attenuation of chemical concentrations over the wellpoint to surface porewater pathway, also accounting for other important transport mechanisms such as advection, sorption, and diffusion. Biodegradation was represented by a first order reaction (i.e., m = 1), which is typical of decay reactions. The model was used to estimate biodegradation rates for mobile chemicals such as benzene and naphthalene that have been most frequently detected in Site porewater at concentrations above surface water screening levels (see Tables 2-3, 3-1, and 4-1).

Biodegradation estimates developed using the Boudreau model are summarized in Table 4-4. Benzene half lives ranged from approximately 0.1 to 0.3 years, while half lives for naphthalene ranged from roughly 1 to 5 years. These values are within the mid- to slower range of anaerobic soil, groundwater, and sediment biodegradation rates reported in the literature (Howard et al. 1991, Aronson and Howard 1997). Thus, the literature comparison corroborates the site-specific estimates derived from the wellpoint/porewater data. Importantly, the Boudreau model results also suggest that nearly all of the observed reduction in concentrations along the wellpoint to porewater flow path was attributable to biodegradation. Due to the relatively large seepage velocities measured at the Quendall Site (1.6 to 30 meters per year; Table 4-1), other processes such as dispersion and mudline exchange (including sedimentation) do not contribute substantively to chemical concentration attenuation along the flow path.

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Table 4-4
Summary of Site-Specific Biodegradation Estimates

Chemical of Potential Concern	Apparent Biodegradation Half-Life (years)					
	WP-19A	WP-19B	WP-19C	WP-20A	QB-04	SO-52
	Wellpoint Flowpath Analysis	Wellpoint Flowpath Analysis	Wellpoint Flowpath Analysis	Wellpoint Flowpath Analysis	Natural Recovery 1990-2003	Natural Recovery 1996-2003
Volatile Organics:						
Benzene	0.17	0.26	0.17	0.11	-	-
Ethylbenzene	1.2	2.2	-	0.26	-	-
Toluene	0.22	1.6	-	0.26	-	-
Low Molecular Weight PAHs:						
Acenaphthene	-	-	-	-	0.94	0.48
Fluorene	-	-	-	-	0.98	0.50
Naphthalene	0.87	4.6	-	-	1.1	0.73
High Molecular Weight PAHs:						
Benzo(a)anthracene	-	-	-	-	1.6	0.67
Benzo(a)pyrene	-	-	-	-	1.9	0.80
Benzo(b)fluoranthene	-	-	-	-	1.5	0.81
Benzo(k)fluoranthene	-	-	-	-	-	0.78
Chrysene	-	-	-	-	1.6	0.75
Dibenzo(a,h)anthracene	-	-	-	-	1.8	0.85
Fluoranthene	-	-	-	-	1.4	0.60
Indeno(1,2,3-cd)pyrene	-	-	-	-	2.2	1.0
Pyrene	-	-	-	-	1.3	0.61

4.3 Sediment Natural Recovery

Over the period of record since 1990 when comparable, validated site characterization data have been collected at the Quendall Site, surface sediment concentrations offshore of the former "T-Dock" at the Site (represented by Stations QB-4 and S-52) have declined roughly 10- to 100-fold (Table 4-5; earlier sediment data available for the Site also corroborate this trend). As described in Anchor and Aspect (2002 and 2003), sediments in this area of the Site appear to recovering naturally from historic spills suspected to have occurred during prior loading/offloading operations at the former T-Dock.

In order to elucidate the relative importance of biodegradation and/or sedimentation/ dispersion processes in contributing to the observed sediment natural recovery in the T-Dock area, the Boudreau model described above was applied to the Table 4-5 recovery data. Since sedimentation rates and other key transport parameters have been measured at these same stations (Table 4-3), the model was set up to back-calculate biodegradation rates

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consistent with the observed natural recovery of PAH concentrations, as described above. Because of its offshore location, this area of the Site is removed from potential groundwater transport influences (Retec and Papadopoulos 1998).

Biodegradation estimates that would explain the observed PAH declines at the Stations QB-4 and S-52 are summarized in Table 4-4. Similar to the wellpoint/ porewater analysis summarized in Section 4.2.2, naphthalene half lives calculated by the Boudreau model averaged approximately 1 year, while half lives for higher molecular weight PAHs such as benzo(a)pyrene were somewhat longer. Again, these values are within the mid- to slower range of anaerobic soil, groundwater, and sediment biodegradation rates reported in the literature (Howard et al. 1991, Aronson and Howard 1997), and corroborate the site-specific estimates derived from the sediment recovery trend data.

A probability plot of the various site-specific biodegradation rate estimates developed using the Boudreau model (i.e., including wellpoint/porewater and sediment natural recovery analyses) is presented in Figure 4-3. Relatively consistent (within a factor of 5) biodegradation estimates were calculated for a range of soil/groundwater and sediment environments at the Quendall Site, spanning a relatively wide range of groundwater flow conditions (seepage velocities ranging from near zero to 30 meters/day) and soil/sediment properties (TOC levels ranging from 0.3 to 11 percent). The consistency of these site-specific biodegradation rates across the Site, as well as their similarity to literature information, supports their broader use in this RA/FS assessment of Site attenuation. These data provide a basis to develop site-specific cleanup standards that are protective of surface water/sediments, facilitating explicit consideration of the uncertainties inherent in the evaluation (see Section 4.5 below). As discussed above, additional data on specific biodegradation mechanisms may be collected during the forthcoming remedial design phase to optimize cleanup designs.

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Table 4-5
Temporal Declines in T-Dock Area Sediment Concentrations

Loc Name Sample Date Depth Interval	QB-4 01/01/1990 0-2 cm	AQT-QB4 09/19/2003 0-10 cm	S-52 11/15/1996 0-10 cm	S-52 09/18/2003 0-10 cm
Elapsed Time (years)		13.7		6.8
Conventionals				
Total Organic Carbon (%)	--	11.2	5.0	4.3
Total solids (%)	--	19.3	27.8	24.7
Grain Size (%)				
Gravel	--	4.91	--	0.1
Sand, Very Coarse	--	3.7	--	2.0
Sand, Coarse	--	3.46	--	2.4
Sand, Medium	--	6.66	--	6.6
Sand, Fine	--	13.2	--	14.0
Sand, Very Fine	--	12.2	--	15.5
Silt	--	42.5	--	48.9
Clay	--	10.4	--	11.6
SVOCs (µg/kg)				
HPAHs				
Benzo(a)anthracene	280,000	1,300	72,000	67
Benzo(a)pyrene	87,000	1,100	38,000	120
Benzo(b)fluoranthene	270,000	1,200	40,000	130
Benzo(k)fluoranthene	2,100 UJ	1,000	46,000	120
Benzo(g,h,i)perylene	24,000	480	7,600	120
Chrysene	290,000	1,600	57,000	120
Dibenzo(a,h)anthracene	13,000	130	5,600	24
Fluoranthene	1,400,000	2,900	230,000	100
Indeno(1,2,3-cd)pyrene	24,000	610	9,600	110
Pyrene	1,200,000	1,900	190,000	87
Total benzofluoranthenes	270,000	2,200	86,000	250
Total HPAH (SMS)	3,588,000	12,220	695,800	998
LPAHs				
2-Methylnaphthalene	150,000	20	500	6
Acenaphthene	570,000	49	100,000	6
Acenaphthylene	1,800 U	23	490	6
Anthracene	350,000	260	32,000	14
Fluorene	510,000	64	70,000	6
Naphthalene	160,000	70	8,100	14
Phenanthrene	2,100,000	600	270,000	46
Total LPAH (SMS)	3,690,000	1,066	480,590	74
Total cPAHs (BaP EQ)	152,500	1,579	57,570	174
Total PAHs	7,428,000	13,306	1,176,890	1,072

4.4 Sediment Confirmatory Bioassays

The RA/FS Work Plan described the assessment of natural recovery in the area surrounding the former T-Dock structure. Sediment sampling of this area in September 2003 revealed that natural recovery processes, primarily biodegradation, had reduced PAH concentrations in the top 10 cm relative to samples collected previously (See Section 4.3 above). Following review of these data, focused bioassay testing was conducted to establish whether toxicity to benthos remained from potential PAH biodegradation products. Consistent with the Ecology-approved Sampling and Analysis Plan (SAP: Appendix A) four test sediment samples were collected from the T-Dock area and two reference sediment samples were collected from Lake Washington on February 13, 2004.

Under the SMS, two acute and one chronic effect bioassays are required when performing confirmatory sediment bioassays. As described in the SAP (Appendix A) the following bioassays were conducted for the purpose of this RA/FS:

- A 20-day *Chironomus tentans* survival and growth test – initiated February 19, 2004
- A 10-day *Hyalella azteca* survival test – initiated February 20, 2004
- Microtox® 100 percent sediment porewater tests – initiated February 25, 2004

All bioassays were conducted in accordance with Ecology requirements and no significant deviations from the SAP were encountered. The data obtained from this investigation are of suitable quality for the purpose of evaluating the targeted sediments. A complete data summary is provided in Appendix C.

Bioassay data were interpreted based on the Quendall Freshwater Data Evaluation Procedure Memorandum (Turvey 2000). Briefly, the three tests were given weighting factors based on the tests' reliability, ecological significance, and sensitivity. If an individual bioassay results in an exceedance of the test sediment quality standard (SQS) biological criteria, a multiplication factor of 1 is applied for calculating an individual bioassay exceedance product. If an individual bioassay results in an exceedance of the test cleanup screening level (CSL) biological criteria, a multiplication factor of 2 is applied for calculating a individual bioassay exceedance product. As described in Turvey (2000), a total bioassay exceedance product greater than 3.4 exceeds the CSL-based Quendall site-specific cleanup action level.

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Two of the four bioassay samples collected (AQT-QB4 and AQT-VS27) exhibited bioassay responses that were no different from the reference samples for the amphipod survival and Chironomus survival and growth endpoints. However, sample AQT-QB4 and AQT-VS27 had CSL- and SQS-level hits for the Microtox test, respectively. Sample AQT-SB52 has CSL-level hits for all endpoints. Sample AQT-S54 had CSL-level hits for Chironomus survival and growth and Microtox and a SQS-level hit for amphipod survival. Overall, based on the Quendall Freshwater Data Evaluation Procedure (Turvey 2000), samples AQT-SB52 and AQT-S54 exceeded the Quendall site-specific cleanup action level based on overall bioassay response, while samples AQT-QB4 and AQT-VS27 did not exceed this action level. Table 4-6 summarizes the T-Dock bioassay results.

Table 4-6
Summary of T-Dock Bioassay Outcomes

Station	Reference Station Pair	Individual Bioassay Endpoint Outcome				Total Bioassay Exceedance Product (1)	Decision
		Amphipod	Chironomus		Microtox		
		% Survival	% Survival	MIW (mg/ind)	T(15)		
AQT-QB4	REF-2	PASS	PASS	PASS	CSL	2.4	PASS
AQT-SB52	REF-1	CSL	CSL	CSL	CSL	11.2	FAIL
AQT-S54	REF-1	SQS	CSL	CSL	CSL	9.7	FAIL
AQT-VS27	REF-1	PASS	PASS	PASS	SQS	1.2	PASS
Weighting Factor		1.5	1.2	1.7	1.2		

(1) Calculation of the Bioassay Exceedance Product based on Turvey (2000). Total Bioassay Exceedance Product greater than 3.4 is considered in Turvey (2000) to be the Quendall site-specific cleanup action level.

The focused bioassay results summarized above confirm that prior natural recovery processes have been sufficient to reduce sediment toxicity to below cleanup action levels near the boundary of the former T-Dock loading/offloading area (represented by Stations AQT-QB4 and AQT-VS27). However, sediment toxicity likely associated with residual PAH biodegradation products is present within the former offloading area (represented by Stations AQT-SB52 and AQT-S54). Potential sediment cleanup areas at the Site are discussed in more detail in Section 5.2 (also see Figure 5-1).

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4.5 Surface Water Protection Modeling – Site-Specific Risk Assessment

The steady-state version of the Boudreau (1997) model discussed in Section 4.3 above was applied to develop estimates of Site groundwater concentrations that are protective of surface water, incorporating attenuation estimates that vary appropriately with distance from the porewater/sediment point of compliance. For this application, the steady-state model also explicitly incorporated variability and uncertainties associated with measured and estimated parameters, so that the confidence in the resulting estimates could be evaluated directly. The uncertainty analysis was performed using Monte Carlo simulations using the steady-state Boudreau model conducted with @RISK software.

The Monte Carlo simulations assumed that many of the key transport parameters may have a range of values over a probability range (e.g., see Figure 4-3). Thus, the combined uncertainty or probability of any chosen condition (e.g., a protective groundwater concentration at "x" distance from the conditional point of compliance within surface sediment porewater) can be determined in a Monte Carlo analysis given the combined variability (or uncertainty) of all the individual input parameters. This technique provides a valuable tool to understanding modeling uncertainty for application to site cleanup.

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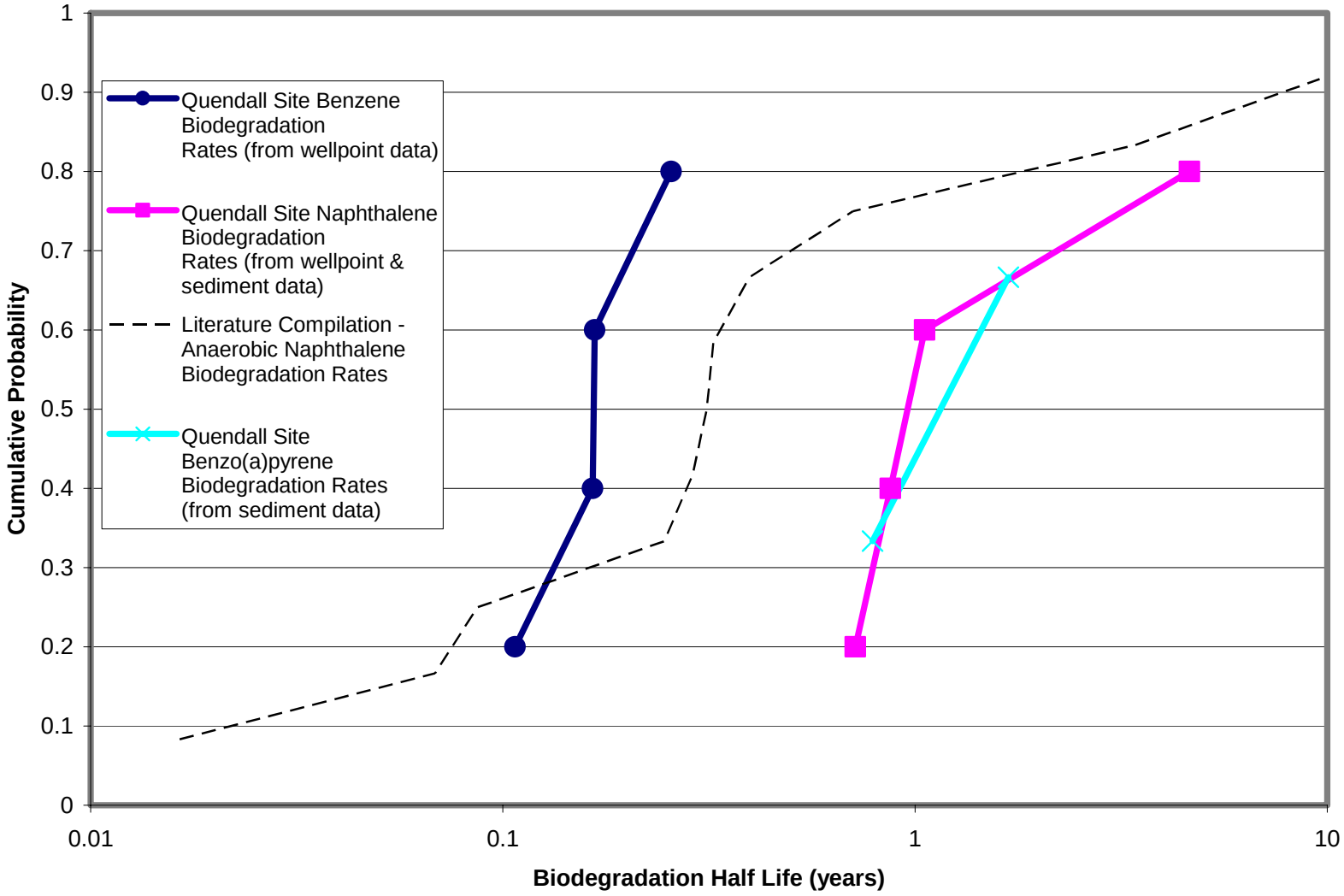

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Figure 4-3
Summary of Site-Specific Hydrocarbon Biodegradation Rates
Port Quendall Terminals Cleanup

A sensitivity analysis performed on the steady-state Boudreau model indicated that model results were controlled to a large degree by three key model parameters:

- Biodegradation rate
- Advective velocity
- Soil/sediment TOC

The measured or calculated range of each of these parameter values also varied considerably, making model output particularly sensitive to the assumed value of each of these three parameters. The variability/uncertainty of these three parameters explained more than 95 percent of the total variability in the steady-state model (based on sensitivity analyses). Accordingly, ranges of probabilistic values were compiled for each of these parameters, based on site measurements (Table 4-1; Figure 4-3). All probabilistic parameter distributions were estimated using a lognormal statistical distribution. An order of magnitude or greater range of these parameter values was assumed between the 5 and 95 percent probability levels.

The Monte Carlo model results were developed as the probability that chemical concentrations in sediment porewater (at the conditional point of compliance for groundwater cleanup levels; 10 cm below mudline) would be less than the surface water and sediment protection cleanup levels, given an assumed groundwater concentration at varying distance from the shoreline. In order to provide for an appropriate level of conservatism in this analysis (for application to the site-specific risk assessment that also incorporated institutional controls; see Section 5 below), model results were expressed as the groundwater concentration that would achieve porewater cleanup levels at the 95 percent confidence level (the porewater-to-sediment pathway is discussed in more detail in Section 5.3).

Figures 4-4 and 4-5 summarize Monte Carlo model estimates of groundwater concentrations of naphthalene and benzene, respectively, that have a 95 percent or greater probability (i.e., confidence) of protecting porewater (and sediment). The plots present site-specific risk assessment-based levels that vary as a function of distance from the surface water point of exposure/compliance (i.e., 10 cm below mudline), since a greater degree of attenuation would occur along a longer flow path. Figures 4-4 and 4-5 also present model runs for

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alternative site-specific risk assessment-based levels for porewater assuming implementation of institutional controls to preclude future drinking water withdrawal in this shoreline area (these are discussed further in Section 5).

The probabilistic site-specific risk assessment modeling summarized in Figures 4-4 and 4-5 confirm that attenuation processes are a major factor controlling fate and transport along the groundwater to surface water pathway at the Quendall Site. At a distance of approximately 25 to 100 feet from shoreline (for naphthalene and benzene, respectively), even groundwater concentrations at the water solubility level (which could occur in the immediate vicinity of DNAPL deposits) are attenuated to levels that do not pose a risk to surface water. Because of greater sorption characteristics, benzo(a)pyrene sources to groundwater (even DNAPL sources) located more than approximately 1 foot from the mudline do not pose a risk to surface water receptors.

These site-specific risk assessment results have important implications to the FS, as they contribute to an understanding of specific areas of groundwater discharge from the shallow and deep aquifers that may be targeted by remedial actions to provide effective surface water protection. For example, control of nearshore sources of recoverable DNAPL may be a particularly appropriate target of remedial actions.

4.6 Supplemental Surface Soil Evaluation

Due to limited historical surface soil data, a supplemental surface soil investigation was performed to provide additional data for assessing potential risks associated with human health and ecological exposures at the Site, as well as to support the identification and evaluation of remedial alternatives. Twenty-two soil samples were collected from the Site on February 27 and March 1, 2004; 11 of these were analyzed for volatile organic compounds (VOCs) by EPA Method 8260B and 11 were analyzed for semivolatile organic compounds (SVOCs) by EPA Method 8270C. The SAP and soil sampling logs are provided in Attachment 1, both of which are included in this RA/FS as part of Appendix C.

Supplemental surface soil sample locations were selected based on previous exceedances of direct contact-based soil cleanup levels within the standard point of compliance (0 to 15 feet below ground surface). A summary of chemical analytical results is provided in Table 4-7.

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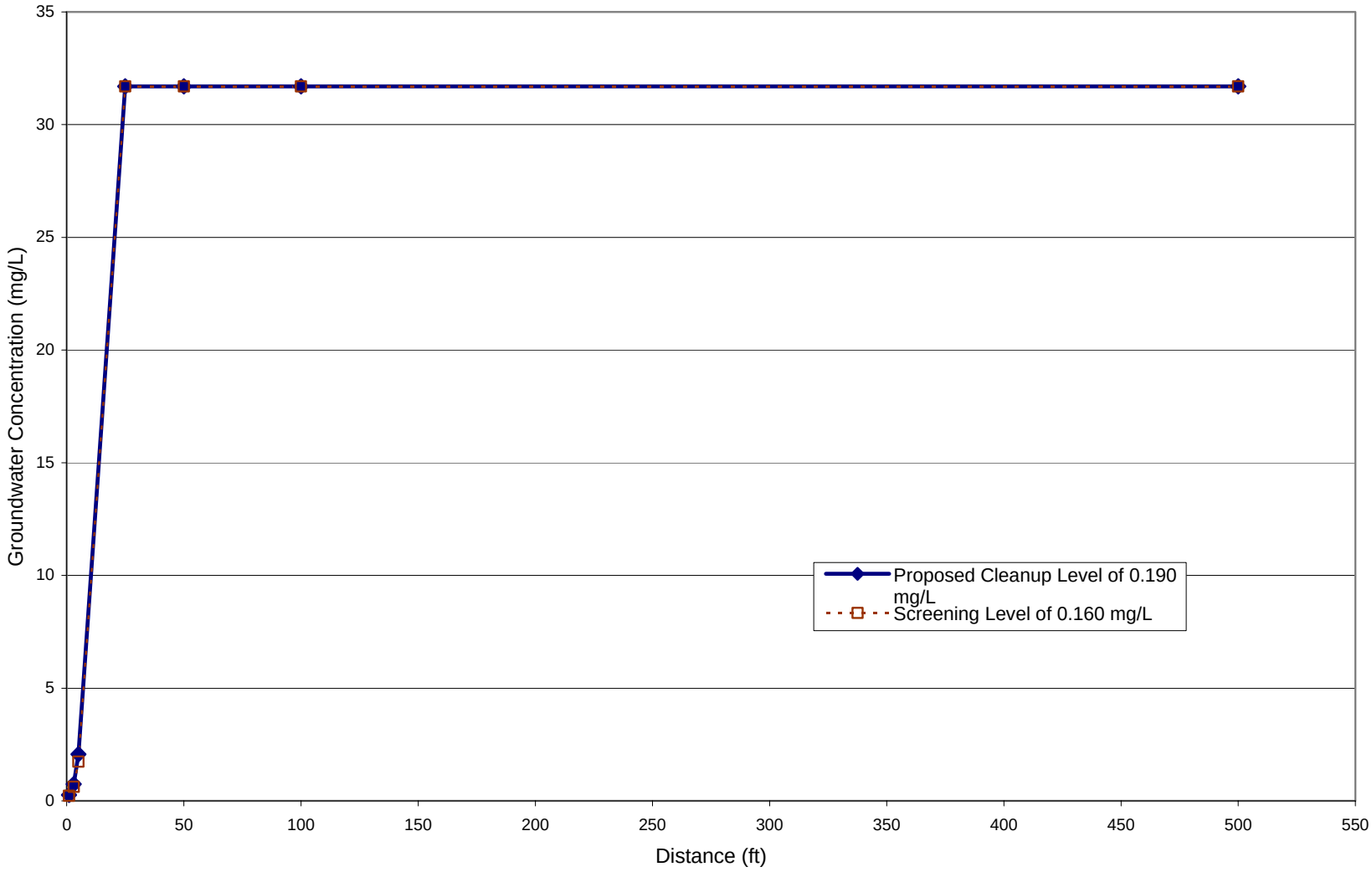

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Figure 4-4
Risk-Based Groundwater Naphthalene Levels for Surface Water Protection
Port Quendall Terminals Cleanup

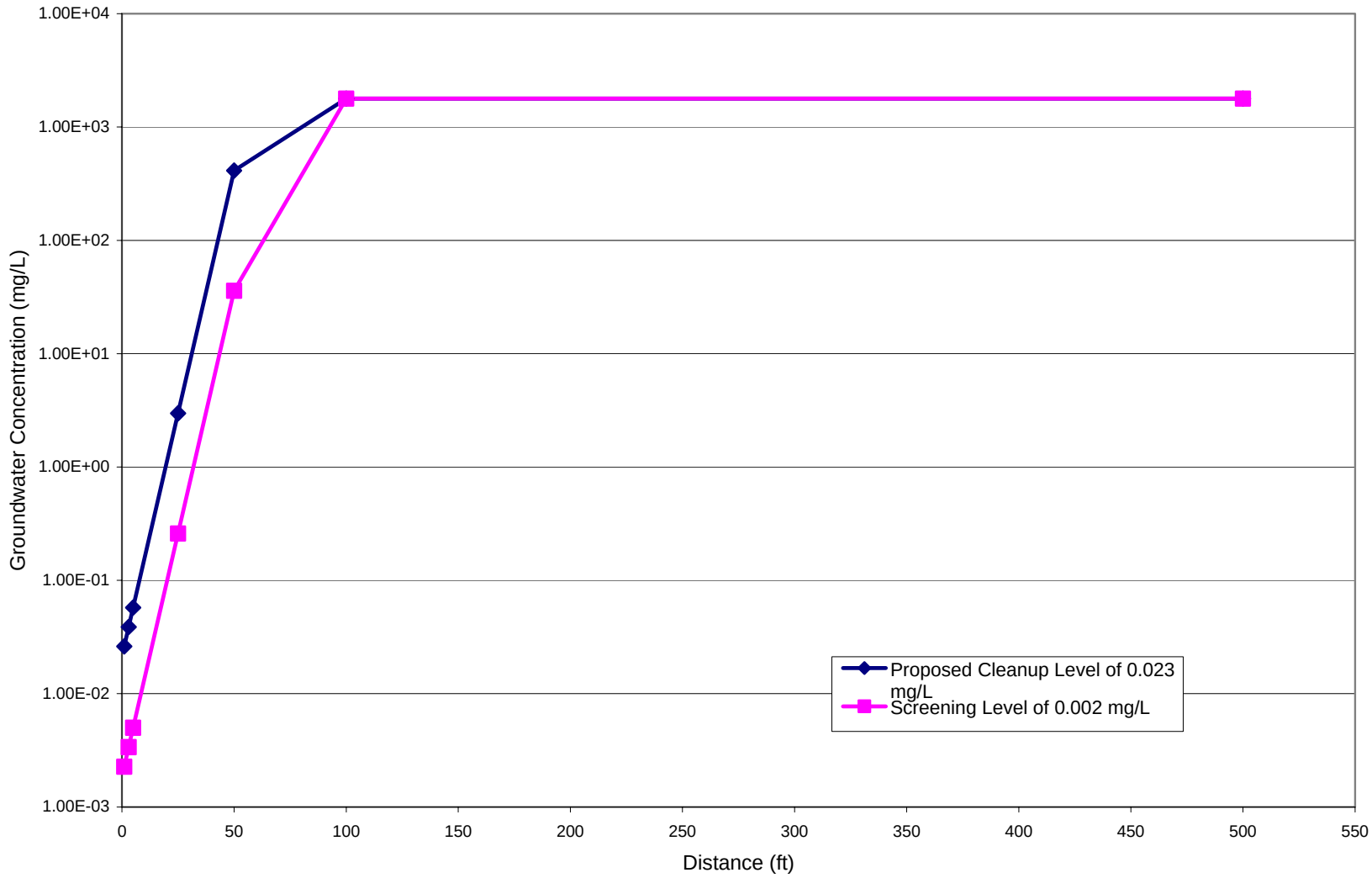

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Figure 4-5

Risk-Based Groundwater Benzene Levels for Surface Water Protection

Port Quendall Terminals Cleanup

Table 4-7
Summary of Supplemental Soil Sample Results

General Location	MTCA Method C Cleanup Level - Industrial Worker (3)	MTCA Migration to Groundater Cleanup Level (4)	Former May Creek Channel		Quendall Pond				South Sump		North Sump		Still House									
Sample Number			SS-HC7-0/3		SS-BH19-0/3		SS-TP4-0/3		SS-BH7-0/3		SS-HC2-0/2.3		SS-HC5-0/3		SS-HC8-0/2.1		SS-BH9-0/2		SS-BH27-0/3		SS-TP2-0/3		SS-TP5-0/3	
Sample Date			3/1/2004		3/1/2004		3/1/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		3/1/2004	
Analyte (mg/kg)																								
PAHs																								
Acenaphthene	210,000	570	**0.042**	**J**	**1.2**		0.39	U	**0.037**	**J**	**0.072**	**J**	**18**		**0.02**	**J**	**49**		**0.27**	**J**	**0.4**	**J**	0.81	U
Naphthalene	14000 / 84	2	**0.052**	**J**	**2.3**		**0.027**	**J**	**0.075**	**J**	**0.094**	**J**	**37**		**0.057**	**J**	**270**		**0.18**	**J**	**0.22**	**J**	0.81	U
Fluorene	27,000	8	**0.063**	**J**	**0.90**		**0.021**	**J**	**0.084**	**J**	**0.050**	**J**	**19**		**0.023**	**J**	**47**		**0.13**	**J**	**0.35**	**J**	0.81	U
Fluoranthene	27,000	5	**0.23**	**J**	**6.0**		**0.18**	**J**	**0.61**		**0.57**	**J**	**28**		**0.12**	**J**	**74**		**1.5**		**3.0**		**0.2**	**J**
Pyrene	20,000	49	**0.33**	**J**	**9.6**		**0.21**	**J**	**0.67**		**0.81**		**32**		**0.17**	**J**	**88**		**2.4**		**3.9**		**0.23**	**J**
Benzo(a)anthracene (1,2)	18	160	**0.17**	**J**	**5.4**		**0.12**	**J**	**0.39**		**0.46**		**10**		**0.092**	**J**	**37**		**1.0**		**2.5**		**0.15**	**J**
Benzo(a)pyrene (1)	7.2	2	**0.19**	**J**	**6.4**		**0.13**	**J**	**0.36**	**J**	**0.65**	**J**	**9.4**		**0.13**	**J**	**35**		**1.3**		**2.9**		**0.18**	**J**
Benzo(b)fluoranthene (1,2)	18	14	**0.16**	**J**	**5.0**		**0.11**	**J**	**0.33**	**J**	**0.56**	**J**	**7.4**		**0.10**	**J**	**29**		**1.1**		**2.5**		**0.18**	**J**
Benzo(k)fluoranthene (1,2)	18	4,300	**0.17**	**J**	**4.0**		**0.11**	**J**	**0.34**	**J**	**0.38**	**J**	**8.9**		**0.094**	**J**	**32**		**0.88**		**1.9**		**0.19**	**J**
Chrysene (1,2)	180	560	**0.27**	**J**	**6.7**		**0.17**	**J**	**0.49**		**0.67**		**14**		**0.14**	**J**	**54**		**1.3**		**3.2**		**0.25**	**J**
Dibenzo(a,h)anthracene (1,2)	4.5	84	**0.041**	**J**	**1.0**		0.038	UJ	**0.067**	**J**	0.44	UJ	**1.7**		0.032	UJ	**7.4**		**0.22**	**J**	**0.54**	**J**	0.071	UJ
Indeno(1,2,3-cd)pyrene (1,2)	18	4,200	**0.14**	**J**	**4.3**		**0.098**	**J**	**0.23**	**J**	4.5	U	**6.7**		**0.092**	**J**	**24**		**0.89**		**2.2**		**0.13**	**J**
Total cPAHs - B[a]P Equivalent	18	na	**0.27**		**8.7**		**0.19**		**0.52**		**1.4**		**14**		**0.18**		**51**		**1.8**		**4.1**		**0.28**	
Semivolatile, Miscellaneous																								
Dibenzofuran	na	na	**0.020**	**J**	**0.19**		**0.39**	**U**	**0.053**	**J**	**0.021**	**J**	**12**		**0.34**	**U**	**33**		**0.036**	**U**	**0.12**	**J**	**0.81**	**U**
Semivolatile, Nitroaromatics																								
n-Nitroso-di-phenylamine	27,000	1	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	0.34	U	0.34	U	0.71	U	0.55	U	0.54	U	0.81	U
Semivolatile, Phenolics																								
2,4-Dimethylphenol	70,000	470	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	**0.13**	**J**	0.34	U	**1.3**		0.55	U	0.54	U	0.81	U
Pentachlorophenol (1)	560	0.03	0.16	UJ	0.29	UJ	0.18	UJ	0.21	UJ	0.2	UJ	1.5	UJ	0.15	UJ	0.27	UJ	0.25	UJ	0.25	UJ	0.32	UJ
Phenol	2,100,000	100	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	**0.23**	**J**	0.34	U	**0.47**	**J**	0.55	U	0.047	J	0.81	U
Semivolatile, Phthalates																								
bis(2-Ethylhexyl)phthalate (1)	9,400	3,600	0.34	U	0.77	U	0.39	U	**0.035**	**J**	0.45	U	0.34	U	**0.047**	**J**	7.1	U	0.55	U	0.05	J	0.81	U
Di-n-octylphthalate	70,000	na	0.34	U	0.77	U	0.39	U	0.46	U	4.5	U	3.4	U	0.34	U	7.1	U	0.55	U	0.54	U	0.81	U
Volatile, Aromatic and Halogenated																								
Benzene (1)	2,400 / 0.8	0.03	0.0063	U	0.0057	U	0.0084	U	0.0083	U	0.0075	U	0.0067	U	0.0057	U	0.1400	UJ	0.0075	U	0.0120	U	0.0110	U
Chloroform (1)	22000/ 0.3	0.6	0.0063	U	0.0057	U	0.0084	U	0.0083	U	0.0075	U	0.0067	U	0.0057	U	0.1300	UJ	0.0075	U	0.0120	U	0.0410	U
Methylene Chloride (1)	1,8000 / 400	0.02	0.0130	U	0.0120	U	0.0170	U	0.0170	U	0.0150	U	0.0140	U	0.0120	U	0.2500	UJ	0.0150	U	0.0230	U	0.0210	U
Ethylbenzene	350,000	13	0.0063	U	0.0057	U	0.0084	U	**0.1100**	**J**	0.0075	U	0.0067	U	0.0057	U	**0.9200**		0.0075	U	0.0120	U	0.0110	U
Styrene (1)	4,400 / 1,500	4	0.0063	U	0.0057	U	0.0084	U	0.0083	U	0.0075	U	0.0067	U	0.0057	U	0.1200	UJ	0.0075	U	0.0120	U	0.0110	U
Toluene	705,000 / 650	12	0.0063	U	0.0057	U	0.0084	U	**0.0063**	**J**	0.0075	U	0.0067	U	0.0057	U	**0.7400**		0.0075	U	**0.1800**	**J**	0.0110	U

Note:

(1) Carcinogenic risk equal to 1E-5. For PAHs, the carcinogenic value presented was based on the assumption that benzo(a)pyrene accounts for 40 percent of the measured PAHs and the remaining carcinogenic PAHs account for 10 percent of the total. The cumulative risk for PAHs was adjusted to 1E-5. The sum of carcinogenic PAHs as B(a)P equivalent concentration will be used to measure site conditions.

(2) Carcinogenic PAHs will be evaluated using the toxicity equivalancy factor method to normalize concentrations to Benzo(a)pyrene.

(3) Second Value is the Soil Screening Level for Inhalation of Volatiles (EPA 1996)

(4) Based on both aquatic life protection and potential future drinking water uses

U Not detected at indicated detection limit

J Estimated value

Bold indicates detected compound

Samples for semivolatile analyses were collected from between 0 to 3 feet. Samples for volatile analyses were collected at a depth of 1.5 feet.

Shading Indicates Exceedance of MTCA Method C Industrial Cleanup Level

Shading Indicates Exceedance of Soil Screening Level for Inhalation of Volatiles (EPA 1996)

Shading Indicates Exceedance of MTCA Migration to Groundwater for Drinking Wate Consumption Cleanup Level

The focused soil characterization data summarized in Table 4-7 indicate that only one surface soil sampling location (Station SS-BH9; former Still House area) currently exceeds the industrial use direct-contact based cleanup level. This same sample location also exceeded EPA (1996) screening levels for air and groundwater protection under an unrestricted site use scenario (see Section 5.5 for further discussion of soil exposure pathway considerations). Potential soil (and DNAPL) cleanup areas at the Site are discussed in more detail in Section 5.5 (also see Figures 5-2 through 5-4).

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5 CLEANUP STANDARDS

The section presents site-specific cleanup levels and points of compliance (including conditional points of compliance) for soil, groundwater, sediment, and surface water/porewater media, given the implementation of institutional controls anticipated at the Site addressing a range of site use scenarios. Conditional points of compliance are subject to Ecology review of the FS, consistent with MTCA requirements. This discussion informed subsequent FS evaluations of the protectiveness of potential remedial action scenarios, such as on-site management of Site contaminants.

5.1 Cleanup Standards versus Remediation Levels

A cleanup standard defines the point of compliance and concentration of a hazardous substance above which a contaminated media must be remediated in some manner. As defined in the MTCA regulation, a remediation level defines the concentration of a hazardous substance in a particular medium above or below which a particular cleanup action component may be used. Remediation levels are site-specific, risk-based values that may be developed using exposure assumptions and other media-specific factors that reflect specific future site conditions under a given remedial alternative scenario. While remediation levels may potentially be developed as an element of the forthcoming Cleanup Action Plan (CAP), they have not been explicitly developed as part of this RA/FS.

5.2 Sediment Cleanup Standards

Site-specific cleanup levels have previously been developed by Ecology for total PAHs, TOC, and PCP. Ecology's (2003) freshwater SQVs are proposed for the remainder of chemicals detected in sediment for which there are criteria. The site-specific sediment cleanup levels are presented in Table 5-1.

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Table 5-1
Porewater/Groundwater and Sediment Cleanup Levels

Chemicals of Potential Concern for Risk Assessment	Porewater and Surface Water (ug/L)		Sediment (mg/kg dry wt.)
	Porewater/ Groundwater Cleanup Level (10 cm)	Cleanup Level Source	Proposed Sediment Cleanup Level at 0 to 10 cm Below Mudline
Conventionals			
Total Organic Carbon		No Cleanup Value	13.5% (Site-specific)
Trace Element			
Arsenic	5.0	5 (natural background)	31 (Ecology 2003 Freshwater LAET)
Chromium (total)	42	10 (Cr^{+6}); 42 (Cr^{+3})(WAC)	95 (Ecology 2003 Freshwater LAET)
Copper	4.7	4.7 (3) (CWA-ecological)	620 (Ecology 2003 Freshwater LAET)
Lead	1.0	1.0 (3) (WAC)	340 (Ecology 2003 Freshwater LAET)
Zinc	42	42 (3) (CWA-ecological)	680 (Ecology 2003 Freshwater LAET)
PAHs			
Acenaphthene	56	640 (MTCA Surface Water); 56 (EPA Tier 1)	Evaluated as total PAH
Benzo(a)anthracene	0.028	0.028 (NTR); 0.30 (MTCA Surface Water)	Evaluated as total PAH
Benzo(a)pyrene	0.0028	0.0028 (NTR); 0.10 (MTCA Surface Water)	Evaluated as total PAH
Benzo(b)fluoranthene	0.028	0.028 (NTR); 0.31 (Sediment Protection)	Evaluated as total PAH
Benzo(k)fluoranthene	0.028	0.028 (NTR); 0.31 (Sediment Protection)	Evaluated as total PAH
Chrysene	0.28	0.028 (NTR); 0.97 (Sediment Protection)	Evaluated as total PAH
Dibenzo(a,h)anthracene	0.0070	0.0070 (NTR); 0.21 (Sediment Protection)	Evaluated as total PAH
Indeno(1,2,3-cd)pyrene	0.028	0.028 (NTR); 0.11 (Sediment Protection)	Evaluated as total PAH
Total cPAH (1)		0.0028 (NTR-HH)	na
Other Polycyclic Aromatic Hydrocarbons			
Fluoranthene	7.1	130 (CWA-HH); 7.1 (EPA Tier 1)	Evaluated as total PAH
Fluorene	39	640 (Method B - Groundwater); 39 (EPA Tier 1)	Evaluated as total PAH
Naphthalene	160	160 (Method B - Groundwater); 190 (EPA Tier 1)	Evaluated as total PAH
Pyrene	5.7	480 (Method B - Groundwater); 5.7 (Sediment Protection)	Evaluated as total PAH
Total PAH		No Cleanup Value	100 (Site-specific)
Semivolatile, Miscellaneous			
Dibenzofuran	2.8	2.8 (Sediment Protection)	0.4 (Ecology 2003 Freshwater LAET)
Semivolatile, Nitroaromatic			
n-Nitroso-di-phenylamine	3.3	3.3 (CWA-HH); 9.7 (MTCA Surface Water)	No Cleanup Value
Semivolatile, Organochlorine			

Table 5-1
Porewater/Groundwater and Sediment Cleanup Levels

Chemicals of Potential Concern for Risk Assessment	Porewater and Surface Water (ug/L)		Sediment (mg/kg dry wt.)
	Porewater/ Groundwater Cleanup Level (10 cm)	Cleanup Level Source	Proposed Sediment Cleanup Level at 0 to 10 cm Below Mudline
Aldrin	0.000049	0.000049 CWA-HH); 0.000082 (MTCA Surface Water)	No Cleanup Value
Semivolatile, Phenolic			
2,4-Dimethylphenol	48	48 (Method B - Groundwater); 550 (MTCA Surface Water)	No Cleanup Value
Pentachlorophenol	0.27	0.27 (CWA-HH); 0.84 (Sediment Protection)	0.5 (Site-specific)
Phenol	300	300 (CWA-HH); 1,100,000 (MTCA Surface Water)	No Cleanup Value
Phthalates			
bis(2-Ethylhexyl)phthalate	1.2	1.2 (2) CWA-HH; 3.6 (MTCA Surface Water)	2.5 (Ecology 2003 Freshwater LAET)
Di-n-octylphthalate	320	320 (Method B - Groundwater)	0.011 (Ecology 2003 Freshwater LAET)
Volatile, Aromatic and Halogenated			
Benzene	1.2	1.2 (NTR-HH); 23 (MTCA Surface Water)	No Cleanup Value
Chloroform	5.7	5.7 (CWA-HH); 280 MTCA Surface Water)	No Cleanup Value
Methylene Chloride	4.6	4.6 (CWA-HH; 960 (MTCA Surface Water)	No Cleanup Value
Ethylbenzene	700	700 (SDWA - Groundwater); 6,900 (MTCA Surface Water)	No Cleanup Value
Styrene	15	15 (2) (SDWA - Groundwater)	No Cleanup Value
Toluene	1,000	1,000 (SDWA - Groundwater); 48,000 (MTCA Surface Water)	No Cleanup Value

Notes:

(1) Carcinogenic PAHs will be evaluated using the toxicity equivalancy factor method to normalize concentrations to Benzo(a)pyrene.
(2) Value presented is risk adjusted ARAR
(3) Hardness adjusted assuming 50 mg/L as $CaCO_3$
WAC - Washington Administrative Code (WAC 173-201A)
NTR - National Toxics Rule
CWA - Clean Water Act
HH - Human Health - Organism + Water Pathway
SDWA - Safe Drinking Water Act

As discussed in Section 3.2, the point of compliance for sediment cleanup levels is the 0 to 10 cm depth interval below the mudline. Recent radioisotope dating evaluations (Appendix A) suggest that the biologically active zone at the Quendall Site does not extend across the 10 cm interval. Thus, use of a default 0 to 10 cm point of compliance in the sediment cleanup standard should provide an additional level of protectiveness at the Quendall Site. Figure 5-1 presents the site sediment areas exceeding biological and chemical cleanup levels, incorporating the recent sediment bioassay data described in Section 4.4, based on Thiessen polygon analysis.

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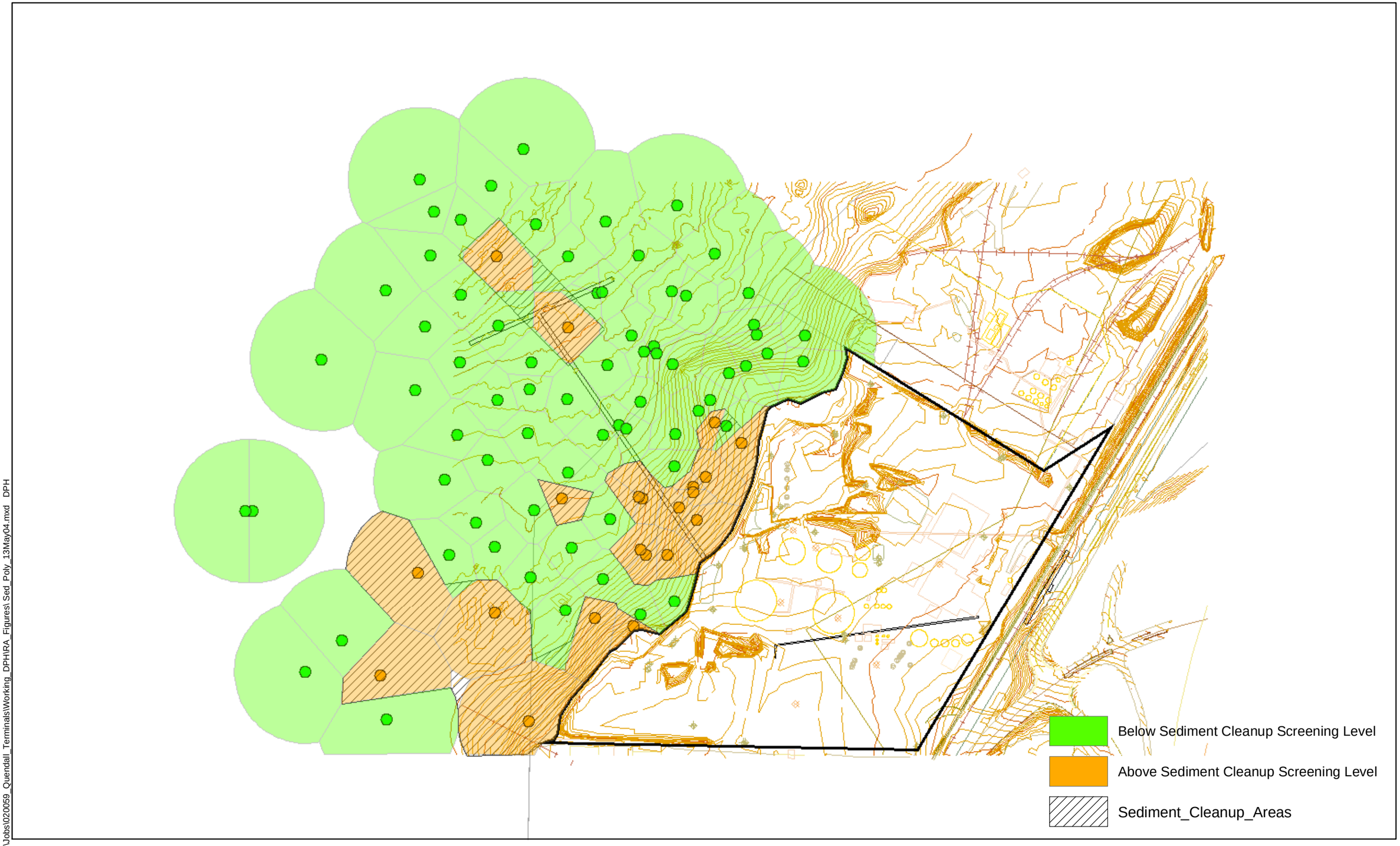

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Note: Outside Boundary Based on 200 ft. Buffer.

Figure 5-1
Quendall Terminals Surface Sediment (0 to 10 cm)
Exceedance of Bioassay and Analytical Cleanup Levels

5.3 Surface Water/Porewater Cleanup Standards

Initial screening of Site COPCs in Section 2 was performed for the baseline scenario assuming unrestricted uses, including potential drinking water withdrawal from a hypothetical shoreline supply intake. However, there is no current or identified future use of surface waters for drinking water within the boundaries of the Site, and existing water rights and associated regulations effectively preclude this potential site exposure pathway at the Quendall Site. The lake was closed to further water appropriation in 1979 (Chapter 173-508 WAC). In addition, the presence of listed species (salmonids) in Lake Washington has led to a determination by Ecology and other resource agencies that additional appropriation of Lake Washington water for potable or any other use will not occur in the foreseeable future.

Consistent with MTCA requirements, further institutional controls may be considered in the FS (e.g., including a deed restriction) to ensure that water supply intakes are not installed at the Site. However, drinking water pathways nevertheless still need to be addressed as part of surface water cleanup levels developed for the Site. Surface water/porewater cleanup levels developed in this manner are summarized in Table 5-1.

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The point of compliance for the protection of human health and the environment resulting from potential surface water exposures is the point of release of porewater into Lake Washington, defined in this case as 10 cm below the mudline.

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The development of cleanup levels and the points of compliance for porewater and groundwater also addressed the groundwater-to-sediment pathway and equilibrium partitioning of chemicals between porewater and sediment. For example, because of the variable solubility of the chemical components of the bulk sediment concentration of total PAHs, the groundwater contribution of individual chemicals to bulk sediment total PAH concentrations is variable. That is, while naphthalene is the most mobile constituent of those that make up the analytes in the total PAH bulk sediment criteria, many other PAH compounds (e.g., high molecular weight PAHs) are much less mobile in porewater. These differences were addressed in the development of porewater cleanup levels for individual PAHs and other COPCs, using the following sequential process:

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- Porewater cleanup levels for were initially set based on the lower of ecological risk (e.g., EPA Tier 1) surface water criteria and MTCA Method B cleanup levels (based on combined drinking water and fish/shellfish consumption pathways).
- Using equilibrium partitioning modeling (EPA 2002a) and the range of surface sediment TOC levels measured at the Site, bulk sediment concentrations were calculated assuming equilibrium conditions between porewater and sediments (i.e., conservatively neglecting biodegradation and dispersion processes that occur in the top 10 cm of the sediment).
- The upper-bound equilibrium-based sediment concentrations (e.g., based on maximum sediment TOC levels) were compared with dry weight-based sediment cleanup levels summarized in Table 5-1 (including summing individual PAHs for comparison with the Total PAH cleanup level).
- If the upper-bound equilibrium sediment concentration exceeded the sediment cleanup level, the porewater concentration was adjusted downward to ensure attainment of the sediment cleanup level.
- The cleanup levels for individual chemicals were adjusted downward as needed to achieve the MTCA-required 1×10^{-5} excess cancer risk for all COPCs combined, based on evaluations of potential cumulative cancer risks from multiple carcinogens (see Section 2.1.3).

Porewater cleanup levels developed in this manner are summarized in Table 5-1. The basis for each cleanup level (i.e., the more restrictive of EPA Tier 1 criteria, MTCA Method B risk equations, or sediment protection criteria) is also noted in the table.

Because of its mobility and prevalence at the Site, benzene and naphthalene concentrations in groundwater wellpoints and surface sediment porewater were used to delineate where a complete groundwater-to-sediment pathway may exist at the Site. Porewater and bulk sediment PAH concentrations were in good agreement with wellpoint benzene and naphthalene concentrations for all locations where synoptic groundwater-porewater-sediment samples existed (Figures 5-2 and 5-3). Areas with relatively low wellpoint groundwater benzene and naphthalene concentrations did not have elevated porewater or bulk sediment total PAH concentrations. Where the groundwater-to-porewater/surface water pathway was confirmed, bulk sediment total PAH concentrations were also elevated.

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Based on this information, the PAH-based sediment remediation area generally delineated in Figures 5-1 through 5-4 appears to fully capture the area of the site where a groundwater to sediment pathway exists.

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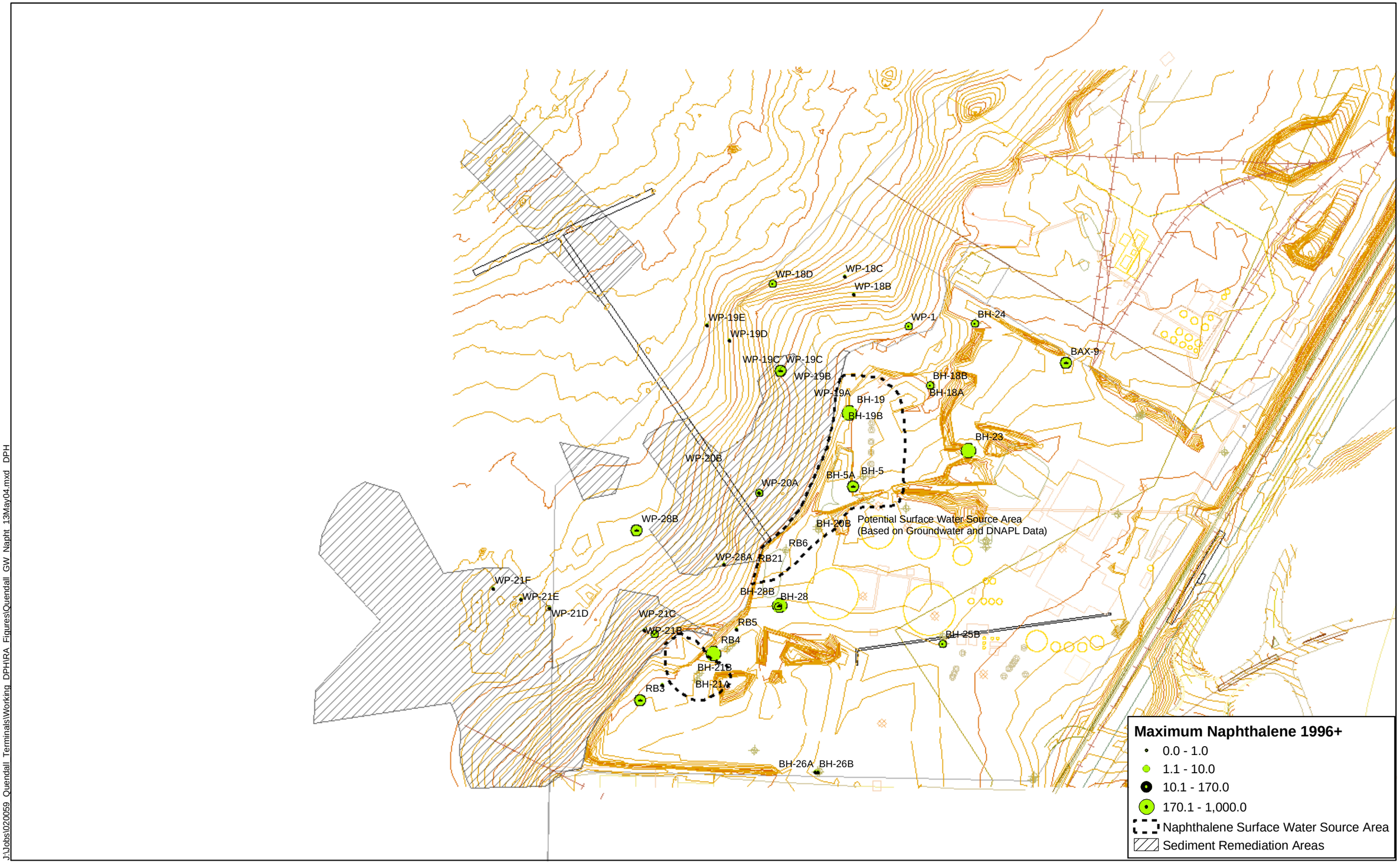

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Figure 5-2
Quendall Terminals
Potential Surface Water Source Areas
Naphthalene

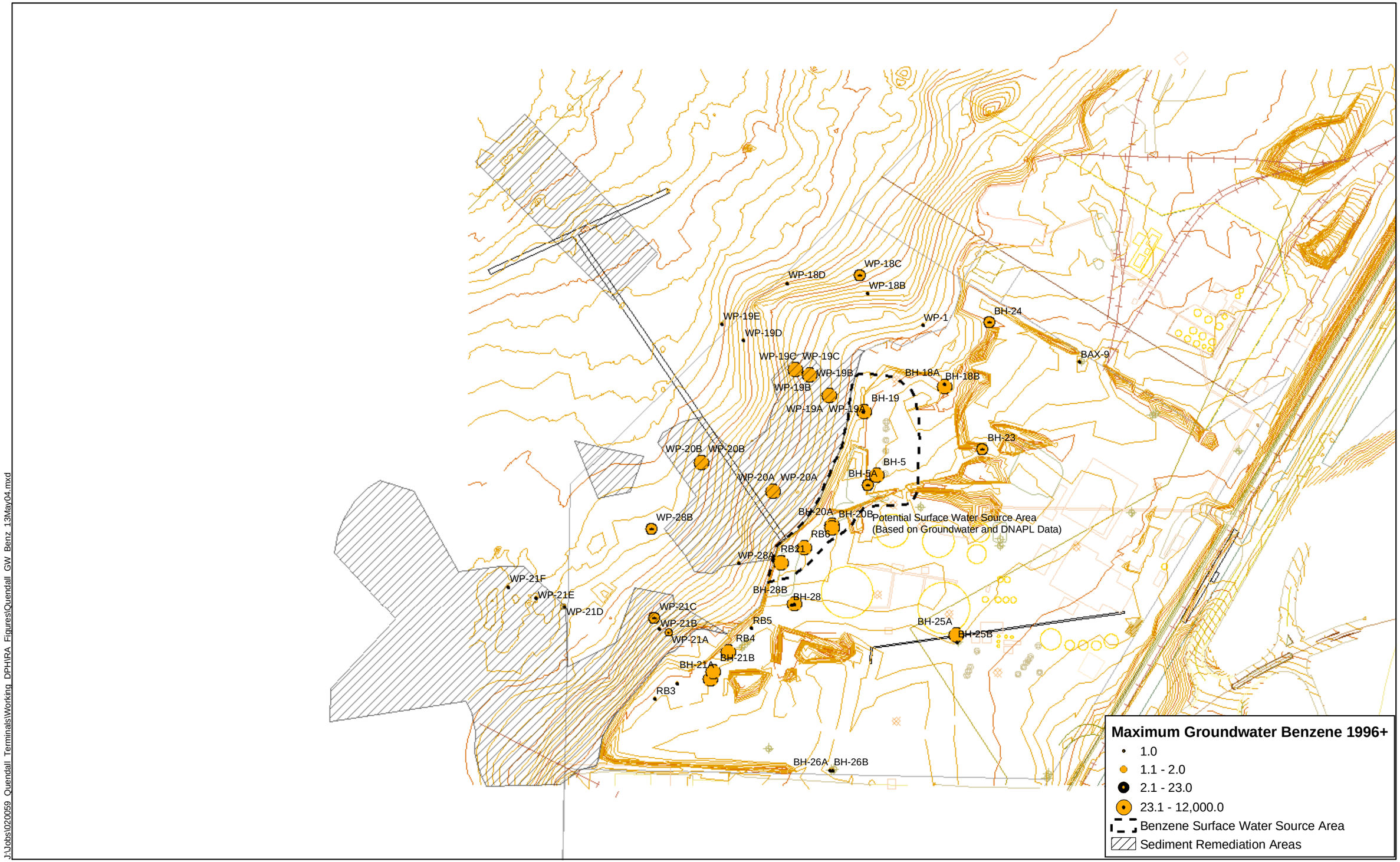

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Figure 5-3
Quendall Terminals
Potential Surface Water Source Areas
Benzene

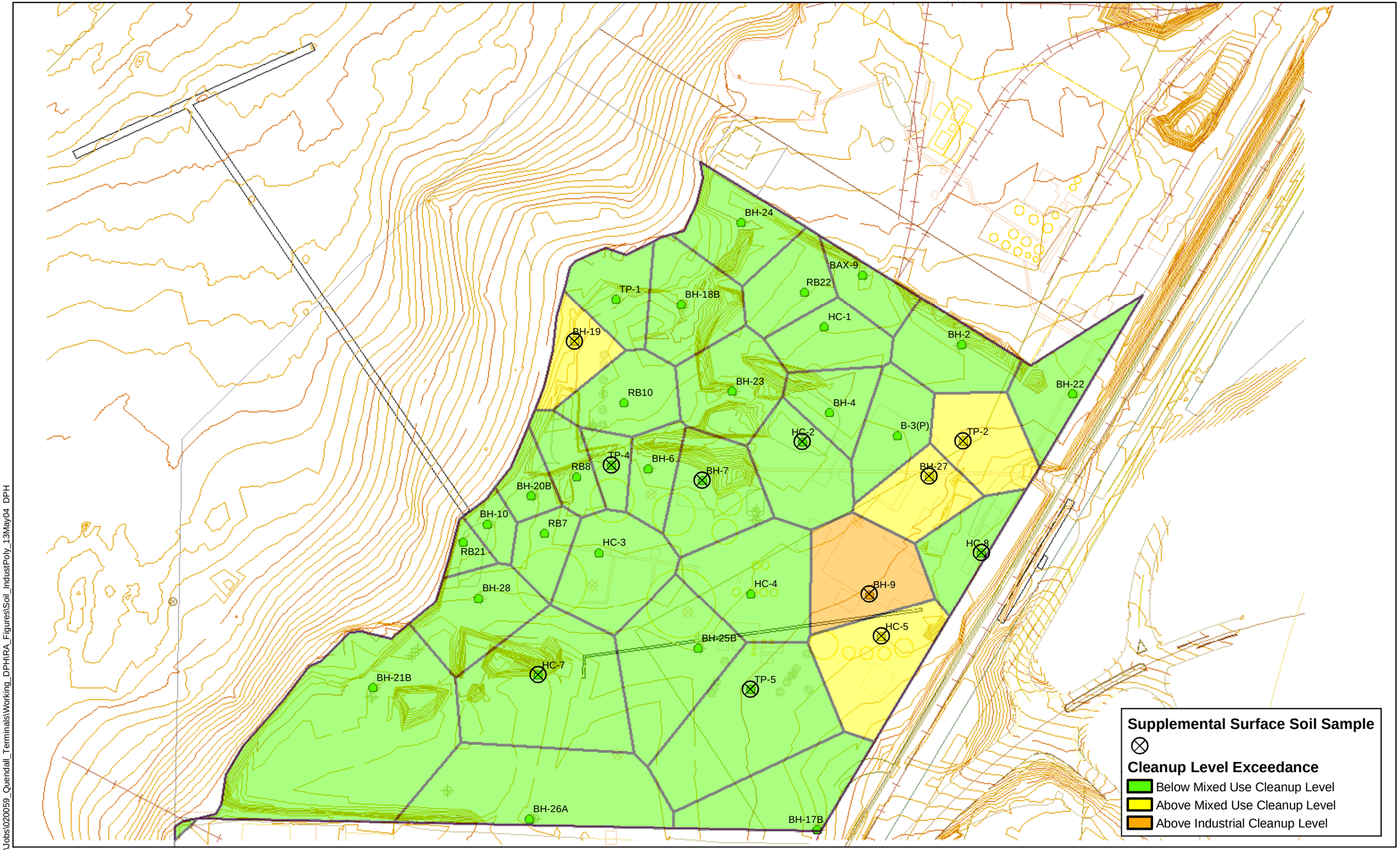

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Figure 5-4
Quendall Terminals Surface Soils:
Exceedances of Industrial or Mixed Use Cleanup Levels

5.4 Groundwater Cleanup Standards

Similar to surface water, screening for COPCs in Site groundwater was also performed for the baseline scenario assuming potential drinking water withdrawal from a hypothetical future water supply well. However, as discussed in the Upland Remedial Investigation Report (Hart Crowser 1997), there is no current or identified future use of groundwater for drinking water within the boundaries of the Site, and existing water supply regulations effectively preclude this potential site exposure pathway at the Quendall Site. Thus, consistent with MTCA requirements, further institutional controls may be considered in the FS (e.g., including a deed restriction) to ensure that water supply wells are not installed at the Site. In this case, a groundwater cleanup level based on the site-specific risk assessment may be developed to ensure protection of other potential exposure pathways such as aquatic life ecological risks and fish/shellfish consumption. This approach was recently implemented by Ecology at the Kenmore Industrial Park Site, which shares a number of similarities with the Quendall Site including its location adjacent to Lake Washington. Site-specific groundwater cleanup levels developed in this manner are summarized in Table 5-1, and are consistent with the surface water cleanup levels discussed in Section 5.3 above.

As defined in the MTCA regulations, the standard point of compliance for groundwater extends from the uppermost level of the saturated zone to the lowest depth that could be potentially affected by Site releases. However, site-specific conditional points of compliance for groundwater cleanup levels may also be considered. Assuming the implementation of appropriate institutional controls as outlined above, site-specific conditional points of compliance for groundwater cleanup levels may be developed for the Quendall Site based on the results of FS analyses of the impracticability of achieving groundwater cleanup levels throughout the Site (see Section 11). The conditional groundwater point of compliance would likely extend to the point of discharge of groundwater into Lake Washington (i.e., 10 cm below mudline).

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Under this scenario, and given attenuation evaluations performed as part of the site-specific risk assessment, a risk-based groundwater concentration may be evaluated based on surface water/porewater protection considerations. The Monte Carlo modeling effort detailed in Section 4 developed risk-based groundwater concentrations that would ensure with 95

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percent confidence that proposed surface water/porewater and groundwater cleanup standards (incorporating proposed points of compliance) would be attained. As illustrated in Figures 4-4 and 4-5, the risk-based groundwater concentration is a function of distance from the porewater point of compliance. In order to establish conservative porewater protection levels at on-site well locations, the shortest seasonal flow path (e.g., using summer high lake water levels) was used to identify groundwater zones that exceed the risk-based concentrations. Groundwater "source areas" of naphthalene and benzene identified in this manner are delineated in Figures 5-2 and 5-3, respectively. Significantly, no exceedances of such risk-based groundwater concentrations have been detected in the deeper aquifer.

5.5 Soil Cleanup Standards

As discussed in Section 2.5, existing industrial storage operations may continue at the Quendall Site into the foreseeable future, meeting the requirement of a "traditional industrial use" under the MTCA regulations (Section 173-340-745 WAC). Thus, industrial use is the appropriate basis for development of baseline site-specific soil cleanup levels. Baseline exposure parameters used in the risk evaluation followed the MTCA Method C industrial soil cleanup level equations.

5.5.1 Direct Contact

For the purpose of informing potential land use decisions at the Site, direct contact-based soil cleanup levels were developed for a range of different restricted and unrestricted access scenarios, including industrial use (existing condition), open space, recreational/sports field, commercial/mixed uses, first floor residential, and unrestricted uses (Table 5-2). Under these existing and potential future land use scenarios, the more restrictive of human health or terrestrial ecological cleanup levels would be applied.

During the March 2004 surface soil sampling described in Section 4.6, only one sample (Station SS-BH9; located near the former Still House; Table 4-7) exceeded the Method C (existing industrial site use) soil cleanup level for volatile or semivolatile COPCs. The surface soil sample at Station SS-BH9 contained a total carcinogenic PAH concentration of approximately 51 mg/kg B(a)P equivalent. However, all other surface soil samples contained total carcinogenic PAH concentrations between approximately 0.2 and 14

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¶
Conditional points of compliance may be considered based on specific land uses and require deed restrictions or other institutional controls to address the potential for future excavations and other site activities. Soil cleanup levels and conditional points of compliance for different land use conditions are discussed in more detail below.¶

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mg/kg B(a)P equivalents. Surface soil areas exceeding the more restrictive of industrial use or ecological protection criteria (assuming a 2-foot point of compliance) are depicted in Figure 5-4.

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The point of compliance for direct contact with soils extends from the ground surface to the reasonable estimated depth of potential future soil excavations (e.g., to accommodate underground garages or similar facilities), which can extend to 15 feet bgs [see WAC 173-340-740(6)(d)]. As set forth in WAC 173-340-740(6)(f), for MTCA cleanup actions that involve containment of hazardous substances, including many of the remedial alternatives evaluated in this RA/FS, soil cleanup levels will typically not be met at the points of compliance specified above. In these cases, the cleanup action may be determined to comply with cleanup standards, provided that:

1. The selected remedy is permanent to the maximum extent practicable using the procedures in WAC 173-340-360 (see Section 11);
2. The cleanup action is protective of human health based on the site-specific human health risk assessment, as described herein;
3. The cleanup action is demonstrated to be protective of terrestrial ecological receptors under WAC 173-340-7490 through 173-340-7494, as described herein;
4. Institutional controls are put in place under WAC 173-340-440 that prohibit or limit activities that could interfere with the long-term integrity of the containment system (see Section 11);
5. Compliance monitoring under WAC 173-340-410 and periodic reviews under WAC 173-340-430 are designed to ensure the long-term integrity of the containment system (see Section 11); and
6. The types, levels and amount of hazardous substances remaining on-site and the measures that will be used to prevent migration and contact with those substances are specified in the draft Cleanup Action Plan (development of which is pending).

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Additional considerations relative to the evaluation of soil cleanup are discussed below.

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5.5.2 Soil to Groundwater Pathway

Based on the analysis presented in Section 4, nearshore DNAPL source areas have been identified as a priority for surface water protection. Recoverable DNAPL has been identified and characterized in the area adjacent to Quendall Pond and near the former May Creek delta (Appendix E). Based on the site-specific risk assessment described previously, potential DNAPL and/or soil source areas to groundwater and surface water were delineated in Figures 5-2 and 5-3 for the more mobile DNAPL constituents naphthalene and benzene, respectively. These are the identified Site source areas that have the potential to result in exceedance of groundwater cleanup levels at the conditional point of compliance in porewater (i.e., 10 cm below mudline) under the baseline (no action) condition.

MTCA also requires that the soil to groundwater pathway be evaluated to evaluate soil concentrations that are protective of groundwater under a hypothetical drinking water beneficial use scenario. The soil to groundwater pathway was evaluated using the fixed parameter three-phase partitioning model (Section 173-340-747 WAC) as applied to surface soils. The soil concentrations determined by modeling to be protective of the groundwater migration pathway for drinking water consumption are presented in Tables 4-7 and 5-2. As summarized in Table 4-7, several SVOCs, but no VOCs, exceeded these conservative soil cleanup levels in surface soils.

The MTCA requirement that soil cleanup levels protect adjacent surface water was also evaluated. Surface water cleanup levels discussed in Section 5.3 were based on both aquatic life protection and potential future drinking water uses. Importantly, the area(s) of groundwater and DNAPL-based surface water source control criteria exceedances (e.g., as depicted on Figure 5-2) also include associated soil media exceedances for groundwater and surface water protection. Because of the nature of the soil to surface water pathway, as described in more detail in Section 4, placement of a permeable upland soil cap (included in many of the FS alternatives described below) would not by itself address the soil to groundwater/surface water pathway, requiring the application of additional remedial technologies to ensure surface water protection. It is also important to note that groundwater monitoring data is included in all remedial

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alternatives evaluated in this RA/FS to assess compliance with the soil to surface water pathway.

5.5.3 Soil to Air Pathway

Under MTCA, the soil to vapor pathway must also be evaluated for VOCs whenever the concentration is significantly higher than a concentration derived for protection of groundwater for drinking water beneficial use. The method used in this RA/FS to evaluate the soil to air pathway included a direct comparison of the March 2004 surface soil sampling data (Table 4-7) with EPA (1996) soil screening levels for inhalation of volatiles under a conservative unrestricted site use (e.g., first floor residential) scenario. The soil screening levels (EPA 1996) are provided in Table 5-2. Consistent with the lack of VOCs detected above conservative groundwater protection criteria (Table 4-7), none of the March 2004 surface soil samples exceeded Method C cleanup levels for volatile site-specific COPCs. Only naphthalene exceeded the soil screening level for inhalation of volatiles and this was only at a single station (SS-BH9). Localized vapor pathways may also exist at the Quendall Pond shoreline. Similar to the soil to groundwater pathway discussion above, all areas of potential soil to air exceedances are already encompassed with the area(s) of industrial direct contact exceedances (as depicted on Figure 5-4; see below) and the nearshore area adjacent to Quendall Pond (see Section 4.1). Remedial actions that address DNAPL discharge and/or direct contact, along with appropriate institutional controls, would also address the soil to air pathway under worst-case exposure conditions.

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Table 5-2
Land Use-Specific Soil Cleanup Levels

	Direct Contact Criteria					Protection of Groundwater	Protection of Air
	Simplified Terrrestrial Ecological Evaluation (MTCA Table 749-2)	Industrial Cleanup Level (MTCA Equations 745-1/ 745-2)	Recreational/ Sports Field Remediation Level (MTCA Equations 740-4/ 740-5) (5)	Commercial/ Mixed Use Remediation Level (MTCA Equations 740-4/ 740-5) (6)	Unrestricted/ First Floor Residential Cleanup Level (MTCA Equations 740-1/ 740-2)	Migration to Groundwater and Surface Water (see Table 4-7)	Inhalation of Volatiles (EPA 1996 Soil Screening Level)
Trace Element							
Arsenic (1)	260	20 (Method A background)	20 (Method A background)	16 (apply Method A background of 20)	20 (Method A background)	29	na
Chromium (III)	135	5,300,000	760,000	280,000	120,000	na	na
Copper	550	130,000	19,000	7,000	2,960	na	na
Lead	220	na			250	400	na
Zinc	570	1,060,000	150,000	56,000	24,000	12,000	na
PAHs							
Acenaphthene	na (4)	210,000	23,000	8,700	4,800	570	na
Benzo(a)anthracene (1,2)	na	18	4.8	2.5	1.4	2	na
Benzo(a)pyrene (1)	300	7.20	1.92	1.00	0.55	8	na
Benzo(b)fluoranthene (1,2)	na	18	4.8	2.5	1.4	5	na
Benzo(k)fluoranthene (1,2)	na	18	4.8	2.5	1.4	49	na
Chrysene (1,2)	na	180	48	25	14	160	na
Dibenzo(a,h)anthracene (1,2)	na	4.5	1.2	0.6	0.3	2	na
Indeno(1,2,3-cd)pyrene (1,2)	na	18	4.8	2.5	1.4	14	na
Fluoranthene	na	27,000	15,000	5,800	3,200	4,300	na
Fluorene	na	27,000	15,000	5,800	3,200	560	na
Naphthalene	na	14,000	7,600	2,900	1,600	84	na
Pyrene	na	20,000	11,000	4,300	2,400	4,200	na
Total cPAHs (BaP EQ)	300	18	4.8	2.5	1.4	na	na
Semivolatile, Miscellaneous							
Dibenzofuran	na	na	na	na	na	na	na
Semivolatile, Nitroaromatic							
n-Nitroso-di-phenylamine (1)	na	27,000	7,200	3,700	2,000	1	na
Semivolatile, Organochlorine							
Aldrin (1)	0.17	100	2.1	1.1	0.6	0.5	na
Semivolatile, Phenolic							
2,4-Dimethylphenol	na	70,000	7,600	2,900	1,600	470	na
Pentachlorophenol (1)	11	560	290	150	83	0.03	na
Phenol	na	2,100,000	230,000	87,000	48,000	100	na
Phthalates							
bis(2-Ethylhexyl)phthalate (1)	na (4)	9,400	2,500	1,300	710	3,600	na
Di-n-octylphthalate	na (4)	70,000	7,600	2,900	1,600	na	na
Volatile, Aromatic and Halogenated							
Benzene (1)	na	2,400	710	470	180	0.03	0.8
Chloroform (1)	na	22,000	6,300	1,900 (3)	800 (3)	0.6	0.3
Methylene Chloride (1)	na	18,000	5,200	3,500	1,300	0.02	13
Ethylbenzene	na	350,000	52,000	19,000	8,000	13	400
Styrene (1)	na	4,400	1,300	800	330	4	1,500
Toluene	na	705,000	104,000	39,000	16,000	12	650

Notes:

(1) Carcinogenic risk equal to 1E-5. For PAHs, the carcinogenic value presented was based on the assumption that benzo(a)pyrene accounts for 40 percent of the measured PAHs and the remaining carcinogenic PAHs account for 10 percent of the total. The cumulative risk for PAHs was adjusted to 1E-5. The sum of carcinogenic PAHs will be used to measure site conditions.

(2) Carcinogenic PAHs will be evaluated using the toxicity equivalancy factor method to normalize concentrations to Benzo(a)pyrene.

(3) Noncarcinogenic value is less than the carcinogenic value at 1E-5 risk

(4) Safe concentration not established. May not be present in soil under conditions set forth in WAC 173-340-7492(2 c)

(5) Body weight (49 kg) and exposure fequency (3 day/week) modified based on EPA 1997.

(6) Exposure fequency (5 day/week during 84 day summer vacation then 2 day/week remainder of year) modified based on EPA 1997.

na - not available or not applicable

5.5.4 Potential Future Land Use Options for FS Analysis

As discussed above, soil cleanup standards were developed to evaluate possible land use options at the Site. Application could also include a range of institutional controls that would be specific to the land use scenario. The analysis presented below was performed solely as a scoping exercise for the FS, and does not represent any plan for a change in the existing industrial use of the site by the property owners. Section 11 of this RA/FS Report provides a further summary of MTCA site cleanup requirements, including institutional controls, under different potential future site use scenarios.

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5.5.4.1 Maintain Existing Industrial Use

There are no existing plans to redevelop the Site, and the existing industrial use will remain in the short term. If the site land use remains industrial, the cleanup action would include appropriate institutional controls, as described in Section 11. Under this scenario, soil cleanup levels would be determined based on MTCA industrial cleanup levels that are protective of groundwater/surface water (see Section 5.5.2), and worker direct contact ingestion of soils, with a 2-foot-thick clean surface containment layer appropriate to specific human and ecological exposure conditions at the Site[5]. Industrial use cleanup levels are presented in Table 5-2.

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5.5.4.2 Restricted Access/Open Space

Institutional controls and access restrictions could be applied to the Site to restrict human access, so that the Site would be accessible only to wildlife. Under this scenario, soil remediation levels would be determined based on groundwater/surface water protection requirements (see Section 5.5.2) and terrestrial

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[5] A 2-foot-thick clean surface layer is suggested for this cleanup/remediation level analysis based on the following considerations per WAC 173-340-740(6)(f) and WAC 173-340-7490(4)(a):

- Soil invertebrates require organic carbon as a food source. The soil horizon containing organic carbon ranges from about 0.5 to 1.5 feet. Soil invertebrates are unlikely to occur below a depth of 2 feet. (Lee 1985)
- The depth to which soil turnover is likely to occur due to soil invertebrates is less than 2 feet, based on the depth of soil containing organic carbon.
- Animals that may burrow and likely to occur at the site include shrew, vole, and skunk. The average burrowing depth of voles and shrews is less than 2 feet. Skunk rarely burrow where more preferable habitat is available. Given the available logs and thickets on the Site, skunk are unlikely to burrow. (CDFG 2004)
- Plant rooting depth will vary by species and soil conditions. The historical and current industrial use of the site has likely resulted in soil compaction and therefore, except for larger trees, rooting depths are expected to be shallow to moderate and mainly within the soil horizon where organic carbon is present.

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ecological exposure considerations, with a 2-foot-thick clean surface containment layer appropriate to specific ecological conditions at the Site. Restricted access/open space remediation levels are presented in Table 5-2 and are identical to the terrestrial ecological risk-based levels.

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5.5.4.3 Recreational/Sports Fields

Another potential land use alternative would allow limited access to the Site for recreational and wildlife uses, potentially represented by a sports field complex constructed on the property. Consistent with EPA's (1997) risk assessment guidelines contained in the "Exposure Factors Handbook," the potential reasonable maximum human exposure (RME) under this scenario is based on adolescent use for team sporting activities such as soccer or baseball occurring on average three times a week throughout the year. Both ingestion and dermal contact with surface soil were included as exposure routes using MTCA Equations 740-4 and 740-5 for non-carcinogenic and carcinogenic COPCs, respectively. MTCA default input parameters were used in the risk calculations, with the exception of modifications specific to the adolescent receptors (e.g., body weight) and associated exposure frequency (EPA 1997).

A 2-foot-thick clean surface containment layer, which could be accomplished by placement of clean fill material or an equivalently protective structural cover (e.g., asphalt) within accessible areas, along with institutional controls and provisions for utility corridors that are protective of worker health and safety and other subsurface activities such as building foundations and landscape excavations, was applied to the recreational/sports field use scenario. Recreational/sports field use remediation levels are presented in Table 5-2. Under the recreational/sports field use scenario, the more stringent of the terrestrial ecological or human health-based levels would be applied. Similar to the other land use conditions evaluated, soil cleanup would also need to address groundwater/surface water protection requirements (see Section 5.5.2).

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5.5.4.4 Commercial/Mixed Use

Contingent on zoning changes and other conditions, a future mixed use commercial and upper-story residential development could be considered for the Site. Consistent with EPA (1997), the RME under this scenario is based on a young child contacting surface soil at the Site up to five times a week during summer vacation and two days per week the remainder of the year (Appendix A). Both ingestion and dermal contact were included as exposure routes using MTCA Equations 740-4 and 740-5 for non-carcinogenic and carcinogenic COPCs, respectively. MTCA default input parameters were used in the risk calculations, with the exception of modifications specific to the child exposure frequency described above (EPA 1997).

Similar to the recreational/sports field use described above, a 2-foot-thick clean surface containment layer, which could be accomplished by placement of clean fill material or an equivalently protective structural cover (e.g., asphalt), along with institutional controls and provisions for utility corridors that are protective of worker health and safety and other subsurface activities such as building foundations and landscape excavations was applied to the commercial/mixed use scenario. Commercial/mixed use remediation levels are presented in Table 5-2, and for most of the COPCs were typically a factor of 2 to 3 more restrictive than recreational/sports field use remediation levels. Under the commercial/mixed use scenario, the more stringent of the terrestrial ecological or human health-based levels would be applied. Similar to the other land use conditions evaluated, soil cleanup would also need to address groundwater/surface water protection requirements (see Section 5.5.2).

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5.5.4.5 1st Floor Residential

As generally described in the MTCA regulations, a land use scenario that provides for first floor residential land uses must meet the unrestricted Method B cleanup levels within the potential soil exposure zone. However, as described Section 11, given appropriate institutional controls, the required thickness of the clean surface containment layer for the first floor residential use scenario could be reduced from the 15-foot MTCA point of compliance to a soil depth interval approximately 0 to 2

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feet bgs. Similar to the recreational and commercial/mixed use scenarios discussed above, suitable human health and ecological protection could be accomplished in this case by placement of clean fill material or an equivalently protective structural cover (e.g., asphalt), along with institutional controls and provisions for utility corridors that are protective of worker health and safety. An additional institutional control would likely need to be added in this scenario to restrict future excavations at the Site, such as for underground garages. First floor residential use cleanup levels are presented in Table 5-2. Again, the more stringent of the terrestrial ecological or human health cleanup levels would be applied. Similar to the other land use conditions evaluated, soil cleanup would also need to address groundwater/surface water protection requirements (see Section 5.5.2).

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6 FEASIBILITY STUDY OVERVIEW

The FS presented in the sections below build upon the considerable site characterization data collected to date (e.g., Hart Crowser 1997, Retec 1997, Retec and Papadopoulos 1998, Exponent 1999, and others), which has previously been submitted to Ecology and incorporated into the existing administrative record for the Site. The FS also is based upon the risk-based cleanup standards as summarized in Section 5. The overall FS evaluation presented below is intended to provide sufficient data and engineering analysis to enable Ecology to select a cleanup action alternative that is protective of human health and the environment.

Alternatives for upland and/or aquatic area cleanup generally have three components:

- General response actions – major categories of cleanup activities such as source control/natural attenuation, institutional controls, containment, or treatment.
- Cleanup technologies – general categories of technologies such as different containment options, ranging from in-place confinement/capping, to excavation coupled with off-site confined disposal at an active upland landfill facility.
- Process options – variations in the way technologies are implemented such as variations in excavation and capping specifications.

Site-wide remedial alternatives are developed in the sections below using technologies retained from the initial screening of technologies. The identification and assembly of cleanup technologies into site-wide alternatives was performed in accordance with the MTCA regulations and associated guidance (e.g., Sediment Management Standards User Manual), along with additional direction provided by Ecology. Each alternative was developed to achieve cleanup standards at the Site, though the alternatives use different remedial technologies and strategies to accomplish this objective. Detailed analysis of each of the alternatives relative to MTCA evaluation criteria is presented in subsequent sections of this RA/FS Report.

6.1 Land Use Considerations

The existing land use designation for the Site – industrial storage – is maintained as a baseline condition under all alternatives. However, potential modifications to each alternative to support land uses other than existing industrial storage operations have also been incorporated into each site-wide alternative, consistent with the cleanup standard

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discussion presented in Section 5. The potential land use options addressed under each alternative include:

- Industrial Use (baseline conditions; e.g., existing storage operations)
- Restricted Access/Open Space (e.g., passive site use)
- Recreational Use (e.g., sports field)
- Commercial/Mixed Use (e.g., upper floor residential)
- First Floor Residential Use

A range of prospective physical modifications to the Site, along with accompanying institutional controls that would achieve land use-specific cleanup standards, are described for each alternative in Section 5. Thus, the resulting FS evaluation essentially develops a "menu" of approaches to accomplish Site cleanup and concurrently address a range of potential future Site land uses.

6.2 Feasibility Study Organization

The remainder of this report is organized as follows:

- Section 7 of this report presents a summary of applicable federal, state, and local laws.
- Section 8 presents an initial screening of cleanup technologies.
- Section 9 presents a description of the site-wide cleanup alternatives retained for detailed evaluation.
- Section 10 evaluates the alternatives against MTCA criteria for cleanup actions.
- Section 11 presents the recommended site-wide cleanup alternative.
- Section 12 presents the references cited in the RA/FS Report.

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7 APPLICABLE FEDERAL, STATE, AND LOCAL LAWS

Many environmental laws may apply to a cleanup action. In addition to meeting MTCA cleanup standard requirements as described in Section 5, a cleanup action must also meet the environmental standards set forth in other applicable laws. The cleanup action must comply with substantive elements of other applicable environmental reviews and permitting requirements. Though a cleanup action performed under formal MTCA authorities (e.g., a Consent Decree) would be exempt from the procedural requirements of certain state and local environmental laws, the action must nevertheless comply with the substantive requirements of such laws. Potentially applicable federal, state and local laws that may impact the implementation of remedial actions at the Quendall Site are summarized below.

7.1 Federal Requirements

Potential federal requirements are specified in several statutes, codified in the U.S. Code (USC), and regulations promulgated in the Code of Federal Regulations (CFR), as discussed in the following sections.

The **Clean Water Act** (CWA) (33 USC Section 1251 *et seq*.) requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. Section 304 of the CWA (33 USC 1314) requires the EPA to publish Water Quality Criteria, which are developed for the protection of human health and aquatic life. Federal water quality criteria are published as they are developed, and many of them are included in Quality Criteria for Water 1986, EPA 440/5-86-001, May 1, 1986 (51 FR 43665), commonly known as the "Gold Book." Publications of additional criteria established since the Gold Book was printed are announced in the Federal Register. Federal water quality criteria are used by states, including Washington, to set water quality standards for surface water. These standards are relevant and appropriate for possible actions at the Quendall Site, and are also adopted under MTCA. Federal water quality criteria (along with related state standards) have been incorporated into the cleanup standards summarized in Section 5.

Discharges of Pollutants into Navigable Waters are regulated under Sections 401 and 404 of the CWA (33 USC 1341 and 1344), 40 CFR Part 230 [Section 404(b)(1) guidelines], 33 CFR Parts 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters

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of the United States). These requirements regulate the excavation of shoreline materials and the placement of fill material (including caps) below the ordinary high water elevation of waters of the United States. The 401/404 regulations are implemented by the U.S. Army Corps of Engineers (Corps) and EPA. Under the Section 404(b)(1) guidelines, 40 CFR 230.10(b), no discharge (i.e., excavation or cap) shall be allowed if it:

- Causes or contributes to violations of water quality standards, pursuant to Section 401 of the CWA, after consideration of local dilution and dispersion.
- Violates any applicable toxic effluent standard or discharge prohibition under Section 307 of the CWA.
- Jeopardizes the continued existence of any endangered or threatened species, or contributes to the destruction or modification of any critical habitat for such species.
- Violates any requirement imposed by the Secretary of Commerce to protect sanctuary areas.

The guidelines in 40 CFR 230.10(c) also provide that no discharge will be authorized that contributes to significant degradation of the waters of the United States. Where there is no practicable alternative to a discharge, 40 CFR 230.10(d) requires the use of appropriate mitigation measures to minimize potential adverse impacts of the discharge on the aquatic ecosystem. The term "practicable" is defined in 40 CFR 230.3(q) to mean "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes." Examples of specific steps that may be taken to minimize adverse impacts are set forth in 40 CFR Part 230, Subpart H. As discussed above, Section 401 and Section 404 requirements of the CWA may be applicable to a shoreline cleanup project if sediment removal and/or capping are implemented.

Cleanup actions at the Quendall Site may be performed under the terms of a MTCA Consent Decree between Ecology and the performing parties. Actions performed under such a Consent Decree typically qualify for a Corps Nationwide Permit 38 (NWP 38; Cleanup of Hazardous and Toxic Waste). Nevertheless, federal consultation under the Endangered Species Act (ESA), Section 401 Water Quality Certification, and other substantive requirements must still be met by the action. Ecology would be responsible for issuing the final approval for the cleanup project, following consultation with other state and local regulators. The Corps would separately be responsible for issuing approval of this

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project under NWP 38, following ESA consultation with the federal services (National Oceanic and Atmospheric Administration [NOAA] Fisheries and U.S. Fish and Wildlife Services [USFWS]), and also incorporating Ecology's 401 Water Quality Certification.

Memorandum of Agreement between EPA and Corps (Mitigation under Clean Water Act Section 404(b)(1)). The Agreement sets forth policy and procedures for developing mitigation for compliance under Section 404, but does not alter any of the requirements under this section. These guidelines for mitigation include, in order of importance, avoidance, minimization, and compensatory mitigation.

Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act (RCRA) addresses the generation and transportation of hazardous waste, and waste management activities at facilities that treat, store, or dispose of hazardous wastes. Subtitle C (Hazardous Waste Management) mandates the creation of a cradle to grave management and permitting system for hazardous wastes. RCRA regulates "solid wastes" that are hazardous because they may cause or significantly contribute to an increase in mortality or serious illness, or that pose a substantial hazard to human health or the environment when improperly managed. In Washington State, RCRA is implemented by Ecology under the State's Dangerous Waste Regulations, Chapter 173-303 WAC.

One objective of RCRA is to minimize both the generation and land disposal of hazardous waste by encouraging process substitution, materials recovery, recycling and reuse, and treatment (see RCRA Section 3003). To further this objective, EPA has set various goals for the Waste Minimization National Plan, including reducing the generation and mobility of hazardous wastes and establishing treatment standards as part of several rulemakings under the Land Disposal Restrictions (LDR) in 40 CFR Part 268.

With the potential exception of materials removed from DNAPL areas, soil, water, or sediment removed from the Quendall Site are not expected to be designated as hazardous or dangerous wastes. Wastes generated at the site are not listed wastes (Ecology 1997) and are not expected to designate as characteristic wastes, based on designation and sampling of investigation derived wastes (Hart Crowser 2002; Ecology 2002), except possible exceedences of the toxicity characteristics. As with other hazardous waste designations, the

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TCLP designation limits are used to determine when more stringent management standards apply than would be applied to typical solid wastes. Thus, the TCLP contaminant-specific criteria may be used to determine cleanup levels or when RCRA-equivalent waste management standards must be met (including LDR). Existing soil quality and TCLP data collected at the Quendall Site do not indicate potential exceedance of characteristic dangerous or hazardous waste criteria for materials that may be removed from the prospective cleanup area. These materials would not be subject to upland LDRs, either under existing regulations or proposed revisions to the LDR (Federal Register: May 28, 1999 [Volume 64, Number 103]).

Federal and State Clean Air Acts (42 USC 7401 *et seq.*; 40 CFR 50; RCW 70.94; WAC 173-400, 403). The Clean Air Act regulates emissions of hazardous pollutants to the air. Controls for emissions are implemented through federal, state and local programs. The Clean Air Act is implemented in the state of Washington through the Washington Clean Air Act (RCW 70.94). The regional air pollution contract authorities, activated under the Washington Clean Air Act, have jurisdiction over regulation and control of the emission of air contaminants and the requirements of state and federal Clean Air Acts in their districts.

Endangered Species Act (16 USC 1536 (a) – (d); 50 CFR Part 402). Section 7(a) of this Act grants authority to and imposes requirements upon federal agencies regarding endangered or threatened species of fish, wildlife, or plants (listed species) and habitat of such species that has been designated as critical. Federal agencies must confer with NOAA Fisheries and USFWS on any action that is likely to jeopardize the continued existence of listed Chinook salmon or bull trout stocks, respectively, or any other proposed species, or result in the destruction or adverse modification of any critical habitat important to these species. The conference/consultation process is directed at making a biological opinion regarding the proposed action. The opinion evaluates whether or not the action will jeopardize the continued existence of a species, or result in the destruction or adverse modification of critical habitat; and may include modification to the action that would avoid the likelihood of adverse effects to listed species or their critical habitat. Formal or informal consultation with NOAA Fisheries and USFWS will be required prior to implementation of those cleanup remedies that trigger a federal action, such as a Section 404 permit (see above).

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U.S. Fish and Wildlife Mitigation Policy (46 FR 7644). This policy establishes guidance for USFWS personnel involved in making recommendations to protect or conserve fish and wildlife resources.

Fish and Wildlife Coordination Act (16 USC 661 *et seq*.). This Act is a federal law requiring consultation with fish and wildlife agencies on activities that could affect fish and wildlife. Protection of Wetlands, Executive Order 11990 (40 CFR Part 6, Appendix A). This executive order requires that federal agencies avoid adversely impacting wetlands wherever possible, minimize wetland destruction, and preserve the value of wetlands. Appendix A of 40 CFR Part 6 provides EPA procedures for managing floodplains and protecting wetlands.

Treaty of Point Elliott (12 Stat. 927), **Treaty of Medicine Creek** (10 Stat. 1132). In 1854 and 1855, Native American Tribes, in what is now the state of Washington, signed treaties with the United States government conveying their right, title, and interest in and to the lands occupied by them. These treaties and subsequent court decisions protect Indian tribes' property and water rights, including their rights to fish and co-manage fishery resources in Lake Washington and Puget Sound.

National Historic Preservation Act (36 CFR 800). When proponents seek a federal approval, the responsible federal agency must consult with the State Historic Preservation Officer and the federal Advisory Council on Historic Preservation to determine if the project would affect cultural or historic sites on or eligible for the National Register of Historic Places.

7.2 Washington State and Local Requirements

MTCA (Chapter 70.105D RCW) authorized Ecology to adopt cleanup standards for remedial actions at sites where hazardous substances are present. The processes for identifying, investigating, and cleaning up these sites are defined and cleanup standards are set for groundwater, soil, surface water, and air in Chapter 173-340 WAC. The cleanup of contaminated sediments is reserved for the SMS process.

In addition to MTCA, potential state requirements are specified in several statutes, codified in the Revised Code of Washington (RCW), and regulations promulgated in the WAC.

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Washington Sediment Management Standards (Chapter 173-204 WAC). The SMS establish numerical values for chemical constituents in sediments. The SMS sets forth a sediment cleanup decision process for identifying contaminated sediment areas and determining appropriate cleanup responses. The SMS governs the identification and cleanup of contaminated sediment sites and establishes two sets of numerical chemical criteria against which surface sediment concentrations are evaluated. The more conservative SQSs provide a regulatory goal by identifying surface sediments that have no adverse effects on human health or biological resources. The SQS is Ecology's preferred cleanup standard, though Ecology may approve an alternate cleanup level within the range of the SQS and the Minimum Cleanup Level (MCUL), if justified by a weighing of environmental benefits, technical feasibility, and cost. The Sediment Cleanup Standard's Users Manual provides guidance for the implementation of Section 5 of the SMS, Sediment Cleanup Standards. Site-specific sediment cleanup standards are presented in Section 5.2.

State Environmental Policy Act (SEPA) (RCW 43.21C; WAC 197-11). The SEPA is intended to ensure that state and local government officials consider environmental values when making decisions. The SEPA process begins when an application for a permit is submitted to an agency, or an agency proposes to take some official action such as implementing a MTCA Cleanup Action Plan. Prior to taking any action on a proposal, agencies must follow specific procedures to ensure that appropriate consideration has been given to the environment. The severity of potential environmental impacts associated with a project determines whether an Environmental Impact Statement (EIS) is required.

Washington Water Pollution Control Act (Chapter 90.48 RCW; Chapter 173 201A WAC). This Act provides for the protection of surface water and groundwater quality. Chapter 173-201A WAC establishes water quality standards for surface waters of the state. Consistent with the requirements of Chapter 90.48 RCW, Ecology issues a water quality certification for any activity, including MTCA cleanup actions, which may result in a discharge to state water. As outlined above, shoreline excavation, dredging, and/or capping actions typically constitute a "discharge" under this state regulation. The need for mitigation resulting from these activities has been further defined by the Washington State

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Legislature in the section below entitled "Compensatory Mitigation Policy for Aquatic Resources."

Washington Shoreline Management Act (Chapter 90.58 RCW; Chapter 173-14 WAC). The Shoreline Management Act and regulations promulgated thereunder establish requirements for substantial developments occurring within water areas of the state or within 200 feet of the shoreline. King County and the City of Renton have set forth requirements based on local considerations such as shoreline use, economic development, public access, circulation, recreation, conservation, and historical and cultural features. Local shoreline management plans are adopted under state regulations, creating an enforceable state law.

Washington Hydraulics Code (Chapter 75.20 RCW; Chapter 220 110 WAC) establishes requirements for performing work that would use, divert, obstruct, or change the natural flow or bed of any salt or fresh waters. Mitigation is required for projects that directly or indirectly harm fish. Consistent with the requirements of Chapter 75.20 RCW, the WDFW issues an Hydraulic Project Approval (HPA) for any project that will use or change the natural flow of any waters of the state. Shoreline excavation, dredging, and/or capping actions would likely require a HPA under this state regulation. In addition, WDFW typically requires that impacts to wetlands or aquatic resources occurring as a result of cleanup actions be mitigated on the project site and with a similar habitat type. The need for mitigation resulting from these activities has been further defined by the Washington State Legislature in the section below entitled "Compensatory Mitigation Policy for Aquatic Resources."

Washington Hazardous Waste Management Act (Chapter 70.105 RCW; Chapter 173 303 WAC). The Act, and regulations promulgated thereunder, is the state equivalent of RCRA requirements for designating certain solid wastes as "dangerous waste." It also presents requirements for management of dangerous waste.

Washington Department of Fisheries Habitat Management Policy, POL 410. This policy includes the following provisions:

- Achieve no net loss of productive capacity of the habitat of food fish and shellfish resources of the state.

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- Create productive capacity of habitats that have been damaged or degraded by natural causes or as a result of human activities.
- Improve the productive capacity of existing habitat and create new habitat.

In addition, in-water actions will need to address the requirements of an HPA, including seasonal fisheries closures and water quality and habitat protection.

Compensatory Mitigation Policy for Aquatic Resources (Chapters 75.20 and 90.48 RCW). In 1997, the Legislature added new sections to Chapters 75.20 and 90.48 RCW to establish a clear state policy relating to the mitigation of wetlands and aquatic habitat for infrastructure development and the cleanup of aquatic resources. Compensatory mitigation is defined to include mitigation that occurs in advance of a project's planned environmental impacts, either on or off the project site, and that may provide different biological functions from the functions impacted by the project. The policy encourages mitigation proposals that are timed, designed, and located in a manner to provide equal or better biological functions and values compared to "traditional" on-site, in-kind mitigation proposals. In addition, the policy provides that the state shall not require mitigation for sediment dredging or capping actions that result in a cleaner aquatic environment and equal or better habitat functions and values, if the actions are taken under a state or federal cleanup action.

Water Resources Act (Chapter 90.54 RCW). The Water Resources Act establishes fundamental water resource policies for preservation of Washington State water resources.

State Aquatic Lands Management Laws Washington State Constitution Articles XV, XVII, XXVII (RCW 79.90 through 79.96; WAC 332-30). The management of state-owned aquatic lands is intended to provide a balance between:

- Encouraging direct public use and access
- Fostering water-dependent uses
- Ensuring environmental protection
- Utilizing renewable resources

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The Washington DNR has the authority to lease state-owned aquatic lands. It has the responsibility to consider the natural values of the land before it leases it and the authority to withhold land from leasing if it determines it has significant natural values.

Growth Management Act (Chapters 36.70A; 36.70.A.150; and 36.70.A.200 RCW). The Growth Management Act (GMA) requires counties and cities to classify and designate natural resource lands and critical areas (which include "waters of the state"). Additionally, the state's fastest growing cities and counties must adopt comprehensive plans and development regulations regarding land use within their jurisdiction. In particular, each plan must identify land within the jurisdiction that is useful for public purposes, and include a process for siting essential public facilities, including solid waste handling facilities.

State Historic Preservation Act (Chapter 27, 34, 44, 53, RCW) is a state law to ensure that cultural resources, such as historical and archaeological sites, are identified and protected.

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8 SCREENING OF CLEANUP TECHNOLOGIES

In this section, cleanup technologies are evaluated following MTCA guidance for possible application to the Quendall Site. Potentially applicable technologies are identified and retained for assembly of site-specific alternatives in Section 9.

Cleanup technologies are typically organized under General Response Actions that represent different conceptual approaches to remediation. At the Quendall Site, five general response actions have been identified:

- Institutional Controls
- Monitored Natural Attenuation/Recovery
- In Situ Containment
- In Situ Treatment
- Removal, Ex Situ Treatment, and Disposal

Technology screening begins by identifying available technologies that do not address Site COPCs or are not able to be implemented for technical reasons. These technologies are eliminated at this initial screening stage. Retained technologies are evaluated further and for each affected medium (soil, groundwater, DNAPL, and surface water/sediment), cleanup technologies under the same general response action are evaluated relative to one another on the basis of the following three criteria:

- **Effectiveness.** The effectiveness criterion evaluates the technology for its protectiveness and reduction in contaminant toxicity, mobility, or volume. Both short-term and long-term effectiveness are evaluated. Short-term effectiveness addresses the construction and implementation periods. Long-term effectiveness evaluates the technology after the action is in place.
- **Implementability.** The implementability criterion evaluates the technology for technical and administrative feasibility. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and meet technology-specific regulations during construction. Administrative feasibility refers to the ability to obtain permits for offsite actions and availability of specific equipment and technical specialists.
- **Cost.** The cost criterion is used to compare different technologies. Typically, the full cost of a given technology cannot be determined at this screening level; however, knowledge

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of typical technology costs obtained from vendors, cost-estimating guides, prior projects, and engineering judgment are used to determine the relative cost of a technology compared with similar technologies.

The evaluation of applicable remedial technologies for each general response action is described below and summarized in Tables 8-1 through 8-4 for DNAPL, soil, groundwater, and surface water/sediment media, respectively. Note that some technologies are classified under multiple general response actions and may be screened differently depending on the intended use. For example, while groundwater pumping can be applied with the objective of either hydraulic containment or removal of contaminants from an aquifer, it is generally more effective as a hydraulic containment measure.

Technologies that pass the screening evaluation are assembled into remedial alternatives in Section 9. When two or more similar technologies are available, or process options are identified within a given technology, a single technology/process option is typically carried forward. Selected technologies/process options, specified as 'retained', are typically proven technologies so that all remedial alternatives consist of reliable technologies that can be evenly compared. Alternate process options ultimately may be selected for a cleanup action during the remedial design phase, based on design-level evaluation of similar options. Promising technologies for which design-level details will need to be developed to fully evaluate their applicability are retained with contingencies such as bench-scale testing.

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Table 8-1
DNAPL Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Institutional Controls	Deed restrictions addressing soil excavation	(See screening summary for soil)			
	Deed restrictions addressing groundwater wells	(See screening summary for groundwater)			
In Situ Containment	Vertical barriers	Medium	High	Medium	Retained
Excavation, Ex Situ Treatment, and Disposal	Pumping from vertical wells or trenches	Medium	Medium	Medium	Retained
	Recycling of recovered DNAPL	High	Low/Medium	Low/Medium	Retained
	Disposal of recovered DNAPL via incineration	High	High	High	Retained as a contingency option
	(Also see removal, *ex situ* treatment, and disposal technologies for soil)				
In Situ Treatment	Steam stripping	Medium	Medium	High	Not retained(1)
	Radio frequency heating	Medium	Low	High	Not retained(1)
	Chemical oxidation	Medium	Medium	High	Not retained(1)
	ElectroChemical remediation technology	Medium	Medium	Medium	Not retained(2)

Notes:

DNAPL Dense non-aqueous-phase liquid

1) These in situ treatment technologies are judged to be significantly less effective, more difficult to implement, and/or more expensive than DNAPL excavation, ex situ treatment, and disposal.

2) The ElectroChemical remediation technology shows promise as an innovative in situ treatment technology, but has not yet been adequately demonstrated.

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Table 8-2
Soil Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Institutional Controls	Fences & warning signs to control access	Medium(1)	High	Low	Retained
	Deed restrictions addressing land use and soil exc.	Medium(1)	High	Low	Retained
In Situ Containment	Permeable soil cover	Medium(1)	High	Low/Medium	Retained
	Low permeability cap	Medium(1)	High	Medium	Retained
In Situ Treatment	Passive venting of soil vapors	Medium	High	Low	Retained(2)
	Vitrification	Medium	Low	High	Not retained(3)
	Solidification/stabilization	Medium	Medium	Medium/High	Not retained(3)
	Soil flushing	Low	Low	High	Not retained(3)
	Soil vapor extraction	Low	Medium	Low/Medium	Not retained(3)
	Chemical oxidation	Medium	Medium	High	Not retained(3)
	Bioremediation	Low	Medium	Medium	Not retained(3)
	ECRT	Medium	Medium	Medium	Not retained(4)
Removal, Ex Situ Treatment, and Disposal	Removal				
	Excavation	High	High	Low	Retained
	Ex Situ Treatment				
	Physical separation	High	High	Low	Retained as a contingency option.
	Solidification/stabilization	High	High	Medium	Retained as a contingency option.
	Thermal desorption	High	High	Medium	Retained as a contingency option.
	Incineration	High	Medium	High	Not retained.(5)
	Solvent extraction	Medium	Low	High	Not retained.(5)
	Soil washing	Low	Low	Medium	Not retained.(5)
	Biotreatment	Medium	Medium	Medium	Not retained.(5)
	Disposal/Reuse				
	Off-site landfill disposal	High	High	Low/Medium	Retained

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Table 8-2
Soil Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Removal, Ex Situ Treatment, & Disposal	Confined on-site disposal	High	Medium	Medium/High	Retained
	On-site reuse	High	High	Low	Retained

Notes:

1) These technologies can be effective in preventing unacceptable exposures, but do not reduce subsurface contamination.

2) Passive venting of soil vapors is retained as a potential technology for protecting structures that may be built on the site while impacted soil remains in-place.

3) These *in situ* treatment technologies are judged to be significantly less effective, more difficult to implement, and/or more expensive than soil excavation and off-site landfill disposal.

4) The ElectroChemical remediation technology shows promise as an innovative *in situ* treatment technology, but has not yet been adequately demonstrated.

5) These *ex situ* treatment technologies are judged to be significantly less effective, more difficult to implement, and/or more expensive than off-site landfill disposal.

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Table 8-3
Groundwater Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Institutional Controls	Deed restriction precluding drinking water use	Medium(1)	High	Low	Retained
Monitored Natural Attenuation	(Note 2)	Medium/High	High	Low	Retained
In Situ Containment	Vertical barriers	Medium/High	High	Medium	Retained
	Pumping from vertical wells or trenches	High	High	High(3)	Retained as a contingency option
	Hydraulic controls	High	High	Low	Retained
In Situ Treatment	Biosparging	Medium/High	High	Medium	Retained as a contingency option
	Treatment wall	Medium/High	Medium	Medium	Retained
	Reactive engineered sediment cap	Medium/High	High	Medium	Retained
Removal, Ex Situ Treatment, & Disposal	Removal				
	Pumping from vertical wells or trenches	Medium	High	Medium	Retained as a contingency option
	Ex Situ Treatment				
	Activated carbon adsorption	High	High	Medium/High	Retained as a contingency option
	Air stripping	Low	High	Low	Not retained(4)
	Advanced oxidation processes	High	High	High	Not retained(5)
	Biological treatment	Medium	Medium	Medium	Retained as a contingency option
	Disposal				
	Discharge to sanitary sewer	High	Medium	Medium	Retained as a

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Table 8-3
Groundwater Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Removal, Ex Situ Treatment & Disposal					contingency option
	Discharge to surface water	High	Medium	Medium	Retained as a contingency option
	Reintroduction to groundwater	High	Medium	Medium	Retained as a contingency option

Notes:

1) Institutional controls can be effective in preventing unacceptable exposures, but do not reduce subsurface contamination.

2) Potentially significant naturally-occurring attenuation mechanisms can include both non-destructive mechanisms (sorption, dispersion, dilution from recharge, and volatilization) and destructive mechanisms (chemical and biological degradation).

3) The comparative cost of "high" for containment via pumping from vertical wells or trenches reflects the fact that the pumped groundwater must be treated and disposed of.

4) Air stripping is not retained as an *ex situ* treatment technology due to low effectiveness.

5) Advanced oxidation processes is not retained as an *ex situ* treatment technology because its cost is judged to be significantly higher than other *ex situ* treatment options.

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Table 8-4
Sediment/Surface Water Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Institutional Controls	Deed restrictions to preclude drinking water use	Medium(1)	High	Low	Retained
	Controls to protect against cap disturbance	Medium(1)	High	Low	Retained
Monitored Natural Recovery	Monitored natural recovery	High	High	Low	Retained
In Situ Containment	Clean sediment cap	Medium(1)	High	Medium	Retained
	Reactive engineered cap	High	Medium	Medium	Retained
	Confined aquatic disposal (no dredging)	High(1)	High	High	Retained
Removal, Ex Situ Treatment and Disposal	Removal				
	Excavation (upland-based)	High	Medium(2)	Medium(2)	Retained
	DryDredging	High	Medium(2)	Medium/High(2)	Retained
	Mechanical dredging	High	Medium(2)	Medium(2)	Retained
	Hydraulic dredging	High	Medium(2)	High(2)	Not retained(3)
	Ex Situ Treatment				
	Physical separation/blending	High	High	Low	Retained.
	Solidification/stabilization	High	High	Medium	Retained
	Thermal desorption	High	High	Medium	Retained as a contingency option
	Incineration	High	Medium	High	Not retained(4)
	Solvent extraction	Medium	Low	High	Not retained(4)
	Soil washing	Low	Low	Medium	Not retained(4)
	Biotreatment	Medium	Medium	Medium	Not retained(4)

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Table 8-4
Sediment/Surface Water Remedial Technology Screening Summary

General Response Action	Potentially Applicable Remedial Technology	Relative Effectiveness	Ease of Implementation	Comparative Cost	Screening Result
Removal, Ex Situ Treatment & Disposal	Disposal/Reuse				
	Off-site (upland) landfill disposal	High	Medium	Medium	Retained
	Confined on-site disposal	High	Medium	Medium/High	Not retained(5)
	On-site (upland) reuse of woodwaste sediments	High	High	Low	Retained
In Situ Treatment	ElectroChemical remediation technology	Low/Medium	Medium	Medium	Not retained(6)

Notes:
1) These technologies can be effective in preventing unacceptable exposures, but do not reduce subsurface contamination.
2) The implementability and cost of sediment removal technologies are highly location-specific.
3) Hydraulic dredging is not retained as a removal technology because its cost is judged to be high relative to other removal options available.
4) These *ex situ* treatment technologies are judged to be significantly less effective, more difficult to implement, and/or more expensive than off-site landfill disposal.
5) Dredged sediments are judged not to be suitable for confined on-site disposal.
6) The ElectroChemical remediation technology shows promise as an innovative *in situ* treatment technology, but has not yet been adequately demonstrated.

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8.1 Institutional Controls

Institutional controls are measures undertaken to limit or prohibit activities that may interfere with a cleanup action or result in exposure to hazardous substances. They may be physical restrictions, such as fences, or legal restrictions, such as use limitations recorded on the property deed.

Potentially applicable institutional controls include the following:

- Fences and warning signs to control access to the Site or specific areas on the Site.
- Deed restrictions addressing land use and soil excavation.
- Deed restrictions to preclude drinking water use.
- Use restrictions and monitoring requirements to prevent disturbance of caps or other engineered controls.

All of the above institutional controls are potentially effective at preventing exposure to hazardous substances, are easy to implement, and can be implemented at relatively low cost. Therefore, they have been retained for further consideration.

8.2 Monitored Natural Attenuation/Recovery

Natural attenuation/recovery is the reduction in concentrations of COPCs in soil, groundwater, and sediment through a combination of naturally occurring physical, chemical, and biological processes. Some natural processes (e.g., sorption of hydrophobic organic contaminants to organic carbon in soil) act as containment mechanisms; others (e.g., biodegradation of contaminants by native bacteria) act as in situ treatment mechanisms.

Natural attenuation of site COPCs (primarily coal tar/creosote constituents) has been widely documented at similar sites. Sorption and biodegradation of key COPCs such as benzene and naphthalene have been documented in a wide range of soil/groundwater and sediment environments at the Quendall Site (see Section 4 of this RA/FS). In particular, relatively consistent (within a factor of 5) biodegradation rates for benzene (0.1 to 0.3 years) and naphthalene (1 to 5 years) have been calculated spanning a wide range of groundwater flow conditions (seepage velocities ranging from 1.6 to 30 meters/day) and soil/sediment properties (TOC levels ranging from 0.3 to 11 percent). The consistency of these site-specific

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biodegradation rates across the Site, as well as their similarity to literature information, supports their broader use in assessments of Site attenuation. Natural recovery of sediments offshore of the Site T-Dock area has also been well documented by the historical record of declining surface and subsurface concentrations of PAHs over the past 13+ years. A more detailed discussion of Natural Attenuation/Recovery at the Quendall Site is provided in Section 4 of this RA/FS.

As a general response action, monitored natural attenuation/recovery provides monitoring to document the presence and effectiveness of natural processes removing or containing Site COPCs. Measures to enhance natural processes are considered under the In Situ Treatment general response action. Potential technologies applied under Monitored Natural Attenuation/Recovery include:

- Characterization and predictive modeling of natural attenuation/recovery processes.
- Performance monitoring of groundwater, soil, and sediment to verify model predictions.

Natural attenuation/recovery will likely be an important mechanism affecting contaminant fate and transport under any cleanup action involving contaminant mass left in place. Monitored natural attenuation/recovery is highly implementable and cost effective at the Quendall Site. Therefore, characterization and monitoring of natural attenuation/recovery of groundwater, soil, and sediment media was carried forward for more detailed analysis in this FS. Because attenuation of relatively high-concentration Site hazardous substance deposits (i.e., DNAPL) has not been demonstrated, natural attenuation/recovery of DNAPL was not carried forward as a potentially applicable technology.

8.3 In Situ Containment

In situ containment involves confining hazardous substances in situ through placement of physical barriers or hydraulic controls. Containment technologies may be designed to prevent contact with and/or migration of the hazardous substances. Use of in situ containment technologies typically results in minimal short-term releases of hazardous substances during construction and can provide a relatively lower cost, effective method of reducing the potential for exposure. The main disadvantage is that containment

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technologies do not typically result in a reduction in contaminant mass, volume, or toxicity. Potentially applicable in situ containment technologies are described below.

8.3.1 Soil Capping

A common method of controlling exposure to soils containing elevated concentrations of COPCs (i.e., above direct contact cleanup levels) is to place an engineered cap over the materials. The long-term cap integrity can be maintained through implementation of appropriate institutional controls. Where practicable, the placement of clean cap materials as necessary to achieve adequate cap thickness may be separated from underlying potentially contaminated materials with a marker (e.g., geotextile fabric) indicating the cap boundary.

Process options for soil capping include:

- **Permeable Soil Capping**. Placing clean soil on the surface provides a barrier that prevents exposure to underlying soil but allows storm water to infiltrate. Permeable soil caps implemented without additional measures (e.g., hydraulic controls) would not address the soil-to-groundwater/surface water pathway for soils beneath the cap. Cap thicknesses of 2 feet are typical in this application, potentially varying based on specific land uses and the presence of existing clean cover materials.
- **Low-Permeability Capping**. A low permeability cap, constructed of low-permeability soil such as clay or an engineered material such as asphalt or concrete, could also be constructed. This cap would not only prevent exposure to underlying soils, but would also minimize storm water infiltration through potentially contaminated materials, thereby reducing mobility of contaminants located in the unsaturated soil zone. Engineered materials could also be used in areas requiring a durable surface, such as high-traffic areas.

Both permeable and low-permeability capping are proven, effective technologies that are easily implemented at the site. Engineered low-permeability caps are significantly more costly, but the added protection may be appropriate under some Site uses to ensure cap integrity. Therefore, both of these technologies have been retained for further consideration of contaminated soil containment.

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8.3.2 Vertical Barriers

The mobility of dissolved-phase contaminants in groundwater and DNAPL can be controlled by installing impermeable vertical barriers across the groundwater flow path. At the Quendall Site, vertical barriers can be keyed into low-permeability soil layers to prevent liquid-phase migration. Typical process options include subsurface walls of interlocking, sealed sheetpile sections, grouted columns, or bentonite slurry.

Although vertical barriers do not reduce contaminant volume or toxicity, they can reduce contaminant mobility for less cost and with fewer short-term impacts than more aggressive removal technologies. Therefore, this technology has been retained for further consideration for containment of contaminated groundwater and DNAPL.

8.3.3 Groundwater Pumping

Migration of contaminants dissolved in groundwater can be controlled by pumping groundwater from vertical wells or trenches, creating a capture zone within which groundwater flows toward the capture point. The effectiveness of this technology to completely capture contaminated groundwater is often limited at sites with heterogeneous soils (such as the Quendall Site). Potential groundwater extraction rates at the Quendall Site are high because of the adjacent lake, and operational costs could be very high if groundwater requires treatment before discharge. Hydraulic containment of groundwater through pumping is also a proven technology; however, its effectiveness is also limited due to the extent of subsurface heterogeneity at the Quendall Site and proximity to the lake. For these reasons, groundwater pumping is not a practicable cleanup method at the Quendall Site. Accordingly, this technology has not been retained for further detailed evaluation in this FS.

8.3.4 Surface Water Controls

Migration of contaminants dissolved in groundwater can also be addressed by controlling hydraulic gradients influenced by surface water. For instance, a hydraulic barrier can be created by collecting and infiltrating storm water and forming a local groundwater 'mound'. Steep hydraulic gradients, caused by surface water accumulation, that mobilize contaminants (e.g., limited and localized discharge of

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hydrocarbon sheen along the shoreline adjacent to Quendall Pond), can be addressed by implementing hydraulic controls that reduce localized infiltration and seepage of stormwater in impacted areas along the shoreline. Hydraulic controls are a relatively cost-effective and easily implementable technology. Therefore, this technology has been retained for further detailed evaluation in this FS.

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8.3.5 Sediment Capping

Similar to upland soil capping, exposure potential can be reduced by placing a layer of clean material above potentially contaminated sediments. Cap monitoring results at other sites in the Puget Sound region have shown capping can provide an opportunity for effective and economical sediment remediation, without the risks involved in removing contaminants by dredging (Sumeri 1996).

Two typical sediment capping technologies are as follows:

- **Thin-Layer Sediment Capping**. Deposition of clean sediment plays a role in the natural recovery of contaminated sediments. Recovery can be enhanced by actively providing a layer of clean sediment to the target area. This is often referred to as "enhanced" natural recovery or thin-layer capping, and generally consists of placing a nominal 6-inch-thick layer of clean sediment over existing contaminated sediments.
- **Thick-Layer Sediment Capping**. Placing a thicker layer of sediment (typically up to 3-feet thick) can provide greater isolation of potentially contaminated sediments. However, thick sediment caps in shallow nearshore areas could eliminate significant areas of aquatic habitat, requiring compensatory mitigation. This technology may potentially be appropriate for consideration in sediment areas with high potential for disturbance (e.g., areas likely to experience propeller wash).

A sediment cap would be designed to effectively contain and isolate contaminated soils and/or sediments from the overlying point of exposure/compliance. The cap would be designed to be thick enough and of sufficient grain size to maintain its integrity under reasonable worst-case environmental and land use conditions. Surface layers of a sediment cap system would likely be constructed of clean sand, and could be placed by

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a number of mechanical and hydraulic methods. Capping has been used frequently in sediment remediation projects conducted in Puget Sound.

Sediment capping is a proven technology to prevent exposure to contaminated sediments and could be easily implemented at the Quendall Site. Thin- and thick-layer sediment caps are relatively inexpensive remediation technologies. Therefore, both technologies have been retained for further consideration for containment of contaminated sediment. Thick-layer sediment caps in shallow nearshore areas are retained contingent on the feasibility of mitigating the potential loss of aquatic habitat.

A variation to traditional sediment capping is discussed in Section 8.4.11, Permeable Reactive/Sorptive Capping, as it incorporates a component of in situ treatment in addition to the containment benefits.

8.3.6 Nearshore Confined Disposal

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Nearshore confined disposal involves the offshore installation of a vertical barrier (Section 8.3.2) in combination with capping (Section 8.3.1) to create a confined disposal facility (CDF) around existing contaminated materials. In some cases, a berm is constructed of clean material near the shoreline, and supplemented with other engineered structures (e.g., sheet piling) to contain contaminated materials in-place. The lower layer of the confined area between the berm and the shoreline consists of contaminated sediment, groundwater, and/or DNAPL. The contaminated materials are covered with clean sediment or fill material to above the ordinary high water level.

Nearshore CDFs can effectively isolate contaminated materials from the adjacent aquatic environment, and they create new land that can be used for water-dependent uses. Nearshore CDFs constructed in the Puget Sound region have often been integrated with upland redevelopment. However, the main disadvantage of a nearshore CDF is that it converts aquatic land to dry land, thereby eliminating aquatic habitat and requiring compensatory mitigation. Nearshore confined disposal has been retained for further consideration contingent on the feasibility of mitigating the potential loss of aquatic habitat.

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8.3.7 Habitat Mitigation for Nearshore Containment Technologies

A key assumption to containment technologies that involve converting aquatic land to dry land is that the lost aquatic habitat can be replaced (i.e., mitigated) at another site location. Aquatic habitat mitigation would involve excavating shoreline upland areas to below the low water mark and creating aquatic habitat with similar characteristics (e.g., depth) to that lost by capping or nearshore confined disposal. This would need to occur in an area that does not result in removal of existing wetland habitat or release of upland contaminants to the newly created aquatic habitat. The feasibility of providing adequate habitat mitigation for containment technologies often depends on design-level details, such as the area of mitigation required.

8.4 In Situ Treatment

A common approach to site remediation is the application of in situ technologies that address contaminant occurrences in the subsurface without removing large volumes of contaminated materials. In situ treatment technologies can potentially reduce the concentration, mobility, and/or toxicity of COPCs. They can also minimize potential releases of hazardous substances and the amount of waste generated. The disadvantage of many in situ treatment technologies is that their effectiveness is often limited by subsurface conditions (e.g., heterogeneous soil layers) that create inefficiencies in treatment processes. In addition to proven in situ technologies, there are a number of innovative treatment technologies at various levels of development that are potentially applicable to the Quendall Site. In general, to the extent that treatment technologies for Site COPCs have been successfully demonstrated at the field scale, they were considered further in this FS. Potentially applicable, demonstrated in situ treatment technologies are described below.

8.4.1 Soil Vapor Extraction

In soil vapor extraction, a vacuum is applied to subsurface soil to remove soil vapor. Volatile contaminants in soil are removed in the vapor stream and are treated above ground. This technology works best on volatile constituents in homogeneous, permeable soils, and is not applicable to saturated zone soils. At the Quendall Site, the groundwater table is very shallow; unsaturated soils are highly heterogeneous and often have a low permeability; and much of the contamination identified in the unsaturated zone consists

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of heavier, semivolatile compounds. Therefore, this technology has not been retained for further consideration.

8.4.2 Passive Soil Venting

Passive soil venting is a less aggressive version of soil vapor extraction that is usually applied to prevent contaminated soil vapors from migrating into buildings or crawl spaces. In passive venting, soil vapors beneath a building foundation are vented to the atmosphere either through atmospheric pressure changes or by applying a low vacuum with a ventilation fan. Vented vapors can be passed through activated carbon for treatment if necessary. Although there are no existing on-site buildings that would require sub-foundation venting, this technology has been retained for consideration under development scenarios that may include permanent, heated buildings.

8.4.3 Steam Stripping

This technology is often used in conjunction with soil vapor extraction to remove volatile and semivolatile compounds from the subsurface. Steam is injected into the subsurface, volatilizing or destroying (by pyrolysis) organic compounds. Contaminated vapors are collected using soil vapor extraction, and contaminants are condensed and/or treated. This technology can be applied to DNAPL and soil in the saturated zone but has the potential for mobilizing contaminants in groundwater by increasing their solubility. Application of this technology at sites with similar contaminants has resulted in inefficient removal, and costs are higher than comparable ex situ treatment technologies. Therefore, this technology has not been retained for further consideration.

8.4.4 Radio-Frequency Heating

This technology is similar to steam stripping in that it applies energy to the subsurface to heat the soil, vaporizing semivolatile contaminants that are then collected and treated using soil vapor extraction. Energy is applied by installing radio frequency antennas in the ground. This technology suffers the same limitations as steam stripping, including potential mobilization of contaminants in groundwater. It also is not a cost-effective technology for treating contamination within the saturated-zone, which significantly limits its application to the Quendall Site. Therefore, this technology has not been retained for further consideration.

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8.4.5 Vitrification

Vitrification involves applying a strong electrical current to the subsurface, heating soil to temperatures above 2,400°F to fuse it into a glassy solid. Organic compounds are destroyed or volatilized by the heating process; volatilized compounds are collected in the off gas and treated. Inorganic compounds are immobilized within the glass. Because of the very high energy requirement, particularly in water-saturated soils, this technology is extremely expensive when compared to other methods of soil treatment, and was not retained for consideration.

8.4.6 Solidification/Stabilization

In this technology, soil or sediment is stabilized by adding amendments to immobilize contaminants. Potential amendments include polymers, pozzolans, and cement. Amendments can be mixed with soil in situ. This treatment method does not destroy contaminants and increases the volume of contaminated material. The ability of this technology to immobilize contaminants in areas containing DNAPL is uncertain, and the cost of in situ stabilization is typically comparable to more reliable, ex situ methods. Therefore, this technology has not been retained for consideration.

8.4.7 Soil Flushing

Soil flushing is an enhancement to groundwater extraction and treatment (described in Section 8.5.6) in which a solution that enhances the solubility of organic contaminants is injected into groundwater, passed through contaminated soil to remove contaminants, and then extracted for treatment. Examples of solutions used include surfactants and alcohols. Field applications of this technology have had mixed results. The effectiveness of soil flushing is limited when applied to heterogeneous, low-permeability soils (such as at the Quendall Site) which cause poor subsurface distribution of the flushing solution and make complete capture of the mobilized contaminants difficult. Incomplete capture of mobilized contaminants at the Quendall Site could result in discharge of hazardous substances to Lake Washington. Therefore, this technology has not been retained for consideration.

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8.4.8 Chemical Oxidation

In this technology, chemical oxidants are injected into the subsurface in solution form to react with and destroy organic contaminants. Common oxidants include hydrogen peroxide, potassium permanganate, ozone, and sodium persulfate, which have been shown to destroy a wide range of contaminants in soil, groundwater, and DNAPL (related electrochemical technologies have also been developed to achieve a similar objective; see Section 8.4.10). The effectiveness of this technology is generally limited in heterogeneous and low-permeability soils due to poor distribution of the oxidants. Additionally, high concentrations of organic matter in the subsurface consume oxidants and decrease treatment efficiency. This technology has also been found to mobilize recalcitrant contaminants by enhancing solubility while providing incomplete destruction. Because the Quendall Site contains heterogeneous soils with peaty layers, and because mobilization of contaminants could adversely impact the adjacent lake, this technology was not retained for further consideration.

8.4.9 Bioremediation

Many of the Quendall Site COPCs, including benzene and naphthalene, can be degraded by native microbial populations. Biodegradation of contaminants under natural conditions is one element of natural attenuation/recovery discussed in Section 8.2. Bioremediation involves adding amendments to the subsurface that support microbial degradation of contaminants. Contaminants at the Quendall Site are primarily hydrocarbons that degrade most efficiently using electron acceptors such as oxygen, nitrate, and sulfate. Oxygen is typically the preferred amendment, but delivery of other electron acceptors is easier under some conditions. Amendments are typically injected into groundwater and can be used to promote bioremediation of groundwater and saturated-zone soil. Bioremediation of unsaturated zone soil is also implementable through bioventing, which is applied similarly to soil vapor extraction (see Section 8.4.1). Bioremediation is generally not applicable to DNAPL, as the high contaminant concentrations restrict microbial growth. Biosparging (adding oxygen to groundwater by injecting air) is typically the most cost-effective bioremediation method.

The effectiveness of bioremediation is limited, like other treatment technologies that rely on subsurface distribution of chemicals, when applied to heterogeneous, low-

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permeability soils. In addition, the large amount of organic matter in shallow soils at the Quendall Site would compete with contaminants as a carbon source, making treatment less efficient. Biosparging could potentially be applied to the deeper groundwater system, which is more homogeneous and permeable. Therefore, bioremediation using biosparging has been retained for further consideration as a contingency option.

8.4.10 ElectroChemical Remediation

ElectroChemical Remediation Technology (ECRT) is an innovative technology for destroying organic contaminants in situ by applying an alternating current across electrodes placed in the subsurface. In theory, the applied voltage creates redox reactions that destroy contaminants. The primary advantage of this technology is that it can treat soil (both within the unsaturated- and saturated-zone), groundwater, and sediment. The disadvantages are that it has produced mixed results at the field level, and studies indicate that treatment is less effective in soils and sediments with high organic carbon content. Therefore, this technology has not been retained for further consideration since it is not a proven technology at the field scale.

8.4.11 Permeable Reactive/Sorptive Capping

This technology is a supplement to the conventional sediment capping options discussed in Section 8.3.4. In permeable reactive/sorptive (PRS) capping, a permeable cap is placed above contaminated sediments, and a material (such as woodwaste, coke, coal, or activated carbon) is placed within the sediment cap to sorb dissolved-phase contaminants, often facilitating further biodegradation, and limiting migration into overlying sediment porewater and surface water. In certain applications, sorptive caps may lose their effectiveness when the sorptive material becomes saturated. Therefore, for continued effectiveness, a sorptive cap should be designed such that one or more of the following design goals are achieved:

- A sufficient volume of sorptive material is added such that its operating lifetime is longer than the projected remediation restoration timeframe.
- A mechanism for replacement of the sorptive layer is incorporated into the design.
- The cap is designed to also biodegrade sorbed contaminants, thereby regenerating the material's sorptive capacity (reactive/sorptive capping).

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Biodegradation within the cap can be enhanced by adding amendments to the sorptive material, such as calcium nitrate. A properly designed cap that combines sorption and biodegradation to treat dissolved-phase contaminants could potentially last indefinitely and not require replacement. Activated carbon (including regenerated products) and more cost-effective coke breeze and coal materials have been used at a number of sites as a sorptive barrier to hydrocarbon mobility, and several promising in situ sediment/porewater treatment technologies are currently undergoing pilot-scale testing in aquatic environments, such as the Anacostia River (Washington, D.C.) demonstration project of reactive cap amendments (including a several inch layer of coke breeze materials underlying a 6-inch-thick permeable sand cap; http://www.hsrc-ssw.org/anacostia/). In addition, organoclay (a modified clay that absorbs free-phase oil and other hydrocarbons) has long been used in water treatment systems to remove sheen or free-phase petroleum before treatment of dissolved-phase contaminants by activated carbon, and has recently been applied as a capping material for sediments containing free-phase hydrocarbon seeps (e.g., the McCormick and Baxter site: http://www.deq.state.or.us/nwr/McCormick_and_Baxter/mccormick.htm).

The PRS cap technology has been retained for further consideration of groundwater treatment in this RA/FS. However, because of the potential for free-phase hydrocarbons to inhibit attenuation properties of the adsorbing layer(s), the PRS cap is only being evaluated in this application to address dissolved groundwater contaminants, not product/sheen discharge.

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Inserted: Organoclay (a modified clay that absorbs free-phase oil and other hydrocarbons) has long been used in water treatment systems to remove sheen or free-phase petroleum before treatment of dissolved-phase contaminants by activated carbon, and has recently been applied as a capping material for sediments containing free-phase hydrocarbon seeps (e.g., the McCormick and Baxter site: http://www.deq.state.or.us/nwr/McCormic

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8.5 Removal, Ex Situ Treatment, and Disposal

Removal of contaminated soil, groundwater, DNAPL, and sediments has been widely applied to contaminated sites. Removed contaminated materials are treated and/or disposed of either on site or at an off-site, permitted disposal facility. This general response action has the advantage of providing (where practicable) the greatest removal of contaminants from a site. Main disadvantages include the potential for short-term releases of hazardous substances during removal operations and technical limitations to removing materials below the water table, particularly near surface water bodies. Potentially applicable

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technologies for removal, ex situ treatment, and disposal of contaminated materials are presented below.

8.5.1 Soil and Sediment Removal Technologies

Contaminated soils and sediments can be effectively removed by dry excavation or dredging; however, some limitations exist as noted in the following evaluation.

Dry Excavation. Excavators, backhoes, and other conventional earth moving equipment are the most common equipment used to remove contaminated soil from upland areas. Dry excavation of nearshore sediments may also be facilitated through the installation of temporary cofferdams and the subsequent lowering of the ground water table. Excavation of upland and extreme nearshore sediments is a proven method; however, costs associated with dewatering are excessive and dewatered fluids would require disposal or treatment prior to discharge into Lake Washington. Therefore, dry excavation is retained for removal of upland soils and extreme nearshore sediments.

Dredging. Dredging is a method of excavation that allows the removal of sediments without the necessary dry conditions required of traditional methods. Dredging is generally accomplished with two main technologies: hydraulic (a method that generally involves pumping material, resulting in a slurry-like material) and mechanical (typically involving the use of a clamshell bucket on a derrick barge).

The main drawback of dredging is that turbidity and oil sheens/slicks may be generated, which in turn may result in reductions in water quality through releases of contaminants associated with sediment particles and DNAPL. Potential transfer of contaminants from the dredging area to adjacent water bodies may be minimized in certain applications through the use of best management practices (BMPs) such as sorbent booms, silt curtains, and temporary sheetpiling. In the case of sheetpiling, a negative hydraulic head may be maintained inside of the sheetpiling to further ensure that dredging-related contamination is contained in the dredging area.

Additional drawbacks associated with hydraulic dredging must be considered. Hydraulic methods produce dredged product that contains approximately 10 to 20

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percent solids by weight. This material, once brought upland, must be dewatered prior to transport off site. The volume of water generated is significantly greater than that produced by mechanical dredging methods. The dewatering fluid, which will likely consist of water and DNAPL, must either be disposed of or treated on site prior to discharge back to Lake Washington. Costs associated with processing and disposal of this additional waste product are high. For these reasons, only mechanical dredging technologies were retained for in-water sediment removal.

8.5.2 Ex Situ Soil and Sediment Treatment Technologies

Potentially applicable treatment technologies for soil and sediment are described and evaluated below.

Physical Separation. The volume of excavated or dredged contaminated materials can be reduced by physically separating the materials into two or more fractions that can be handled separately. For example, cobbles can be screened from contaminated soil and beneficially used. Excess water can be removed from sediments and saturated soils using process options such as a filter press or a hydrocyclone, allowing separate treatment and/or disposal of the liquid and solid fractions. Processing may further be performed on the solid fraction to separate coarse and fine-grained material, as contaminants are generally bound to finer grained particles and not coarser sands and gravels. Physical separation typically can be accomplished at relatively low cost and can reduce overall treatment/disposal costs by reducing contaminant volume. Therefore, this technology has been retained for further consideration.

Solidification/stabilization. This technology involves adding amendments to excavated soil or sediment that immobilize and/or bind contaminants within the stabilized product. Depending upon the proportion of amending agents, the end product may take on the form of a quasi-soil/concrete material that could later be used as bulk fill or a solid mass that could be used as building blocks or tiles. A common application of this technology is to produce construction-grade concrete by adding cement to contaminated soils. In some cases, stabilization agents are added to materials to promote a primary goal of dewatering high solids mixtures; reductions in contaminant mobility then become a secondary benefit of the process.

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While stabilization has been successful using relatively coarse soils and sediments, the generally fine-grained nature of materials at the Quendall Site would require the addition of sand and/or gravel to achieve typical structural requirements. Further, the presence of organic materials typically found in site soils and sediments are of significant concern when applying this process. High organics content can substantially affect stabilization performance and increase costs. Because the stabilization process does not permanently destroy chemical contaminants, the permanence (e.g., long-term durability) of the stabilized matrix would need to be addressed in bench-scale testing. Therefore, this technology was retained for further consideration, contingent on design-level bench-scale testing of its applicability to the Quendall Site.

Thermal Desorption and Combustion. Low-temperature thermal desorption involves heating soils or sediments to temperatures between 200° and 600°F until volatile and semi-volatile compounds such as BTEX and PAHs evaporate. Exhaust gases produced by the process are typically combusted. Thermal desorption systems can be designed to operate without producing liquid or solid secondary wastes, to meet clean air standards, and to achieve very low levels of residual contaminants in soil. Limitations include high energy requirements for treating wet soils, difficulty in completely treating soils containing high levels of organics (such as the woodwaste and peaty soils at the Quendall Site), and the extensive permitting requirements for on-site thermal desorption systems. Thermal desorption may be accomplished on site with a mobile treatment unit or off site at a permanent treatment facility. Compared to off-site landfill disposal, thermal desorption is typically more expensive, but has the advantage of providing treatment and destruction of contaminants rather than containment. Therefore, this technology has been retained for further consideration, contingent on design-level evaluation of its applicability to Site soil and sediment.

Incineration. When soil or sediment is heated to temperatures above 1,400°F, contaminants are directly oxidized. This technology can achieve high treatment efficiencies, but is also extremely expensive, with typical costs two to three times greater that of thermal desorption. Therefore, this technology has not been retained for further consideration.

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Soil Washing. In soil washing, soil or sediment is contacted with an aqueous solution to remove contaminants from the soil particles. The suspension is often also used to separate fine particles from coarser particles, allowing beneficial use of the coarser fraction (if sufficiently clean) at the site. The aqueous solution can contain surfactants or other additives to promote dissolution of contaminants. Soil washing is typically more expensive than thermal desorption, and has limited effectiveness for removing strongly hydrophobic chemicals such as PAHs, particularly from soils with a high organic content. Therefore, this technology was not retained for further consideration.

Solvent Extraction. Solvent extraction is a variant of soil washing in which an organic solvent (instead of an aqueous solution) is contacted with the soil to remove contaminants. This technology is more effective than soil washing at removing hydrophobic organic compounds such as PAHs, but incurs substantial additional costs because the solvent must be carefully controlled, collected, treated, and recycled. Therefore, this technology was not retained for further consideration.

Biotreatment. Biodegradation of contaminants by indigenous soil microbes can be enhanced by amending excavated soil or sediment with nutrients, moisture, and oxygen (typically provided by mixing). Although many of the Quendall Site COPCs are biodegradable and potentially amenable to biotreatment, the recalcitrant nature of many COPCs (particularly the cPAHs in fine-grained soil and DNAPL matrices) would require long treatment times, and complete degradation to proposed soil cleanup levels may not be feasible. Therefore, biotreatment of site soils and sediments was not retained for further consideration.

8.5.3 Soil and Sediment Disposal Technologies

Excavated soils and sediments may either be disposed of directly or treated, using one or more of the technologies retained in the analysis above, and then disposed. At a minimum, saturated soils and sediments would likely require dewatering before disposal. Disposal options for soil and sediment are described below.

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On-Site Beneficial Use. Excavated soils or dredged sediments may potentially be beneficially used on site if they meet applicable cleanup standards. Contaminated soils and sediments could be treated to achieve cleanup standards and then beneficially used on site. Examples of potential beneficial uses of soil and sediments excavated at the Quendall Site include upland use of woodwaste or clean sediments removed as part of habitat mitigation, or reuse of clean overburden soils removed during upland excavation actions. Depending on the application (e.g., topsoil or landscaping materials), dredged woodwaste may require amendment through blending (with sand or other granular material) prior to on-site beneficial use. On-site beneficial use is the most preferred and likely the least costly method of soil and sediment disposal. Therefore, on-site beneficial use has been retained for further consideration.

On-Site Confined Disposal. Excavated soils or dredged sediments exceeding applicable cleanup standards could potentially be placed on site in a specially designed upland CDF. Depending on the leachability of confined materials, the CDF could potentially include a liner and a liquid collection system to prevent leachate from contaminating groundwater. On-site confined disposal can be cheaper than off-site confined disposal, but requires long-term on-site management of contaminated materials. This disposal technology has been retained for further consideration contingent on design-level evaluation of its implementability and cost.

Off-Site Landfill Disposal. Contaminated soils or sediments from the Quendall Site may be transported to an off-site, permitted disposal facility. Contaminated soils at the Quendall Site will likely be characterized as non-hazardous solid wastes, and could be shipped via railcar to facilities such as the Klickitat County Landfill in Roosevelt, Washington. This disposal method provides for secure, long-term containment of non-hazardous solid wastes. Therefore, this disposal technology has been retained for further consideration.

8.5.4 Groundwater and DNAPL Removal Technologies

Groundwater and DNAPL can be removed from the subsurface by pumping fluids from wells or trenches. Process options include:

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Vertical Wells. Vertical wells can be installed with carefully placed screen sections to maximize removal of groundwater or DNAPL from targeted zones. Wells can include sumps for collecting DNAPL if the underlying confining layer is adequately thick. The main disadvantage of vertical wells is the potential for incomplete capture of fluids in heterogeneous soils as well as limited radius of influence in low permeability soils. In some cases, this can be overcome by installing vertical wells at multiple levels and through effective spacing. Because vertical wells are a proven technology, they have been retained as a potential technology for groundwater and DNAPL removal.

Horizontal or Angled Wells. Horizontal drilling techniques have been used at some cleanup sites to install non-vertical wells that provide access to areas where the surface is inaccessible to drilling rigs. This technology could be applied in the nearshore Quendall Pond area to recover DNAPL; however, angled wells targeted to relatively shallow contamination (as observed in this area) would add only a minimal lateral extent compared to vertical wells. Construction of horizontal DNAPL recovery wells is not a proven technology. Therefore, horizontal and angled wells have not been retained for further consideration.

Trenches. Trenches generally allow more effective capture of groundwater and DNAPL than individual vertical wells by providing an expanded zone of influence (capture). Trenches are typically the preferred method for groundwater collection at sites with heterogeneous subsurface soils and a shallow water table (such as the Quendall Site), but constructing trenches for collecting DNAPL may require significant dewatering - which is a significant constraint when working adjacent to the lake. Additionally, in areas of stratified DNAPL occurrences (as observed in the Quendall Pond area) trenching could increase DNAPL vertical mobility. Because of the potential benefit in effectiveness and cost, trenches have been retained as a potential technology for groundwater and DNAPL removal in areas with suitable subsurface stratigraphy.

Groundwater and DNAPL pumped from wells or trenches can either be recovered together or separately. DNAPL that is more viscous than water (as exists at the Quendall Site), and is typically most efficiently recovered separately by low-flow or intermittent pumping, often from a sump constructed in the well or trench, which allows DNAPL in

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the surrounding soil to drain by gravity into the well and collect. When combined with groundwater pumping, oil-wet soil surrounding the well can become water-wet, limiting DNAPL flow toward the well. A variety of pumping options are available for DNAPL and groundwater under both low-flow and high-flow pumping applications, including above-ground pumps (e.g., peristaltic pumps) and down-well pumps (e.g., electric submersible pumps).

8.5.5 Ex Situ Groundwater Treatment Technologies

Potentially applicable treatment technologies for groundwater are described and evaluated below. Inclusion of these technologies in remedial alternatives could occur either if groundwater pumping is selected or if short-term groundwater dewatering is required as part of construction. Groundwater would not need treatment if it meets discharge requirements (e.g., if minimally impacted groundwater is extracted as a containment measure). Disposal options for groundwater are discussed in Section 8.5.6.

Activated Carbon Adsorption. Adsorption of dissolved organic contaminants onto activated carbon is one of the most widely used water treatment technologies. In this technology, contaminated groundwater is passed through a bed of granulated activated carbon, and hydrophobic organic compounds in solution adsorb onto the carbon until the carbon becomes saturated. Advantages of activated carbon adsorption include its proven effectiveness for site COPCs, particularly for achieving high treatment efficiencies. Disadvantages include the need to periodically replace the activated carbon and regenerate or dispose of the used carbon. Because of its proven effectiveness, this treatment technology has been retained for further consideration in combination with groundwater removal technologies.

Air Stripping. In air stripping, contaminated groundwater and air are typically passed counter-currently through a tower, and volatile contaminants (such as benzene and, to a lesser extent, naphthalene) transfer from the water to the air. The contaminant-laden air is usually treated by activated carbon and then discharged to the atmosphere. Air stripping can be cost effective for volatile compounds such as benzene, but it is typically not effective for less volatile compounds like PAHs. Treatment efficiencies for air stripping are generally less than for activated carbon, and air stripping may require

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water polishing by activated carbon for some discharge options. Therefore, this technology has not been retained for further consideration.

Advanced Oxidation Processes. A number of technologies exist that involve adding chemicals that directly oxidize organic contaminants in water. Process options include ozonation, hydrogen peroxide (with or without catalysts such as Fenton's Reagent or ultraviolet light), and permanganate. These technologies can effectively destroy organic chemicals, but treatment costs are generally significantly higher than treatment by activated carbon. Therefore, this technology has not been retained for further consideration.

Biological Treatment. In biological treatment, contaminated groundwater is passed through a biological reactor in which a contaminant-degrading microbial culture is maintained, generally by adding nutrients and oxygen and controlling temperature, pH, and other parameters. Process options include bioslurry reactors, fixed-film bioreactors, and constructed wetlands. Biological treatment has the potential for providing a low-cost treatment method for site COPCs, but the treatability of recalcitrant COPCs (particularly cPAHs) would have to be demonstrated in bench-scale and/or pilot tests. Bioreactors are generally most cost effective for large-scale groundwater treatment systems. This treatment technology has been retained for further consideration in combination with groundwater removal technologies, contingent on bench-scale testing and design-level evaluation.

8.5.6 Groundwater Disposal Technologies

Potential disposal methods of groundwater are described and evaluated below. Some disposal methods may require pre-treatment depending on the quality of the extracted groundwater. Inclusion of these technologies in remedial alternatives could occur if short-term groundwater dewatering is required as part of construction.

Discharge to Sanitary Sewer. In this disposal option, groundwater is discharged to the local sanitary sewer system. Pre-treatment of groundwater may not be required if concentrations of COPCs meet discharge criteria. Water containing high concentrations of solids (e.g., from construction dewatering) would likely need to be passed through a

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settling tank or filter to meet discharge requirements. Fees for disposal of groundwater to the sanitary sewer are based on the volume discharged, and periodic chemical and physical monitoring of discharges are typically required. Allowable discharge volumes may be limited, particularly in the wet season. Because this option may allow discharge of groundwater without substantial on-site treatment, it has been retained for further consideration.

Discharge to Surface Water. Extracted groundwater may also be discharged to surface water, although this discharge option would likely require an NPDES permit. Water discharged to surface water would have to meet strict water quality requirements and would likely require treatment before discharge. However, no discharge fee (besides permitting fees) would be incurred. This technology has been retained for further consideration.

Reintroduction to Groundwater. Extracted groundwater may also be discharged on-site to groundwater via infiltration galleries or injection wells. Contaminated groundwater would likely require treatment before discharge via this method. This is often the preferred method of disposal for water generated during construction at large sites such as the Quendall Site when practicable. Therefore, this technology has been retained for further consideration.

8.5.7 DNAPL Treatment and Disposal Technologies

Treatment and disposal technologies for soil and sediment contaminated with DNAPL are discussed in Section 8.5.3. DNAPL collected from liquid pumping or separated from other waste materials may be classified as a hazardous waste. Disposal options for DNAPL include:

- **Recycling/Reuse**. If available, recycling of DNAPL is the preferred and lowest cost method of disposal, but may not be practicable because of the potential for hazardous waste classification and the low demand for this product. This technology has been retained for further consideration contingent on waste characterization and/or finding an acceptable use.
- **Incineration**. If DNAPL classifies as a hazardous waste and recycling/reuse is found to be impractical, it would likely need to be shipped to a hazardous waste

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treatment facility and incinerated. This is typically a very expensive disposal technology, but the high energy content of DNAPL may reduce the cost somewhat. This technology has been retained for further consideration if recycling/reuse is not practicable.

8.6 Summary of Retained Technologies

Based on the detailed evaluation discussed in the above sections, the following retained technologies were retained for application to site-wide alternatives developed in Section 9.

Monitoring. Under a site monitoring program, the occurrence and transport of Site COPCs would be periodically measured. A detailed monitoring program would be developed in future documents. Potential components of a monitoring program include:

- Sampling and analysis of sediment porewater to monitor chemical concentrations at the conditional point of compliance prior to discharge into surface water (i.e., for groundwater protection of aquatic life, at least 10 cm below the mudline; see Section 5.4).
- Sampling and analysis of groundwater to document natural attenuation processes.
- Sampling and analysis of sediments in the biologically active zone (0 to 10 cm below mudline) to document natural recovery processes.
- Measuring DNAPL location and thickness to monitor mobility of residual free product.
- Inspection of cap integrity and soil sampling.
- Evaluating natural recovery of contaminated media.

Access Restrictions. Access to the Site could be restricted by constructing and maintaining fencing and signs. Where practicable, access by workers to areas of the Site containing subsurface concentrations of COPCs above industrial cleanup levels could also be controlled through the placement of surface caps, geotextile markers, pre-determined utility corridors, and associated institutional controls.

Restrictive Covenants. Effective limitations of future Site uses may be recorded with the property deed. Specific restrictions would be developed in future documents. Potential restrictions include:

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- Restricted use of groundwater or surface water as drinking water.
- Construction requirements in potentially contaminated areas.
- Restrictions on intrusive work (e.g., excavation, pile driving) to ensure cap integrity.

DNAPL Recovery. To recover potentially mobile DNAPL, recovery wells with screened intervals across the DNAPL zone would be installed in areas of recoverable DNAPL. DNAPL would be pumped out of wells, collected, and appropriately reused or disposed off-site. DNAPL pumping would be performed at each well at a rate to minimize water collection. The expected operating period of a DNAPL recovery system is approximately 5 years based on the Site DNAPL recovery pilot test and typical performance of DNAPL recovery systems.

Upland Capping. A protective cap could be placed over parts of the Site as needed based on the intended land use. The upland cap in this application would likely consist of a layer of clean soil or an engineered material such as asphalt. The thickness and composition of the cap would depend on the proposed use of the area: for light uses, a clean sand or gravel cap would likely be sufficiently protective but would not address the soil-to-groundwater pathway without the implementation of additional remedial technologies. For moderate uses, such as light vehicle traffic, asphalt or other engineered cap may be appropriate. For light commercial use, a 2-foot thick cap for landscaped areas would likely be protective, whereas for ground-floor residential use, a 3-foot thick cap may be needed.

Subaqueous Sand Placement. An in situ subaqueous sand cap could be placed over woodwaste-affected and hydrocarbon-impacted sediments that exceed cleanup standards. The cap would be comprised primarily of sand, but may be enhanced with gravel armoring or synthetic materials for additional support against scour and erosion. Alternatively, a relatively thin section of sand (e.g., 6-inches) could also be placed over sediments that are marginally above sediment cleanup levels (e.g., in the T-Dock area) to accelerate natural recovery processes.

Permeable Reactive/Sorptive Sediment Cap. A permeable reactive/sorptive sediment cap could be placed over hydrocarbon-impacted sediments that exceed sediment cleanup levels, to isolate contaminants below the point of compliance, while providing a sorptive barrier to

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dissolved constituent migration and enhancing natural biodegradation processes. Depending on final remedial design analyses, the reactive cap could be constructed using layers of geotextile materials and regenerated active carbon or coarse-grained coke breeze or coal materials. The reactive material would adsorb contaminants as groundwater flows through the cap and enhance existing biodegradation processes. As discussed above, because of the potential for free-phase hydrocarbons to inhibit the attenuation properties of the adsorbing layer(s), the PRS cap was only evaluated in this application to address dissolved groundwater contaminants, not product/sheen discharge.

Offshore DNAPL Cutoff Wall. A vertical, impermeable cutoff could be constructed to contain and prevent migration of affected groundwater and potentially mobile DNAPL. The process options for vertical containment include a slurry wall, grout curtain, or sealed sheet pile wall. The wall could be located offshore along the outer boundary of the mobile DNAPL plume, as described by the conceptual model (Section 4), and would extend into the low permeability, peaty silt layer that serves as an aquitard.

Permeable Reactive/Sorptive Treatment Wall. A subsurface trench perpendicular to groundwater flow could be constructed and backfilled with a sorptive material such as woodwaste (potentially including beneficial use of materials dredged from offshore) to further enhance biodegradation of dissolved-phase contaminants from groundwater. Design of such a permeable wall would likely require bench- and pilot-scale testing to determine appropriate treatment materials and other design criteria. Because groundwater moves through the treatment layer from natural hydraulic gradients (passive treatment), no pumping or aboveground treatment would likely be required in this situation.

Soil Excavation. DNAPL-impacted soil could either be: 1) excavated and either treated on-site and used as backfill; or 2) disposed of off-site, using clean imported materials for backfill. Sediment woodwaste materials may also be used as backfill for upland excavated areas, if the materials meet the chemical and geotechnical requirements for planned site uses. Upland excavations would likely require temporary sheetpile shoring and dewatering systems. Water removed from excavation areas would likely require treatment to remove solids, DNAPL, and dissolved chemicals of concern and then either be discharged on site or to the sanitary sewer.

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Sediment Dredging. Woodwaste and hydrocarbon-impacted sediments that exceed cleanup levels could potentially be dredged and beneficially used on-site (if the materials meet the chemical and geotechnical requirements for planned site uses), or disposed off-site. In this situation, dredging would likely require use of BMPs for water quality controls such as silt curtains, oil booms, bubble curtains, and/or temporary sheet pile containment. Water generated by during dredging and dewatering operations would likely require treatment to remove solids, DNAPL, and dissolved chemicals of concern and then either be discharged on site or to the sanitary sewer. Dredged sediments would be dewatered using a filter press or other equivalent technology to meet disposal requirements. In site areas where woodwaste-affected sediments exceed cleanup levels, woodwaste could be dredged and, as practicable, beneficially used on-site as fill. For beneficial use, the woodwaste may require amendment through blending and/or cement stabilization depending upon the end use of the material (e.g., upland bulk fill or topsoil).

Habitat Mitigation. Capping of nearshore sediment and installation of an offshore cutoff wall would cause a lakeward displacement of the current shoreline. Mitigation would likely be required to compensate for the net loss of aquatic habitat resulting from these actions. For in-kind mitigation, one-to-one (1:1) (aquatic area basis) area replacement may be provided on-site, potentially through the creation of a pocket bay(s) along the northern or southern areas of the site, or on adjacent parcels (pending agreement with such property owners and completion of permitting requirements). Clean materials removed by these activities may be beneficially used as on-site fill.

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9 DESCRIPTION OF SITE-WIDE CLEANUP ALTERNATIVES

Section 8 above describes potentially applicable remedial technologies and process options for the Quendall Site, and evaluates those technologies based on the MTCA criteria of relative cost, effectiveness, and implementability, for application to the Site. In this section, these retained technologies are combined to formulate a range of remedial action alternatives.

The cleanup technologies suitable for the various areas of the Site that contain COPCs in soil, groundwater, and sediment media exceeding cleanup standards (see Section 5) can be grouped in numerous combinations. However, the remedial alternatives are limited to compatible cleanup technologies that are combined to protect human health and the environment. The technologies applied to each media also need to be complementary when implemented in combination.

For the purpose of this FS, a broad range of remediation alternatives that represent a wide spectrum of potentially appropriate remedial technologies and process options was developed. These alternatives include different combinations of natural recovery, capping, removal, disposal, and treatment. When viewed together, the alternatives present a full range of potential remediation options available for the Quendall Site, and highlight tradeoffs associated with implementation of different remedial technologies, consistent with the objectives of the FS.

The remedial alternatives described below have been left intentionally broad with respect to certain remedial options that cannot or should not be specified at the FS level. For example, alternatives that involve excavating contaminated soil may include disposal off-site at a permitted landfill or treatment (either on- or off-site) by thermal desorption prior to disposal or beneficial use. Although thermal desorption could potentially be a feasible process option to treat certain contaminants (as discussed in Chapter 8), site soil characteristics (e.g., the presence of wood waste, peat, and certain metals) could make thermal desorption less effective in certain applications. If selected and identified for further evaluation in the forthcoming Cleanup Action Plan, detailed treatability study and analysis of remedial options, as appropriate, would be accomplished during the design phase.

The following sections include descriptions of each of the six alternatives carried forward into the detailed FS evaluation, arranged in general order of MTCA preference for degree of

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permanence reflected in generally increasing removal/disposal volumes and costs (Table 9-1). Section 10 presents a detailed MTCA evaluation of each alternative.

9.1 Alternative 1: No Action

This is the required baseline alternative. Under this alternative, there would be no cleanup, monitoring, or associated land use actions. The Site would continue to recover naturally over time. No monitoring of natural attenuation/recovery is provided in this alternative.

9.2 Alternative 2: Source Control/Monitored Natural Recovery

All action alternatives evaluated in this FS (i.e., Alternatives 2 through 6) include source controls through removal of recoverable DNAPL within the Quendall Pond and former May Creek channel areas of the Site. Alternative 2 would utilize natural attenuation and monitored natural recovery of downgradient groundwater and sediments to achieve cleanup standards. Long-term monitoring would be performed to verify natural recovery using chemical and/or biological testing methods, and to identify the need and/or scope of possible contingency measures. Hydraulic controls would be implemented to control surface water accumulation and perched groundwater mounding in the Quendall Pond area and potential localized sheen discharges to Lake Washington. Upland soil capping would occur as needed to support specific land uses, but no sediment capping or removal would occur under this alternative. Exposure to contaminated media would be controlled by implementing institutional controls. A plan view and cross section of Alternative 2 is presented in Figures 9-1 and 9-2, respectively.

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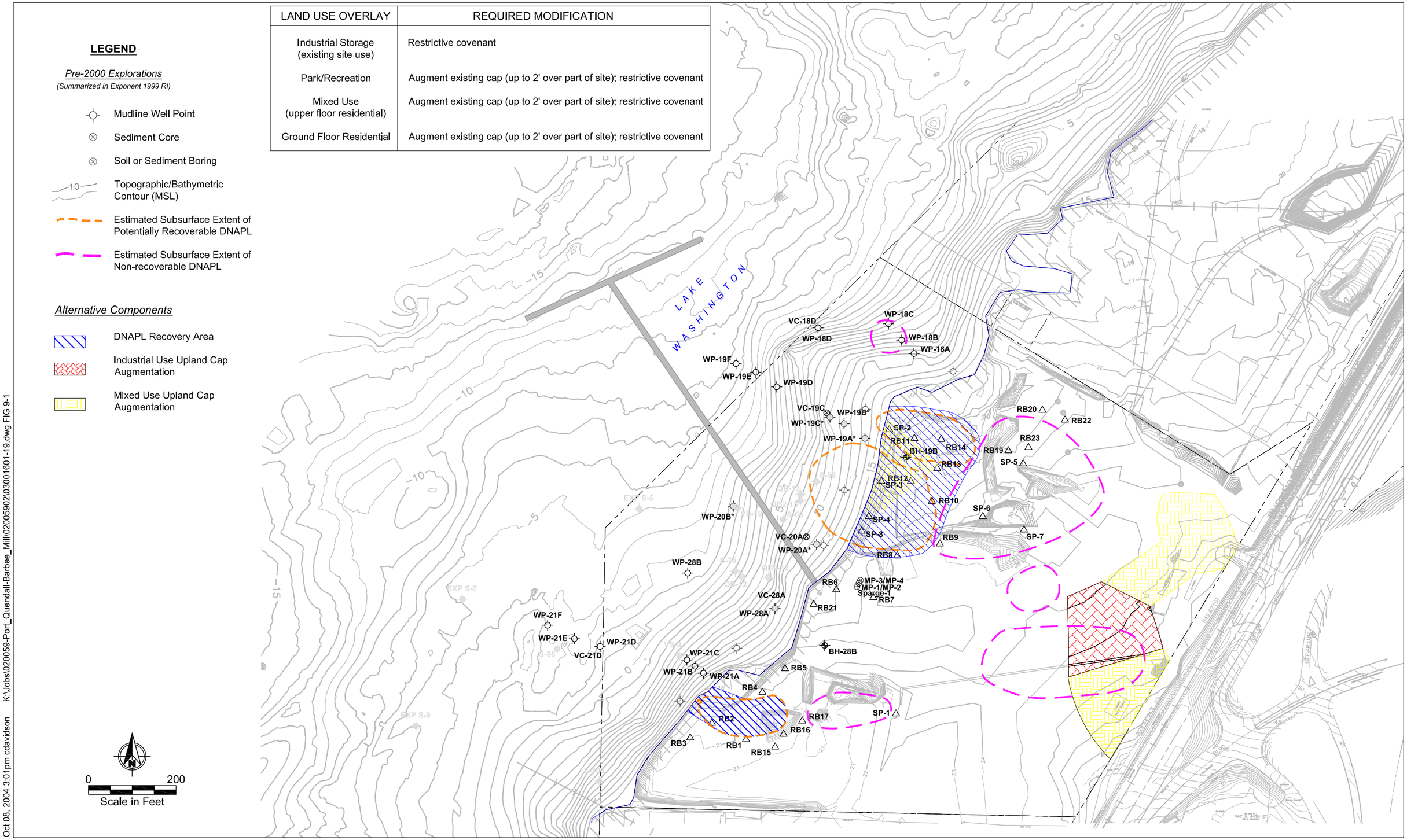
Table 9-1
Remedial Alternatives

Alternative	Components	Application Extent
1 - No Action	None	
2 - Source Control/Monitored Natural Recovery	Upland Cap	Cap enhancement of areas with surface soil exceedences
	Restrictive Covenant	Soil and groundwater
	DNAPL Recovery	Former May Creek Channel and Quendall Pond areas
	Hydraulic Controls	Quendall Pond Area
	Monitoring	Focus on DNAPL, porewater, and sediments
3 - In-Place Containment	Upland Cap	Cap enhancement of areas with surface soil exceedences
	Restrictive Covenant	Soil and groundwater
	Woodwaste Cap - Sand with Armor	Woodwaste-affected sediments near south site boundary
	Sediment Cap - Sand with Armor	Areas with surface sediment or pore water exceedences
	Enhanced Sediment Natural Recovery	Area near former T-Dock
	Offshore DNAPL Cutoff Wall	Former May Creek Channel area and at boundary of Quendall Pond "tongue"
	Focused DNAPL Recovery	Upgradient of cutoff wall - former May Creek and Quendall Pond areas
	Hydraulic Controls	Quendall Pond Area
	Habitat Mitigation	Excavate pocket bay near north site boundary
	Monitoring	Focus on DNAPL, porewater, and sediments
4 - DNAPL Recovery, Woodwaste Dredging/Beneficial Use, PRS Sediment Cap, and Soil Cap	Upland Cap	Cap enhancement of areas with surface soil exceedences
	Restrictive Covenant	Soil and groundwater
	DNAPL Recovery	Former May Creek Channel and Quendall Pond areas
	Hydraulic Controls	Quendall Pond Area
	Woodwaste Dredging	Woodwaste-affected sediments near South site boundary
	Permeable Sorptive/Reactive Sediment Cap	Above areas with sediments or pore water exceedences
	Enhanced Sediment Natural Recovery	Area near former T-Dock
	Habitat Mitigation	Excavate pocket bay near north site boundary
	Monitoring	Focus on DNAPL, porewater, and sediments
5 - Nearshore DNAPL, Soil, and Sediment Removal/Off-Site Disposal, Woodwaste Dredging/Beneficial Use, and Soil Cap	Upland Cap	Cap enhancement of areas with surface soil exceedences
	Restrictive Covenant	Soil and groundwater
	DNAPL Recovery	Former May Creek Channel and Quendall Pond areas
	Soil & DNAPL Excavation/Disposal	Nearshore - Quendall Pond and May Creek Channel area
	Permeable Sorptive/Reactive Treatment Wall	Former May Creek Channel and Quendall Pond areas upgradient of excavated area
	Woodwaste Dredging	Woodwaste-affected Sediments near South Site Boundary
	Sediment Dredging & Disposal	Quendall Pond and May Creek Channel Area
	Enhanced Sediment Natural Recovery	Area near former T-Dock
	Monitoring	Focus on DNAPL, porewater, and sediments
6 - Soil and Sediment Removal/Off-Site Disposal to Support Unrestricted Upland Site Use	Upland Soils Excavation	Surface to 15-ft deep of contaminated soil & accessible DNAPL
	Woodwaste Dredging	Woodwaste-affected Sediments near South Site Boundary
	Sediment Dredging & Disposal	All accessible contaminated sediments
	Restrictive Covenant	Groundwater during restoration period
	Monitoring	Groundwater during restoration period

LAND USE OVERLAY	REQUIRED MODIFICATION
Industrial Storage (existing site use)	Restrictive covenant
Park/Recreation	Augment existing cap (up to 2' over part of site); restrictive covenant
Mixed Use (upper floor residential)	Augment existing cap (up to 2' over part of site); restrictive covenant
Ground Floor Residential	Augment existing cap (up to 2' over part of site); restrictive covenant

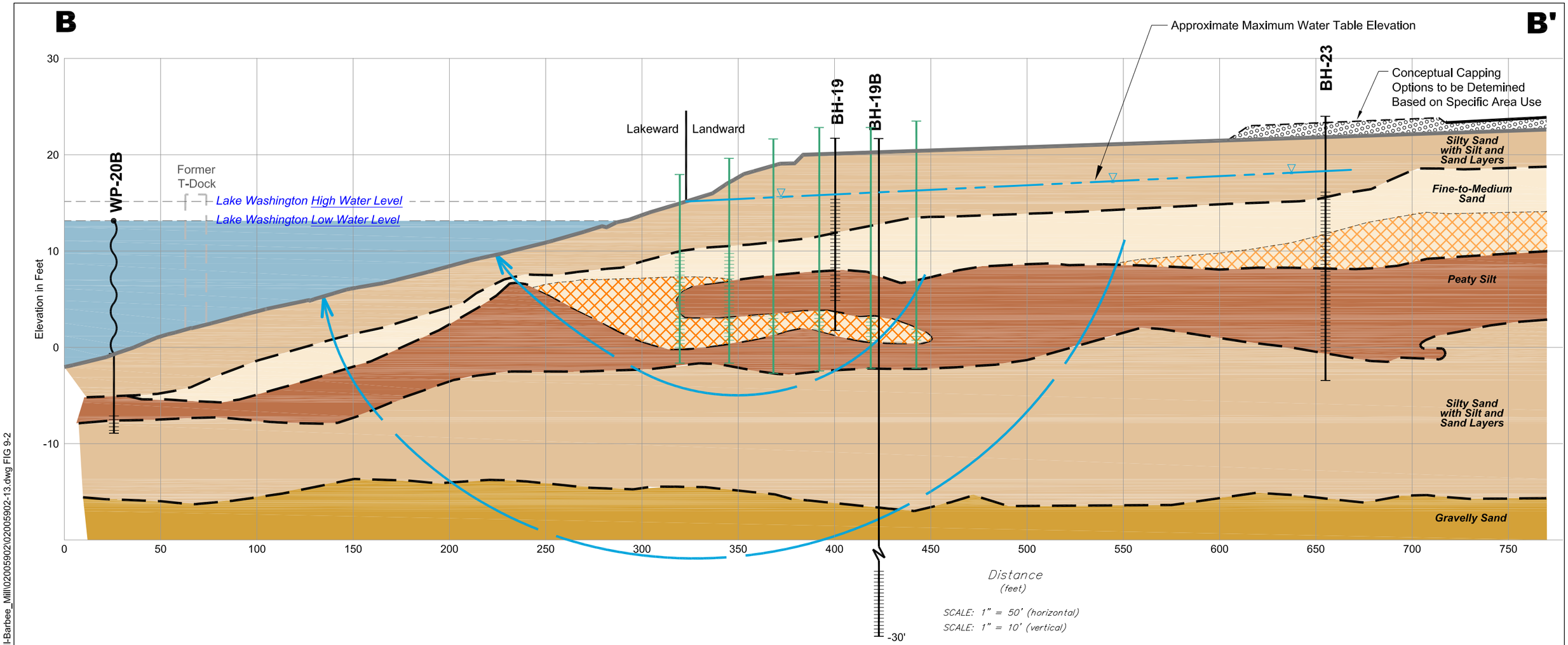


Oct 08, 2004 3:01pm cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\03001601-19.dwg FIG 9-1

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-1
Plan View
Alternative 2: Source Control/Monitored Natural Recovery
Port Quendall Terminals Site



LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Silt and Sand Layers
- Gravelly Sand
- Generalized Groundwater Flow Path [Based on Groundwater Modeling (Retec 1998)]

MONITORING LEGEND

BH-19
- Groundwater Monitoring Well
- Top of Casing
- Screened Interval
- Bottom of Well

WP-20B
- Groundwater Monitoring Well Point
- Top of Casing (Float with Cap)
- Flexible Tubing
- Mud Line
- Well Point Casing
- Screened Interval
- Bottom of Well Point

DNAPL RECOVERY

DNAPL Recovery Well
- Top of Casing
- Screened Interval
- Sump
- Bottom of Well

LAND USE BASED SOIL ACTION

- Clean Soil Cap *(Potentially Applicable for Alternative Site Uses)*
- Asphalt or Concrete Cap *(Potentially Applicable for Alternative Site Uses)*

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

May 28, 2004 11:13am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-13.dwg FIG 9-2

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-2
Cross Sectional View
Alternative 2: Source Control/Monitored Natural Recovery
Port Quendall Terminals Site

This alternative includes the following components:

- **Access Restrictions**. Depending on upland land uses, a fence could be constructed around the upland property boundary to provide access controls. Under alternative land uses, different access restrictions may be appropriate.
- **Restrictive Covenant**. A restrictive covenant would be filed to control the extraction of groundwater, the disturbance of upland caps, and activities potentially encountering or disturbing hazardous materials. A restrictive covenant or other equivalent institutional control (e.g., Consent Decree requirement) would also be executed to ensure implementation of appropriate construction methods for future land use development as needed, including subsurface utilities and structural piling.
- **DNAPL Recovery**. Supplemental subsurface profiling would be conducted to refine the delineation of potentially recoverable DNAPL in the former May Creek Channel and Quendall Pond areas, and support remedial design of an appropriate recovery system. DNAPL recovery wells would be installed in areas where potentially recoverable DNAPL was identified. DNAPL recovery would be performed at each recovery well as practicable. For the purpose of this FS evaluation, DNAPL was assumed to be recovered by pumping from vertical wells and treated through incineration.
- **Hydraulic Controls**. Stormwater would be diverted away from Quendall Pond to alternate detention/infiltration areas to reduce hydraulic mounding in the Quendall Pond area and the potential for localized sheen discharages. Diversion controls would likely include interception ditches and/or constructing a soil berm around the pond.
- **Upland Capping**. Areas with subsurface soils exceeding direct contact and/or ecological risk-based levels would be capped to prevent exposure to affected soils. The design of the cap, including material composition and required thickness, will depend on the intended land use. Results of the recent (2004) sampling of the upper 3 feet of soil at the Quendall Site were used to refine the general extent of additional clean capping material that may be needed to achieve compliance with land use-based cleanup/remediation levels (Table 5-2). Based on these data, certain areas of the Site depicted on Figure 9-1 may require augmentation of existing clean overburden soils to achieve compliance with existing (industrial) or possible future site uses (e.g., commercial/mixed use), with a greater degree of augmentation

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potentially required for certain future site uses. As discussed above, the upland cap in this application would likely consist of a layer of clean soil or an engineered material such as asphalt. The thickness and composition of the cap would depend on the proposed use of the area: for light uses, a clean sand or gravel cap would likely be sufficiently protective. For moderate uses, such as light vehicle traffic, an asphalt or other engineered cap may be appropriate.

- **Monitoring**. The monitoring program would focus on occurrence of DNAPL in the subsurface and occurrence of chemicals of concern in porewater and surface sediments. Monitoring would include ensuring that a surface layer of clean soil is maintained as required based on site use (e.g., industrial, mixed-use) and that hydraulic controls effectively reduce stormwater accumulation and perched groundwater mounding in Quendall Pond and eliminate the discharge of hydrocarbon sheen along the shoreline. Occurrences of chemicals of concern in groundwater and soil would also be periodically monitored to document natural recovery.

9.3 Alternative 3: In-Place Containment

In this alternative, exposure to affected media would be controlled by institutional controls and engineered containment structures. A variety of containment technologies are used to achieve compliance with cleanup standards at the Site, including access restrictions or permeable soil caps as needed to support specific upland uses, conventional sand and gravel sediment caps, and sheet pile placed within the Quendall Pond shoreline area, resulting in construction of a nearshore CDF. On-site habitat mitigation is included in this alternative. Waste production would be minimized and monitoring performed to document natural recovery of affected media. A plan view and cross section of Alternative 3 is presented in Figures 9-3 and 9-4, respectively.

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LAND USE OVERLAY	REQUIRED MODIFICATION
Industrial Storage (existing site use)	Restrictive covenant
Park/Recreation	Augment existing cap (up to 2' over part of site); restrictive covenant
Mixed Use (upper floor residential)	Augment existing cap (up to 2' over part of site); restrictive covenant
Ground Floor Residential	Augment existing cap (up to 2' over part of site); restrictive covenant

LEGEND

Pre-2000 Explorations
(Summarized in Exponent 1999 RI)

- Mudline Well Point
- Sediment Core
- Soil or Sediment Boring
- Topographic/Bathymetric Contour (MSL)
- Estimated Subsurface Extent of Potentially Recoverable DNAPL
- Estimated Subsurface Extent of Non-recoverable DNAPL

Alternative Components

- DNAPL Recovery Area
- Industrial Use Upland Cap Augmentation
- Mixed Use Upland Cap Augmentation
- Subaqueous Sand Cap
- Enhanced Sediment Natural Recovery
- Displaced Shoreline Area
- Potential Mitigation Area
- DNAPL Cutoff Wall
- Potential DNAPL Cutoff Wall

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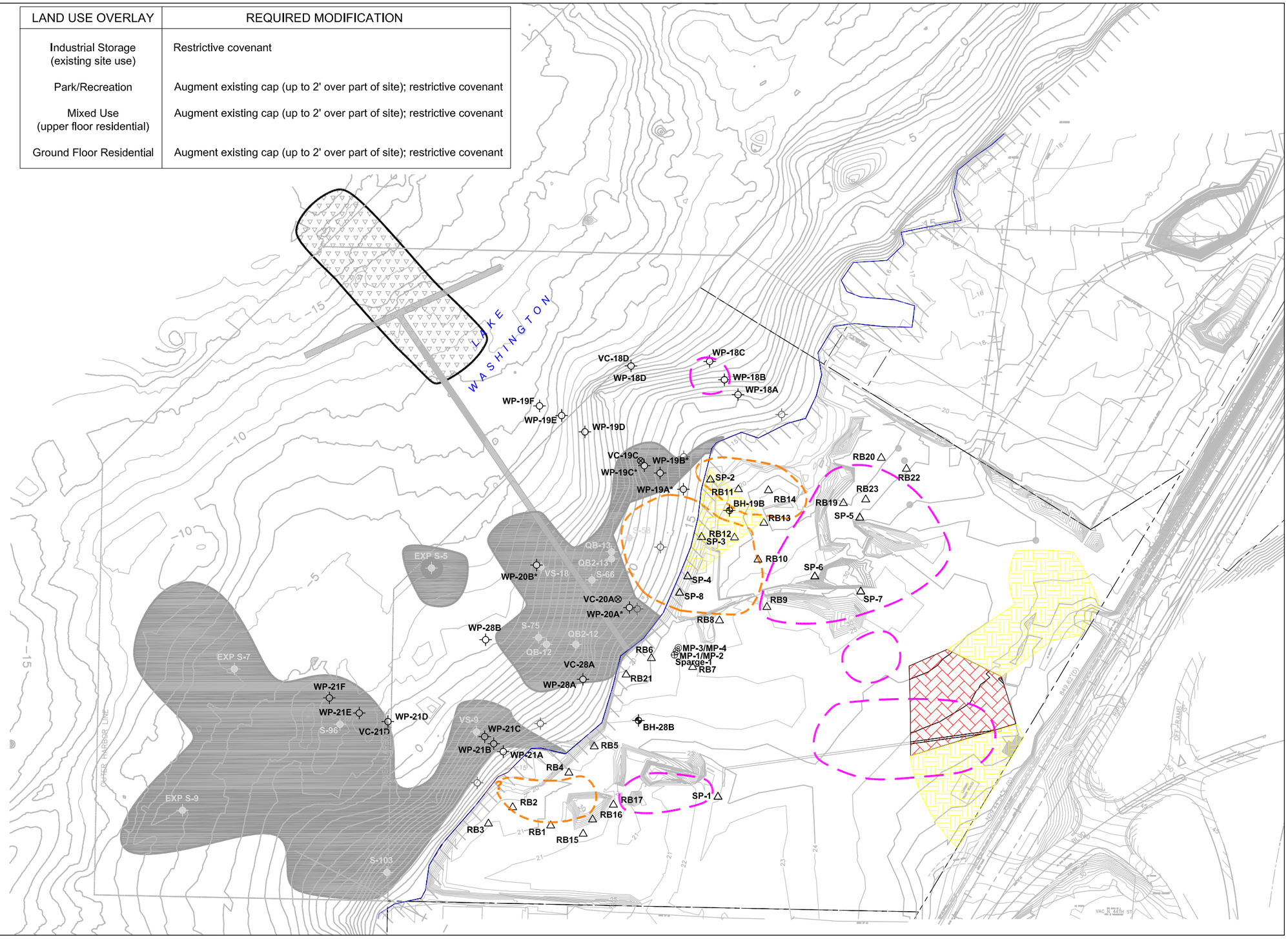
Scale in Feet

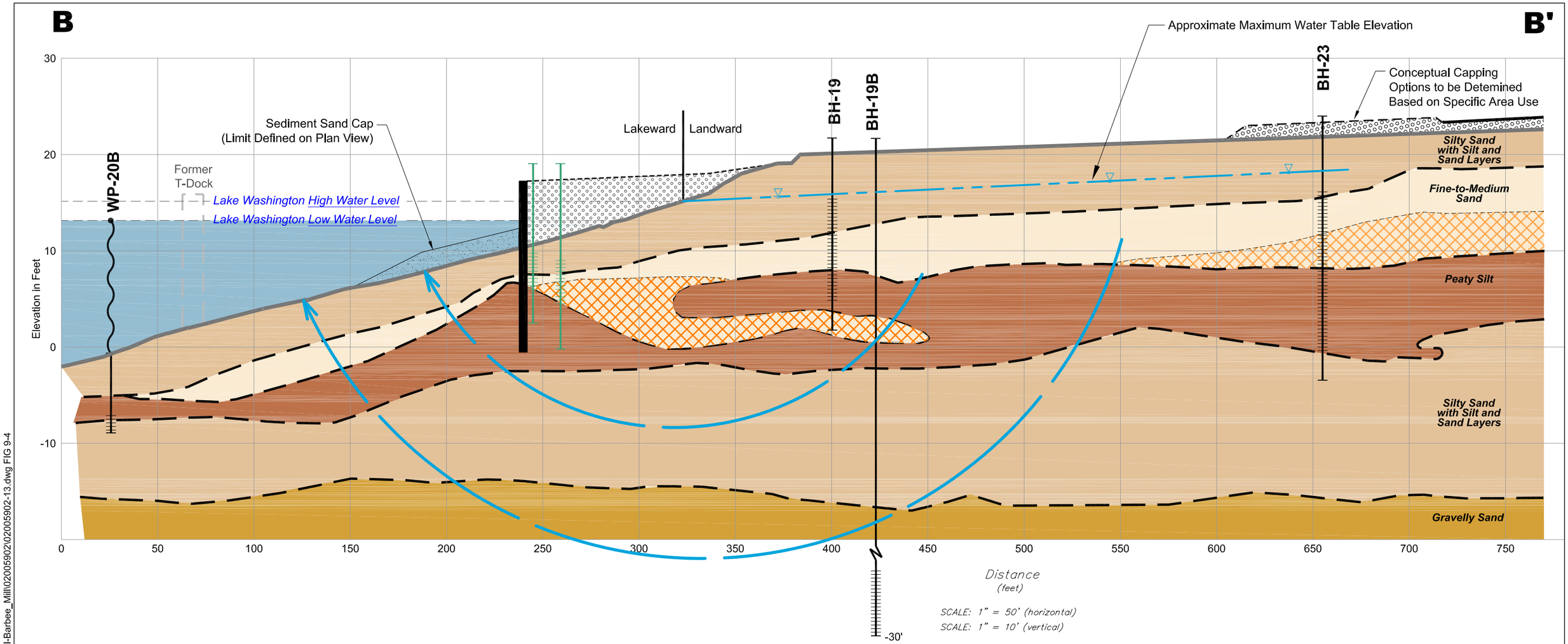


Oct 08, 2004 3:04pm cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\03001601-22.dwg FIG 9-3

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-3
Plan View
Alternative 3: In-Place Containment
Port Quendall Terminals Site



LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Silt and Sand Layers
- Gravelly Sand
- Generalized Groundwater Flow Path [Based on Groundwater Modeling (Retec 1998)]

MONITORING LEGEND

BH-19
- Groundwater Monitoring Well
- Top of Casing
- Screened Interval
- Bottom of Well

WP-20B
- Groundwater Monitoring Well Point
- Top of Casing (Float with Cap)
- Flexible Tubing
- Mud Line
- Well Point Casing
- Screened Interval
- Bottom of Well Point

DNAPL CONTAINMENT WALL

- DNAPL Cutoff Wall
- Clean Soil Fill
- Sediment Sand Cap

FOCUSED DNAPL RECOVERY

- DNAPL Recovery Well
- Top of Casing
- Screened Interval
- Sump
- Bottom of Well

LAND USE BASED SOIL ACTION

- Clean Soil Cap *(Potentially Applicable for Alternative Site Uses)*
- Asphalt or Concrete Cap *(Potentially Applicable for Alternative Site Uses)*

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

May 28, 2004 11:15am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-13.dwg FIG 9-4

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-4
Cross Sectional View
Alternative 3: In-Place Containment
Port Quendall Terminals Site

The components of this alternative include:

- **Access Restrictions**. Depending on upland land uses, a fence could be constructed around the upland property boundary to provide access controls. Under alternative land uses, different access restrictions may be appropriate.
- **Restrictive Covenant**. A restrictive covenant would be filed to control the extraction of groundwater, the disturbance of upland and aqueous caps, and activities potentially encountering or disturbing hazardous materials. A restrictive covenant or other equivalent institutional control (e.g., Consent Decree requirement) would also be executed to ensure implementation of appropriate construction methods for future land use development as needed, including subsurface utilities and structural piling.
- **Hydraulic Controls**. Although seep discharges would be eliminated by placement of the DNAPL cutoff wall, hydraulic controls would still be necessary to minimize groundwater mounding behind the wall. Therefore, as in Alternative 2, stormwater would be diverted away from Quendall Pond to alternate detention/infiltration areas. Diversion controls would likely include interception ditches and/or constructing a berm around the pond.
- **Upland Capping**. Similar to Alternative 2, certain areas of the Site may require augmentation of existing clean overburden soils to achieve compliance with land use-based cleanup/remediation levels. Figure 9-3 depicts general capping area under a representative range of possible future site uses (i.e., industrial and commercial/mixed use).
- **Subaqueous Sand Cap**. A nominal 2-foot sand cap would be placed above the wood debris-contaminated sediment area along the southern portion of the Site and over hydrocarbon-impacted sediments.
- **Enhanced Sediment Natural Recovery**. Natural recovery of sediments near the former T-Dock area that still exhibit residual toxicity (likely attributable to the presence of PAH degradation products) would be accelerated through the placement of a relatively thin layer (nominal 6-inch thickness) of sand materials.
- **Offshore DNAPL Cutoff Wall**. An impermeable cutoff wall would be installed around potentially mobile DNAPL occurrences in the Quendall Pond area and along the shoreline in the former May Creek Channel area. For the purpose of the FS evaluation, the containment wall was assumed to be constructed of sealed steel

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sheetpile sections. The cutoff wall would extend offshore as needed based on the extent of DNAPL occurrences. Aquatic habitat behind the cutoff wall would be filled using on-site materials as practicable, or with clean imported fill. The toe of the wall would be graded with habitat substrate from the ordinary high water line to the existing slope of the lake bottom.

- **Focused DNAPL Recovery**. A focused DNAPL recovery well system would be installed immediately upgradient of the cutoff wall. DNAPL would be recovered as practicable from these wells to prevent buildup of DNAPL behind the wall. For the purpose of this FS evaluation, DNAPL was assumed to be recovered by pumping from vertical wells and treated through incineration.
- **Habitat Mitigation**. Displaced shoreline, as the result of capping and installation of the cutoff wall, would be mitigated at a 1:1 aquatic area ratio based on the ordinary high water line of Lake Washington. Approximately 1 acre of on-site, in-kind mitigation would likely be required under this alternative.
- **Monitoring.** The monitoring program would focus on occurrence of DNAPL in the subsurface and occurrence of chemicals of concern in porewater and surface sediments. Monitoring would also include ensuring a surface layer of clean soil will be maintained as required based on site use, and that aquatic cap integrity is maintained. Occurrences of COPCs in groundwater and soil would be periodically monitored to document natural recovery.

9.4 Alternative 4: DNAPL Recovery, Woodwaste Dredging/Beneficial Use, PRS Sediment Cap, and Soil Cap

Under this alternative, source control would be accomplished by removing recoverable DNAPL from the subsurface to the extent practicable. Exposure to contaminated media would be controlled by dredging woodwaste-affected sediments, installing a reactive sediment cap, and implementing institutional controls. Hydraulic controls would be implemented to enhance reactive cap performance by controlling surface water accumulation and perched groundwater mounding in the Quendall Pond area and preventing potential localized sheen discharges along the shoreline. Monitoring would document natural recovery of site soils, groundwater, and sediments. On-site habitat mitigation is included in this alternative, though less mitigation is required compared to

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Alternative 3. A plan view and cross section of Alternative 4 is presented in Figures 9-5 and 9-6, respectively.

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LAND USE OVERLAY	REQUIRED MODIFICATION
Industrial Storage (existing site use)	Restrictive covenant
Park/Recreation	Augment existing cap (up to 2' over part of site); restrictive covenant
Mixed Use (upper floor residential)	Augment existing cap (up to 2' over part of site); restrictive covenant
Ground Floor Residential	Augment existing cap (up to 2' over part of site); restrictive covenant

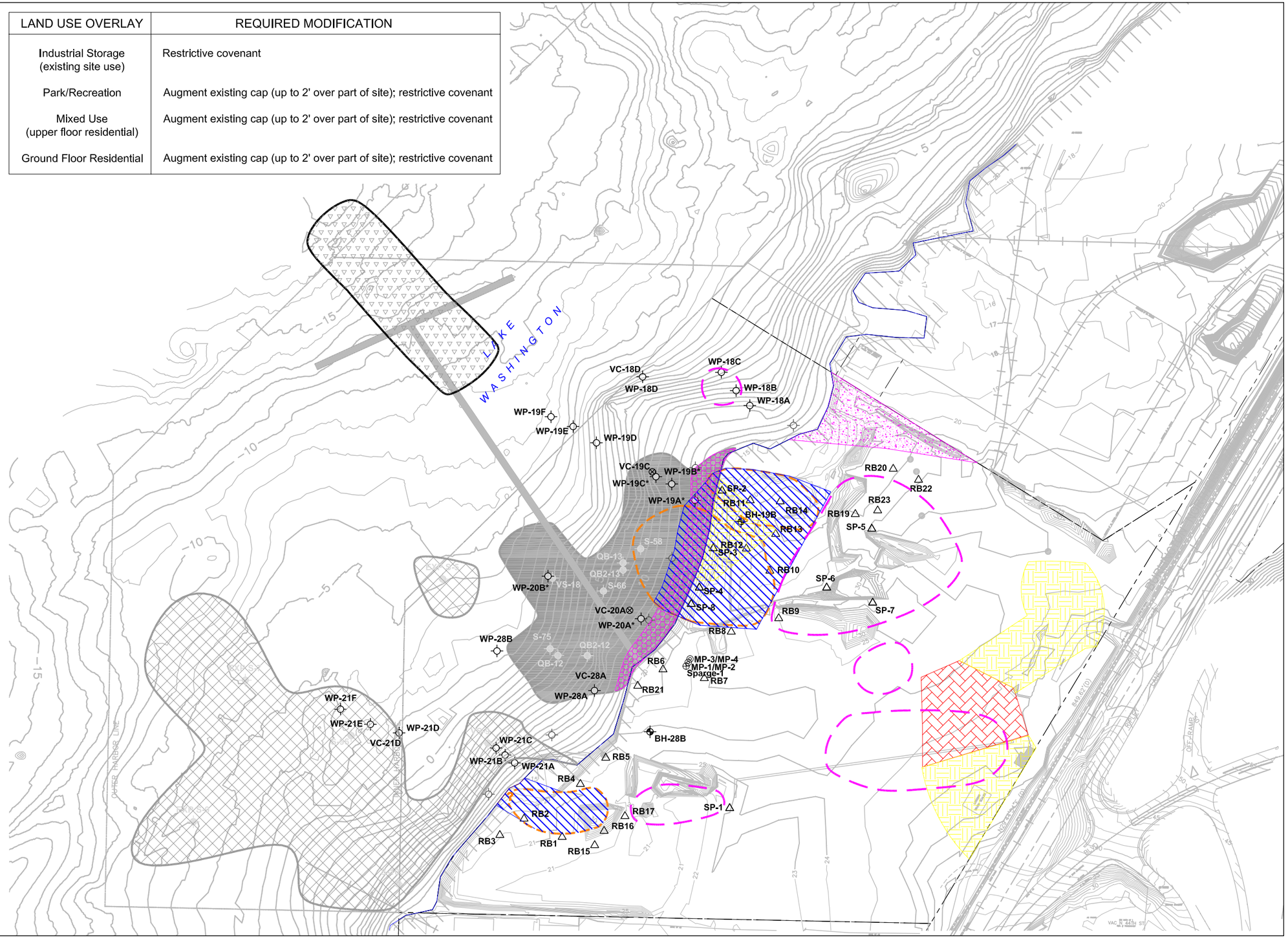
LEGEND

Pre-2000 Explorations
(Summarized in Exponent 1999 RI)

- Mudline Well Point
- Sediment Core
- Soil or Sediment Boring
- Topographic/Bathymetric Contour (MSL)
- Estimated Subsurface Extent of Potentially Recoverable DNAPL
- Estimated Subsurface Extent of Non-recoverable DNAPL

Alternative Components

- DNAPL Recovery Area
- Industrial Use Upland Cap Augmentation
- Mixed Use Upland Cap Augmentation
- Enhanced Sediment Natural Recovery
- Woodwaste Dredging Area
- Displaced Shoreline Area
- Potential Mitigation Area
- Reacitve Sediment Cap

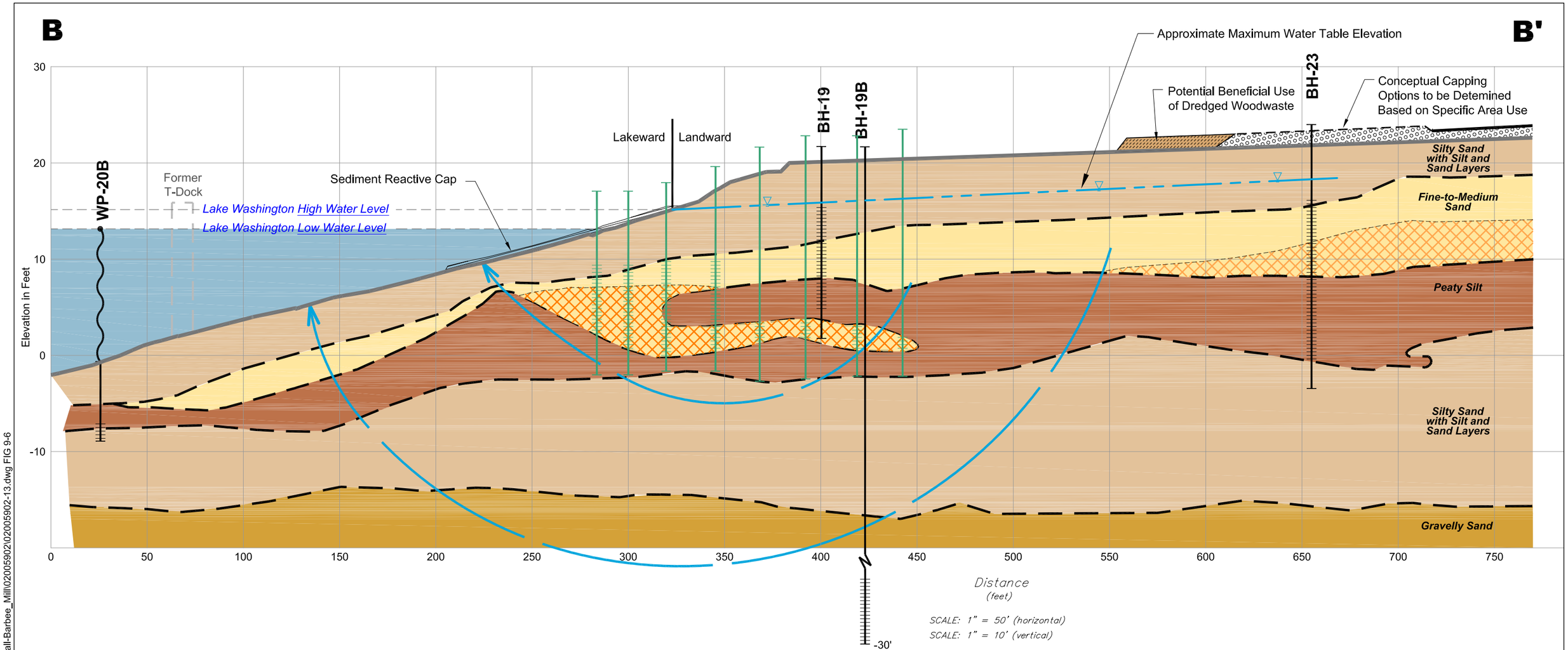


Oct 08, 2004 3:03pm cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\03001601-21.dwg FIG 9-5

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-5
Plan View
Alternative 4: DNAPL Recovery, Woodwaste Dredging/Beneficial Use, PRS Sediment Cap, and Soil Cap
Port Quendall Terminals Site



LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Silt and Sand Layers
- Gravelly Sand
- Generalized Groundwater Flow Path [Based on Groundwater Modeling (Retec 1998)]

MONITORING LEGEND

BH-19
- Groundwater Monitoring Well
- Top of Casing
- Screened Interval
- Bottom of Well

WP-20B
- Groundwater Monitoring Well Point
- Top of Casing (Float with Cap)
- Flexible Tubing
- Mud Line
- Well Point Casing
- Screened Interval
- Bottom of Well Point

DNAPL RECOVERY

DNAPL Recovery Well
- Top of Casing
- Screened Interval
- Sump
- Bottom of Well

LAND USE BASED SOIL ACTION

- Clean Soil Cap *(Potentially Applicable for Alternative Site Uses)*
- Asphalt or Concrete Cap *(Potentially Applicable for Alternative Site Uses)*
- Potential Beneficial Use of Dredged Woodwaste
- Sediment Reactive Cap

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

May 28, 2004 11:22am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-13.dwg FIG 9-6

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-6
Cross Sectional View
Alternative 4: DNAPL Recovery, Woodwaste Dredging/Beneficial Use, PRS Sediment Cap, and Soil Cap
Port Quendall Terminals Site

This alternative includes the following components:

- **Access Restrictions**. Depending on upland land uses, a fence could be constructed around the upland property boundary to provide access controls. Under alternative land uses, different access restrictions may be appropriate.
- **Restrictive Covenant**. A restrictive covenant would be filed to control the extraction of groundwater, the disturbance of upland and aqueous caps, and activities potentially encountering or disturbing hazardous materials. A restrictive covenant or other equivalent institutional control (e.g., Consent Decree requirement) would also be executed to ensure implementation of appropriate construction methods for future land use development as needed, including subsurface utilities and structural piling.
- **Hydraulic Controls**. As in Alternative 2, stormwater would be diverted away from Quendall Pond to alternate detention/infiltration areas. Diversion controls would likely include interception ditches and/or constructing a berm around the pond.
- **Upland Capping**. Similar to Alternatives 2 and 3, certain areas of the Site may require augmentation of existing clean overburden soils to achieve compliance with land use-based cleanup/remediation levels. Figure 9-5 depicts general capping area under a representative range of possible future site uses (i.e., industrial and commercial/mixed use).
- **DNAPL Recovery**. As in Alternative 2, supplemental subsurface profiling would be conducted to refine the delineation of potentially recoverable DNAPL in the former May Creek Channel and Quendall Pond areas, and support design of a recovery system. DNAPL recovery wells would be installed in areas where potentially recoverable DNAPL was identified. DNAPL recovery would be performed at each recovery well as practicable. The area to be addressed is greater than in Alternative 2 because the sediment cap in this alternative (see below) will create upland access to areas that are now aquatic lands. For the purpose of this FS evaluation, DNAPL was assumed to be recovered by pumping from vertical wells and treated through incineration.
- **Woodwaste Dredging**. Woodwaste-affected areas would be dredged and, as practicable, beneficially used on-site as fill. For on-site beneficial use, the woodwaste may require amendment through blending and/or cement stabilization depending upon the end use of the material (e.g., fill behind the cutoff wall or topsoil). For the

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purpose of this FS evaluation, woodwaste dredging was assumed to be performed with mechanical dredging equipment with perimeter silt curtains installed to minimize transport of suspended sediment.

- **PRS Sediment Cap**. A reactive sediment cap would be placed in areas where sediments and porewater exceed cleanup levels. The reactive cap would be designed to enhance existing biodegradation processes, likely through the addition of regenerated activated carbon, coke breeze materials, select coal materials (e.g., anthracite, with suitably low concentrations of accessory chemicals) and/or other amendments (e.g., nitrate or sulfate-releasing compounds). The design of the reactive cap is expected to be informed by an ongoing field-scale reactive cap demonstration project in the Anacostia River (http://www.hsrc-ssw.org/anacostia/). For the purpose of this FS evaluation, the permeable sorptive/reactive sediment cap was assumed to consist of a thin layer (2 inches) of coke or suitable coal materials, overlain with a nominal 1-foot-thick layer of sand and erosion protection materials (e.g., gravel/cobble). For the FS analysis, the required thickness of the coal/coke layer was estimated by applying the Monte Carlo contaminant transport model described in Section 4.5 to the PRS cap scenario, assuming that worst-case groundwater concentrations of benzene and naphthalene (up to the water solubility level) could potentially occur underneath the active layer (much lower concentrations were actually observed at the well point locations; see Table 4-1). A typical TOC level of coke and coal materials of 80 percent (dry weight basis) was used in the model. The modeling runs suggested that a 2-inch thickness of coke or coal placed on the existing sediment surface, overlain with 1 feet of sand, would have a 95 percent or greater confidence of achieving porewater (and sediment) cleanup levels well below the point of exposure/compliance (i.e., more than 10 cm below the top of the sand cap). Given the conservative assumptions used in this FS analysis, a 2-inch-thick coke/coal layer was assumed to provide more than sufficient protection. Further analyses would be performed during remedial design to verify the required layer thicknesses and optimize performance of the PRS cap system. Again, because of the potential for free-phase hydrocarbons to inhibit attenuation properties of the adsorbing layer(s), the PRS cap was only evaluated in this application to address dissolved groundwater contaminants, not product/sheen discharge. Up-front DNAPL recovery and upland hydraulic controls are integrated into this alternative

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to ensure that free-phase product migration does not have the potential to adversely affect the performance of the PRS cap. In order to allow sufficient time to implement such upland source control actions, the target implementation schedule for the PRS cap is 5 years from the effective date of the Consent Decree, similar to the implementation time frames for other nearshore DNAPL control options evaluated in this FS. Implementation time frames are discussed in more detail in Section 10.2.1.

- **Enhanced Sediment Natural Recovery**. Natural recovery of sediments near the former T-Dock area that still exhibit residual toxicity (likely attributable to the presence of PAH degradation products) would be accelerated through the placement of a relatively thin layer (nominal 6-inch thickness) of sand materials.
- **Habitat Mitigation**. Displaced shoreline, as the result of capping, would be mitigated at a 1:1 aquatic area ratio based on the ordinary high water line of Lake Washington. Approximately 0.6 acres of mitigation would be required under this alternative.
- **Monitoring**. The monitoring program would focus on occurrence of DNAPL in the subsurface and occurrence of chemicals of concern in porewater and surface sediments. Monitoring would include ensuring a surface layer of clean soil is maintained as required based on site use, and that aquatic cap integrity is maintained. Occurrences of COPCs in groundwater and soil would also be periodically monitored to document natural recovery.

9.5 Alternative 5: Nearshore DNAPL, Soil, and Sediment Removal/Off-Site Disposal, Woodwaste Dredging/Beneficial Use, and Soil Cap

Under this alternative, source control would be accomplished by removing DNAPL from the subsurface to the extent practicable and by excavating DNAPL-contaminated sediments. Exposure to contaminated media would be controlled by dredging woodwaste-affected sediments, installing a passive treatment wall, and implementing institutional controls. Monitoring would document natural recovery of site soils, groundwater, and sediments. No habitat mitigation would be required under this alternative. A plan view and cross section of Alternative 5 is presented in Figures 9-7 and 9-8, respectively.

This alternative includes the following components:

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- **Access Restrictions**. Depending on upland land uses, a fence could be constructed around the upland property boundary to provide access controls. Under alternative land uses, different access restrictions may be appropriate.
- **Restrictive Covenant.** A restrictive covenant would be filed to control the extraction of groundwater, the disturbance of upland and aqueous caps, and activities potentially encountering or disturbing hazardous materials. A restrictive covenant or other equivalent institutional control (e.g., Consent Decree requirement) would also be executed to ensure implementation of appropriate construction methods for future land use development as needed, including subsurface utilities and structural piling.
- **Upland Capping.** Similar to Alternatives 2 through 4, certain areas of the Site may require augmentation of existing clean overburden soils to achieve compliance with land use-based cleanup/remediation levels. Figure 9-7 depicts general capping area under a representative range of possible future site uses (i.e., industrial and commercial/mixed use).
- **DNAPL Recovery.** As in Alternative 2, supplemental subsurface profiling would be conducted to refine the delineation of potentially recoverable DNAPL in the former May Creek Channel and Quendall Pond areas. DNAPL recovery wells would be installed in areas where potentially recoverable DNAPL was identified. DNAPL recovery would be performed at each recovery well as practicable. The area to be addressed is less than in Alternatives 2 and 4 because much of the mobile DNAPL area would be removed by nearshore soil excavation and sediment dredging (see below). For the purpose of this FS evaluation, DNAPL was assumed to be recovered by pumping from vertical wells and treated through incineration.
- **Nearshore Soil Excavation.** During dredging of contaminated sediments (see below), accessible contaminated soil and DNAPL would be excavated from nearshore areas where soil concentrations exceed cleanup levels. Excavated areas would be backfilled to the current grade. For the purpose of this FS evaluation, dewatering would be used to facilitate dry excavation of upland soil below the water table. Excavated soils would be further dewatered (using mechanical methods) as appropriate, transported via rail, and disposed of off-site at a permitted facility such as the Klickitat County Landfill, located in Roosevelt, Washington.

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- **Passive PRS Treatment Wall.** Along the upland boundary of the excavated area, dredged woodwaste deemed suitable for on-site fill would be placed as a vertical, permeable treatment wall to treat dissolved-phase contaminants migrating in groundwater from areas not excavated. For the purpose of this FS evaluation, the PRS treatment wall was assumed to be constructed of a mixture of woodwaste and gravel.
- **Enhanced Sediment Natural Recovery.** Natural recovery of sediments near the former T-Dock area that still exhibit residual toxicity (likely attributable to the presence of PAH degradation products) would be accelerated through the placement of a relatively thin layer (nominal 6-inch thickness) of sand materials.
- **Woodwaste Dredging.** Woodwaste-affected areas would be dredged and, as practicable, beneficially used on-site as fill. For beneficial use, the woodwaste may require amendment through blending and/or cement stabilization depending upon the end use of the material (e.g., fill behind the cutoff wall or topsoil).
- **Sediment Dredging.** Sediments exceeding cleanup levels, including subsurface DNAPL-impacted sediments near Quendall Pond, would be dredged. Material generated during dredging may be separated and/or cement stabilized as practicable, and disposed of offsite. Dredging of this material may require the use of best management practices for water quality controls, including silt curtains, oil booms, bubble curtains, temporary sheetpiling, or some combination of these process options. For the purpose of this FS evaluation, sediment dredging was assumed to be performed with mechanical dredging equipment with temporary sheetpiling to prevent transport of suspended sediment and DNAPL. Dredged areas would be backfilled to current grade.
- **Monitoring.** The monitoring program would focus on occurrence of DNAPL in the subsurface and occurrence of chemicals of concern in porewater and surface sediments. Monitoring would include ensuring a surface layer of clean soil is maintained as required based on site use. Occurrences of COPCs in groundwater and soil would also be periodically monitored to document natural recovery.

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LAND USE OVERLAY	REQUIRED MODIFICATION
Industrial Storage (existing site use)	Restrictive covenant
Park/Recreation	Augment existing cap (up to 2' over part of site); restrictive covenant
Mixed Use (upper floor residential)	Augment existing cap (up to 2' over part of site); restrictive covenant
Ground Floor Residential	Augment existing cap (up to 2' over part of site); restrictive covenant

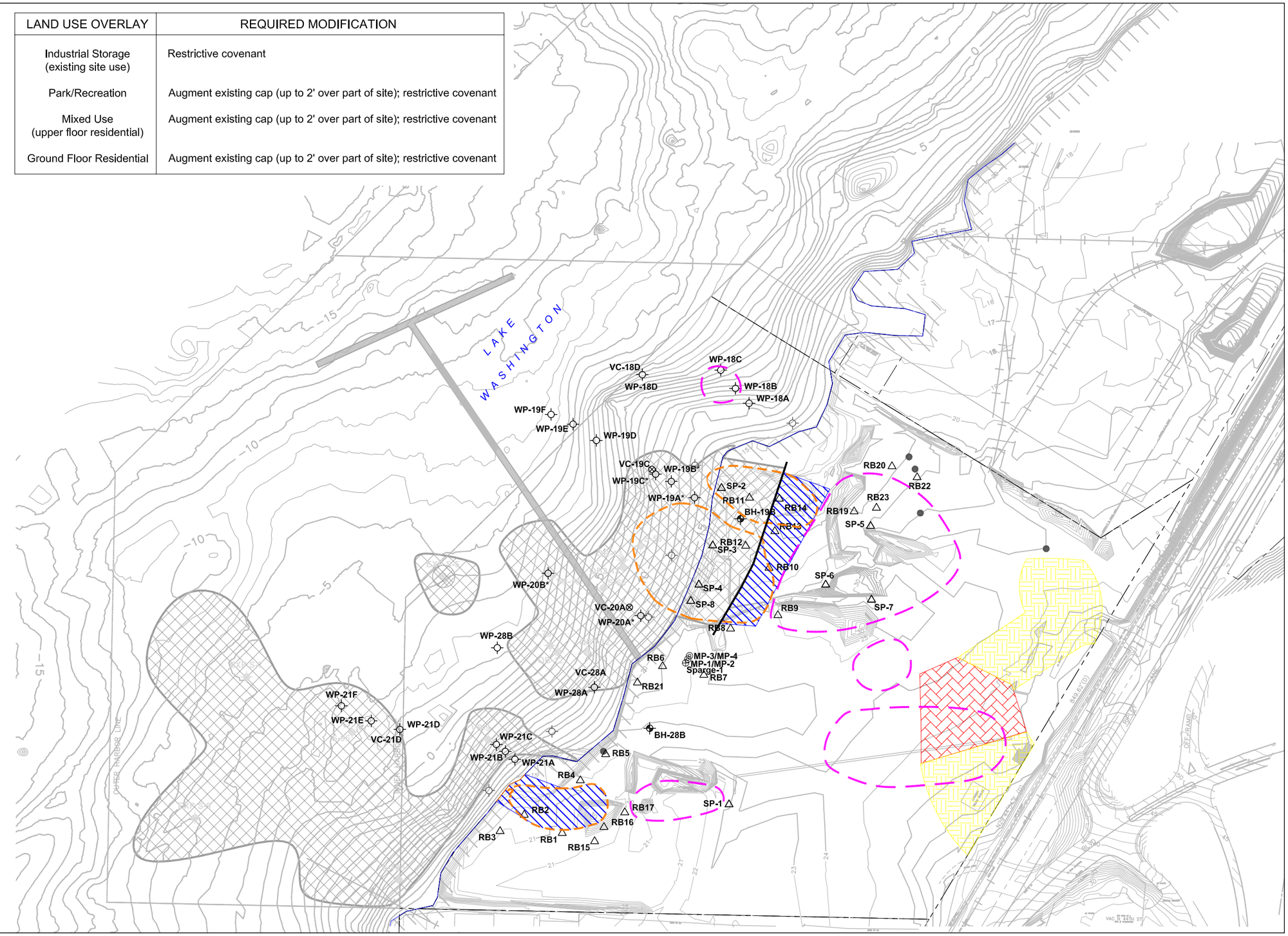
LEGEND

Pre-2000 Explorations
(Summarized in Exponent 1999 RI)

- Mudline Well Point
- Sediment Core
- Soil or Sediment Boring
- Topographic/Bathymetric Contour (MSL)
- Estimated Subsurface Extent of Potentially Recoverable DNAPL
- Estimated Subsurface Extent of Non-recoverable DNAPL

Alternative Components

- DNAPL Recovery Area
- Woodwaste & Sediment Dredging/Nearshore Excavation Area
- Passive Treatment Wall
- Industrial Use Upland Cap Augmentation
- Mixed Use Upland Cap Augmentation
- Enhanced Sediment Natural Recovery

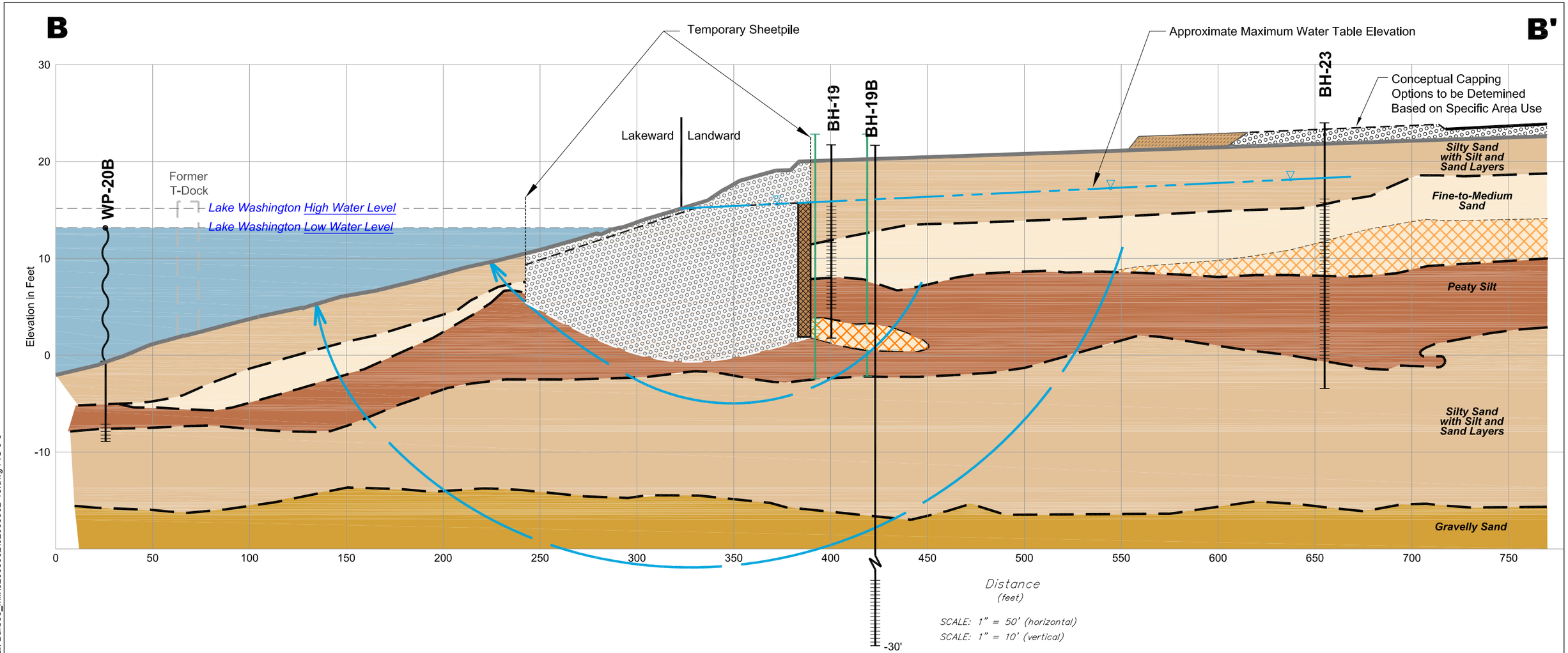


Oct 08, 2004 3:06pm cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\03001601-20.dwg FIG 9-7

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-7
Plan View
Alternative 5: Nearshore DNAPL, Soil, and Sediment Removal/Off-Site Disposal, Woodwaste Dredging/Beneficial Use, and Soil Cap
Port Quendall Terminals Site



LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Silt and Sand Layers
- Gravelly Sand
- Generalized Groundwater Flow Path [Based on Groundwater Modeling (Retec 1998)]

MONITORING LEGEND

BH-19
- Groundwater Monitoring Well
- Top of Casing
- Screened Interval
- Bottom of Well

WP-20B
- Groundwater Monitoring Well Point
- Top of Casing (Float with Cap)
- Flexible Tubing
- Mud Line
- Well Point Casing
- Screened Interval
- Bottom of Well Point

DNAPL RECOVERY

DNAPL Recovery Well
- Top of Casing
- Screened Interval
- Sump
- Bottom of Well

ALTERNATIVE 5 REMEDIATION

- Passive Treatment Wall *(Woodwaste)*
- **Area of Soil Excavation and Backfill**
  Clean Soil Backfill
- **Potential Beneficial Use of Dredged Woodwaste**

LAND USE BASED SOIL ACTION

- Clean Soil Cap *(Potentially Applicable for Alternative Site Uses)*
- Asphalt or Concrete Cap *(Potentially Applicable for Alternative Site Uses)*

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

May 28, 2004 11:24am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-13.dwg FIG 9-8

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Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-8
Cross Sectional View
Alternative 5: Nearshore DNAPL, Soil, and Sediment Removal/Off-Site Disposal, Woodwaste Dredging/Beneficial Use, and Soil Cap
Port Quendall Terminals Site

9.6 Alternative 6: Soil and Sediment Removal/Off-Site Disposal to Support Unrestricted Upland Site Use

This alternative consists of the maximum technically feasible removal of impacted soils and sediments to achieve cleanup standards. The goal of this alternative is to minimize the restrictions and institutional controls necessary at the Site. A cross section of Alternative 6 is presented in Figure 9-9.

To maintain the existing site use, this alternative would include the following components:

- **Soil Excavation**. All accessible DNAPL-impacted soils and soils exceeding site use cleanup/remediation levels, to a maximum depth of 15 feet, would be removed. The Site would be backfilled with clean materials to current grades. For the purpose of this FS evaluation, dewatering would be used to facilitate dry excavation of upland soil below the water table. Excavated soils would be further dewatered (using mechanical methods) as appropriate, transported via rail, and disposed of off-site at a permitted facility such as the Klickitat County Landfill, located in Roosevelt, Washington.
- **Sediment Dredging**. All accessible woodwaste- and hydrocarbon-impacted sediments, including T-Dock sediments with residual toxicity, would be removed. Dredged areas would be backfilled with clean materials to current grades. Dredged sediments would be rehandled on site uplands, dewatered (using mechanical methods) as appropriate, transported via rail, and disposed of off-site at a permitted facility such as the Klickitat County Landfill, located in Roosevelt, Washington.
- **Restrictive Covenant**. Under this alternative, contaminated groundwater beyond the practicable extent of excavation would likely be left in place for the short term until natural recovery removes residual contamination. Therefore, a restrictive covenant would be filed to control the extraction of groundwater until the restoration period is complete.
- **Monitoring**. The monitoring program would include verification sampling of soils and sediments left in place after excavation and dredging. Monitoring after the soil and sediment removal action would focus on the occurrence of COPCs in groundwater until data indicate the restoration period is complete.

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For alternative land uses with a minimum of restrictions, this alternative would include the above components but all soil to a depth of 15 feet exceeding cleanup levels would be excavated and removed. As above, a short-term restoration period for deep groundwater is expected, and during this period a restrictive covenant would be filed to control the extraction of groundwater and a groundwater monitoring program conducted.

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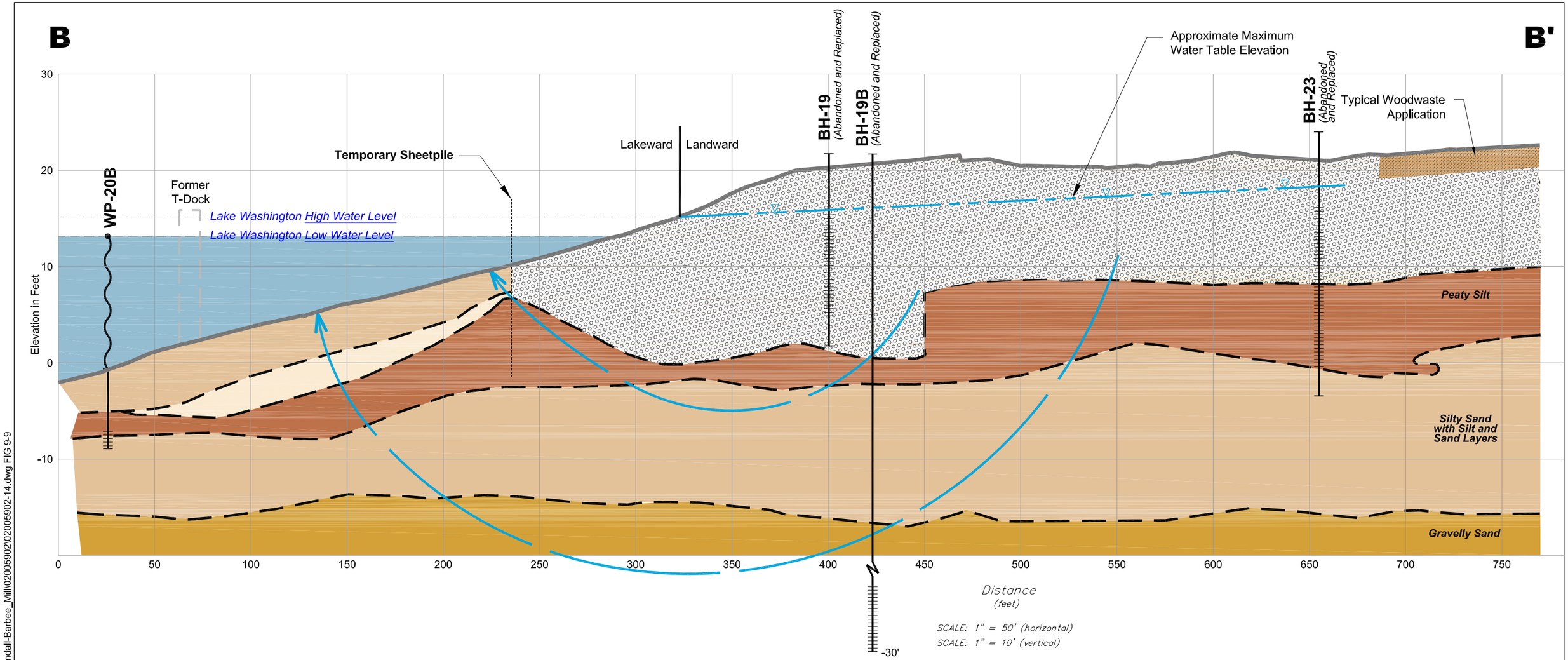

May 28, 2004 11:25am cdavidson K:\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-14.dwg FIG 9-9

LEGEND

- Inferred Geologic Contact
- Fine-to-Medium Sand
- DNAPL
- Peaty Silt
- Silty Sand with Silt and Sand Layers
- Gravelly Sand
- Generalized Groundwater Flow Path [Based on Groundwater Modeling (Retec 1998)]

MONITORING LEGEND

BH-19
- Groundwater Monitoring Well
- Top of Casing
- Screened Interval
- Bottom of Well

WP-20B
- Groundwater Monitoring Well Point
- Top of Casing (Float with Cap)
- Flexible Tubing
- Mud Line
- Well Point Casing
- Screened Interval
- Bottom of Well Point

ALTERNATIVE 6 REMEDIATION

- **Area of Soil Excavation and Backfilll**
  Clean Soil Backfill
- Potential Beneficial Use of Dredged Woodwaste

Notes

Datum: Horizontal: NAD27, Washington State Plane (North Zone)
Vertical: (MSL)

Stratigraphy below 0 feet elevation is conceptual based on observed stratigraphy and typical geomorphology of detail deposits.

ANCHOR ENVIRONMENTAL, L.L.C.

Aspect consulting IN-DEPTH PERSPECTIVE

Figure 9-9
Cross Sectional View
Alternative 6: Soil and Sediment Removal/Off-Site Disposal to Support Unrestricted Upland Site Use
Port Quendall Terminals Site

10 EVALUATION OF REMEDIAL ALTERNATIVES

This section provides a comparative evaluation of the six remedial alternatives described in Section 9, to support selection of a preferred cleanup action in accordance with MTCA requirements. MTCA identifies specific criteria against which alternatives are to be evaluated, and categorizes them as either "threshold" or "other" criteria. All cleanup actions must meet the requirements of the threshold criteria. The other MTCA criteria are considered when selecting from among the alternatives that fulfill the threshold requirements. The six remedial alternatives are evaluated against the threshold criteria in Section 10.1, and against the other MTCA criteria in Section 10.2.

Although this section is organized to specifically address MTCA evaluation criteria, cleanup action requirements under other ARARs (as summarized in Section 7) are also incorporated into the discussion as appropriate. For example, the guidelines in 40 CFR 230.10(c) regulating discharges to waters of the U.S. were considered in evaluations of short-term risks (e.g., potential for contaminant releases during construction) and the effectiveness over the long term (e.g., potential for long-term discharges to surface water). Similarly, the Compensatory Mitigation Policy for Aquatic Resources (Chapters 75.20 and 90.48 RCW) was also considered in the evaluation of ARAR compliance of individual alternatives.

The six remedial alternatives were evaluated assuming the existing industrial storage use as the baseline land use condition. These remedial alternatives were evaluated for other land use options after modifying selected cleanup components as necessary to address risks and exposures associated with each potential site use. These modifications affect the extent to which a particular remedial technology is applied (e.g., different cap thicknesses and provisions for institutional controls dictating appropriate construction methods for subsurface utilities and structural piling). However, these potential upland land use options do not require implementation of technologies that are not already part of the baseline alternative. Where these modifications affect the evaluation of the remedial alternatives (e.g., with respect to cost), they are identified and discussed in the text.

The remedial alternatives described in Section 9 include process options that have been left intentionally broad at the feasibility-study level. Selection between specific remedial process options requires a detailed evaluation that is appropriately performed in the remedial design

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phase. For example, alternatives that involve removing DNAPL, soil, and/or sediments do not specify whether these materials will be treated (either on- or off-site), disposed off-site at a permitted landfill, and/or beneficially used. Detailed analysis of remedial process options, potentially requiring focused treatability testing, would be accomplished during the remedial design phase.

10.1 Threshold Criteria

The threshold MTCA requirements for a selected cleanup action are as follows:

- Protect Human Health and the Environment
- Comply with Cleanup Standards and Applicable State and Federal Laws
- Provide for Compliance Monitoring

In Section 5, site-specific cleanup levels for site COPCs and conditional points of compliance for environmental media were developed in consideration of applicable laws. Taken together, the site-specific cleanup levels and points of compliance are referred to as cleanup standards. The overall protectiveness that a cleanup alternative provides depends on its ability to meet cleanup standards for site COPCs. All six alternatives are expected to ultimately achieve compliance with cleanup standards and ARARs, although the estimated time required to accomplish such compliance (restoration time frame, evaluated below) may vary among the alternatives.

In addition to achieving cleanup standards, MTCA also requires that groundwater cleanup actions provide protectiveness by removing free-phase product to the extent practicable and providing containment for non-recoverable product. Alternatives 2 through 6 address this requirement by providing active removal of identified recoverable DNAPL deposits through pumping and/or excavation within the Quendall Pond and former May Creek channel areas. However, DNAPL deposits present in off-shore sediments may not be recovered under all alternatives. Nevertheless, site characterization data indicate that further migration of DNAPL occurring off-shore below the lakebed sediments is currently controlled by low-permeability soil layers (e.g. stratified peat) acting as stratigraphic traps, preventing direct discharge of DNAPL into Lake Washington. This feature of the conceptual site model, discussed in more detail in Section 4, was integrated into the protectiveness evaluation summarized below.

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Of the proposed alternatives, Alternative 1 (No Action) does not meet threshold requirements because it does not provide for DNAPL removal and does not include monitoring to ensure compliance with cleanup standards. Based on the site conceptual model presented in Section 4, Alternatives 2 through 6 all achieve the threshold requirements, as these alternatives protect human health and the environment, will result in compliance with cleanup standards, and provide for appropriate protection and compliance monitoring. More detailed assessments of restoration time frames and other relevant MTCA considerations are provided below.

10.2 Other MTCA Criteria

In this section, the remedial alternatives are comparatively evaluated against the following MTCA criteria:

- Provision for a reasonable restoration time frame
- Permanence
- Effectiveness over the long term
- Management of short-term risks
- Technical and administrative implementability
- Consideration of public concerns
- Cost

Similar evaluation criteria are specified under the SMS. The definition of each of these criteria and a summary of how they relate to evaluation criteria under the SMS are provided in Table 10-1.

This comparative evaluation of remedial alternatives was based on quantitative analysis where possible, and included preliminary FS-level cost estimates. For criteria which could not be accurately quantified, a qualitative analysis was performed. The degree to which the alternatives meet the evaluation criteria is summarized in Table 10-2.

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Table 10-1

MTCA/SMS Feasibility Study Evaluation Requirements

MTCA *WAC Chapter 173-340-360(3)(f)*	SMS *WAC Chapter 173-204-560(4)*
(i) Protectiveness. Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.	**(f)(iii)(A)** Overall protection of human health and the environment, time required to attain the cleanup standard(s), and on-site and off-site environmental impacts and risks to human health resulting from implementing the cleanup alternatives **(f)(iii)(B)** Attainment of the cleanup standard(s) and compliance with applicable federal, state, and local laws
(ii) Permanence. The degree to which the alternative permanently reduces the toxicity, mobility or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.	
(iii) Cost. The cost to implement the alternative, including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are cost recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analytical, labor, and waste management costs. The design life of the cleanup action shall be estimated and the cost of replacement or repair of major elements shall be included in the cost estimate.	**(h)** Cost, including consideration of present and future direct and indirect capital, operation, and maintenance costs and other foreseeable costs
(iv) Effectiveness over the long term. Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain onsite at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.	**(f)(iii)(D)** Long-term effectiveness, including degree of certainty that the alternative will be successful, long-term reliability, magnitude of residual, biological and human health risk, and effectiveness of controls for ongoing discharges and/or controls required to manage treatment residues or remaining wastes cleanup and/or disposal site risks
(v) Management of short-term risks. The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.	**(f)(iii)(C)** Short-term effectiveness, including protection of human health and the environment during construction and implementation of the alternative
(vi) Technical and administrative implementability. Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.	**(g)** Ability to be implemented. The ability to be implemented including the potential for landowner cooperation, consideration of technical feasibility, availability of needed off-site facilities, services and materials, administrative and regulatory requirements, scheduling, monitoring requirements, access for construction, operations and monitoring, and integration with existing facility operations and other current or potential cleanup actions
(vii) Consideration of public concerns. Whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.	**(i)** The degree to which community concerns are addressed
	(j) The degree to which recycling, reuse, and waste minimization are employed[1]
	(k) Environmental impact. Sufficient information shall be provided to fulfill the requirements of chapter 43.21C RCW, the State Environmental Policy Act. Discussions of significant short-term and long-term environmental impacts, significant irrevocable commitments of natural resources, significant alternatives including mitigation measures, and significant environmental impacts which cannot be mitigated shall be included.[1]

Notes
1) Criteria applicable only to the evaluation of sediment remediation components of the alternatives.

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Table 10-2
Summary of Evaluation Results with Respect to MTCA Criteria

Alternative	Compliance with Cleanup Standards; Protection of Human Health and the Environment	Evaluation Criterion [1,2]					Cost	
		Reasonable Restoration Time Frame	Permanence	Long-Term Effectiveness	Short-Term Risk Management	Implement-ability	Industrial Storage	Mixed Commercial
1 - No Action	-	-	-	-	+	+	$0	$0
2 - Source Control with Monitored Natural Recovery	+	-/o	o	o	+	+	$2.7 Million	$3.1 Million
3 - In-Place Containment and Nearshore DNAPL Recovery	+	+	o/+	+	+	o/+	$6.4 Million	$6.7 Million
4 - Source Control, Woodwaste Dredging/Reuse, and Reactive Sediment Cap	+	+	+	o/+	+	+	$5.7 Million	$6.1 Million
5 - Woodwaste Dredging, Sediment Dredging, and Nearshore DNAPL Recovery	+	+	+	+	o	o	$17 Million	$17 Million
6 - Soil and Sediment Removal and Disposal	+	+	o/+	+	-	-	$110 Million	$110 Million

Legend:

- The alternative satisfies the criterion to a low degree.
o The alternative satisfies the criterion to a moderate degree.
+ The alternative satisfies the criterion to a high degree.

Notes:

(1) The threshold criteria discussed in Section 10.1, which must be satisfied for an alternative to be acceptable under MTCA, are not included in this table. All alternatives except Alternative 1 are judged to satisfy the threshold criteria.

(2) Consideration of public concerns is not addressed in this table since the public has not yet had an opportunity to provide comments.

10.2.1 Provision for a Reasonable Restoration Time Frame

For the purposes of this FS evaluation, the restoration time frame for each medium was considered to be the time until cleanup standards are met at the point of compliance for that medium. Calculation details supporting the restoration time frame analysis below is presented in Appendix D. The restoration time frame analysis used as its basis the estimated percentage of contaminant mass at the Quendall Site that would be addressed by treatment or containment actions. The restoration time frame calculations were based in large part on estimates of the area of DNAPL occurrences over which individual technologies could be applied under the different remedial alternatives, as discussed below.

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Pilot testing has demonstrated the effectiveness of DNAPL recovery through pumping in the Quendall Pond and former May Creek Channel areas. Placement of a DNAPL recovery system along the shoreline may also be effective at removing recoverable DNAPL in off-shore sediments adjacent to the site. However, the degree of effectiveness for recovery of off-shore DNAPL is uncertain. Subsurface characterization of the near shore area (see Section 4) indicates that DNAPL in the off-shore areas is contained or isolated by low-permeability peaty-silt deposits which effectively limit further lateral movement toward the lake. The remedial design program would include collection of additional data to evaluate the effectiveness of different DNAPL recovery process options, leading to optimization of the design as practicable.

DNAPL recovery through pumping will not remove all of the DNAPL mass at the site. The recoverable mass of total DNAPL is a function of the soil characteristics and nature of the DNAPL free product and is generally limited to that fraction present above residual saturation within the soils/sediment. Non-recoverable, residual DNAPL has been observed in other areas of the site (e.g., in the North Sump area). Calculation of the percentage of DNAPL removed under the various DNAPL recovery programs under each alternative is provided in Appendix D. The underlying assumptions used in DNAPL recovery calculations included:

- A 1,400 square foot area of influence of a DNAPL recovery well
- An average DNAPL recovery rate of 50 gallons per year
- A DNAPL recovery operation lifetime of 5 years

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The estimated percentage of recovered DNAPL ranged from 4 to 6 percent of the total DNAPL mass estimated to be at the site. The DNAPL recovery estimates are rough, order-of-magnitude estimates because site-specific long-term performance data for DNAPL recovery are currently not available. The recovery rates observed during the DNAPL pilot test (Appendix E) indicate that initial DNAPL recovery rates can be as high as 100 gallons per year, but the removal rate is expected to decline with time. The majority of recoverable DNAPL is expected to be removed over a 5 year period, based on DNAPL recovery programs at other sites, but a longer recovery time frame (potentially up to 10 years) may occur in some areas.

Estimated restoration time frames for each alternative are summarized in Table 10-3. The underlying assumptions used to calculate these time frames are discussed below. Due to the large uncertainties associated with estimating long restoration time frames (e.g., for alternatives which depend on natural attenuation processes), estimates longer than 100 years are reported in Table 10-3 as 'greater than 100 years', consistent with USGS guidance (USGS 2003). Restoration time frames associated with each FS alternative also considered prospective design and permitting requirements as well as associated pilot tests and associated time frames for regulatory approvals, potentially resulting in implementation time frames greater than 5 years for all in-water alternatives.

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Table 10-3
Estimated Restoration Time Frame

	Estimated Restoration Time Frame in Years [1]				
Medium	**Soil [3]**		**Groundwater**	**Surface Water**	**Sediment**
Exposure Pathway	**Direct Contact**	**Ecological**	**Drinking Water**	**Surface Water**	**Surface Sediments**
Conditional Point of Compliance	**See Note 4**	**See Note 4**	**(porewater in the biologically active zone) (10 cm below mudline)**	**(including porewater in the biologically active zone) (10 cm below mudline)**	**(in the biologically active zone) (0 to 10 cm below mudline)**
Alternative					
1 - No Action	>100 [2]	>100 [2]	>100	>100	>100
2 - Source Control and Monitored Natural Recovery	<5	<5	>100	>100	>100
3 - In-Situ Containment	<5	<5	5 to 10	5 to 10	5 to 10
4 - Source Control, Woodwaste Dredging, Reactive Sediment Cap	<5	<5	5 to 10	5 to 10	5 to 10
5 - Woodwaste Dredging, Sediment Dredging, DNAPL Recovery	<5	<5	5 to 10	5 to 10	5 to 10
6 - Soil and Sediment Removal	5 to 10	5 to 10	5 to 10	5 to 10	5 to 10

Notes:

1) Restoration time frame is defined as the time to achieve site-specific cleanup levels at the conditional point of compliance. See text for discussion.

2) Restoration time frame could not be estimated due to insufficient data. However, a restoration time frame greater than 100 years is anticipated due to the presence of recalcitrant COPCs.

3) The restoration time frame for soil via the soil-to-groundwater pathway is assumed to be the same as the restoration time frame for groundwater.

4) For industrial storage use, the conditional point of compliance for soil for the direct contact and ecological exposure pathways is assumed to be 2 feet in areas that are accessible.

Alternative 1. For Alternative 1, the restoration time frames for all media depend on the rate of natural attenuation and recovery at the site. For industrial storage use of the site, soil direct contact and ecological exposure pathways extend over the 0 to 2-foot-depth interval in areas that are accessible. Unlike Alternatives 2 through 6, soil capping is not a component of Alternative 1. Site-specific data are available to reliably calculate the rate of natural attenuation of soils within the upper 2 feet of the ground surface. However, the restoration time frame could be greater than 100 years due to the recalcitrant nature of some soil COPCs (e.g., benzo[a]pyrene).

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The point of compliance for achieving groundwater and surface water cleanup standards is porewater in the biologically active zone (at a depth of 10 cm below the mudline) of Lake Washington sediments. As discussed in Section 4, current exceedences of these cleanup standards are largely attributable to the presence of DNAPL in nearshore soils and sediments. Groundwater modeling results provided in Section 4 indicate that natural attenuation of dissolved-phase constituents in groundwater currently occurs at a sufficiently rapid rate such that DNAPL occurrences more than approximately 50 feet from the point of discharge into Lake Washington will not result in groundwater or surface water exceedences at the porewater point of compliance, even under reasonable worst case site conditions (e.g., zones of preferential groundwater flow). Therefore, the restoration time frame for groundwater/surface water in Alternative 1 can be approximated by calculating the time for natural attenuation to degrade contaminant mass, including DNAPL, located less than 50 feet from the Lake Washington shoreline. Alternative 1 does not provide any removal of DNAPL but rather relies on natural degradation processes, resulting in the longest estimated restoration timeframe of any of the alternatives. The rate of DNAPL degradation by natural attenuation can typically be approximated by the rate of dissolution of DNAPL into groundwater (USGS 2003), which primarily depends on the solubility of the DNAPL constituents, the distribution and quantity of DNAPL in the subsurface, and the rate of groundwater flow. These calculations are provided in Appendix D. Based on this analysis, the estimated restoration time frame for groundwater is significantly greater than 100 years for Alternative 1.

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For Alternatives 1 through 5 the restoration time frame for soil via the soil-to-groundwater pathway is directly linked to achieving groundwater cleanup levels at the point of compliance. Therefore, for Alternative 1, the restoration time frame for soil with respect to the soil-to-groundwater pathway is greater than 100 years.

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The point of compliance for achieving sediment cleanup levels is near-surface sediments in the biologically active zone (0 to 10 cm below the mudline). Alternative 1 relies on natural attenuation to address impacted sediments, and, based on the Section 4 conceptual site model is dependent upon the restoration timeframe for groundwater discharge. Thus, the restoration time frame for sediments under this alternative is expected to be similar to that of groundwater - estimated to be greater than 100 years.

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Alternative 2. Alternatives 2 through 6 employ upland soil capping and/or removal technologies that directly address direct contact and ecological exposure pathways. In these alternatives, soil cleanup/remediation levels addressing both exposure pathways would be achieved over the 0 to 2-foot exposure interval as soon as the technology is implemented. For the purpose of this evaluation, it was assumed that upland soil capping in Alternative 2 could be implemented within 5 years of the effective date of the Consent Decree. Therefore, a restoration time frame of less than 5 years was estimated for soil with respect to the direct contact and ecological exposure pathways.

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Alternative 2 relies on natural attenuation to achieve cleanup standards for groundwater, but unlike Alternative 1, also provides source control by removing recoverable DNAPL from the subsurface. Removal of the recoverable DNAPL will hasten soil and groundwater cleanup at the site. Based on experience from other sites, the rate and efficiency of DNAPL recovery will decline over time to an extent that continued operation is no longer practicable. Although the pilot test of DNAPL recovery has provided useful information on the relative recoverability of DNAPL present in different areas of the site (e.g. Quendall Pond area versus North Sump), the scale of recovery has been insufficient to cause observable changes in product thickness to provide an empirical basis for estimating recovery timeframe. It is anticipated that DNAPL recovery will continue until an asymptotic limit in the rate of recovery is observed. The time to complete DNAPL recovery will be estimated during design and

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refined as full-scale recovery is implemented and operational data is collected. Performance criteria for defining the DNAPL recovery endpoint will be developed in the Cleanup Action Plan. Residual (non-recoverable) DNAPL will remain at the site under all of the recovery actions except excavation, both in the upland and off-shore areas. However, localized occurrences of off-shore DNAPL may not be effectively removed by DNAPL recovery wells located along the shoreline.

Based on a review of site data, including initial DNAPL pumping tests at the site, along with experiences at other similar sites, recovery of 5 to 30 percent of the total nearshore DNAPL may be achievable. Since a large portion of the DNAPL located less than 50 feet from the Lake Washington shoreline would remain in contact with groundwater, groundwater and surface water cleanup standards would continue to be exceeded at the point of compliance until sufficient removal and degradation of residual DNAPL occurred. DNAPL recovery efforts would decrease the time for natural attenuation to achieve cleanup standards relative to Alternative 1. Applying the same assumptions as in Alternative 1 but considering that approximately 10 to 20 percent of the subsurface contaminant mass in the nearshore area may be removed by a DNAPL recovery program, an order-of-magnitude estimate of the restoration time frame for groundwater under Alternative 2 can be calculated. These calculations are included in Appendix D. The restoration time frame, based on conservative assumptions, is greater than 100 years. Insufficient data exists at this time to more accurately predict the response in groundwater quality to DNAPL recovery. Should DNAPL recovery be selected as an element of the Cleanup Action Plan, the remedial design program could likely include collection of additional data to evaluate the effectiveness of different DNAPL recovery process options, leading to optimization of the design and potential acceleration of the restoration time frame. Alternative 2 (as well as Alternatives 3 through 5) also includes compliance monitoring to evaluate the effectiveness of the remedy over time, facilitating adaptive management actions based on these data to potentially further accelerate the restoration time frame.

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Alternative 2 relies on natural attenuation to achieve cleanup standards for near-surface sediments. Sediment recovery is also influenced by potential improvements to groundwater quality associated with removal of recoverable DNAPL in the shoreline

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area. However, some off-shore DNAPL may not be recoverable given access constraints (this condition would be revisited during remedial design). Therefore, the estimated restoration time frame for sediments under Alternative 2 is the same as in Alternative 1 (potentially 100 years or greater).

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Alternatives 3 through 6. Provisions for upland soil capping in Alternatives 3 through 5 are the same as for Alternative 2. Therefore, the restoration time frame for soil direct contact and ecological exposure pathways is estimated to be less than five years. For the purpose of this evaluation, it was assumed that removal of impacted upland soil in Alternative 6 (a much more complex cleanup action requiring substantially more permitting and design than capping) could potentially be implemented in 5 to 10 years.

Alternatives 3 through 6 include active remediation methods that directly address contaminant occurrences at the points of compliance for groundwater, surface water, and sediment. Groundwater/surface water would be addressed using containment technologies in Alternative 3, in-situ treatment technologies in Alternatives 4 and 5, and soil removal technologies in Alternatives 5 and 6. Sediments would be addressed using capping technologies in Alternatives 3 through 4, and removal technologies in Alternatives 4 through 6. As discussed above with regard to soil capping addressing direct contact and ecological exposure pathways, groundwater, surface water, and sediment cleanup standards would be achieved at the respective points of compliance as soon as these technologies are implemented. For the purpose of this evaluation, the following schedule (beginning with the effective date of the Consent Decree) was assumed:

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- Upland capping, woodwaste dredging, and thin-layer natural recovery could be implemented in within a 5-year period
- DNAPL recovery could be implemented within a 5 year period, however system optimization is anticipated to occur over a 5 to 10 year period
- Reactive sediment capping, treatment wall construction, cutoff wall construction, soil excavation, contaminated sediment dredging, and habitat restoration could be implemented in 5 to 10 years, because of the substantially greater permitting, pilot testing, and design requirements for these technologies

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Therefore, restoration time frames of either "less than 5 years" or "5 to 10 years" are estimated for these media in Alternatives 3 through 6, as summarized in Table 10-3.

As discussed above, prospective design and permitting requirements as well as associated pilot tests and associated time frames for regulatory approvals, may potentially result in implementation time frames greater than 5 years for all in-water alternatives. In Alternative 4, DNAPL recovery and upland hydraulic controls would be implemented early during the remedial action to ensure that free-phase product migration does not have the potential to adversely affect the performance of the PRS cap. In order to allow sufficient time to implement such upland source control actions, the target implementation schedule for the PRS cap is 5 years from the effective date of the Consent Decree, similar to the implementation time frames for other nearshore DNAPL control options evaluated in this FS.

Summary. Table 10-2 summarizes the results of the comparative evaluation of alternatives with respect to the reasonable restoration time frame criterion. Based on the evaluation, Alternative 1 would satisfy this criterion to a low degree, since restoration time frames of greater than 100 years are estimated for all contaminated media and exposure pathways. Soil capping in Alternative 2 could quickly achieve cleanup standards for the soil direct contact and ecological exposure pathways, but estimated restoration time frames for groundwater, surface water, and sediment may potentially be greater than 100 years, though there may be opportunities for design optimization and adaptive management to accelerate this time frame. Therefore, Alternative 2 would address this criterion to a moderate degree. Alternatives 3 through 6 are expected to achieve cleanup standards in the range of 5 to 10 years for all contaminated media and exposure pathways, and therefore satisfy this criterion to a high degree.

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10.2.2 Permanence

The permanence of a cleanup action is measured by the degree to which it permanently reduces the toxicity, mobility, or volume of hazardous substances. For example, treatment actions that destroy contaminants (thereby reducing toxicity, mobility, and volume) are considered under MTCA as more permanent than containment actions (which only reduce the mobility). Treatment processes included in the various remedial

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alternatives include DNAPL removal and biodegradation (both in situ and enhanced with reactive walls or sediment caps). For the purpose of this evaluation, soil excavation and sediment dredging were both assumed to result in off-site containment, due to the high uncertainty in the cost for on-site treatment options. Material left in-place and not subject to biodegradation was assumed to be contained on site (through capping and/or containment walls).

The toxicity and volume of contaminants that are addressed by containment will be reduced over the long term by natural attenuation, even though the time to reduce contaminant toxicity and volume may vary (e.g., the rate of natural attenuation behind the cutoff wall of Alternative 3 would likely be reduced by the lower rate of groundwater flow through the system). Therefore, all alternatives provide a high degree of permanence over the long term. To evaluate the relative permanence of these alternatives, a comparative analysis of the degree of permanence of the remedial alternatives over the short-term is presented below.

Alternative 1 does not significantly reduce the toxicity and volume of hazardous substances in the short term.

Alternatives 2 through 5 reduce the toxicity, mobility, and volume of DNAPL in the upland area through DNAPL recovery. The estimated percentage of mass removal using DNAPL recovery under each alternative varies between 3 and 6 percent because of differences in the accessible nearshore area (Alternatives 2 through 4) or the removal of DNAPL through excavation (Alternative 5).

Alternative 2 controls the mobility of dissolved contaminant constituents in groundwater by natural attenuation processes (see Section 4).

Alternative 3 provides containment of off-shore DNAPL using a vertical cutoff wall around the DNAPL area. Creating the upland area behind the cutoff wall would also enable access for recovery of DNAPL currently below the lake in the nearshore environment. Because of the cutoff wall will restrict the inflow of fresh groundwater,

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natural attenuation of contaminants may occur over a longer time frame than under Alternative 2.

Alternative 4 augments natural attenuation of groundwater occurring at the Site by providing further treatment of dissolved-phase contaminants in groundwater using a permeable sorptive/reactive sediment cap. Capping would increase the upland area in the Quendall Pond area, allowing greater access for recovery of DNAPL beyond the existing shoreline. Dredging and upland beneficial use of woodwaste would reduce the toxicity and volume of contaminated sediments.

Alternative 5 provides similar short-term permanence as Alternatives 3 and 4. DNAPL-affected sediments and nearshore soils would be excavated and placed in an off-site containment facility, and groundwater would be treated with a passive reactive/sorptive treatment wall.

Alternative 6 does not reduce the volume or toxicity of hazardous materials in dredged/excavated sediment and soils, but it reduces mobility by placing contaminated materials in an off-site containment facility. No treatment would be performed under this alternative.

DNAPL recovery reduces the toxicity, mobility, and volume of contaminant mass under Alternatives 3 through 5 to approximately the same extent. Under all alternatives, contaminant mass not removed by DNAPL recovery is generally contained and treated over the long-term by natural attenuation either on- or off-site. Alternative 2 reduces the mobility of DNAPL but does not reduce the mobility of contaminants in groundwater discharging to surface water in the short term; therefore, this alternative has moderate permanence to other alternatives. Alternatives 3 through 6 effectively reduce the mobility of contaminants left in place, and provide a high degree of permanence relative to Alternatives 1 and 2. However, long-term removal of contaminant mass by natural attenuation is reduced under Alternative 3 by the off-shore containment wall, and short-term mass removal is minimal under Alternative 6 (all contaminated materials are contained off site). Therefore, these alternatives have a slightly lower overall permanence than Alternatives 4 and 5.

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10.2.3 Effectiveness over the Long Term

Long term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the restoration time frame, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage remaining hazardous substances. MTCA ranks the following types of cleanup action components in descending order of relative long-term effectiveness:

- Reuse and recycling (and waste minimization under SMS)
- Destruction or detoxification
- Immobilization or solidification
- On-site or off-site disposal in an engineered, lined and monitored facility
- On-site isolation or containment with attendant engineering controls
- Institutional controls and monitoring

Appendix D provides a comparative analysis of degree to which the individual alternatives incorporate the above cleanup action components. A qualitative evaluation of relative long-term effectiveness of each alternative is provided below and summarized in Table 10-2.

Alternative 2 includes institutional controls, monitoring, and upland capping, which are technologies proven to effectively manage risk. DNAPL recovery has been shown in pilot testing to effectively remove DNAPL. In addition, the length of time until natural recovery can achieve cleanup standards is longer than all other alternatives except the no action alternative. Under this alternative, the recoverable fraction of DNAPL will be removed and treated. Contaminated material left on the site will be managed through on-site containment with hydraulic and engineering controls, institutional controls, and monitoring, including inspection and maintenance of upland caps. Natural attenuation and recovery will reduce the volume of contaminants left on site over the long term. Waste production is minimized by removing only highly concentrated contaminants (DNAPL). Compared with the other alternatives, Alternative 2 has moderate long-term effectiveness, largely due to uncertainties associated with the ability of natural attenuation (without enhancement) to successfully control the discharge of contaminants to surface water and the potential for exposure to contaminated sediments.

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Alternative 3. In addition to the upland controls described in Alternative 2, this alternative controls potential exposure in aquatic areas using a cutoff wall and armored sediment cap, which are proven technologies for containing hazardous substances. Under this alternative, the recoverable fraction of DNAPL will be removed and treated. Contaminated material left on the site will be managed through on-site containment with engineering controls, institutional controls, and monitoring, including inspection and monitoring of upland and aquatic caps. Natural attenuation and recovery will reduce the volume of contaminants left on site over the long term. This alternative has greater long-term effectiveness than Alternative 2 because contaminated groundwater and sediments are controlled through isolation and on-site containment as well as institutional controls and monitoring. Waste production is minimized by removing only highly concentrated contaminants (DNAPL). This alternative is considered to have high long-term effectiveness relative to other alternatives because it consists of proven technologies.

Alternative 4. In addition to the upland controls described in Alternative 2, this alternative would control potential exposure in aquatic areas using a passive reactive/sorptive sediment cap. Capping is a proven technology for containing contaminated sediments. Results from prior bench-scale tests and field-scale pilot projects (e.g., Anacostia River demonstration of reactive cap amendments; http://www.hsrc-ssw.org/anacostia/) indicate a high potential effectiveness of reactive/sorptive caps for treating contaminated groundwater, though limited long-term performance data are currently available. Under Alternative 4, the recoverable fraction of DNAPL would be removed and treated. Contaminated material left on the site would be managed through treatment of contaminated groundwater, on-site containment with engineering controls, institutional controls, and monitoring, including inspection and monitoring of upland and aquatic caps. Natural attenuation and recovery would result in degradation of contaminants left on site over the long term. Waste production would be minimized by removing only highly concentrated contaminants (DNAPL). This alternative has high long-term effectiveness, subject to confirmation (during ongoing demonstration projects and potential remedial design studies) verifying the performance of the reactive/sorptive sediment cap.

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Alternative 5. In addition to the upland controls described in Alternative 2, this alternative would control potential exposure in aquatic areas by removing contaminated sediments and nearshore soils, and contaminated groundwater would be treated using a passive reactive/sorptive treatment wall. Excavation and dredging are proven technologies for removing contaminated soils and sediments. Full scale reactive and/or sorptive treatment walls for treating contaminated groundwater have been installed at other sites but long-term performance data (more than 5 years) are not available. Under Alternative 5, DNAPL-affected sediments and nearshore soils would be removed and contained in an off-site, permitted facility. The recoverable fraction of DNAPL remaining in the upland would be removed and treated. Contaminated material left on the site would be managed through treatment of contaminated groundwater, on-site containment with engineering controls, institutional controls, and monitoring, including inspection and monitoring of upland caps. Natural attenuation and recovery would reduce the volume of contaminants left on site over the long term. Overall this alternative ranks higher in terms of long-term effectiveness than Alternative 1 and 2, and similar to Alternatives 3 and 4.

Alternative 6. In this alternative, all accessible contaminated materials would be removed and disposed of in an off-site, permitted facility. Low volumes of contaminants that are inaccessible (e.g., in deep groundwater) would be remediation through natural attenuation processes (see Section 4), with institutional controls and monitoring to control exposure during the restoration period. Excavation and dredging are proven technologies for removing contaminated soils and sediments, and natural attenuation/recovery is a demonstrated technology at the Quendall Site. Under Alternative 5, the vast majority of contaminated materials would be removed and contained in an off-site, engineered facility, which is a less preferred cleanup action under MTCA relative to DNAPL recovery and treatment. No treatment would be performed under this alternative. Because this technology employs proven technologies and provides off-site containment at an engineered facility rather than on site, this alternative is considered to have a high long-term effectiveness.

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10.2.4 Management of Short-Term Risks

Management of short-term risks (a.k.a. short-term effectiveness) is the degree to which human health and the environment are protected during construction and implementation of the alternative. Potential risks of implementing each alternative and the potential effectiveness of best management practices at controlling short-term risks are discussed below.

Alternative 1 does not present additional short-term risks to human health and the environment because there is no construction or implementation planned with this alternative.

Alternative 2 presents minimal additional short-term risks to human health or the environment associated with implementation of the remedy. Releases of and exposure to potentially contaminated materials during construction of DNAPL recovery wells and DNAPL pumping would be controlled by standard personal protective equipment and by using double containment for product recovery piping and equipment. Drilling in DNAPL-contaminated areas would result in slight short-term releases of volatile contaminants to the air. This alternative would provide effective management of short-term risks resulting from implementation of the remedy.

Alternative 3 presents a slightly higher short-term risk during construction than Alternative 2. Potential risks during implementation of DNAPL recovery would be controlled by standard practices and equipment. Placing aquatic cap materials is generally a low-impact process and is not expected to cause releases of in-place contaminants or degrade water quality. During aquatic work, best management practices would be used to contain and minimize water quality impacts; however, during construction of this alternative, localized impacts to aquatic habitat quality would be unavoidable. Compared with the other alternatives, Alternative 3 provides relatively highly effective management of short-term risks.

Alternative 4 results in short-term risks similar to Alternative 3. Potential risks from DNAPL recovery would be controlled by standard practices and equipment. Placement of aquatic cap materials is not expected to cause releases of in-place contaminants or

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degrade water quality during placement. As in Alternative 3, some short-term impacts to aquatic habitat quality are expected because of the removal and replacement of in-water materials; however, the area that would be affected under Alternative 4 is less than half that potentially impacted under Alternative 3. However, additional dredging and associated short-term water quality impacts associated with this activity are greater under Alternative 4. Overall, this alternative provides highly effective management of short-term risks, similar to Alternative 3.

Alternative 5 involves potential for releases to air and surface water during excavation and dredging of DNAPL-contaminated soils and sediments. Because of the presence of volatile chemicals such as benzene and the disturbance caused by construction activities, site workers would likely require a high level of personal protective equipment such as full-face respirators. Stockpiled materials would require containment measures to prevent emissions of hazardous chemicals through dust or runoff. Impacts to surface water quality could be controlled by using temporary sheetpile, but short-term impacts could occur during sheetpile removal. Relative to the other alternatives, Alternative 5 provides moderately effective management of short-term risks.

Alternative 6 includes similar activities as Alternative 5 but presents a greater short-term risk because activities of concern (dredging and excavation) are applied on a much larger scale. Excavation of a large portion of the site would be a lengthy process and short-term releases of contaminants to air and surface water could occur over an extended period. Overall, this alternative provides less effective management of short-term risks than other alternatives.

10.2.5 Technical and Administrative Implementability

Evaluating an alternative's technical and administrative implementability includes consideration of the following:

- Potential for landowner cooperation
- Whether the alternative is technically possible
- Availability of necessary facilities, services, and materials
- Administrative and regulatory requirements;
- Scheduling

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- Size and complexity of the alternative
- Monitoring requirements
- Access for construction and monitoring
- Integration of existing operations with the remedial action

The ability of each alternative to be implemented at the Quendall Site is discussed below.

Alternative 1, no action, by definition is the easiest to implement.

Alternative 2 consists of demonstrated technologies that are relatively easy to implement. Existing operations would not be significantly affected because they do not use the areas that would require the most site activity (DNAPL recovery areas near Quendall Pond and the former May Creek channel). Although a ramping-up phase to optimize full scale DNAPL recovery is anticipated, all components of this alternative could be implemented without additional bench-scale or pilot testing. Compared with the other alternatives, Alternative 2 is highly implementable.

Alternative 3 also consists of demonstrated technologies. Although this alternative will likely require permitting and regulatory agency review, the alternative layout includes on-site, in-kind habitat mitigation to address applicable resource management requirements. Most site operations would not be affected by implementing this alternative. Compared with the other alternatives, Alternative 3 is moderately to highly implementable.

Alternative 4 also involves aquatic work but less aquatic habitat would need to be replaced. Because the aquatic work (placing a subaqueous cap) is less invasive than driving sheetpile, filling and dredging, the administrative implementability of this alternative is relatively straightforward, but permitting and agency review will still be a component of the design process. Most site operations would not be affected by implementing this alternative. Compared with the other alternatives, Alternative 4 is highly implementable.

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Alternative 5 does not involve removing or creating aquatic habitat, but it includes dredging DNAPL-contaminated sediment. The potential for short-term impacts from dredging highly contaminated materials will make meeting regulatory requirements more difficult. Most current site operations would likely not be affected. The implementability is anticipated to be constrained because of soil (heaving conditions) and dewatering issues.. Because DNAPL has been observed below 15 feet in depth, it is uncertain whether this alternative could be implemented to completion. This alternative has a moderate implementability relative to other alternatives because of potential administrative and technical limitations to fully implementing sediment and DNAPL dredging.

Alternative 6 is similar to Alternative 5 except that dredging and excavation are applied on a much larger scale. The same limitations of Alternative 5 – an involved permitting process due to potential short-term risks, and technical uncertainties in excavating below 15 feet in depth – apply to Alternative 6. The technical limitations are more severe in this alternative because of the much larger volume of soil to be excavated. In addition, site operations will likely be restricted. This alternative is considerably more difficult to implement than other alternatives.

10.2.6 Consideration of Public Concerns

The Draft RA/FS Report will be made available for public review and comment. The degree to which each alternative considers public concerns will be evaluated after public comments are received.

10.2.7 Cost

Estimated costs for remedial alternatives are summarized in Table 10-2 and details are provided in Table 10-4. Cost estimates include design, Ecology oversight, capital and long-term operation and maintenance costs, but do not include legal costs. Cost estimates are feasibility-study level (+50/-30 percent).

For alternate land uses, the extent of upland area requiring capping and the required cap thickness would depend on the specific intended site use. Table 10-2 presents the estimated costs for each alternative under current (baseline–industrial storage) and

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mixed commercial land uses. The increase in cleanup cost to accommodate mixed commercial use in Alternatives 2 through 5 is associated with capping a larger area of the upland soils at the Site. In general, the cost difference for a change in land use would be the same for Alternatives 2 through 5, since they all include capping of upland soils. The estimated cost for Alternative 6 under a mixed commercial land use scenario is expected to be higher than the current industrial storage use scenario because of the increased volume of soil that would require excavation to meet soil cleanup/remediation levels to address direct contact exposure.

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Table 10-4
Estimated Cost of Remediation Alternatives

Remedial Component	Units	Unit Cost	ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 6	
			# of Units	Cost	# of Units	Cost	# of Units	Cost	# of Units	Cost	# of Units	Cost	# of Units	Cost
A. Restrictive Covenant														
Soil and Groundwater	Lump Sum	$10,000		$0	1	$10,000	1	$10,000	1	$10,000	1	$10,000	1	$10,000
Subtotal				**$0**		**$10,000**		**$10,000**		**$10,000**		**$10,000**		**$10,000**
B. Upland Cap														
Site Access Restrictions	Linear Feet	$27		$0	2,600	$69,420	2,600	$69,420	2,600	$69,420	2,600	$69,420	0	$0
General Mobilization/Demobilization	Lump Sum	$30,000		$0	1	$30,000	1	$30,000	1	$30,000	1	$30,000	1	$30,000
Import Fill (2-foot cap - Industrial use)	Ton	$6		$0	3,500	$21,000	3,500	$21,000	3,500	$21,000	3,500	$21,000	0	$0
Hydraulic Controls for Quendall Pond	Lump Sum	$50,000		$0	1	$50,000	1	$50,000	1	$50,000	0	$0	0	$0
Woodwaste Beneficial Use	Cubic Yard	$5		$0	0	$0	0	$0	33,135	$165,675	33,135	$165,675	44,200	$221,000
Backfill and Compact	Cubic Yard	$6		$0	2,410	$14,460	2,410	$14,460	2,410	$14,460	2,410	$14,460	0	$0
Vegetation	Acre	$2,175		$0	23	$50,025	23	$50,025	23	$50,025	23	$50,025	23	$50,025
Topographic Survey	Lump Sum	$8,000		$0	1	$8,000	1	$8,000	1	$8,000	1	$8,000	1	$8,000
Construction Oversight and Management	% of Item	5%		$0	-	$12,145	-	$12,145	-	$20,429	-	$17,929	-	$15,451
Subtotal				**$0**		**$255,050**		**$255,050**		**$429,009**		**$376,509**		**$324,476**
C. DNAPL Recovery														
Recovery Wells with Piping, Valves	Each	$7,000		$0	50	$350,000	35	$245,000	60	$420,000	30	$210,000		$0
Pump Station with Controls	Each	$50,000		$0	2	$100,000	2	$100,000	2	$100,000	2	$100,000		$0
Utility Hookup	Lump Sum	$20,000		$0	1	$20,000	1	$20,000	1	$20,000	1	$20,000		$0
Collection Tank and Containment	Each	$7,500		$0	2	$15,000	2	$15,000	2	$15,000	2	$15,000		$0
Waste Disposal	Gallons	$5		$0	13,000	$65,000	8,800	$44,000	15,000	$75,000	7,500	$37,500		$0
Recovery System O&M	Year	$25,000		$0	5	$125,000	5	$125,000	5	$125,000	5	$125,000		$0
Construction Oversight and Management	% of Item	15%		$0	-	$82,500	-	$63,600	-	$94,500	-	$57,375		$0
Subtotal				**$0**		**$757,500**		**$612,600**		**$849,500**		**$564,875**		**$0**
D. Offshore Cutoff Wall														
General Mobilization/Demobilization	Lump Sum	$200,000		$0		$0	1	$200,000		$0		$0		$0
Sheetpile Wall Installed	Linear Feet	$1,000		$0		$0	700	$700,000		$0		$0		$0
Import Fill to Grade	Ton	$6		$0		$0	8,950	$53,700		$0		$0		$0
Backfill and Compact	Cubic Yard	$15		$0		$0	6,170	$92,550		$0		$0		$0
Construction Oversight and Management	% of Item	5%		$0		$0	-	$52,313		$0		$0		$0
Subtotal				**$0**		**$0**		**$1,098,563**		**$0**		**$0**		**$0**
E. Sediment/Woodwaste Cap (Sand and ENR Thin-layer)														
General Mobilization/Demobilization	Lump Sum	$35,000		$0		$0	1	$35,000	0.33	$11,550	1	$35,000		$0
Import Sand (2 feet - Thick Cap)	Ton	$8		$0		$0	42,440	$339,520	0	$0	0	$0		$0
Import Habitat Substrate/Armoring (1 foot)	Ton	$11		$0		$0	21,950	$232,670	0	$0	0	$0		$0
Import Sand (0.5 feet - ENR at T-Dock)	Ton	$8		$0		$0	1,770	$14,160	1,770	$14,160	1,770	$14,160		$0
Place Cap Material	Cubic Yard	$13		$0		$0	45,125	$586,625	1,220	$15,860	1,220	$15,860		$0
Bathymetric Surveys	Lump Sum	$15,000		$0		$0	2	$30,000	0.67	$10,050	0.67	$10,050		$0
Water Quality Monitoring	Week	$14,000		$0		$0	6	$84,000	1	$14,000	1	$14,000		$0
Confirmatory Sampling	Each	$500		$0		$0	45	$22,500	7	$3,500	7	$3,500		$0
Maintenance	% of Item	5%		$0		$0	-	$67,224	-	$3,456	-	$4,629		$0
Construction Oversight and Management	% of Item	5%		$0		$0	-	$67,224	-	$3,456	-	$4,629		$0
Subtotal				**$0**		**$0**		**$1,478,923**		**$76,032**		**$101,827**		**$0**
F. Permeable Reactive Cap														
General Mobilization/Demobilization	Lump Sum	$35,000		$0		$0		$0	0.33	$11,550		$0		$0
Furnish and Place Reactive Layer (2 inches)	Square Foot	$8.0		$0		$0		$0	130,160	$1,041,280		$0		$0
Import Sand (0.5 feet - Intermediate Layer)	Ton	$8.0							3,495	$27,960				
Import Habitat Substrate/Armoring (0.5 feet)	Ton	$11		$0		$0		$0	3,615	$38,319		$0		$0
Place Cap Cover Material	Cubic Yard	$13		$0		$0		$0	7,110	$92,430		$0		$0
Bathymetric Surveys	Lump Sum	$15,000		$0		$0		$0	0.67	$10,050		$0		$0
Water Quality Monitoring	Week	$14,000		$0		$0		$0	2	$28,000		$0		$0

Table 10-4
Estimated Cost of Remediation Alternatives

			ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 6	
Remedial Component	**Units**	**Unit Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**
Confirmatory Sampling	Each	$500		$0		$0		$0	13	$6,500		$0		$0
Maintenance	% of Item	5%		$0		$0		$0	-	$62,804		$0		$0
Construction Oversight and Management	% of Item	5%		$0		$0		$0	-	$62,804		$0		$0
Subtotal				**$0**		**$0**		**$0**		**$1,381,698**		**$0**		**$0**
G. Sediment Dredging														
General Mobilization/Demobilization	Lump Sum	$35,000		$0		$0		$0	0.33	$11,550	1	$35,000	1	$35,000
Mechanical Dredging (Woodwaste & Sediment)	Cubic Yard	$10		$0		$0		$0	33,135	$331,350	43,900	$439,000	63,560	$635,600
BMP - Temporary Sheetpile	Square Feet	$23		$0		$0		$0	0	$0	20,000	$460,000	20,000	$460,000
BMP - Surface Water Level Reduction	Gallons	$0.20		$0		$0		$0	0	$0	250,000	$50,000	750,000	$150,000
Treatment/Dewatering for Offsite Transport	Cubic Yard	$15		$0		$0		$0	0	$0	10,765	$161,475	30,425	$456,375
Tranpsort/Dispose of Sediments at Landfill	Ton	$40		$0		$0		$0	0	$0	15,610	$624,400	44,114	$1,764,560
Import Sand to Grade	Ton	$8		$0		$0		$0	0	$0	15,610	$124,880	44,114	$352,912
Place Sand	Cubic Yard	$13		$0		$0		$0	0	$0	10,765	$139,945	30,425	$395,525
Bathymetric Survey	Lump Sum	$15,000		$0		$0		$0	0.67	$10,050	0.67	$10,050	2	$30,000
Water Quality Monitoring	Week	$14,000		$0		$0		$0	3	$42,000	5	$70,000	6	$84,000
Confirmatory Sampling	Each	$1,000		$0		$0		$0	8	$8,000	11	$11,000	16	$16,000
Construction Oversight and Management	% of Item	5%		$0		$0		$0	-	$20,148	-	$106,288	-	$218,999
Subtotal				**$0**		**$0**		**$0**		**$423,098**		**$2,232,038**		**$4,598,971**
H. Nearshore/Upland DNAPL Excavation (Soil and Sediment)														
General Mobilization/Demobilization	Lump Sum	$65,000		$0		$0		$0		$0	1	$65,000	1	$65,000
Temporary Sheetpile	Square Feet	$23		$0		$0		$0		$0	40,000	$920,000	80,000	$1,840,000
Surface and Groundwater Level Reduction	Gallons	$0.04		$0		$0		$0		$0	2,900,000	$116,000	27,000,000	$1,080,000
Excavation of Soil and Sediment	Cubic Yard	$15		$0		$0		$0		$0	48,230	$723,450	556,600	$8,349,000
Treatment/Dewatering for Offsite Transport	Cubic Yard	$15		$0		$0		$0		$0	48,230	$723,450	556,600	$8,349,000
Tranpsort/Dispose of Sediments at Landfill	Ton	$40		$0		$0		$0		$0	69,940	$2,797,600	807,075	$32,283,000
Import Fill to Grade	Ton	$6		$0		$0		$0		$0	69,940	$419,640	807,075	$4,842,450
Backfill and Compact	Cubic Yard	$15		$0		$0		$0		$0	48,230	$723,450	556,600	$8,349,000
Bathymetric Survey	Lump Sum	$15,000		$0		$0		$0		$0	0.67	$10,050	0	$0
Water Quality Monitoring	Week	$14,000		$0		$0		$0		$0	3	$42,000	0	$0
Confirmatory Sampling	Each	$1,000		$0		$0		$0		$0	12	$12,000	55	$55,000
Construction Oversight and Management	% of Item	5%		$0		$0		$0		$0	-	$327,632	-	$3,260,623
Subtotal				**$0**		**$0**		**$0**		**$0**		**$6,880,272**		**$68,473,073**
I. Permeable Sorptive/Reactive Treatment Wall														
Bench-Scale Testing	Lump Sum	$25,000		$0		$0		$0		$0	1	$25,000		$0
Installation	Square Feet	$9		$0		$0		$0		$0	8,000	$72,000		$0
Performance Monitoring	Lump Sum	$400,000		$0		$0		$0		$0	1	$400,000		$0
Construction Oversight and Management	% of Item	5%		$0		$0		$0		$0		$24,850		$0
Subtotal				**$0**		**$0**		**$0**		**$0**		**$521,850**		**$0**
J. Long-term Monitoring														
Bathymetric Surveys	Periodic Survey	$15,000		$0	5	$75,000	5	$75,000	5	$75,000	5	$75,000	1	$15,000
Surface Sediment Sampling and Analysis	Periodic Survey	$20,000		$0	20	$400,000	5	$100,000	5	$100,000	5	$100,000	1	$20,000
Monitoring Reports	Periodic Survey	$10,000		$0	20	$200,000	5	$50,000	5	$50,000	5	$50,000	1	$10,000
Project Management	% of Monitoring	5%		$0	-	$33,750	-	$11,250	-	$11,250	-	$11,250	-	$2,250
Subtotal				**$0**		**$708,750**		**$236,250**		**$236,250**		**$236,250**		**$47,250**
K. Habitat Mitigation														
Excavation of In-Place Dewatered Soils	Acre	$400,000		$0		$0	1	$400,000	0.55	$220,000		$0		$0
On-Site Beneficial Use of Clean Soils	Ton	-$6		$0		$0	12,450	-$74,700	3,500	-$21,000		$0		$0
Riparian Planting and Maintenance	Lump Sum	$20,000		$0		$0	1	$20,000	1	$20,000		$0		$0
Construction Oversight and Management	% of Item	10%		$0		$0		$34,530		$21,900		$0		$0
Subtotal				**$0**		**$0**		**$379,830**		**$240,900**		**$0**		**$0**

Table 10-4
Estimated Cost of Remediation Alternatives

			ALTERNATIVE 1		ALTERNATIVE 2		ALTERNATIVE 3		ALTERNATIVE 4		ALTERNATIVE 5		ALTERNATIVE 6	
Remedial Component	**Units**	**Unit Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**	**# of Units**	**Cost**
SUBTOTAL WITHOUT DESIGN/CONTINGENCY				***$0***		***$1,731,300***		***$4,071,215***		***$3,646,486***		***$10,923,621***		***$73,453,769***
L. Remedial Design														
Pre-Remedial Design Evalation/Pilot Studies	% of Construction	5%		$0		$86,565		$203,561		$182,324		$546,181		$3,672,688
Design Documentation	% of Construction	10%		$0		$173,130		$407,122		$364,649		$1,092,362		$7,345,377
Project Management	% of Construction	5%		$0		$86,565		$203,561		$182,324		$546,181		$3,672,688
		Adjustment										*-$218,472*		*-$3,672,688*
Subtotal				**$0**		**$346,260**		**$814,243**		**$729,297**		**$1,966,252**		**$11,018,065**
M. Overall Contingency	% of Subotal	30%		**$0**		**$623,268**		**$1,465,637**		**$1,312,735**		**$3,866,962**		**$25,341,550**
PLANNING TOTAL				**$0**		**$2,700,828**		**$6,351,096**		**$5,688,519**		**$16,756,834**		**$109,813,385**

10.3 Summary Evaluation of Remedial Alternatives

Table 10-2 provides a qualitative comparison of the degree to which each alternative meets the criteria discussed in Section 10.2, along with the preliminary estimated cost of implementing the alternatives. Alternative 2 is easy to implement, has fewer short-term risks, and is less costly than other alternatives, but is associated with a longer restoration time frame, relative to the other alternative. Because Alternatives 3 through 6 have a high certainty of being protective, the main differentiating factors among these alternatives are cost, implementability, short-term risks during construction, long term reliability/ permanence of the technologies.

10.4 Effect of Alternative Land Uses on Alternative Evaluation

In general, applying the alternate land uses discussed earlier in the FS to the above evaluation does not affect whether an alternative meets the minimum requirements for a cleanup action. The main difference would be the estimated cost – more sensitive land uses, with accompanying lower soil cleanup levels for direct contact, could potentially require an upland cap that is thicker than 2 feet and/or applied over a larger area. Estimated costs for applying alternatives under a ground-floor residential land use are included in Tables 10-2 and 10-4. The added cost to each alternative is consistent (with the exception of Alternative 6, which only increases the disproportionate cost of this alternative), and therefore does not change the disproportionate cost analysis.

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11 RECOMMENDED CLEANUP ACTION ALTERNATIVE

The preceding sections present and evaluate six site-wide remediation alternatives that represent a wide range of remedial technologies and process options. When viewed together, the relative benefits and tradeoffs associated with implementation of different alternatives are apparent. The comparative MTCA evaluation of remedial alternatives is summarized in Table 10-2.

This section identifies the recommended cleanup action alternative for the Site, consistent with MTCA requirements. As discussed in Section 10.2.6 above, the community's comments will also be considered by Ecology when selecting the cleanup remedy for the site under MTCA.

Pending community comment, based on a comparative evaluation of the other evaluation criteria presented above, the provisional preferred alternative for the Quendall Terminals Site is Alternative 4. This alternative blends a number of remedial technologies, including: Upland Soil Cap, DNAPL Recovery, Hydraulic Controls, PRS Cap, Woodwaste Dredging/Beneficial Use, and Enhanced Natural Recovery of T-Dock Sediments. The following attributes contribute to the provisional identification of Alternative 4 as the recommended cleanup remedy for the Site.

- Complies with MTCA and with other applicable standards and laws.
- Achieves human health and environmental protection in a relatively rapid time frame, compared with the range of alternatives evaluated.
- Uses ex situ and in situ treatment technologies for recoverable DNAPL and groundwater remediation, respectively, to the maximum extent practicable.
- Includes protective, engineered in situ confinement of soil and nearshore sediment residuals that are not practicable to remove.
- Has minimal short-term construction risks, compared with the range of alternatives evaluated.
- Uses multiple technologies (e.g., DNAPL recovery in the shoreline and PRS capping in the nearshore area) to provide maximum long-term effectiveness.
- Is implementable.
- Is cost effective, relative to the range of alternatives evaluated.
- Provides for potential beneficial use of dredged woodwaste (e.g., as upland landscaping materials).

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- Allows for a wide range of potential future land uses at the Site such as a mixed use development, which may potentially require a thicker upland cap applied over a larger area. Potential future land use actions would need to conform to all local, state, and federal regulations, including procedural requirements.

When compared with the recommended alternative, the costs associated with implementing all of the other alternatives evaluated (esp. Alternatives 5 and 6) are substantial and disproportionate and do not provide any incremental degree of increased environmental protection. The preferred alternative provides a high degree of human health and environmental protection.

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The FS analyses summarized above, particularly in Section 10.2.1, demonstrate that it is not practicable to meet cleanup levels throughout the Quendall Site within a reasonable restoration time frame, particularly for groundwater. Consistent with MTCA requirements set forth in WAC 173-340-350 through -390 and WAC 173-340-720(8), Ecology may approve a conditional point of compliance for groundwater at the Quendall Site that is located as close as practicable to the source of hazardous substances, not to exceed the property boundary in Lake Washington, given the following demonstrations:

1. All practicable methods of treatment are used in the site cleanup (inclusion of active DNAPL recovery and PRS capping into the recommended alternative satisfies this requirement);
2. The point of compliance is located within the surface water as close as technically possible to the point or points where ground water flows into the surface water (setting the groundwater point of compliance at 10 cm below mudline satisfies this requirement);
3. It has been demonstrated that the contaminated ground water is entering the surface water and will continue to enter the surface water even after implementation of the selected cleanup action (this is demonstrated in Section 4);
4. Use of a mixing zone under WAC 173-201A-100 to demonstrate compliance with surface water cleanup levels shall not be allowed (no such mixing zone is included in the recommended alternative);
5. Ground water discharges shall be provided with all known available and reasonable methods of treatment before being released into surface waters (groundwater treatment limitations at this Site are discussed in Section 8);

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6. Ground water discharges shall not result in violations of sediment quality values (Section 5 demonstrates that groundwater cleanup levels are protective of sediments at this Site);
7. Ground water and surface water monitoring shall be conducted to assess the long-term performance of the selected cleanup action including potential bioaccumulation problems resulting from surface water concentrations below method detection limits (compliance monitoring is included with the recommended alternative, with detailed plans to address MTCA requirements to be developed in the Cleanup Action Plan); and
8. Before approving the conditional point of compliance, a notice of the proposal shall be mailed to the natural resource trustees, the Washington Department of Natural Resources and the United States Army Corps of Engineers. The notice shall be in addition to any notice provided under WAC 173-340-600 and invite comments on the proposal (formal notice will be provided as part of public and stakeholder review of this RA/FS and forthcoming Cleanup Action Plan).

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11.1 Summary of Recommended Alternative

A plan view and cross section of Alternative 4 is presented in Figures 9-5 and 9-6, respectively. Under this alternative, source control would be accomplished by removing recoverable DNAPL from the subsurface to the maximum extent practicable, which would be determined during remedial design and modified as needed during the system start-up phase. Exposure to contaminated media would be controlled by capping of upland soils (to address the direct contact pathway), installing a reactive sediment cap (to control the groundwater to surface water pathway), dredging woodwaste-affected sediments, and implementing institutional controls. On-site habitat mitigation is included, resulting in no net loss of aquatic area and a net gain in habitat functions. Long-term monitoring would document attainment of cleanup standards in site soils, groundwater, surface water, and sediments.

Upland Soil Capping. Figure 9-5 depicts general capping areas at the Site under a representative range of possible future site uses (i.e., industrial and commercial/mixed use). Capping to achieve industrial land use direct contact cleanup levels would be implemented initially. Additional remedial technologies would be necessary to meet the soil cleanup levels for protection of groundwater/surface water. Augmentation of the upland soil cap to

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achieve compliance with potential future land use-based cleanup/remediation levels would be phased to coincide with land use redevelopment activities (Section 11.3). Additional soil sampling may potentially be performed during remedial design to better define the extent of soil cap needed for future site use/development plans. The schedule for Upland Soil Capping will be developed in the Cleanup Action Plan.

DNAPL Recovery. Ongoing DNAPL recovery activities initiated by the property owners during the RA/FS would be continued. During remedial design, supplemental subsurface profiling would be conducted to refine the delineation of potentially recoverable DNAPL and subsurface stratigraphy in the former May Creek Channel and Quendall Pond areas, supporting design and optimization of the recovery system. As appropriate, DNAPL recovery wells or trenches would be installed in areas where potentially recoverable DNAPL is identified. After an initial demonstration period, followed by performance monitoring and adaptive management/optimization of the recovery system, full-scale DNAPL recovery would be performed at each recovery well or trench as practicable. Recovered DNAPL would either be recycled (as appropriate) or treated through incineration.

Hydraulic Controls. After determining surface water flow patterns in the area of Quendall Pond, physical controls (e.g., berms or interception ditches) would be constructed to divert stormwater away from the pond. Stormwater would be directed to areas of the site where data indicate uncontaminated shallow soils for detention and/or infiltration. In addition, any subsurface drains conveying stormwater into Quendall Pond would be eliminated. Direct discharge of surface water to Lake Washington would be controlled. After stormwater controls are implemented, a monitoring program would be instituted that would include measuring lake, pond, and groundwater elevations and inspecting the shoreline to document the effectiveness of the hydraulic controls to prevent the discharge of localized hydrocarbon sheen along the shoreline.

Permeable Reactive Sediment (PRS) Cap. Following initial pre-design investigations to characterize existing biodegradation processes and identify rate-limiting factors, a PRS capping pilot study would be performed at the Site to verify the effectiveness of the more promising process options supporting remedial design. Because of retardation

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characteristics and resulting slow contaminant migration velocities through prospective reactive cap materials (e.g., regenerated activated carbon, coke breeze, select coal materials, and/or nitrate/sulfate amendments), pilot monitoring will be required to adequately inform the remedial design effort. PRS cap design is also expected to be informed by an ongoing field-scale demonstration project in the Anacostia River, which will likely be collecting performance data over the next 5+ years (http://www.hsrc-ssw.org/anacostia/). The PRS cap monitoring period would also appropriately coincide with the period of DNAPL recovery system ramp-up and adaptive management, as discussed above. Following completion of the pilot study, the PRS cap would be designed and permitted. Displaced shoreline areas (approximately 0.6 acres) would be mitigated as appropriate. Pending final design, the PRS cap is likely to consist of a relatively thin layer (several inches) of reactive materials, overlain with a nominal 1-foot thick layer of sand and erosion protection materials (e.g., gravel/cobble).

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As discussed above, under the recommended alternative, upland hydraulic controls and DNAPL recovery would be implemented early during the remedial action to ensure that free-phase product migration does not have the potential to adversely affect the performance of the PRS cap. In order to allow sufficient time to implement such upland source control actions, the target implementation schedule for the PRS cap is 5 years from the effective date of the Consent Decree, similar to the implementation time frames for other nearshore DNAPL control options evaluated in this FS. A more detailed schedule for the PRS pilot study, monitoring, final design, permit and construction will be developed in the Cleanup Action Plan.

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Woodwaste Dredging/Beneficial Use. Following remedial design and permitting, woodwaste-affected areas would be dredged and stockpiled in on-site upland areas and incorporated into site redevelopment as appropriate. These materials would be beneficially used on-site as fill or landscape materials as practicable. For on-site beneficial use, the woodwaste may require amendment through blending and/or cement stabilization depending upon the end use of the material. Pre- and post-dredging area delineation and confirmation sampling requirements, along with a schedule for design and construction, will be developed in the Cleanup Action Plan.

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Enhanced Natural Recovery of T-Dock Sediments. Natural recovery of sediments near the former T-Dock area that exhibited residual toxicity during the most recent FS sampling (Section 4; likely attributable to the presence of PAH degradation products) would be accelerated through the placement of a relatively thin layer (nominal 6-inch thickness) of sand materials. The enhanced natural recovery (ENR)/sand layer would be placed following initial remedial design and permitting activities.

Monitoring. Beginning with pre-design data collection activities, a long-term soil, DNAPL, groundwater, surface water, and sediment monitoring program would be implemented at the Site to inform remedial design and follow-on adaptive management activities, and to document attainment of cleanup standards. For groundwater, the point of compliance would be set at a depth of 10 cm below the mudline in Lake Washington, which is as close as practicable to the source of hazardous substances in the nearshore area (see discussion above).

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Deleted: As described in Section 10, it is not practicable to achieve the groundwater cleanup level throughout the Site within a reasonable restoration time under any of the alternatives evaluated. Moreover, consistent with the requirements of WAC 173-340-720(8), all practicable methods of treatment are used in Alternative 4 to achieve cleanup. The conditional groundwater point of compliance in this case would be located as close as practicable to the offshore subsurface sediment source of contamination, as required by MTCA.

Institutional Controls. A notice would be placed on the property deed to notify future owners of the presence of COPCs on the property. In addition, a deed restriction would also be placed on the property with conditions to prohibit the extraction and use of groundwater and nearshore surface water at the Site; maintain the integrity of upland and sediment caps; and require adherence of measures for protection of construction workers who may come in contact with COPCs at the Site.

The Consent Decree/Cleanup Action Plan for the recommended alternative would include the following elements, which pertain to the PRS cap as well as other key elements of the selected remedy (e.g., DNAPL recovery and product/sheen controls):

- An Ecology-approved Monitoring Plan;
- An Ecology-approved set of Performance Standards by which data collected pursuant to the Monitoring Plan would be used to evaluate the effectiveness of the selected remedy;
- An Ecology-approved Contingency Plan to be implemented in the event that Performance Standards are not met; and.
- An Ecology-approved implementation schedule for all of the above.

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11.2 Land Use Redevelopment Contingency Actions

There are no existing plans for site redevelopment. However, land use redevelopment actions are expected to be implemented at the Site over a period of between 7 and 15 years following execution of the Consent Decree. As the land use changes, additional remedial actions (i.e., capping) will be completed. This type of alternative land use approach has been approved by Ecology at other sites (e.g., see Kenmore Industrial Park Cleanup Action Plan; Ecology 2001).

The Consent Decree/Cleanup Action Plan and associated Restrictive Covenants for the property would address possible site cleanup requirements under a range of potential future site uses, as generally represented in this RA/FS. The Cleanup Action Plan is also expected to identify response actions associated with certain specific subsurface activities (e.g., utility corridors) for different land uses, but would not be intended to address all subsurface activities. Subsequent Ecology approval of the Engineering Design Report (EDR) and associated design documents such as the Operations, Maintenance, and Monitoring Plan (OMMP) would address those subsurface activities specific to a particular land use condition. Prior to future changes in land use Ecology must approve changes to the EDR and/or Restrictive Covenant, as appropriate.

The OMMP would be developed during the remedial design phase, based on a specific land use and/or redevelopment condition. As appropriate, the OMMP, EDR, and/or Restrictive Covenant would address a range of specific institutional controls, including:

- Site access controls including fencing and signage of all areas of the Site under active construction/redevelopment.
- Erosion controls for areas under active construction and/or awaiting redevelopment.
- Health and safety monitoring during construction activities.
- Augmentation of the thickness and areal extent of upland cap materials to support the intended future land use, potentially including more detailed soil characterization to refine the design of the cap to ensure compliance with use-specific cleanup standards (see Section 5).
- Placement of pre-planned utility corridors as appropriate for the specific land use redevelopment activity. For example, where utility or other work is required at the Site that would require excavation below the upland caps, trenches could be

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constructed in accordance with local standards, with the additional requirement that 1 foot of overexcavation, or a geofabric lining, be used to provide a clean perimeter around the outside of the utility trench.

- Construction of appropriate pile installations for new structures, as appropriate. Subject to confirmation of their effectiveness during remedial design, appropriate pile installation and construction methods and materials at the Quendall Terminals Site may include cast-in-place, driven grout, or other appropriate technologies to minimize pile-induced carry-down of DNAPL into subsurface soils.
- Periodic monitoring of the integrity of upland and shoreline caps, porewater quality (10 cm below mudline), and surface sediment quality (0 to 10 cm below mudline) for COPCs at the points of compliance to be set forth in the forthcoming Cleanup Action Plan for the Site.

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In accordance with WAC 173-340-420, Ecology will review the cleanup action and redevelopment plans no less frequently than every five years to ensure adequate protection of human health and the environment.

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APPENDIX A

SEDIMENT NATURAL RECOVERY STUDY

DRAFT
SAMPLING AND ANALYSIS PLAN

SEDIMENT FEASIBILITY STUDY
PORT QUENDALL TERMINALS SITE

Prepared for

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June 2003

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1 INTRODUCTION

This Sampling and Analysis Plan (SAP) presents the detailed methodology for gathering additional data to support the Port Quendall Terminals Site (Site) Feasibility Study (FS). As discussed in the Risk Assessment/Feasibility Study (RA/FS) Work Plan for the Site (Anchor and Aspect 2003), approved by the Washington Department of Ecology (Ecology) in April 2003, additional data are needed to inform forthcoming detailed FS evaluations of the potential effectiveness of alternative natural recovery, capping, and dredging technologies to remediate contaminated sediments at the Site.

As discussed in more detail herein, high-resolution sediment cores will be collected within target sediment cleanup areas, focusing on those with the highest near-surface (0 to 10 cm) polynuclear aromatic hydrocarbon (PAH) and total organic (TOC) concentrations, and over a range of water depths. These data will be used to support FS evaluations of upland source control requirements, natural recovery, capping, and management of dredge residuals. Sediment traps are also proposed to be collected at these locations to improve the understanding of local sediment transport dynamics. Finally, geotechnical testing will be performed at representative locations to assess the strength and stability of existing sediments for the purpose of assessing the feasibility of capping in this setting, and to determine if a follow-on sediment capping pilot study may be needed, as set forth in the RA/FS Work Plan.

The remainder of this SAP is organized into the following sections:

- Section 2.0 - Project Management and Responsibilities
- Section 3.0 - Sample Collection
- Section 4.0 - Physical and Chemical Analysis
- Section 5.0 - References

Tables and figures are grouped together at the end of the SAP.

2 PROJECT MANAGEMENT AND RESPONSIBILITIES

This section describes the overall project management strategy for implementing and reporting on the SAP.

The Project Manager for Anchor Environmental L.L.C. (Anchor) will be responsible for overall project coordination, including production of all project deliverables and administrative coordination to assure timely and successful completion of the project.

Two field personnel from Anchor will provide overall direction for the field sampling effort in terms of logistics, personnel assignments, and field operations. They will supervise field collection of the sediment core, trap, and grab samples. They will also be responsible for assuring accurate sample positioning; recording sample locations, depths and identification; assuring conformance to sampling and handling requirements including field decontamination procedures; physical evaluation and logging the samples; and completing Chain-of-Custody (COC) forms.

The sampling and analysis will be completed with equipment and vessels (see Section 3.3 for details) either owned or rented by Anchor. Anchor will be responsible for the submittal of environmental samples to Analytical Resources Incorporated (ARI), the designated laboratory for chemical analyses. CAS is accredited with the Washington State Department of Ecology (Ecology) for chemical and of environmental samples. The Laboratory Project Manager at CAS will provide analytical support and will be responsible for providing certified, pre-cleaned sample containers, sample preservatives (as appropriate), ensuring that all chemical analyses meet the project data quality objectives and other specifications detailed in the SAP.

3 SAMPLE COLLECTION

This section provides a detailed description of the field sampling schedule, station location and sample types, sampling vessel and station positioning, subsurface sediment core collection and processing procedures, and vane shear test and radioisotope procedures. This section also describes sample nomenclature, field documentation and Quality Assurance/Quality Control procedures, waste disposal and sample rehandling.

3.1 Field Sampling Schedule

The field sampling program is projected to be initiated in June 2003 with sediment trap deployment. The sediment traps will remain in place until sufficient sediment is collected for the appropriate chemical and physical analysis. The additional sediment recovery field activities will be conducted simultaneously with sediment trap retrieval and is expected to occur in September 2003. The actual start and end dates for the sampling event will depend on Ecology approval of this SAP and coordination with subcontractors. Other conditions that may affect the sampling schedule are weather and equipment conditions.

3.2 Station Location and Sample Types

To support the FS, high-resolution sediment cores will be collected within target sediment cleanup areas. A single subsurface core extending to a depth below mudline of at least 3 ft will be collected from the following sampling stations, as shown on Figure 1: VS18/WP-20B, QB-4, and S052. In addition, sediment traps will be deployed and vane shear tests (VSTs) will be conducted at these locations. The sample station coordinates are provided in Table 1.

3.3 Sampling Vessel and Station Positioning

Anchor will provide the sampling vessel, and all equipment necessary for the safe operation of the boat to support subsurface sampling operations. The sampling vessel will be a 14 ft skiff with a davit and wench connection with 150 pound capacity. The sampling stations will be located using a handheld GPS unit with an accuracy of plus or minus 10 ft. All sampling station coordinates will be provided in the state plane North American Datum (NAD 83) Washington State, North Zone coordinate system. These coordinates are listed in Table 1.

Upon locating the sampling station and prior to sampling, the depth to mudline will be measured using a lead line. All water depths will be converted to vertical elevations using the Army Corps of Engineers (Corps) gage located at the Hiram M. Chittenden Locks.

3.4 Sediment Core Collection and Processing Procedures

Subsurface sediment cores will be collected using a piston corer or similar type coring device. Table 2 provides the proposed chemical and physical analyses for the target sampling stations (locations provided in Figure 1). Table 3 shows the radioisotope analyses proposed for each core sampling interval at the target sampling stations.

3.4.1 Sediment Core Collection

A piston corer fitted with polycarbonate tubing (7.6-cm inner diameter [i.d.]) will be used to collect sediment cores from sampling stations VS18/WP-20B, QB-4, and S052 (coordinates provided in Table 1). All cores will be driven to a depth of at least 3 feet below the mudline elevation. The core tubes will be decontaminated immediately prior to use following the procedures outlined in Section 3.8. Care will be taken during sampling to avoid contact of the sample tube with potentially contaminated surfaces. Extra sample tubes will be available during sample operations for uninterrupted sampling in the event of a potential core tube breakage or contamination. Core tubes suspected to have been accidentally contaminated will not be used.

The piston depth will be set at approximately 20-cm above the measured sediment-water interface elevation, and the piston cable will be tied-off to the deck of the vessel. The corer will be driven (i.e., hand pushed) into the sediment with drive rods capable of extending to the appropriate mudline elevations identified. Penetration and recovery will be assessed using Velcro® on the outside of the core tube. The corer will be retrieved slowly and steadily to avoid agitating the sample. Prior to lifting the core tube into the vessel, a plug will be inserted into the bottom of the core tube to prevent sediment from slipping out of the bottom. When retrieved, each core will be inspected and a physical description of the material at the mouth of the core will be entered into the core log. Following inspection, the core will be transported to land for core processing immediate core processing.

Logs and field notes of all core samples will be maintained during core collection. The following information will be included in this log:

- Elevation of each sampling station corrected to the appropriate Lake Washington water elevation
- Location of each sampling station
- Date and collection time of each sediment core sample
- Names of field supervisor and person(s) collecting and logging the sample
- Observations made during sample collection including: weather conditions, complications, and other details associated with the sampling effort
- The sample station number denoted in Table 1
- Length and depth intervals of each core section and recovery for each sediment sample
- Qualitative notation of apparent resistance of sediment column to coring, including notes on debris
- Any deviation from the Ecology approved sampling plan

3.4.2 Sediment Core Processing

After the core is secured on board the sampling vessel, the core tube with the sample will be inspected. Each core will be evaluated for acceptability using the following criteria:

- At least 5 cm of overlying water is present
- The overlying water is not excessively turbid
- The sediment surface is relatively undisturbed
- At least 80 percent core recovery (measured directly following core retrieval) versus penetration is achieved

If a sediment core fails to meet any of the above criteria, the sediment will be extruded and placed into a storage container for future waste disposal (see Section 3.10), and an additional core will be collected from the sampling station. Immediately following inspection, the core will be transported to shore for immediate core processing.

Core processing will begin by removing the piston from the top of the core tube and extruding the sediment from the base of the core using a pneumatic core extruder.

Sediment samples will be collected from the intervals defined in Table 1 and Table 2. As the sediment is extruded out of the top of the core tube, physical descriptions of the core length will be noted on a core profile form. Each discreet depth interval will be extruded into a stainless-steel or high density polyethylene (HDPE) bucket for homogenization. The sediment will be homogenized by thorough mixing with stainless-steel utensils until the sediment appears uniform in color and texture. Once homogenized, the sediment will be distributed to appropriate, certified, pre-cleaned, pre-labeled sample containers with Polytetrafluoroethylene (PTFE) – lined lids. Immediately after sample containers are filled, they will be placed in a cooler on ice.

3.5 Sediment Trap Placement, Collection, and Handling Procedures

Sediment traps will be deployed in June 2003 and remain in place until sufficient sediment is available for the proposed chemical analysis listed in Table 4.

3.5.1 Sediment Trap Placement and Collection

Sediment traps will be deployed at sampling stations VS18/WP-20B, QB-4, and S052, as shown in Figure 1. Prior to deployment, the traps will be decontaminated following the procedures outlined in Section 3.8. The traps will be positioned approximately 3 ft above the mudline and left in place for approximately 2 months at which point the trap will be examined to determine if sufficient sediment is available for the proposed chemical analyses. The sediment traps will be installed and retrieved in a vertical fashion to decrease suspension and/or loss of suspended sediments within the trap.

3.5.2 Sediment Trap Processing

Upon retrieval of the traps, the water overlying the sediment surface will be slowly removed via a peristaltic pump and discarded. The appropriate volume of sediment in the sediment trap will be transferred into appropriately sized pre-cleaned, pre-labeled containers. The containers will be stored on ice until shipment to CAS.

3.6 Vane Shear Testing Procedures

Vane shear tests (VST) will be conducted at eleven stations in the North Section, co-located with surface sediment sampling. Testing will be completed with general accordance with

ASTM D 2573-94 using the Roc Test, Inc. Model M-3 shear vane. VST will be conducted at the mudline elevation and at a depth of 1 foot below mudline.

3.7 Sample Location Identification Scheme

Each sediment sample station will be assigned a unique 4 to 6-digit alpha numeric identifier according to the method described below. The identifiers facilitate sample tracking by incorporating identifying information. The alpha-numeric identifiers will be assigned as follows:

- The first three characters identify the geographical sample location: AQT = Anchor Quendall Terminal
- The next two characters identify the sample station: 01 = Station 01

For example, location number AQT-01 indicates Station 01.

Each sediment sample will be assigned a unique 6 to 8-digit alpha numeric identifier according to the method described below. The alpha-numeric identifiers will be assigned as follows:

- The first three characters identify the geographical sample location: AQT = Anchor Quendall Terminal
- The next two characters identify the sample station: 01 = Station 01
- For subsurface cores, the next two characters are coded as SD followed by a dash followed by a consecutive letter that is used to denote the depth interval (A – first depth interval, B – second depth interval, etc.): AQT-01SD-A
- For sediment traps, the next two characters are coded as ST: AQT-01ST
- For VSTs, the next two characters are coded as VST followed by a dash followed by a consecutive letter that is used to denote the depth interval (A – surface interval and B – 1 ft interval): AQT-01VST

For example, sample number AQT-02VST indicates a surface sediment sample obtained from Station 02. AQT-03SD-A indicates a subsurface core sample obtained from Station 03 from depth interval A, where A will be defined in the field notebook during field sampling.

Field quality assurance samples will be coded as follows:

- The filter wipe will be coded as AQT-FW
- The trip blank shipped to the laboratory on a certain date will be coded as TB-01-MMDDYY. A trip blank shipped in an additional cooler on the same date will be coded as TB-02-MMDDYY.

3.8 Field Equipment Decontamination Procedures

The core tubes will be decontaminated prior to use by the following procedure:

- Rinse with potable water and wash with scrub brush until free of sediment
- Wash with phosphate-free detergent (Alconox®)
- Rinse with potable water
- Visually inspect the sampler and repeat the scrub and rinse step, if necessary
- Rinse three times with site water prior to use

All sample homogenizing equipment will be decontaminated prior to and between processing cores at each station using the following procedure:

- Rinse with potable water or site water and wash with scrub brush until free of sediment
- Wash with Alconox®
- Rinse with potable water or site water
- Rinse three times with distilled water

3.9 Field Quality Assurance and Quality Control

Field quality assurance samples will be issued to evaluate the efficiency of field decontamination procedures. A filter wipe will be collected by wiping down all decontaminated coring equipment (i.e., stainless steel spoons and bowls). The filter wipe will be archived pending inspection of analytical results for potential contamination by indicator chemicals. All field quality control samples will be documented in the site logbook.

3.10 Waste Disposal

All sediment remaining after subsampling will be returned to Lake Washington unless discharge of this sediment creates a visible sheen on the lake surface. In this unlikely event,

the excess sediment will be drummed and transported off-site to an approval disposal facility.

All disposable materials used in sample processing, such as paper towels and disposable coveralls and gloves, will be placed in heavy weight garbage bags or other appropriate containers. Disposable supplies will be removed from the site by sampling personnel and placed in a normal refuse container for disposal at a solid waste landfill. Phosphate free detergent-bearing liquid wastes from decontamination of the sampling equipment will be washed overboard.

3.11 Sampling Handling

This section describes the sample containers, sample handling and storage, COC forms, and sample shipping for all sediment sampling activities.

3.11.1 Sample Containers for Analysis

All sample containers received from the analytical lab will be pre-cleaned, certified, and EPA-approved. Prior to shipping, the analytical laboratory will add preservative, where required.

3.11.2 General Sample Handling and Storage

The guidelines for sample handling and storage for samples obtained via piston core and sediment trap methods are provided in Table 5. Sample containers, instruments, working surfaces, technician protective gear, and other items that may come into contact with sediment sample material must meet high standards of cleanliness. All equipment and instruments used to remove sediment from the sampler will be made of glass, stainless steel, or PTFE, and will be cleaned prior to each day's use and between sampling or compositing events.

All working surfaces and instruments will be thoroughly cleaned, decontaminated, and covered with aluminum foil to minimize outside contamination between sampling events. Disposable gloves will be discarded after processing each station and replaced prior to handling decontaminated instruments or work surfaces. Sample containers will be kept in packaging as received from the analytical lab until use; a sample container

will be withdrawn only when a sample is to be collected and returned to a cooler containing completed samples.

3.11.3 Sample Transport and Chain-of-Custody Procedures

All containerized sediment samples will be transported to the analytical laboratory after preparation is completed. Specific sample shipping procedures will be as follows:

1. The shipping containers will be clearly labeled with sufficient information (name of project, time and date container was sealed, person sealing the container and consultant's office name and address) to enable positive identification
2. Individual sample containers will be placed in a sealable plastic bag, packed to prevent breakage and transported in a sealed ice chest or other suitable container
3. Glass jars will be separated in the shipping container by shock absorbent material (e.g., bubble wrap) to prevent breakage
4. Ice will be placed in separate plastic bags and sealed
5. A sealed envelope containing COC forms will be enclosed in a plastic bag and taped to the inside lid of the cooler
6. The cooler lids will be secured by wrapping the coolers in strapping tape
7. Signed and dated COC seals will be placed on all coolers prior to shipping
8. Each cooler or container containing the sediment samples for analysis will be shipped to the laboratory within 24 hours of being sealed

Upon transfer of sample possession to the analytical laboratory, the persons transferring custody of the sample container will sign the COC form. Upon receipt of samples at the laboratory, the shipping container seal will be broken and the condition of the samples recorded by the recipient. COC forms will be used internally in the lab to track sample handling and final disposition.

3.11.4 Sample Shipping

Prior to shipping, sample containers (wrapped in bubble wrap) will be securely packed inside a cooler with ice packs or crushed ice. COC forms will be filled out and the original signed COC forms will be placed in a sealable plastic bag and taped to the inside lid of the cooler. Fiber tape will be wrapped completely around the cooler. On each side of the cooler a *This Side Up* arrow label will be attached, a *Glass—Handle with*

Care label will be attached to the top of the cooler, and the cooler will be sealed with a custody seal. Samples will be shipped via courier to CAS.

4 PHYSICAL AND CHEMICAL ANALYSES

This section summarizes the physical and chemical analyses performed for the characterization of sediments in the various study areas.

All sample analyses will be conducted in accordance with methods, protocols, and guidelines contained within the ITM (USEPA/USACE 1998). Table 6 presents the proposed analytes, the analytical methods to be used, and the targeted detection limits for the evaluation of sediments. All samples will be maintained according to the appropriate holding times and temperatures for each analysis, as presented in Table 5.

In addition, the following methods will be used for physical testing of sediments:

- Grain size - ASTM D 422
- Atterberg Limits - ASTM D 4318

4.1 Laboratory Reporting Requirements

CAS will prepare a detailed report to be included as an appendix in the final report documenting all activities associated with the sample analyses. Included in this report will be:

- Project Narrative: A detailed report that describes the samples received, analyses performed, and corrective actions undertaken
- COC Documentation: Laboratory policy requires that COC documentation be available for all samples received. The COC will document basic sample demographics such as client and project names, sample identification, analyses requested, and special instructions
- Data Summary Form: A tabular listing of concentrations and/or detection limits for all target analytes. The data report will also list other pertinent information such as amount of sample analyzed, dilution factors, sample processing dates, extract cleanups, and surrogate recoveries
- QA Summary: Includes results of all quality control analyses, specifically recovery information. Laboratory control samples will be reported with each batch. Additional QC analysis may include laboratory replicates, matrix spikes and standard reference materials

- Instrument Calibration Forms and Raw Data: Includes initial and continuing calibration summaries and instrument tuning data, laboratory bench sheets, and log book pages

CAS will also provide electronic deliverables in EQuIS® format.

5 REFERENCES

USACE. September 30, 1987. Confined Disposal of Dredged Material, EM 1110-2-5027, United States Army Corps of Engineers.

U.S. EPA. 1986. General QA/QC consideration for collecting environmental samples in Puget Sound. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Puget Sound Estuary Program, Seattle, WA.

USEPA/USACE. 1998. Evaluation of dredged material proposed for discharge in waters of the U.S. testing manual - inland testing manual. U.S. Environmental Protection Agency/U.S. Army Corps of Engineers. EPA-823-B-94-002. U.S. Environmental Protection Agency, Office of Water (4305).

Table 1
Proposed Sampling Station Locations and Coordinates

	Sample Coordinates (NAD 83, Washington North Zone)	
Sample Station ID	**Northing**	**Easting**
VS18/WP-20B	1661736.1900	197536.4800
QB-4	1661619.3583	198108.5207
S052	1661337.5300	198209.9300

Table 2
Sediment Coring Interval Depths and Analysis

Interval (cm)	Analyte List
0-10	PAHs, total organic carbon, total solids, grain size, Atterberg limits
10-20	PAHs, total organic carbon, total solids, grain size, Atterberg limits
20-30	PAHs, total organic carbon, total solids, grain size, Atterberg limits
30-40	PAHs, total organic carbon, total solids, grain size, Atterberg limits
40-50	PAHs, total organic carbon, total solids, grain size, Atterberg limits
50-60	PAHs, total organic carbon, total solids, grain size, Atterberg limits

Table 3
Sediment Coring Interval Depths for Radioisotope Analysis

Interval	^{7}Be Analysis Subsample Depth (cm)	^{137}Cs Analysis Subsample Depth (cm)	^{210}Pb Analysis Subsample Depth (cm)
A	0-4	0-10	0-10
B	4-8	10-20	10-20
C	8-12	20-30	20-30
D	12-16	30-40	30-40
E	-----	40-50	40-50
F	-----	50-60	50-60

Table 4
Sediment Trap Sampling Stations and Analysis

Sampling Station	Target Analyses
VS18/WP-20B	PAHs, total organic carbon, total solids, grain size, total dry weight, ^{210}PB
QB-4	PAHs, total organic carbon, total solids, grain size, total dry weight, ^{210}PB
S052	PAHs, total organic carbon, total solids, grain size, total dry weight, ^{210}PB

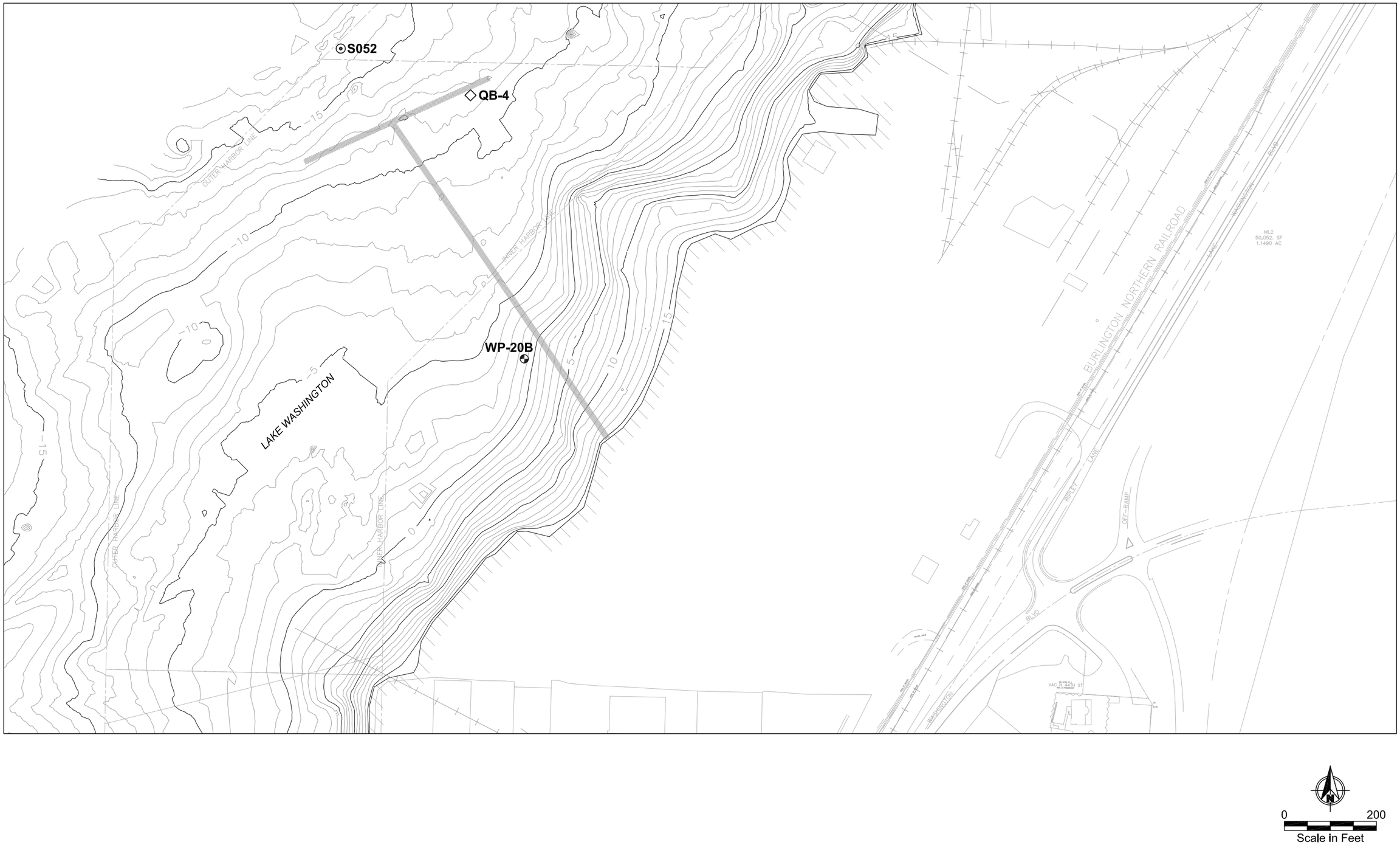
Table 5
Guidelines for Sample Handling and Storage

Parameter	Container Size and Type	Holding Time	Preservative
Semivolatile organic compounds	16-oz Glass	14 days until extraction	Cool/4° C
		1 year until extraction	Freeze
		40 days after extraction	
Total solids	4-oz Glass	6 months	Freeze
		14 days	Cool/4° C
Total organic carbon	4-oz Glass	6 months	Freeze
		14 days	Cool/4° C
Grain size	16-oz Glass	6 months	Cool/4° C

Table 6
Analytes, Analysis Methods, and Targeted Detection Limits

Parameter	CAS Number	Preparation Method	Analytical Method	Targeted Detection Limit
Total solids (%)	NA	NA	PSEP	0.1
Total organic carbon (%)	NA	NA	SM5301b	0.1
Grain size (%)	NA	NA	PSEP	0.1
Organic Compounds (µg/kg dry weight)				
LPAHs				
Naphthalene	91203	US EPA Method 3550	US EPA Method 8270	20
Acenaphthylene	208968	US EPA Method 3550	US EPA Method 8270	20
Acenaphthene	83329	US EPA Method 3550	US EPA Method 8270	20
Fluorene	86737	US EPA Method 3550	US EPA Method 8270	20
Phenanthrene	85018	US EPA Method 3550	US EPA Method 8270	20
Anthracene	1201727	US EPA Method 3550	US EPA Method 8270	20
2-Methylnaphthalene	91576	US EPA Method 3550	US EPA Method 8270	20
HPAHs				
Fluoranthene	206440	US EPA Method 3550	US EPA Method 8270	20
Pyrene	129000	US EPA Method 3550	US EPA Method 8270	20
Benz(a)anthracene	56553	US EPA Method 3550	US EPA Method 8270	20
Chrysene	218019	US EPA Method 3550	US EPA Method 8270	20
Benzofluoranthene	205992	US EPA Method 3550	US EPA Method 8270	20
Benzo(a)pyrene	50328	US EPA Method 3550	US EPA Method 8270	20
Indeno(1,2,3-cd)pyrene	193395	US EPA Method 3550	US EPA Method 8270	20
Dibenz(a,h)anthracene	53703	US EPA Method 3550	US EPA Method 8270	20
Benzo(g,h,i)perylene	191242	US EPA Method 3550	US EPA Method 8270	20

Note: NA = Not Applicable
PSEP = Puget Sound Estuary Protocol



Jun 05, 2003 3:33pm cdavidson I:\CAD\Jobs\020059-Port_Quendall-Barbee_Mill\02005902\02005902-03.dwg FIG 1

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Figure 1
Proposed Sediment Feasibility Study Sampling Locations
Port Quendall Terminal Cleanup

Table A-1
Quendall Terminals
Summary of Sediment Data

Location ID	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-QB4	AQT-S052	AQT-S052
Loc Name																	
Sample ID	AQT-QB4-CA	AQT-QB4-PCB	AQT-QB4-PCC	AQT-QB4-PCD	AQT-QB4-PCE	AQT-QB4-PCF	AQT-QB4-BeA	AQT-QB4-BeB	AQT-QB4-BeC	AQT-QB4-BeD	AQT-QB4-CB	AQT-QB4-CC	AQT-QB4-CD	AQT-QB4-CE	AQT-QB4-CF	AQT-S052-CA	AQT-S052-PCA
Sample Date	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/18/2003	09/18/2003
Depth Interval cc	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-4 cm	0-4 cm	0-4 cm	0-4 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	0-10 cm	0-10 cm
Conventionals																	
Total Organic Carbon	11.2	--	--	--	--	--	--	--	--	--	1.41	0.72	0.25	4.35	19.9 *	4.29	--
Total solids	19.3	--	--	--	--	--	--	--	--	--	55.4	66.1	76.1	39.5	14.6	24.7	--
Grain Size (%)																	
Gravel	4.91	--	--	--	--	--	--	--	--	--	2.84	6.74	0.36	3.73 J	0.62	0.09	--
Sand, Very Coarse	3.70	--	--	--	--	--	--	--	--	--	1.44	1.88	3.14	7.86 J	7.66	2.02	--
Sand, Coarse	3.46	--	--	--	--	--	--	--	--	--	3.86	7.48	13.3	12.0 J	11.5	2.39	--
Sand, Medium	6.66	--	--	--	--	--	--	--	--	--	21.9	24.2	39.1	42.8 J	21.0	6.58	--
Sand, Fine	13.2	--	--	--	--	--	--	--	--	--	37.1	37.1	35.5	37.8 J	27.4	14.0	--
Sand, Very Fine	12.2	--	--	--	--	--	--	--	--	--	9.25	16.4	6.22	12.7 J	11.5	15.5	--
Silt	42.5	--	--	--	--	--	--	--	--	--	21.2	7.09	1.33	10.4 J	12.2	48.9	--
Clay	10.4	--	--	--	--	--	--	--	--	--	4.26	1.20	0.13	4.56 J	10.4	11.6	--
Radiochemistry																	
Beryllium 7 (dpm/g)	--	--	--	--	--	--	0.308 U	0.305 U	0.228 U	0.287 U	--	--	--	--	--	--	--
Cesium 137 (pCi/g)	--	0.856	0.139 U	-0.0237 U	0.0294 U	-0.0113 U	--	--	--	--	--	--	--	--	--	--	0.706
Lead 210 (dpm/g)	--	2.05	0.566	0.403	0.263	0.147	--	--	--	--	--	--	--	--	--	--	2.46
PAHs - Alkylated (µg/kg)																	
C1-Chrysenes	1000	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	74	--
C1-Dibenzothiophenes	16	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C1-Fluoranthenes/Pyrenes	1400	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	64	--
C1-Fluorenes	62	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C1-Phenanthrenes/Anthracenes	570	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	29	--
C2-Chrysenes	380	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	36	--
C2-Dibenzothiophenes	63	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C2-Fluorenes	82	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C2-Naphthalenes	24	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C2-Phenanthrenes/Anthracenes	410	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	19	--
C3-Chrysenes	130	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C3-Dibenzothiophenes	65	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C3-Fluorenes	84	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C3-Naphthalenes	48	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C3-Phenanthrenes/Anthracenes	580	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	32	--
C4-Chrysenes	180	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C4-Naphthalenes	64	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	12 U	--
C4-Phenanthrenes/Anthracenes	1500	--	--	--	--	--	--	--	--	--	--	--	3.7 U	--	--	87	--
SVOCs (µg/kg)																	
HPAHs																	
Benzo(a)anthracene	1300	--	--	--	--	--	--	--	--	--	1200	13	3.7 U	7.2 U	20 U	67	--
Benzo(a)pyrene	1100	--	--	--	--	--	--	--	--	--	980	10	3.7 U	7.2 U	20 U	120	--
Benzo(b)fluoranthene	1200	--	--	--	--	--	--	--	--	--	920	11	3.7 U	7.2 U	20 U	130	--
Benzo(k)fluoranthene	1000	--	--	--	--	--	--	--	--	--	910	8.7	3.7 U	7.2 U	20 U	120	--
Benzo(g,h,i)perylene	480	--	--	--	--	--	--	--	--	--	340	8.5	3.7 U	7.2 U	20 U	120	--
Chrysene	1600	--	--	--	--	--	--	--	--	--	1300	13	3.7 U	7.2 U	20 U	120	--
Dibenzo(a,h)anthracene	130	--	--	--	--	--	--	--	--	--	99	4.4 U	3.7 U	7.2 U	20 U	24	--
Fluoranthene	2900	--	--	--	--	--	--	--	--	--	1200	46	3.7 U	7.2 U	20 U	100	--
Indeno(1,2,3-cd)pyrene	610	--	--	--	--	--	--	--	--	--	460	8.7	3.7 U	7.2 U	20 U	110	--
Pyrene	1900	--	--	--	--	--	--	--	--	--	720	32	3.7 U	7.2 U	20 U	87	--
Total benzofluoranthenes	2200	--	--	--	--	--	--	--	--	--	1830	19.7	3.7 U	7.2 U	20 U	250	--
Total HPAH (SMS)	12220	--	--	--	--	--	--	--	--	--	8129	150.9	3.7 U	7.2 U	20 U	998	--
Benz(a)anthracene/chrysene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LPAHs																	
2-Methylnaphthalene	20	--	--	--	--	--	--	--	--	--	24	4.4 U	3.7 U	7.2 U	20 U	12 U	--
Acenaphthene	49	--	--	--	--	--	--	--	--	--	40	4.4 U	3.7 U	7.2 U	20 U	12 U	--
Acenaphthylene	23	--	--	--	--	--	--	--	--	--	71	4.4 U	3.7 U	7.2 U	20 U	12 U	--
Anthracene	260	--	--	--	--	--	--	--	--	--	430	4.4 U	3.7 U	7.2 U	20 U	14	--
Fluorene	64	--	--	--	--	--	--	--	--	--	180	4.4 U	3.7 U	7.2 U	20 U	12 U	--
Naphthalene	70	--	--	--	--	--	--	--	--	--	39	4.4 U	3.7 U	7.2 U	20 U	14	--
Phenanthrene	600	--	--	--	--	--	--	--	--	--	960	11	3.7 U	7.2 U	20 U	46	--
Total LPAH (SMS)	1066	--	--	--	--	--	--	--	--	--	1720	11	3.7 U	7.2 U	20 U	74	--
Total cPAHs (BaP EQ)	1579	--	--	--	--	--	--	--	--	--	1381.6	14.27	3.7 U	7.2 U	20 U	173.5	--
Total PAHs (Site-Specific)	13306	--	--	--	--	--	--	--	--	--	9873	161.9	3.7 U	7.2 U	20 U	1072	--

Table A-1
Quendall Terminals
Summary of Sediment Data

Location ID	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-S052	AQT-WP20B	AQT-WP20B
Loc Name																
Sample ID	AQT-S052-PCB	AQT-S052-PCC	AQT-S052-PCD	AQT-S052-PCE	AQT-S052-PCF	AQT-S052-BeA	AQT-S052-BeB	AQT-S052-BeC	AQT-S052-BeD	AQT-S052-CB	AQT-S052-CC	AQT-S052-CD	AQT-S052-CE	AQT-S052-CF	AQT-WP20B-CA	AQT-WP20B-PCB
Sample Date	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/18/2003	09/19/2003	09/19/2003
Depth Interval cc	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-4 cm	0-4 cm	0-4 cm	0-4 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm	0-10 cm	0-10 cm
Conventionals																
Total Organic Carbon	--	--	--	--	--	--	--	--	--	46 *	21.9 *	18.5 *	15.1 *	13	10.7	--
Total solids	--	--	--	--	--	--	--	--	--	34.3	11	13.1	14.3	17.7	21.3	--
Grain Size (%)																
Gravel	--	--	--	--	--	--	--	--	--	0.07	0.22	2.54	0.00	0.00	31.9	--
Sand, Very Coarse	--	--	--	--	--	--	--	--	--	2.84	6.29	25.1	0.66	0.94	5.04	--
Sand, Coarse	--	--	--	--	--	--	--	--	--	3.45	13.6	49.3	19.3	16.7	4.02	--
Sand, Medium	--	--	--	--	--	--	--	--	--	10.2	16.9	27.0	18.4	49.9	4.76	--
Sand, Fine	--	--	--	--	--	--	--	--	--	15.7	20.5	1.86	15.2	6.15	6.86	--
Sand, Very Fine	--	--	--	--	--	--	--	--	--	14.8	19.0	0.870	13.5	5.11	9.77	--
Silt	--	--	--	--	--	--	--	--	--	38.7	19.9	10.6	24.8	22.0	37.8	--
Clay	--	--	--	--	--	--	--	--	--	14.5	10.5	8.78	16.2	14.6	6.20	--
Radiochemistry																
Beryllium 7 (dpm/g)	--	--	--	--	--	0.228 U	0.209 U	0.253 U	0.265 U	--	--	--	--	--	--	--
Cesium 137 (pCi/g)	0.0693 U	-0.00505 U	-0.0331 U	-0.0612 U	0.00365 U	--	--	--	--	--	--	--	--	--	--	0.712
Lead 210 (dpm/g)	0.0930	0.169	0.313	0.451	0.377	--	--	--	--	--	--	--	--	--	--	0.888
PAHs - Alkylated (µg/kg)																
C1-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6400	--
C1-Dibenzothiophenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	130	--
C1-Fluoranthenes/Pyrenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5200	--
C1-Fluorenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	740	--
C1-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2900	--
C2-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1400	--
C2-Dibenzothiophenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	320	--
C2-Fluorenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	590	--
C2-Naphthalenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3800	--
C2-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1200	--
C3-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	400	--
C3-Dibenzothiophenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	210	--
C3-Fluorenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	420	--
C3-Naphthalenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1600	--
C3-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4600	--
C4-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	270 U	--
C4-Naphthalenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	880	--
C4-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	270 U	--
SVOCs (µg/kg)																
HPAHs																
Benzo(a)anthracene	--	--	--	--	--	--	--	--	--	120	26 U	22 U	20 U	16 U	5800	--
Benzo(a)pyrene	--	--	--	--	--	--	--	--	--	320	26 U	22 U	20 U	16 U	16000	--
Benzo(b)fluoranthene	--	--	--	--	--	--	--	--	--	290	26 U	22 U	20 U	16 U	14000	--
Benzo(k)fluoranthene	--	--	--	--	--	--	--	--	--	260	26 U	22 U	20 U	16 U	13000	--
Benzo(g,h,i)perylene	--	--	--	--	--	--	--	--	--	260	26 U	22 U	20 U	16 U	8300	--
Chrysene	--	--	--	--	--	--	--	--	--	280	26 U	22 U	20 U	16 U	11000	--
Dibenzo(a,h)anthracene	--	--	--	--	--	--	--	--	--	60	26 U	22 U	20 U	16 U	1800	--
Fluoranthene	--	--	--	--	--	--	--	--	--	99	26 U	22 U	20 U	16 U	6200	--
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	--	--	--	--	270	26 U	22 U	20 U	16 U	8100	--
Pyrene	--	--	--	--	--	--	--	--	--	88	26 U	22 U	20 U	16 U	5900	--
Total benzofluoranthenes	--	--	--	--	--	--	--	--	--	550	26 U	22 U	20 U	16 U	27000	--
Total HPAH (SMS)	--	--	--	--	--	--	--	--	--	2047	26 U	22 U	20 U	16 U	90100	--
Benz(a)anthracene/chrysene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LPAHs																
2-Methylnaphthalene	--	--	--	--	--	--	--	--	--	8.2 U	26 U	22 U	20 U	16 U	1100	--
Acenaphthene	--	--	--	--	--	--	--	--	--	8.2 U	26 U	22 U	20 U	16 U	5300	--
Acenaphthylene	--	--	--	--	--	--	--	--	--	8.2 U	26 U	22 U	20 U	16 U	210	--
Anthracene	--	--	--	--	--	--	--	--	--	20	26 U	22 U	20 U	16 U	1800	--
Fluorene	--	--	--	--	--	--	--	--	--	8.2 U	26 U	22 U	20 U	16 U	2500	--
Naphthalene	--	--	--	--	--	--	--	--	--	9.3	26 U	22 U	20 U	16 U	990	--
Phenanthrene	--	--	--	--	--	--	--	--	--	57	26 U	22 U	20 U	16 U	6900	--
Total LPAH (SMS)	--	--	--	--	--	--	--	--	--	86.3	26 U	22 U	20 U	16 U	17700	--
Total cPAHs (BaP EQ)	--	--	--	--	--	--	--	--	--	440.8	26 U	22 U	20 U	16 U	20920	--
Total PAHs (Site-Specific)	--	--	--	--	--	--	--	--	--	2133.3	26 U	22 U	20 U	16 U	108900 *	--

Table A-1
Quendall Terminals
Summary of Sediment Data

Location ID	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B	AQT-WP20B
Loc Name													
Sample ID	AQT-WP20B-PCC	AQT-WP20B-PCD	AQT-WP20B-PCE	AQT-WP20B-PCF	AQT-WP20B-BeA	AQT-WP20B-BeB	AQT-WP20B-BeC	AQT-WP20B-BeD	AQT-WP20B-CB	AQT-WP20B-CC	AQT-WP20B-CD	AQT-WP20B-CE	AQT-WP20B-CF
Sample Date	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003	09/19/2003
Depth Interval cc	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-4 cm	0-4 cm	0-4 cm	0-4 cm	10-20 cm	20-30 cm	30-40 cm	40-50 cm	50-60 cm
Conventionals													
Total Organic Carbon	--	--	--	--	--	--	--	--	8	6.18	5.82	3.33	2.14
Total solids	--	--	--	--	--	--	--	--	29.8	35	34.1	44.2	54.8
Grain Size (%)													
Gravel	--	--	--	--	--	--	--	--	16.0	0.15	0.39	0.06	0.10
Sand, Very Coarse	--	--	--	--	--	--	--	--	5.23	2.33	2.94	1.21	0.73
Sand, Coarse	--	--	--	--	--	--	--	--	5.53	3.09	14.3	10.5	2.78
Sand, Medium	--	--	--	--	--	--	--	--	6.03	11.9	27.0	19.2	6.04
Sand, Fine	--	--	--	--	--	--	--	--	11.2	10.5	12.3	5.86	10.6
Sand, Very Fine	--	--	--	--	--	--	--	--	17.2	23.8	6.48	5.72	27.5
Silt	--	--	--	--	--	--	--	--	32.7	39.8	28.8	44.9	45.1
Clay	--	--	--	--	--	--	--	--	6.31	5.91	7.06	6.74	7.22
Radiochemistry													
Beryllium 7 (dpm/g)	--	--	--	--	0.313 U	0.314 U	0.297 U	0.185 U	--	--	--	--	--
Cesium 137 (pCi/g)	0.0113 U	0.0132 U	-0.0305 U	-0.00946 U	--	--	--	--	--	--	--	--	--
Lead 210 (dpm/g)	0.502	0.842	0.644	0.368	--	--	--	--	--	--	--	--	--
PAHs - Alkylated (µg/kg)													
C1-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C1-Dibenzothiophenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C1-Fluoranthenes/Pyrenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C1-Fluorenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C1-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C2-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C2-Dibenzothiophenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C2-Fluorenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C2-Naphthalenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C2-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C3-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C3-Dibenzothiophenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C3-Fluorenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C3-Naphthalenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C3-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C4-Chrysenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C4-Naphthalenes	--	--	--	--	--	--	--	--	--	--	--	--	--
C4-Phenanthrenes/Anthracenes	--	--	--	--	--	--	--	--	--	--	--	--	--
SVOCs (µg/kg)													
HPAHs													
Benzo(a)anthracene	--	--	--	--	--	--	--	--	45000	73000	57000	600	220
Benzo(a)pyrene	--	--	--	--	--	--	--	--	77000	91000	120000	880	840
Benzo(b)fluoranthene	--	--	--	--	--	--	--	--	89000	88000	110000	730	640
Benzo(k)fluoranthene	--	--	--	--	--	--	--	--	77000	80000	110000	690	510
Benzo(g,h,i)perylene	--	--	--	--	--	--	--	--	46000	63000	65000	440	650
Chrysene	--	--	--	--	--	--	--	--	79000	74000	82000	1200	510
Dibenzo(a,h)anthracene	--	--	--	--	--	--	--	--	11000	15000	17000	140	150
Fluoranthene	--	--	--	--	--	--	--	--	58000	80000	93000	990	190
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	--	--	--	48000	68000	72000	520	640
Pyrene	--	--	--	--	--	--	--	--	65000	77000	95000	850	200
Total benzofluoranthenes	--	--	--	--	--	--	--	--	166000	168000	220000	1420	1150
Total HPAH (SMS)	--	--	--	--	--	--	--	--	595000	709000	821000	7040	4550
Benz(a)anthracene/chrysene	--	--	--	--	--	--	--	--	--	--	--	--	--
LPAHs													
2-Methylnaphthalene	--	--	--	--	--	--	--	--	57000	150000	140000	3500	1200
Acenaphthene	--	--	--	--	--	--	--	--	31000	63000	67000	1700	210
Acenaphthylene	--	--	--	--	--	--	--	--	1300	1900	1900	47	6.5
Anthracene	--	--	--	--	--	--	--	--	15000	25000	34000	480	63
Fluorene	--	--	--	--	--	--	--	--	18000	38000	44000	780	23
Naphthalene	--	--	--	--	--	--	--	--	13000	120000	38000	610	580
Phenanthrene	--	--	--	--	--	--	--	--	60000	90000	120000	1200	170
Total LPAH (SMS)	--	--	--	--	--	--	--	--	138300	337900	304900	4817	1052.5
Total cPAHs (BaP EQ)	--	--	--	--	--	--	--	--	108090	128640	162520	1202	1106.1
Total PAHs (Site-Specific)	--	--	--	--	--	--	--	--	790300 *	1196900 *	1265900 *	15357	6802.5

APPENDIX B

T-DOCK BIOASSAY STUDY

SAMPLING AND ANALYSIS PLAN

PORT QUENDALL TERMINALS SITE

T-DOCK SUPPLEMENTAL SEDIMENT ASSESSMENT

Prepared for

J.H. Baxter & Company
P.O. Box 10797
Eugene, Oregon 97402

Altino Properties, Inc.
P.O. Box 359
Renton, Washington 98055

Prepared by

Anchor Environmental, L.L.C.
1423 Third Avenue, Suite 300
Seattle, Washington 98101

January 2004

SAMPLING AND ANALYSIS PLAN

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January 2004

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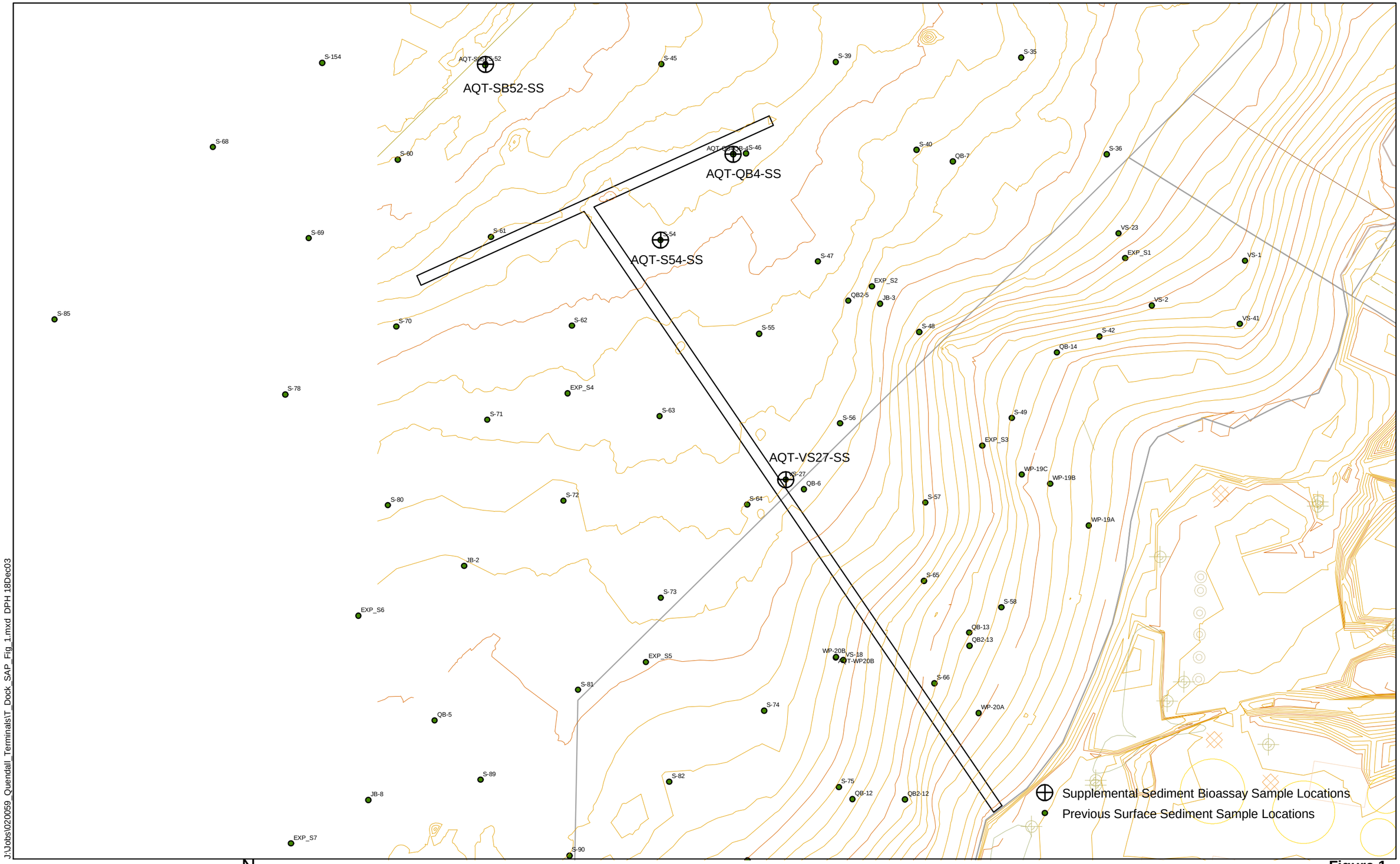
1 INTRODUCTION

The Quendall Terminals Site ("Site") is a 23-acre property located on the southeast shore of Lake Washington. Shortly after the lowering of Lake Washington in 1916 to construct the Lake Washington Ship Canal, the Site, including newly exposed portions of the former May Creek delta, was developed into a creosote manufacturing facility. Up until 1969, creosote was manufactured on Site by refining and processing coal tar and oil-gas tar residues. From 1969 to approximately 1977, some of the above-ground tanks at the Site were used intermittently for crude oil, waste oil, and diesel storage. Since 1977, the Site has been used primarily for log sorting and storage. Aquatic lands adjacent to the facility and managed by the Washington Department of Natural Resources ("DNR") have been leased for log rafting and vessel storage uses since approximately 1936.

The considerable site characterization data collected to date on the Site by Hart Crowser, Retec, and Exponent have previously been submitted to Ecology, and have been incorporated into the existing administrative record for the Site. The principal findings from the more recent investigations were summarized in the Data Gap Memo (Anchor and Aspect 2002) and Work Plan (Anchor and Aspect 2003). Based on a review of these data, polynuclear aromatic hydrocarbons ("PAHs") and other organic chemicals such as benzene and wood waste have previously been detected at the Site at concentrations that trigger actions under the Washington State Model Toxics Control Act ("MTCA"; Chapter 173-340 WAC; Chapter 70.105D RCW). The Site has been listed by the Washington Department of Ecology ("Ecology") as a hazardous substance cleanup site.

In fall 2002, Ecology, J.H. Baxter & Company and Altino Properties executed the Third Amendment to Agreed Order No. DE 92TC-N335, which established a scope of work and schedule to complete a Risk Assessment ("RA") and Feasibility Study ("FS") of the Quendall Terminals Site, consistent with MTCA requirements. Consistent with the requirements of the amended Agreed Order, on April 21, 2003 Ecology approved the Final Work Plan (Anchor and Aspect 2003) detailing the specific tasks to conduct the RA/FS. Task 2 of the RA/FS Work Plan included an assessment of natural recovery in the area surrounding the T-Dock structure (Figure 1). Sediment sampling of this area in September 2003 revealed that natural recovery processes, primarily biodegradation, had reduced PAH concentrations in the top 10 cm relative to samples collected previously. Following review of these recent data, Ecology requested that

focused bioassay testing be conducted to establish whether toxicity to benthos remained from potential PAH biodegradation products. This Sampling and Analyses Plan (SAP) details the field collection and laboratory testing methods to be used to verify that T-Dock sediments comply with confirmatory bioassay provisions of the Washington Sediment Management Standards (SMS).



ANCHOR ENVIRONMENTAL, L.L.C.

Figure 1
Quendall Terminals
T-Dock Supplemental Sediment Assessment
Proposed Sampling Locations

2 SAMPLING PROGRAM OVERVIEW

Four test sediment samples will be collected from the T-Dock area (Figure 1) and two reference sediment samples will be collected from Lake Washington. In addition to bioassay testing, the samples will be analyzed for grain size, total organic carbon, total volatile solids, and solid phase and porewater ammonia and sulfides. Sediment samples will also be collected and archived for possible future chemical analyses. Test and reference sediment samples will be wet sieved in the field to ensure that the reference sediment samples closely match the grain size, in percent fines, of the test samples.

Under the SMS, two acute and one chronic effect bioassays are required to establish compliance. The following bioassays were recommended by Ecology and will be conducted:

- A 20-day *Chironomus tentans* survival and growth test,
- A 10-day *Hyalella azteca* survival test, and
- A Microtox® 100 percent sediment porewater test.

The tests will be conducted in accordance with standard protocols established by the Environmental Protection Agency (EPA; 2000), the American Society for Testing and Materials (2000) and the Sediment Sampling and Analysis Plan Appendix (SAPA; Ecology 2003a). Sediments with similar physical characteristics to the test sediments will be used as reference sediments for all toxicity tests.

All field work associated with this project will follow current Puget Sound Estuary Program (PSEP) protocols for sampling and analysis (PSEP 1986 and 1997a,b). Laboratories performing the physical and biological analyses are certified by Ecology for the tests performed in conjunction with this project.

The laboratory data reports, data analyses, summary tables, and data validation report will be provided as an appendix to the RA/FS.

3 SEDIMENT SAMPLING AND HANDLING

3.1 Field Personnel

Dan Hennessy of Anchor Environmental (Anchor) will be the field manager for the collection and handling of the sediment samples. Mr. Hennessy, or a designee, will be responsible for assuring accurate sample location positioning; recording sample locations, depths and identification; assuring conformance to sampling and handling requirements including field decontamination procedures; physical evaluation and logging the samples; and chain-of-custody of the samples.

3.2 Sampling Platform

All surface sediment sampling will be conducted from Anchor's 21 foot Wooldridge Sport Utility Vessel, the RV Rooster Tail. The boat is equipped with a davit and power capstan to deploy and retrieve sampling gear. A stainless steel table across the stern will be used to hold the grab sampler while sediment is collected. Extra sediment will be rinsed over the side.

3.3 Horizontal Positioning and Vertical Control

Horizontal positioning at each sampling location will be determined using a handheld GPS. Station positions will be recorded in latitude and longitude to the nearest 0.01 second in both NAD 27 (for inclusion into the SEDQUAL database) and NAD 83. The accuracy of the horizontal coordinates will be within 10 feet.

Mudline elevation of each sampling station will be determined relative to mean sea level (MSL) by measuring the water depth with a lead line and adjusting for the Lake Washington's lake elevation as identified at the Hiram Chittenden (Ballard) Locks.

3.4 Station and Sample Identification

Identification numbers (IDs) for discrete samples will be the same as the respective station IDs. Each station ID will be an alphanumeric combination. Each will begin with the 3-letter prefix AQT to identify the station as an Anchor/Quendall Terminals sample. The historical station designation will be indicated next, followed by the letters SS to indicate the sample matrix is surface sediment. For example, the sampling station at historical station QB-4 will be identified as AQT-QB4-SS

3.5 Station Locations

Station locations were selected to maximize the use of existing data, focusing on station locations within the T-Dock area that historically exhibited the highest PAH concentrations. The sediment sampling station coordinates are provided in Table 1.

Table 1
Proposed Station IDs and Geographic Coordinates

Station ID	Longitude (Dec Deg in NAD 27)	Latitude (Dec Deg in NAD 27)	Longitude (Dec Deg in NAD 83)	Latitude (Dec Deg in NAD 83)
AQT-QB4-SS	122.2031913	47.53484839	122.2044245	47.53467025
AQT-SB52-SS	122.2043372	47.53511465	122.2055705	47.5349365
AQT-S54-SS	122.2035184	47.53457713	122.2047516	47.53439899
AQT-VS27-SS	122.2029211	47.53383746	122.2041543	47.53365932
AQT-REF1-SS	TBD	TBD	TBD	TBD
AQT-REF2-SS	TBD	TBD	TBD	TBD

3.6 Field Sample Collection, Handling, and Shipping

The following subsections provide details of the field procedures to be used. The field approach is based on the SAPA (Ecology 2003a).

3.6.1 Surface Sediment Collection

Surface sediment samples from the 0 to 10-cm biologically active zone will be collected for chemical, physical, and biological testing using a van Veen-type grab sampler, in accordance with PSEP protocols (PSEP 1997a). Samples will be collected in the following manner:

- Jaw assembly will be decontaminated
- Jaw assembly will be deployed
- The winch cable to the grab sampler will be drawn taut and vertical
- Location of the cable hoist will be measured and recorded by the location control personnel
- The jaw assembly will be closed to collect the sediment sample to a penetration depth of approximately 15 cm

- The sediment sample will be retrieved and evaluated against the following PSEP acceptability criteria:
  - Grab sampler is not overfilled (i.e., sediment surface is not against the top of sampler)
  - Sediment surface is relatively flat, indicating minimal disturbance or winnowing
  - Overlying water is present, indicating minimal leakage
  - Overlying water has low turbidity, indicating minimal sample disturbance
  - Desired penetration depth is achieved
- Overlying water will be siphoned off and a stainless steel trowel or similar device will be used to collect 0 to 10 cm sediment layer from inside the sampler, taking care not to collect sediment in contact with the sides/surface of the sampler

The collected sediment will be placed in a stainless steel mixing container. When sufficient sample volume has been collected, the sediment will be homogenized using a stainless steel spoon.

3.6.2 Sample Processing and Handling

All test and reference sediment samples will be wet sieved in the field to determine percent fines[1]. Homogenized sediment will be placed into appropriate pre-labeled sample containers (certified, pre-cleaned) and stored in a cooler equipped with ice or other cold source to keep the samples at approximately 4° C prior to final packing for transport to the laboratory. Sediment for bioassays will be stored under a nitrogen atmosphere at approximately 4°C prior to toxicity testing. Table 2 lists temperature, preservation, and maximum holding times for each analysis.

[1] In order to facilitate the matching of reference and test sediment samples, all samples will be wet sieved in the field to determine percent fines using PSEP (1997a) protocols. Test sediments will be collected first and the field-determined percent fines recorded. A minimum of three reference sediment samples will be collected from the Lake Washington sediment reference area (located south of Coal Creek) used previously by Exponent (2001). The samples will be field wet sieved to achieve the closest possible matching percent fines content. The two samples that most closely bracket the range of field-determined percent fines in the test samples will be retained for testing.

Sample containers for sediments for physical analysis will be obtained from the analytical laboratory. Sample containers for toxicity testing will be provided by the bioassay laboratory and decontaminated prior to use.

Table 2
Storage Temperatures, Preservation, and Maximum Holding Times for Physical Analyses and Sediment Toxicity Tests

Sample Type	Storage Temperature	Maximum Holding Time
Grain Size	Cool, 4°C	6 months
Total Organic Carbon	Cool, 4°C	14 days
Ammonia and Total Sulfides	Cool, 4°C	7 days
Total and Volatile Solids	Cool, 4°C	14 days
Sediment Toxicity Test	Cool, 4°C	2 weeks[a]
Porewater Sulfides	Cool, 4°C	N/A [b]
Porewater Ammonia	Cool, 4°C	N/A [b]

a The PSEP (1995) protocols recommend a maximum holding time of 2 weeks.
b Porewater measures of ammonia and sulfide will be made as close as possible to test initiation and at test termination..

3.6.3 Field QA/QC Samples

Field quality assurance and quality control (QA/QC) will be achieved through rigorous field decontamination procedures (Section 3.7). All field quality control issues will be documented in the site logbook.

3.6.4 Field Documentation

A complete record of all field activities will be maintained. Record keeping will include the following:

- Documentation of all field activities in a field logbook
- Documentation of all samples collected for analysis

The Field Manager or designee will maintain the field logbook, which will consist of bound, numbered pages. All on-site activities, including health and safety entries and field observations will be documented in a site logbook. All entries will be made in indelible ink. The field logbook is intended to provide sufficient data and observations to enable readers to reconstruct events that occurred during the sampling period. These entries will include the following:

- Date and time
- Sampling personnel
- Weather
- Sampling location
- Water depth
- Sample depth
- Characteristics/observations of sediment sample
- Penetration depth
- Other comments

The field logbook will include clear information concerning any modifications to the details and procedures identified in this SAP. Surface sediment collection log sheets will be completed for each sediment grab. In addition to standard entries of personnel, date, and time, the log sheet will also include information regarding station coordinates, penetration of the sampler, and physical characteristics of the sediment such as texture, color, odor, stratification, and sheens.

3.6.5 Chain of Custody and Sample Shipping

Chain of custody (COC) procedures will be followed for all samples throughout the collection, handling, and analysis process. The principal document used to track possession and transfer of samples is the COC form. A COC form will accompany each cooler of samples to the analytical and biological laboratories. Each person who has custody of the samples will sign the COC form and ensure that the samples are not left unattended unless properly secured. Copies of all COC forms will be retained in the project files.

All sediment samples will be shipped to the analytical laboratory no later than the second day after collection. Specific sample shipping procedures are as follows:

- Each cooler or container containing the sediment samples for analysis will be shipped via overnight delivery to the appropriate laboratory.
- Coolant ice will be sealed in separate plastic bags and placed in the shipping containers.

- Individual sample containers will be placed in a sealable plastic bag, packed to prevent breakage, and transported in a sealed ice chest or other suitable container.
- Glass jars will be separated in the shipping container by shock absorbent material (e.g., bubble wrap) to prevent breakage.
- The shipping containers will be clearly labeled with sufficient information (name of project, time and date container was sealed, person sealing the container, and consultant's office name and address) to enable positive identification.
- A sealed envelope containing chain-of-custody forms will be enclosed in a plastic bag and taped to the inside lid of the cooler.
- Signed and dated COC seals will be placed on all coolers prior to shipping.

Upon transfer of sample possession to the laboratory, the persons transferring custody of the sample container will sign the COC form. Upon receipt of samples at the laboratory, the shipping container seal will be broken and the receiver will record the condition of the samples. COC forms will be used internally in the lab to track sample handling and final disposition.

3.7 Field Equipment Decontamination

To prevent sample cross-contamination, all sampling and processing equipment in contact with the sediment samples will undergo the following decontamination procedures prior to and between collection activities:

- Rinse with site water and wash with scrub brush until free of sediment
- Wash with phosphate-free detergent and tap water
- Rinse with site water
- Rinse three times with distilled water

3.8 Disposal of Excess Sediment and Other Materials

All sediment remaining after sampling and processing will be washed back into Lake Washington following completion of sampling at all sediment stations.

All disposable sampling materials and personnel protective equipment used in sample processing, such as disposable coveralls, gloves, and paper towels, will be placed in heavy

duty garbage bags or other appropriate containers. Disposable supplies will be placed in a normal refuse container for disposal as solid waste.

4 PHYSICAL TESTING

Grain size, total organic carbon, sulfides, ammonia, and total volatile solids testing of test and reference sediment samples will be conducted by Columbia Analytical Services, Inc (CAS) of Kelso, Washington. CAS is an Ecology-certified laboratory. The physical testing will adhere to the most recent PSEP quality assurance/quality control procedures (PSEP 1997b) and PSEP analysis protocols.

5 BIOLOGICAL TESTING

5.1 Bioassays

Sediment samples will be submitted for immediate bioassay testing. Bioassay testing will be conducted in accordance with protocols set forth in the American Society of Testing for Materials (ASTM) (2000) and the SAPA (Ecology 2003a). Bioassays will be conducted by AMEC at their laboratory in Fife, Washington. Three freshwater sediment toxicity bioassays will be conducted for each sample:

- A 10-day amphipod mortality test with *Hyalella azteca*
- A 20-day midge mortality and growth test using *Chironomus tentans*
- A Microtox® 100 percent sediment porewater extract test

5.2 Reference Samples for Bioassay Testing

Bioassay interpretation requires that test sediments be matched and tested simultaneously with appropriate reference sediment. Reference sediments will be collected by Anchor. Reference samples will be collected the same week that the test sediment sampling is conducted at the study area. Up to two reference sediments, free from any known contamination, will be selected from Point Webster in Lake Washington. The approach to selecting reference sediment samples is outlined below:

- The primary determinant for the selection of reference sediment will be based on grain size distribution, in particular the percent fines (silt + clay). The reference stations will be selected to represent the range of the percent fines observed at the stations in the T-Dock area.
- The reference sediment will be collected from locations with similar geomorphologic features as the study area. The reference sediment sampling location will be recorded to the nearest 0.01 second latitude and longitude (NAD 27 and NAD 83) using GPS location control.

5.3 Bioassay Quality Control

The three sediment toxicity tests will incorporate standard QA/QC procedures to ensure that the test results are valid. Standard QA/QC procedures include the use of negative controls, positive controls, reference sediment samples, replication, and measurement of water quality parameters during testing. Sulfides and ammonia analyses in the test

chambers will also be conducted. The frequency of the water quality monitoring and the determination of test acceptability will be in accordance with SAPA (Ecology 2003a) protocols.

6 DATA EVALUATION AND REPORTING

The sediment data obtained from this investigation will be evaluated according to SMS guidelines including the SAPA (Ecology 2003a) and Phase II Report: Freshwater Sediment Quality Values for Use in Washington (Ecology 2003b) . Bioassay test results will be interpreted against current SMS biological effects criteria, which are summarized in Table 3.

Table 3
Sediment Management Standards Biological Effects Criteria for Freshwater Sediments

Test and Endpoint	Control Performance	Reference Performance	SQS Criteria	CSL Criteria
Hyalella azteca 10-day Survival	C ≤ 20	R ≤ 25	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 10%	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 25%
Chironomus tentans 20-day Survival	C ≤ 32	R ≤ 35	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 15%	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 25%
Chironomus tentans 20-day Survival and Growth	CF ≥ 0.48 mg/ind. AFDW	RF/CF ≥ 0.8.	The test sediment has a mean individual weight that is significantly less (t-test, P<0.05) than the mean individual weight in the reference sediment, and T/R < 0.75	The test sediment has a mean individual weight that is significantly less (t-test, P<0.05) than the mean individual weight in the reference sediment, and T/R < 0.6
Microtox® Biolumnescence	CF/CI ≥ 0.72 CF/CI ≤ 1.1	RF/CF ≥ 0.8 CF/CI ≤ 1.1	The mean light output of the highest concentration of the test sediment is less than 85 percent of the mean light output of the reference sediment, and the two means are significantly different (t-test, P<0.05)	The mean light output of the highest concentration of the test sediment is less than 75 percent of the mean light output of the reference sediment, and the two means are significantly different (t-test, P<0.05)

Source: Ecology (2000 and 2003).
C = Control, CI = Control Initial, CF = Control Final
R = Reference, RF = Reference Final
T = Test Sample

Data summary tables containing the results of sediment sample analyses will be submitted to Ecology for initial review. Following an evaluation of the results, the complete data report will

be included as an appendix to the RA/FS. The data deport will comply with the guidelines detailed in Section 8.3 of the SAPA (2003a). The content of the report will be as follows:

1. A brief statement of the purpose of the sediment investigation.
2. A summary of the field sampling and laboratory analytical procedures (reference can be make to this SAP with deviations noted).
3. A general vicinity map showing the location of the site with respect to familiar landmarks and a sampling station map showing the relationship of the station locations to outfalls and other pertinent nearby features. Coordinates will be reported in an accompanying table for all stations. All geographical coordinates submitted to Ecology for inclusion in the SEDQUAL database will be in the NAD 83, Washington South Zone.
4. Bioassay results data table summarizing all biological test results, including the results of any statistical analyses of the biological results. Biological test data and statistical analysis will be reported according to the endpoints established by the SMS, summarized in Table 3.
5. Interpretation of the results of the sediment investigation including discussion of any biological exceedance of the SQS or CSL.
6. Copies of complete laboratory data packages.
7. Quality assurance reports consisting of narrative of quality assurance results and all quality assurance data.
8. Copies of applicable sections of the field log, as appendices or attachments.
9. Copies of signed COC forms, as appendices or attachments.

A high-density 3.5 inch disk containing completed SEDQUAL templates will be submitted with the data report.

7 REFERENCES

ASTM. 2000. Test Method for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates. ASTM Standard No. E1706-00e1. American Society for Testing and Materials, Philadelphia, PA.

Ecology. 2003a. Sediment Sampling and Analysis Plan Appendix (SAPA). Department of Ecology, Sediment Management Unit, Olympia, WA. Ecology Publication # 03-09-043.

Ecology. 2003b. Phase II Report: Development of Freshwater Sediment Quality Values for Freshwater Sediments in Washington State. Department of Ecology, Sediment Management Unit, Olympia, WA. Ecology Publication # 03-09-088.

EPA. 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates, Second Edition. EPA 600/R-99/064. Office of Research and Development, Mid-Continent Ecology Division, U.S. Environmental Protection Agency, Duluth, Minnesota 55804. Office of Science and Technology, Office of Water U.S. Environmental Protection Agency, Washington, D.C. 20460.

Exponent. 2001. Sediment Sampling Results for the Quendall Terminals Property. Prepared for the City of Renton. February 2001.

PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Prepared for the U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

PSEP. 1997a. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final Report. Prepared for U.S. Environmental Protection Agency, Seattle, Washington, and the Puget Sound Water Quality Action Team, Olympia, Washington.

PSEP. 1997b. Recommended quality assurance and quality control guidelines for the collection of environmental data in Puget Sound. Draft Report. Prepared for U.S. Environmental Protection Agency, Seattle, Washington.

Table B-1
Sediment Mangement Standards Biological Effects Criterial for Freshwater Sediments

Test and Endpoint	Control Performance	Reference Performance	SQS Criteria	CSL Criteria
Hyalella azteca 10-day Survival	C ≤ 20	R ≤ 25	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 10%	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 25%
Chironomus tentans 20-day Survival	C ≤ 32	R ≤ 35	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 15%	The test sediment has a significantly higher (t test, P<0.05) mean mortality than the reference sediment, and T-R > 25%
Chironomus tentans 20-day Survival and Growth	CF ≥ 0.48 mg/ind. AFDW	RF/CF ≥ 0.8.	The test sediment has a mean individual weight that is significantly less (t-test, P<0.05) than the mean individual weight in the reference sediment, and T/R < 0.75	The test sediment has a mean individual weight that is significantly less (t-test, P<0.05) than the mean individual weight in the reference sediment, and T/R < 0.6
Microtox® Biolumnescence	CF/CI ≥ 0.72	RF/CF ≥ 0.8	The mean light output of the highest concentration of the test sediment is less than 85 percent of the mean light output of the reference sediment, and the two means are significantly different (t-test, P<0.05)	The mean light output of the highest concentration of the test sediment is less than 75 percent of the mean light output of the reference sediment, and the two means are significantly different (t-test, P<0.05)
	CF/CI ≤ 1.1	CF/CI ≤ 1.1		

Source: Ecology (2000 and 2003).

C = Control, CI = Control Initial, CF = Control Final

R = Reference, RF = Reference Final

T = Test Sample

Table B-2
Summary of Sediment Data

Location ID	AQT-REF1	AQT-REF2	AQT-QB4	AQT-SB52	AQT-SS4	AQT-VS27
Sample ID	AQT-REF1-SS	AQT-REF2-SS	AQT-QB4-SS	AQT-SB52-SS	AQT-SS4-SS	AQT-VS27-SS
Sample Date	02/13/2004	02/13/2004	02/13/2004	02/13/2004	02/13/2004	02/13/2004
Depth Interval	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-10 cm	0-10 cm
Conventionals						
Ammonia (mg/kg)	51	19	34	52	48	57
Sulfide (mg/kg)	158 J	36 J	69 J	172 J	228 J	347 J
Total Organic Carbon (%)	3.47	1.69	3.87	7.82	7.17	9.41
Total solids (%)	28.7	43.5	37.2	22.6	22.8	20.4
Total volatile solids (%)	8.55	4.57	9.99	25.1	17.1	25.6
Grain Size (%)						
Gravel	0.13	6.79	12.3	4.4	6.18	1.23
Sand, Very Coarse	1.63	5.36	18.1	6.28	5.32	2.76
Sand, Coarse	1.46	11.6	17.2	5.46	3.87	3
Sand, Medium	4.17	18.1	11.4	6.44	5.1	4.59
Sand, Fine	13.8	21.3	5.94	8.49	7.34	7.24
Sand, Very Fine	15.6	10.8	4.87	7.51	8.6	10.5
Silt	46.2	23.1	22.5	45	47.9	53.2
Clay	17.7	6.52	8	18.1	12.8	12.3
Percent Fines	63.9	29.62	30.5	63.1	60.7	65.5

Table B-3
Quendall Terminals
Summary of Bioassay Results

Station	Individual Bioassay Endpoint			
	Amphipod	Chironomus		Microtox
	% Survival	% Survival	MIW (mg/ind)	T(15)
Control	90	84	1.73	0.91 and 0.85
REF-1	86	80	2.67	0.62 and 0.59
REF-2	91	90	2.52	0.79 and 0.84
AQT-QB4	81	88	2.64	0.73
AQT-SB52	4	0	-	0.13
AQT-S54	66	48	0.790	0.68
AQT-VS27	90	88	2.08	0.75

Table B-4
Summary of Bioassay Outcomes

Station	Reference Station Pair	Individual Bioassay Endpoint Outcome				Total Bioassay Exceedance Product (1)	Decision
		Amphipod	Chironomus		Microtox		
		% Survival	% Survival	MIW (mg/ind)	T(15)		
AQT-QB4	REF-2	PASS	PASS	PASS	CSL	2.4	
AQT-SB52	REF-1	CSL	CSL	CSL	CSL	11.2	CSL Failure
AQT-S54	REF-1	SQS	CSL	CSL	CSL	9.7	CSL Failure
AQT-VS27	REF-1	PASS	PASS	PASS	SQS	1.2	
Weighting Factor		1.5	1.2	1.7	1.2		

(1) Calculation of the Bioassay Exeeedance Product based on Turvey (2000). Total Bioassay Exceedance Product greater than 3.4 is considered a CSL-level failure

Table B-5
10-Day Amphipod Survival Test (*Hyalella azteca*)
Initiated February 20, 2004

Site	Replicate	# Alive	% Survival	Mean % Survival	St. Dev.	Compared to Control p-values [a]		Compared to Reference p-values [a]	
						Survival	Growth	Survival	Growth
Control	1	19	95	90	7.9				
	2	20	100						
	3	18	90						
	4	16	80						
	5	17	85						
REF1	1	16	80	86	6.5				
	2	17	85						
	3	16	80						
	4	18	90						
	5	19	95						
REF2	1	17	85	91	6.5				
	2	18	90						
	3	17	85						
	4	20	100						
	5	19	95						
QB4	1	16	80	81	18.2				
	2	18	90						
	3	10	50						
	4	19	95						
	5	18	90						
SB52	1	0	0	4	4.2				
	2	2	10						
	3	1	5						
	4	0	0						
	5	1	5						
S54	1	9	45	66	20.4				
	2	18	90						
	3	12	60						
	4	10	50						
	5	17	85						
VS27	1	18	90	90	9.4				
	2	19	95						
	3	20	100						
	4	15	75						
	5	18	90						

Table A-6
20-Day Midge Larve Suvival and Growth (*Chironomus tentans*)
Initiated February 19, 2004
Preliminary Results

		Survival				Growth					
Site	Replicate	# Alive	% Survival	Mean % Survival	St. Dev.	Pan Wgt. (mg)	Total Wgt (mg)	Ashed Wgt (mg)	Weight per Org (mg)	Mean Weight (AFDW) per Org (mg)a	St. Dev.
Control	1	9	90	84	11.4	53.46	69.33	55.73	1.511	1.731	0.25
	2	8	80			79.79	94.07	81.31	1.595		
	3	8	80			66.51	81.26	68.47	1.599		
	4	7	70			64.42	78.78	65.97	1.830		
	5	10	100			67.52	91.18	69.97	2.121		
REF1	1	7	70	80	10.0	65.99	88.71	70.09	2.660	2.667	0.22
	2	8	80			58.94	86.24	63.72	2.815		
	3	9	90			59.66	89.38	65.77	2.623		
	4	9	90			56.04	88.28	62.14	2.904		
	5	7	70			52.24	72.08	55.75	2.333		
REF2	1	10	100	90	12.2	56.06	83.88	62.12	2.176	2.520	0.42
	2	9	90			63.88	92.71	70.06	2.517		
	3	7	70			62.97	87.55	67.33	2.889		
	4	10	100			60.03	85.70	65.44	2.026		
	5	9	90			58.82	91.34	64.41	2.992		
QB4	1	10	100	88	11.0	58.84	97.71	72.65	2.506	2.644	0.56
	2	10	100			68.93	92.40	72.19	2.021		
	3	8	80			71.39	104.05	78.14	3.239		
	4	8	80			59.28	89.81	64.08	3.216		
	5	8	80			59.47	83.07	65.16	2.239		
SB52	1	0	0	0	0.0				-	-	-
	2	0	0						-		
	3	0	0						-		
	4	0	0						-		
	5	0	0						-		
S54	1	3	30	48	20.5	65.10	68.84	66.11	0.910	0.790	0.44
	2	7	70			51.02	59.05	52.92	0.876		
	3	4	40			55.52	58.63	56.40	0.558		
	4	7	70			54.72	66.33	56.56	1.396		
	5	3	30			65.57	66.43	65.79	0.213		
VS27	1	10	100	88	13.0	62.07	90.33	67.44	2.289	2.078	0.68
	2	9	90			57.97	79.20	61.48	1.969		
	3	10	100			58.92	80.83	62.63	1.820		
	4	7	70			57.49	67.65	59.05	1.229		
	5	8	80			58.74	88.30	63.62	3.09		

Table B-7
Microtox 100 Percent Sediment Porewater Test
February 25, 2004

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	Ref 2 $T_{(mean)}/R_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings $_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	93	92	90	79	94	90					
	$I_{(5)}$	93	90	90	77	92	88			0.99		
	$I_{(15)}$	84	82	83	74	86	82			0.91		
	$C_{(5)}$	1.00	0.98	1.00	0.97	0.98	0.99					
	$C_{(15)}$	0.90	0.89	0.92	0.94	0.91	0.91					
Ref 1	$I_{(0)}$	57	55	59	55	56	56					0.63
	$I_{(5)}$	51	54	54	50	50	52				0.59	
	$I_{(15)}$	50	53	51	50	48	50				0.62	
	$R_{(5)}$	0.57	0.60	0.60	0.56	0.56	0.58					
	$R_{(15)}$	0.56	0.59	0.57	0.56	0.54	0.56					
Ref 2	$I_{(0)}$	77	78	67	73	70	73					0.81
	$I_{(5)}$	74	75	65	70	70	71				0.80	
	$I_{(15)}$	67	70	59	65	63	65				0.79	
	$T_{(5)}$	0.96	0.96	0.97	0.96	1.00	0.97					
	$T_{(15)}$	0.87	0.90	0.88	0.89	0.90	0.89					
QB4	$I_{(0)}$	66	57	64	60	70	63					0.71
	$I_{(5)}$	62	53	62	58	68	61					
	$I_{(15)}$	60	50	59	55	65	58					
	$T_{(5)}$	0.69	0.59	0.69	0.65	0.76	0.68	0.70	0.69			
	$T_{(15)}$	0.67	0.56	0.66	0.61	0.73	0.65	0.73	0.71			
VS27	$I_{(0)}$	70	65	61	65	62	65					0.72
	$I_{(5)}$	66	63	59	66	60	63					
	$I_{(15)}$	64	60	55	61	58	60					
	$T_{(5)}$	0.74	0.70	0.66	0.74	0.67	0.70	0.72	0.71			
	$T_{(15)}$	0.71	0.67	0.61	0.68	0.65	0.67	0.75	0.73			

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. $I_{(t)}/I_{(0)}$

Quality Control Steps:

1. Is control final mean output greater than 72% control initial mean output?

$I_{(5)}$: $F_{c(mean)}/I_{c(mean)}$=99%

$I_{(15)}$: $F_{c(mean)}/I_{c(mean)}$=91%

Control results are acceptable

2. Does the reference final mean exceed 80% of control final mean?

Ref 1 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=59% Ref 2 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=80%

$I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=62% $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=79%

Ref 1 is not acceptable. Ref 2 is acceptable to be used in statistical analyses.

3. Is the reference initial mean > 80% of control initial mean?

Ref 1: $I_{R(mean)}/I_{C(mean)}$=63% Ref 2: $I_{R(mean)}/I_{C(mean)}$=81%

Ref 1: Use control initial mean to calc. Change in final light readings

Ref 2: Use Ref 2 initial mean to calculate change in light readings at $I_{(5)}$ and $I_{(15)}$ for reference site.

4. Are test initial mean values > 80% of control initial mean values?

QB4: $I_{T(mean)}/I_{C(mean)}$=71%, use control initial mean to calculate change in light readings.

VS27: $I_{T(mean)}/I_{C(mean)}$)=72%, use control initial mean readings to calculate change in light readings.

Table B-8
Microtox 100 Percent Sediment Porewater Test
February 25, 2004

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	Ref 2 $T_{(mean)}/R_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	104	105	104	103	99	103					
	$I_{(5)}$	91	102	101	98	96	98			0.95		
	$I_{(15)}$	81	91	91	88	87	88			0.85		
	$C_{(5)}$	0.88	0.97	0.97	0.95	0.97	0.95					
	$C_{(15)}$	0.78	0.87	0.88	0.85	0.88	0.85					
Ref 1	$I_{(0)}$	58	54	56	54	57	56					0.54
	$I_{(5)}$	53	50	52	50	54	52				0.53	
	$I_{(15)}$	54	50	52	49	53	52				0.59	
	$R_{(5)}$	0.51	0.49	0.50	0.49	0.52	0.50					
	$R_{(15)}$	0.52	0.49	0.50	0.48	0.51	0.50					
Ref 2	$I_{(0)}$	89	88	84	83	79	85					0.82
	$I_{(5)}$	79	82	82	84	78	81				0.83	
	$I_{(15)}$	72	73	76	76	71	74				0.84	
	$T_{(5)}$	0.77	0.80	0.80	0.82	0.76	0.79					
	$T_{(15)}$	0.70	0.71	0.74	0.74	0.69	0.71					
S54	$I_{(0)}$	49	47	50	46	46	48					0.46
	$I_{(5)}$	50	48	51	48	47	49					
	$I_{(15)}$	52	49	52	49	50	50					
	$T_{(5)}$	0.49	0.47	0.50	0.47	0.46	0.47	0.60	0.50			
	$T_{(15)}$	0.50	0.48	0.50	0.48	0.49	0.49	0.68	0.58			
SB52	$I_{(0)}$	10	10	10	10	8	10					0.09
	$I_{(5)}$	10	9	9	10	8	9					
	$I_{(15)}$	10	9	10	10	9	10					
	$T_{(5)}$	0.10	0.09	0.09	0.10	0.08	0.09	0.11	0.09			
	$T_{(15)}$	0.10	0.09	0.10	0.10	0.09	0.09	0.13	0.11			

$I_{(0)}$ is the light reading after the initial five minute incubation period
$I_{(5)}$ is the light reading five minutes after $I_{(0)}$
$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$
$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. $I_{(t)}/I_{(0)}$

Quality Control Steps:

1. Is control final mean output greater than 72% control initial mean output?
   $I_{(5)}$: $F_{c(mean)}/I_{c(mean)}$=95%
   $I_{(15)}$: $F_{c(mean)}/I_{c(mean)}$=85%
   Control results are acceptable

2. Does the reference final mean exceed 80% of control final mean?
   Ref 1 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=53% Ref 2 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=83%
   $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=59% $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=84%
   Ref 1 is not acceptable. Ref 2 is acceptable to be used in statistical analyses.

3. Is the reference initial mean > 80% of control initial mean?
   Ref 1: $I_{R(mean)}/I_{C(mean)}$=54% Ref 2: $I_{R(mean)}/I_{C(mean)}$=82%
   Ref 1: Use control initial mean to calc. Change in final light readings
   Ref 2: Use control initial mean to calculate change in light readings at $I_{(5)}$ and $I_{(15)}$ for reference site.

4. Are test initial mean values > 80% of control initial mean values?
   S54: $I_{T(mean)}/I_{C(mean)}$=46%, use control initial mean to calculate change in light readings.
   SB52: $I_{T(mean)}/I_{C(mean)}$=9%, use control initial mean readings to calculate change in light readings.

Collection Date: 2/12/04
Shipping Date: 2/12/04

ANCHOR ENVIRONMENTAL, L.L.C.

Surface Sediment Field Sample Record

Project Name: Quendall **Project No:** 020059-02 **Station ID:** 554

Sampling Crew: Keithly / Parker
Sampling Vessel: Sampling Method: Van Veen
Subcontractor(s): Research Support
Station Coordinates: N / Lat. per SAP Weather:
E / W / Long.
Datum: NAD 83 / WGS 84 Zone:

Sample Number: AQT-554-SS
Analysis: Metals / BNAs / VOCs / PCBs / Pest / Herb / TBTs / Diox-Furans
TS / Grain Size / TOC / TVS / Ammonia / Sulfides
(Circle Appropriate Analyses)

Field Test Results Comments:
Salinity: ppt
Ammonia: mg/L
Grain Size: ml Coarse: ~~39~~ 11 ml Fines: 439
78% fine (<230um)

Grab Number: 1 Water Depth: 23.9 Penetration/Sampled Depth: 15cm Time: 0940
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	shells
gravel	gray	slight	Petroleum	woody debris
sand C M F	black	moderate	other:	
silt clay	brown redish	strong		
organic matter	brown surface redish	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Recorded by: J. Keithly

ANCHOR ENVIRONMENTAL, L.L.C.

Surface Sediment Field Sample Record

Collection Date: 2/13/04
Shipping Date: 2/13/04

Project Name: Quendall **Project No:** 020059-02 **Station ID:** QB4

Sampling Crew: Kathy / Parker
Sampling Vessel:
Sampling Method: Van Veen
Subcontractor(s): Research Support
Station Coordinates: N / Lat. per SAP
E / W / Long.
Weather: Clear
Datum: NAD 83 / WGS 84 Zone:

Sample Number: AQT-QB4-SS
Analysis: Metals / BNAs / VOCs / PCBs / Pest / Herb / TBTs / Diox-Furans
TS / Grain Size / TOC / TVS / Ammonia / Sulfides
(Circle Appropriate Analyses)

Field Test Results
Salinity: ppt
Ammonia: mg/L
Grain Size: 60% fines (<230 um) ml Coarse: 20 ml Fines: 30
Comments:

Grab Number: 1 Water Depth: 24.5 Penetration/Sampled Depth: 15cm Time: 0915
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:	
cobble	D.O.	none	H2S
gravel	gray	slight	Petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	brown surface	overwhelming	

Comments: some woody debris
no sheen
no odor
layer of coarse sand in grab

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:	
cobble	D.O.	none	H2S
gravel	gray	slight	Petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	brown surface	overwhelming	

Comments:

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:	
cobble	D.O.	none	H2S
gravel	gray	slight	Petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	brown surface	overwhelming	

Comments:

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:	
cobble	D.O.	none	H2S
gravel	gray	slight	Petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	brown surface	overwhelming	

Comments:

Recorded by:

Collection Date: 2/13/04
Shipping Date: 2/13/04

ANCHOR ENVIRONMENTAL, L.L.C.

Surface Sediment Field Sample Record

Project Name: Quendall **Project No:** 020059-02 **Station ID:** SB52

Sampling Crew: Keith / Parker
Sampling Vessel: Sampling Method: Van Veen
Subcontractor(s): Research Support
Station Coordinates: N / Lat. Per Ship Weather: Clear
E / W / Long.
Datum: NAD 83 / WGS 84 Zone:

Sample Number: AQT-SB52-SS
Analysis: Metals / BNAs / VOCs / PCBs / Pest / Herb / TBTs / Diox-Furans
TS / Grain Size / TOC / TVS / Ammonia / Sulfides
(Circle Appropriate Analyses)

Field Test Results
Salinity: ppt
Ammonia: mg/L
Grain Size: ml Coarse: 20 ml Fines: 30
60% fines (<230 um)
Comments:

Grab Number: 1 Water Depth: 30.5 Penetration/Sampled Depth: 14cm Time: 0816
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	wood debris (bark)
gravel	gray	slight	Petroleum	free product - NAPL in sample
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Strong Sheen

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Recorded by: J. Keith

Collection Date: 2/13/04
Shipping Date: 2/13/04

ANCHOR ENVIRONMENTAL, L.L.C.

Surface Sediment Field Sample Record

Project Name: Quendall **Project No:** 020059-02 **Station ID:** Ref 1

Sampling Crew: Kethly / Parker
Sampling Vessel:
Sampling Method: Van Veen
Subcontractor(s): Research Support
Station Coordinates: N / Lat. 47.56390
E / W / Long. 122.19434
Weather: Clear
Datum: NAD 83 / WGS 84 Zone:

Sample Number: AQT-REF2-SS
Analysis: Metals / BNAs / VOCs / ~~PCBs / Pest / Herb~~ / TBTs / Diox-Furans
~~TS / Grain Size~~ / TOC / TVS / Ammonia / Sulfides
(Circle Appropriate Analyses)

Field Test Results
Salinity: ppt
Ammonia: mg/L AK 2/16/04
Grain Size: ml Coarse: ~~20~~ 12 ml Fines: ~~30~~ 38
76% fines (<230um) ~~60% fines (<230 um)~~
Comments:

Grab Number: 1* Water Depth: 35' Penetration/Sampled Depth: 15 Time: 1245
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

* Van Veen weight removed to avoid over-penetration

Recorded by: J. Kethly

ANCHOR ENVIRONMENTAL, L.L.C.

Surface Sediment Field Sample Record

Collection Date: 2/13/04
Shipping Date: 2/13/04

Project Name: Quendall **Project No:** 020059-02 **Station ID:** REF2

Sampling Crew: Kathly / Parker
Sampling Vessel:
Sampling Method: Van Veen
Subcontractor(s): Research Support
Station Coordinates: N / Lat. 47.56379
E / W / Long. 122.19415
Weather:
Datum: NAD 83 / WGS 84 Zone:

Sample Number:
Analysis: Metals / BNAs / VOCs / PCBs / Pest / Herb / TBTs / Diox-Furans
TS / Grain Size / TOC / TVS / Ammonia / Sulfides
(Circle Appropriate Analyses)

Field Test Results
Salinity: ppt
Ammonia: mg/L
Grain Size: ml Coarse: 20 ml Fines: 30
60% fines (<230um)

Comments:

Grab Number: 1* Water Depth: 31.5' Penetration/Sampled Depth: 14 Time: 1325p
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

* Van Veen weights removed to avoid over penetration

Recorded by: J. Kathly

Collection Date: 2/13/04
Shipping Date: 2/13/04

ANCHOR ENVIRONMENTAL, L.L.C.

Surface Sediment Field Sample Record

Project Name: Quendall **Project No:** 026059-02 **Station ID:** VS27

Sampling Crew: Keithly/Parker
Sampling Vessel: Sampling Method: Van Veen
Subcontractor(s): Research Support
Station Coordinates: N / Lat. per SAP Weather: Clear
E / W / Long.
Datum: NAD 83 / WGS 84 Zone:

Sample Number: AQT-VS27-SS
Analysis: Metals / BNAs / VOCs / PCBs / Pest / Herb / TBTs / Diox-Furans
TS / Grain Size / TOC / TVS / Ammonia / Sulfides
(Circle Appropriate Analyses)

Field Test Results Comments:
Salinity: ppt
Ammonia: mg/L MC 2/16/04
Grain Size: 78% fines (<230um) ml Coarse: ~~39~~ 11 ml Fines: ~~11~~ 39

Grab Number: 5* Water Depth: 20' Penetration/Sampled Depth: 15 Time: 1040
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	slight sheen with debris
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong	soil	
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Grab Number: Water Depth: Penetration/Sampled Depth: Time:
Bioassay / Chemistry (circle) AVS/SEM; Total Sulfides; VOC Sample (circle)

Sediment Type:	Sediment Color:	Sediment Odor:		Comments:
cobble	D.O.	none	H2S	
gravel	gray	slight	Petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

* Van Veen weights were removed to avoid over-penetration

Recorded by: J. Keithly

Toxicity Evaluation of Port Quendall Terminal Sediments

Prepared for
Anchor Environmental
1423 3rd Avenue, Suite 300
Seattle, WA 98107

Prepared by
AMEC Earth & Environmental
Northwest Bioassay Laboratory
5009 Pacific Hwy. E., Suite 2
Fife, WA 98424
253-922-4296

29 March 2004

INTRODUCTION

As part of an environmental investigation being conducted by Anchor Environmental (Anchor), toxicity tests were conducted on freshwater sediment collected from Port Quendall Terminal located in Renton, Washington. Sediment toxicity tests were performed to evaluate survival of the amphipod *Hyalella azteca*, survival and growth of the larval midge *Chironomus tentans*, and bioluminescence the bacterium *Vibrio fischeri*. This report documents the results of these tests.

METHODS

Samples

Six sediment samples were collected into 2-liter (L) HDPE wide-mouth jars on 13 February 2004. The sediments were identified as AQT-REF1-SS, AQT-REF2-SS, AQT-QB4-SS, AQT-SB52-SS, AQT-S54-SS, and AQT-VS27-SS. The samples were transported in coolers the day of collection to the AMEC Earth & Environmental toxicity testing laboratory located in Fife, Washington. Upon receipt, the coolers were opened and the contents of the coolers inspected and compared with documentation provided on the chain-of-custody forms. The temperatures of the samples were measured upon receipt of the coolers. Samples were held in the dark under nitrogen atmosphere at 4 ±2°C prior to initiation of the tests.

Porewater was extracted by centrifugation of the samples and these subsamples were used for analyses of interstitial ammonia and total sulfides. The sediment samples were not sieved prior to analysis.

Hyalella azteca 10-day survival test

The 10-day survival test with *H. azteca* was conducted according to procedures described in USEPA (2000) and ASTM (2000), and summarized in Table 1. Test organisms were obtained from Aquatic BioSystems (Fort Collins, Colorado) on 19 February 2004.

Water used in the test was moderately hard synthetic freshwater (MHSW) prepared according to EPA 2002. Control sediment consisted of clean, washed beach sand obtained from Dash Point, Washington mixed with peat (2% by weight).

Five replicates each containing 20 organisms were used for evaluation of the samples and the control. Tests were conducted in 300-mL glass beakers using approximately 100-mL of sediment and 175-mL of MHSW. Sediment and water were added to the test containers, randomized, and allowed to equilibrate for 24 hours prior to addition of the test organisms. Tests were conducted at 20±1°C with 16 hours of light and 8 hours of dark. MHSW was added throughout the testing period as necessary to replace water lost due to evaporation. Each test chamber was provided 1 ml of food 3 times per week. The food consisted of a mixture of 2 grams (g) ground Tetramin® flakes mixed with 100 mL MHSW. The feeding regime was reduced if the presence of excess food was observed on the sediment surface in several test chambers. Gentle aeration of the overlying water was provided throughout testing, and water quality parameters (dissolved oxygen, pH, conductivity, and temperature) were measured at test initiation and termination, as well as at 24-hr intervals throughout the test. Ammonia and sulfides were measured in the interstitial and overlying water and test initiation and termination. An additional replicate was included for each site as a sacrificial test chamber for the routine water quality measurements.

After 10 days of exposure, the contents of each replicate were gently sieved and the number of live organisms were enumerated and recorded. The number of surviving amphipods was evaluated statistically to determine whether any samples exhibited a significant decrease in survival relative to the control ($p<0.05$). The criterion for acceptable test performance was ≥80% survival of control organisms.

A reference toxicant test was conducted using *H. azteca* and copper chloride as the toxicant. Test organisms were exposed to 187.5, 375, 750, 1500, and 3000 micrograms per liter (μg/L) Cu for 96-hr and results of this test were compared with historical data for this species to determine whether the sensitivity of the organisms was appropriate.

Chironomus tentans 20-day survival and growth test

The 20-day survival and growth test was conducted using the midge larvae *C. tentans*. Test procedures were conducted according to USEPA (2000) and ASTM (2000), and summarized in Table 2. Egg cases of *C. tentans* were obtained from Aquatic BioSystems (Fort Collins, Colorado) on 17 February 2004.

Water used in the test was moderately hard synthetic freshwater (MHSW) prepared according to EPA 2002. Control sediment consisted of clean, washed beach sand obtained from Dash Point, Washington mixed with peat (2% by weight).

Five replicates each containing 10 organisms were used for evaluation of the samples and the control. Tests were conducted in 300-mL glass beakers using approximately 100-mL of sediment and 175-mL of MHSW. Sediment and water were added to the test containers, randomized, and allowed to equilibrate for 24 hours prior to addition of the test organisms. Tests were conducted at 20±1°C with 16 hours of light and 8 hours of dark. MHSW was added throughout the testing period as necessary to replace water lost due to evaporation. Each test chamber was provided 1 ml of food 3 times per week. The food consisted of a mixture of 2 grams (g) ground Tetramin® flakes mixed with 100 mL MHSW. The feeding regime was reduced if the presence of excess food was observed on the sediment surface in several test chambers. Gentle aeration of the overlying water was provided throughout testing, and water quality parameters (dissolved oxygen, pH, conductivity, and temperature) were measured at test initiation and termination, as well as at 24-hr intervals throughout the test. Ammonia and sulfides were measured in the interstitial and overlying water and test initiation and termination. An additional replicate was included for each site as a sacrificial test chamber for the routine water quality measurements.

After the 20-day exposure, the contents of the test containers were sieved and the live organisms were enumerated, rinsed, dried in a 60°C oven, and weighed. The weight of sediment remaining in the gut of *C. tentans* at test termination can misrepresent the actual growth of organisms. Consequently, ash-free dry weight (AFDW) of the larvae was measured to better estimate the gut contents of the larvae. After measuring weights on larvae dried for 24 hours at 60°C, the pans were placed in a muffle furnace at 550°C for 2 hours and weighed again. Tissue weight of the larvae was then determined by subtracting the AFDW from the dried weight.

Survival and growth were compared statistically with control values to determine significant adverse effects ($p<0.05$). The critierion for acceptable control performance was ≥70% survival and mean weight ≥0.48 milligram (mg) AFDW per surviving organism.

A 96-hr reference toxicant test was conducted using *C. tentans* and copper chloride as the toxicant. Test organisms were exposed to 250, 500, 1000, 2000, and 4000 µg/L Cu and results of this test were compared with historical data for this species to determine whether the sensitivity of the organisms was appropriate.

Microtox® test

The luminescent marine bacterium *Vibrio fischeri* was used as the test organism for the Microtox® test. The bacteria were exposed to porewater extracted from sediment samples and light readings were measured after a 5 minute incubation period and then after an additional 5 minutes and 15 minutes of exposure. Test equipment included the Microtox Model 500 Analyzer which measures light output and is equipped with a 15°C chamber to maintain test temperature in the samples and a 4°C chamber to keep the rehydrated bacterial chilled.

The tests were conducted in accordance with WDOE (2003) test protocol and summarized in Table 3. Approximately 50 mL of porewater was extracted from each sample by centrifuging for 30 minutes at 4500 G. Each porewater extract was adjusted to a salinity of 20 parts per thousand (ppt) with Forty Fathoms artificial seasalt. The dissolved oxygen in was adjusted to saturation of 50 to 100 percent, if necessary. The pH was adjusted to 7.8 to 8.2 units using NaOH or HCl. The control was deionized water adjusted to 20 ppt with artificial seasalt.

Tests were conducted using five replicates. Disposable glass cuvettes were placed in the Microtox test wells and 1 mL of salinity adjusted porewater was added. The rehydrated bacteria (reagent) were thoroughly mixed and 10µL was added to each test cuvette. After an initial incubation period of 5 minutes, the control cuvette was placed in the read chamber of the Microtox Analyzer to set the instrument. Initial light readings (I_o) were then taken by placing each cuvette in the read chamber of the Microtox Analyzer and measurements were recorded on a data sheet. Light output was measured in each cuvette after an additional 5 minutes (I_5) and 15 minutes (I_{15}) of exposure. Test acceptability criterion was final mean control light output greater than or equal to 72% of initial control mean output and test mean output not greater than 110% of control or reference mean output. The data were evaluated statistically by conducting one-tailed t-tests on the change in output over time for test sediment porewaters compared to the control or reference sediments. Statistical analyses were conducted for test sediments showing a greater than 10 percent reduction compared to the temporal change for the control or reference sediments.

A reference toxicant test using 5.6, 11.3, 22.5, and 45 mg/L phenol was conducted in conjunction with the sediment porewater test to ensure that the test was within the acceptable range of historical values determined in this laboratory.

Table 1. Summary of testing conditions for the *Hyalella azteca* test.

Test initiation date	20 February 2004
Test organism source	Aquatic BioSystems; Fort Collins, Colorado
Organism age at test initiation	5-8 days
Feeding	1 mL of Tetramin mixture every 2 to 3 days; frequency reduced if excess food observed
Test chamber	300-mL glass beaker
Volume of test sediment	100 mL
Dilution water type & volume	175 mL Moderately Hard Synthetic Water (MHSW)
Control sediment	Sand mixed with peat (2% by weight)
Number of organisms/replicate	20
Number of replicates/sample	5
Test temperature	20 ± 1°C
Photoperiod	16 hours light : 8 hours dark
Aeration	Continuous, approximately 3 bubbles/second
Test acceptance criterion	80% survival of control organisms
Reference toxicant	Copper chloride

Table 2. Summary of testing conditions for the *Chironomus tentans* test

Test initiation date	19 February 2004
Test organism source	Aquatic BioSystems; Fort Collins, Colorado
Organism age at test initiation	1 day post hatch, 1st instar
Feeding	1 mL of Tetramin mixture every 2 to 3 days; frequency reduced if excess food observed
Test chamber	300-ml glass beaker
Volume of test sediment	100 mL
Dilution water type & volume	175 mL Moderately Hard Synthetic Water (MHSW)
Control sediment	Sand mixed with peat (2% by weight)
Number of organisms/replicate	10
Number of replicates/sample	5
Test temperature	20 ± 1°C
Photoperiod	16 hours light : 8 hours dark
Aeration	Continuous, approximately 3 bubbles/second
Test acceptance criterion	70% survival of control organisms 0.48mg/L AFDW per surviving control organism
Reference toxicant	Copper chloride

Table 3. Summary of testing conditions for the Microtox test

Test date	25 February 2004
Test organism source	Strategic Diagnostics
Batch number and expiration date	Lot# 3J6034, Expiration date 09/05
Control	Saltwater (20 ppt) prepared with Forty Fathoms Sea Salts
Sample preparation	Centrifugation at 4500G for 30 minutes; salinity adjustment to 20 ppt using 40 Fathoms Sea Salts; pH adjustment to 7.8 - 8.2 with HCl or HaOH
Test chamber	Glass cuvette
Test volume	1 mL
Volume of inoculum/replicate	10 µL
Number of replicates/sample	5
Test temperature	15 ± 1°C
Aeration	None
Test acceptance criterion	Mean control light output at I_5 and I_{15} 72% initial light output; and mean test light output not >110% of control and reference mean output
Reference toxicant	Phenol

RESULTS

Results of toxicity tests conducted using the *H. azteca*, *C. tentans*, and Microtox tests are provided in Tables 4 through 6. Data for these tests are provided in Appendix A and measurements of water quality parameters, including ammonia and sulfide measurements, are provided in Appendix B.

Samples SB52 and S54 exhibited significantly decreased survival of *H. azteca* and *C. tentans* and reduced growth of *C. tentans*. In addition, there was a greater temporal reduction in light output exhibited by bacteria exposed to all four samples, QB4, VS27, S54, and SB52, compared to the control and Ref 2 sediment.

Table 4. Data (means and standard deviations) for *Hyalella azteca* survival. Bolded data indicates a significant adverse effect relative to the control (p<0.05).

Sample	Survival (%)			p-values
Control	90	±	7.9	---
AQT-REF1-SS	86	±	6.5	0.18
AQT-REF2-SS	91	±	6.5	NA
AQT-QB4-SS	81	±	18.2	0.15
AQT-SB52-SS	**4**	**±**	**4.2**	**<0.001**
AQT-S54-SS	**66**	**±**	**20.4**	**0.02**
AQT-VS27-SS	90	±	9.4	NA

NA - No statistical comparison, results greater than or equal to control.

Table 5. Data (means and standard deviations) for *Chironomus tentans* survival and growth. Bolded data indicates a significant adverse effect relative to the control (p<0.05).

Sample	Survival (%)			p-values	Growth (mg/organism AFDW)			p-values
Control	84	±	11.4	---	1.73	±	0.25	---
AQT-REF1-SS	80	±	10.0	0.24	2.67	±	0.22	NA
AQT-REF2-SS	90	±	12.2	NA	2.52	±	0.42	NA
AQT-QB4-SS	88	±	11.0	NA	2.64	±	0.56	NA
AQT-SB52-SS	**0**	**±**	**0.0**	**No survival**	---		---	---
AQT-S54-SS	**48**	**±**	**20.5**	**0.006**	**0.79**	**±**	**0.44**	**0.003**
AQT-VS27-SS	88	±	13.0	NA	2.08	±	0.68	NA

NA - No statistical comparison, results greater than or equal to control.
AFDW - Ash Free Dry Weight

Table 6. Data (means and standard deviations) for the Microtox test. Bolded data indicates a significant adverse effect relative to the control (p<0.05).

Sample	Mean % change in light output at I_5	p-values	Mean % change in light output at I_{15}	p-values
Test 1				
Control	99 ± 1.3	---	91 ± 1.7	---
AQT-REF1-SS	**58 ± 2.3**	**<0.001**	**56 ± 2.0**	**<0.001**
AQT-REF2-SS	97 ± 1.7	0.07	89 ± 1.2	0.02[b]
AQT-QB4-SS	**68 ± 6.2**	**<0.001[a]**	**65 ± 6.3**	**<0.001[a]**
AQT-VS27-SS	**70 ± 3.7**	**<0.001[a]**	**67 ± 3.8**	**<0.001[a]**
Test 2				
Control	95 ± 4.2	---	85 ± 4.1	---
AQT-REF1-SS	**50 ± 1.7**	**<0.001**	**50 ± 2.0**	**<0.001**
AQT-REF2-SS	**79 ± 2.4**	**<0.001**	**71 ± 2.2**	**<0.001**
AQT-S54-SS	**47 ± 1.6**	**<0.001[a]**	**49 ± 1.5**	**<0.001[a]**
AQT-SB52-SS	**9 ± 0.8**	**<0.001[a]**	**9 ± 0.1**	**<0.001[a]**

[a] Statistical comparison to control and REF2 produced the same p-values.
[b] Percent difference from control is less than 10%.

QA/QC

The temperatures of the samples received on 13 February 2004 were 9.3°C. The containers were received in good condition. The documentation provided on the chain-of-custody form was confirmed with the sampler and matched with the labeling of the sample containers. A copy of the chain-of-custody form is provided in Appendix D.

The test organisms were all received within one day of shipping and appeared to be healthy. Water qualities of the cultures were within tolerable ranges for each of the test organisms upon receipt.

Control acceptability criteria were met for all tests. Water quality parameters (pH, dissolved oxygen, temperature, and conductivity) remained within the acceptable ranges in all tests.

The results of reference toxicant tests and corresponding acceptable historical ranges (mean ± two standard deviations) are provided in Appendix C and summarized in Table 7. Reference toxicant test results fell within the acceptable range for all of the tests, indicating that the sensitivity of the organisms used in this study was appropriate.

Table 7. Reference toxicant test results and acceptable ranges.

Species	Endpoint	Current results	Acceptable range (Mean ± 2SD)
H. azteca	Survival	847 mg/L Cd	517 ± 391
C. tentans	Survival	205 mg/L Cd	494 ± 441
Microtox – I_5	Luminescence	12.6 mg/L phenol	14.8 ± 5.0
Microtox – I_{15}	Luminescence	14.8 mg/L phenol	16.3 ± 6.6

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APPENDIX A

RESULT SUMMARIES

HYALELLA AZTECA

Appendix Table A-1. 10-Day Amphipod Survival Test (*Hyalella azteca*)
Port Quendall Terminals Project
Anchor Environmental
Initiated 20 February 2004

Site	Replicate	# Alive	% Survival	Mean % Survival	St. Dev.	p-values[a] Compared to Control	p-values[a] Compared to REF2
Control	1	19	95	90	7.9		
	2	20	100				
	3	18	90				
	4	16	80				
	5	17	85				
REF1	1	16	80	86	6.5	0.18	
	2	17	85				
	3	16	80				
	4	18	90				
	5	19	95				
REF2	1	17	85	91	6.5	NA	
	2	18	90				
	3	17	85				
	4	20	100				
	5	19	95				
QB4	1	16	80	81	18.2	0.15	0.12
	2	18	90				
	3	10	50				
	4	19	95				
	5	18	90				
SB52	1	0	0	4	4.2	<0.001	<0.001
	2	2	10				
	3	1	5				
	4	0	0				
	5	1	5				
S54	1	9	45	66	20.4	0.02	0.01
	2	18	90				
	3	12	60				
	4	10	50				
	5	17	85				
VS27	1	18	90	90	9.4	NA	0.46
	2	19	95				
	3	20	100				
	4	15	75				
	5	18	90				

[a] One-tailed t-test. Survival data arcsine square-root transformation prior to t-test.
NA-Organism survival in site greater than control organism survival. No statistical comparison conducted.

CHIRONOMUS TENTANS

Appendix Table A-2. 20-Day Midge Larvae Survival & Growth (*Chironomus tentans*)
Port Quendall Terminals Project
Anchor Environmental
Initiated 19 February 2004

		Survival				Growth (AFDW)			p-values [b]			
									Compared to Control		Compared to REF2	
Site	Replicate	# Alive	% Survival	Mean % Survival	St. Dev.	Weight per Org (mg)	Mean Weight per Org (mg)[a]	St. Dev.	Survival	Growth	Survival	Growth
Control	1	9	90	84	11.4	1.51	1.73	0.25				
	2	8	80			1.60						
	3	8	80			1.60						
	4	7	70			1.83						
	5	10	100			2.12						
REF1	1	7	70	80	10.0	2.66	2.67	0.22	0.24	NA		
	2	8	80			2.82						
	3	9	90			2.62						
	4	9	90			2.90						
	5	7	70			2.33						
REF2	1	10	100	90	12.2	2.18	2.52	0.42	NA	NA		
	2	9	90			2.52						
	3	7	70			2.89						
	4	10	100			2.03						
	5	9	90			2.99						
QB4	1	10	100	88	11.0	2.51	2.64	0.56	NA	NA	0.42	NA
	2	10	100			2.02						
	3	8	80			3.24						
	4	8	80			3.22						
	5	8	80			2.24						
SB52	1	0	0	0	0.0	-	-	-	---	---	---	---
	2	0	0			-						
	3	0	0			-						
	4	0	0			-						
	5	0	0			-						
S54	1	3	30	48	20.5	0.91	0.79	0.44	0.006	0.003	0.002	<0.001
	2	7	70			0.88						
	3	4	40			0.56						
	4	7	70			1.40						
	5	3	30			0.21						
VS27	1	10	100	88	13.0	2.29	2.08	0.68	NA	NA	NA	0.13
	2	9	90			1.97						
	3	10	100			1.82						
	4	7	70			1.23						
	5	8	80			3.09						

[a] Larvae were 1 days old at test initiation and initial weight was below detection limit.
[b] One-tailed t-test. Survival data arcsine square-root transformation prior to t-test.
AFDW-Ash Free Dry Weight
NA-Organism survival/growth in site greater than control organism survival/growth. No statistical comparison conducted.

MICROTOX

Appendix Table A-3a. Microtox 100 Percent Sediment Porewater Test
Port Quendall Terminals Project
Anchor Environmental
Test Date: 25 February 2004

Site	Light Reading	Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean)}/Ref2_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	93	92	90	79	94	90						
	$I_{(5)}$	93	90	90	77	92	88				0.99		
	$I_{(15)}$	84	82	83	74	86	82				0.91		
	$C_{(5)}$	1.00	0.98	1.00	0.97	0.98	0.99	0.01					
	$C_{(15)}$	0.90	0.89	0.92	0.94	0.91	0.91	0.02					
Ref 1	$I_{(0)}$	57	55	59	55	56	56						0.63
	$I_{(5)}$	51	54	54	50	50	52					0.59	
	$I_{(15)}$	50	53	51	50	48	50					0.62	
	$R_{(5)}$	0.57	0.60	0.60	0.56	0.56	0.58	0.02					
	$R_{(15)}$	0.56	0.59	0.57	0.56	0.54	0.56	0.02					
Ref 2	$I_{(0)}$	77	78	67	73	70	73						0.81
	$I_{(5)}$	74	75	65	70	70	71					0.80	
	$I_{(15)}$	67	70	59	65	63	65					0.79	
	$T_{(5)}$	0.96	0.96	0.97	0.96	1.00	0.97	0.02					
	$T_{(15)}$	0.87	0.90	0.88	0.89	0.90	0.89	0.01					
QB4	$I_{(0)}$	66	57	64	60	70	63						0.71
	$I_{(5)}$	62	53	62	58	68	61						
	$I_{(15)}$	60	50	59	55	65	58						
	$T_{(5)}$	0.69	0.59	0.69	0.65	0.76	0.68	0.06	0.70	0.69			
	$T_{(15)}$	0.67	0.56	0.66	0.61	0.73	0.65	0.06	0.73	0.71			
VS27	$I_{(0)}$	70	65	61	65	62	65						0.72
	$I_{(5)}$	66	63	59	66	60	63						
	$I_{(15)}$	64	60	55	61	58	60						
	$T_{(5)}$	0.74	0.70	0.66	0.74	0.67	0.70	0.04	0.72	0.71			
	$T_{(15)}$	0.71	0.67	0.61	0.68	0.65	0.67	0.04	0.75	0.73			

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. I(t)/I(0)

Quality Control Steps:

1. Is control final mean output greater than 72% control initial mean output?

   $I_{(5)}$: $F_{c(mean)}/I_{c(mean)}$=99%

   $I_{(15)}$: $F_{c(mean)}/I_{c(mean)}$=91%

Control results are acceptable

2. Does the reference final mean exceed 80% of control final mean?

Ref 1 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=59% Ref 2 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=80%

$I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=62% $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=79%

Ref 1 is not acceptable. Ref 2 is acceptable to be used in statistical analyses.

3. Is the reference initial mean > 80% of control initial mean?

   Ref 1: $I_{R(mean)}/I_{C(mean)}$=63% Ref 2: $I_{R(mean)}/I_{C(mean)}$=81%

Ref 1: Use control initial mean to calc. Change in final light readings

Ref 2: Use Ref 2 initial mean to calculate change in light readings at $I_{(5)}$ and $I_{(15)}$ for reference site.

4. Are test initial mean values > 80% of control initial mean values?

   QB4: $I_{T(mean)}/I_{C(mean)}$=71%, use control initial mean to calculate change in light readings.

   VS27: $I_{T(mean)}/I_{C(mean)}$=72%, use control initial mean readings to calculate change in light readings.

Appendix Table A-3b. Microtox 100 Percent Sediment Porewater Test
Port Quendall Terminals Project
Anchor Environmental
Test Date: 25 February 2004

Site	Light Reading	Replicate 1	2	3	4	5	Mean	St.Dev.	$T_{(mean)}/Ref2_{(mean)}$	$T_{(mean)}/C_{(mean)}$	Change in light readings compared to initial control $I_{(t)(mean)}/I_{(0)C(mean)}$	Change in light readings compared to final control $I_{(t)(mean)}/I_{(t)C(mean)}$	Evaluation of initial light output $I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	104	105	104	103	99	103						
	$I_{(5)}$	91	102	101	98	96	98				0.95		
	$I_{(15)}$	81	91	91	88	87	88				0.85		
	$C_{(5)}$	0.88	0.97	0.97	0.95	0.97	0.95	0.04					
	$C_{(15)}$	0.78	0.87	0.88	0.85	0.88	0.85	0.04					
Ref 1	$I_{(0)}$	58	54	56	54	57	56						0.54
	$I_{(5)}$	53	50	52	50	54	52					0.53	
	$I_{(15)}$	54	50	52	49	53	52					0.59	
	$R_{(5)}$	0.51	0.49	0.50	0.49	0.52	0.50	0.02					
	$R_{(15)}$	0.52	0.49	0.50	0.48	0.51	0.50	0.02					
Ref 2	$I_{(0)}$	89	88	84	83	79	85						0.82
	$I_{(5)}$	79	82	82	84	78	81					0.83	
	$I_{(15)}$	72	73	76	76	71	74					0.84	
	$T_{(5)}$	0.77	0.80	0.80	0.82	0.76	0.79	0.02					
	$T_{(15)}$	0.70	0.71	0.74	0.74	0.69	0.71	0.02					
S54	$I_{(0)}$	49	47	50	46	46	48						0.46
	$I_{(5)}$	50	48	51	48	47	49						
	$I_{(15)}$	52	49	52	49	50	50						
	$T_{(5)}$	0.49	0.47	0.50	0.47	0.46	0.47	0.02	0.60	0.50			
	$T_{(15)}$	0.50	0.48	0.50	0.48	0.49	0.49	0.01	0.68	0.58			
SB52	$I_{(0)}$	10	10	10	10	8	10						0.09
	$I_{(5)}$	10	9	9	10	8	9						
	$I_{(15)}$	10	9	10	10	9	10						
	$T_{(5)}$	0.10	0.09	0.09	0.10	0.08	0.09	0.01	0.11	0.09			
	$T_{(15)}$	0.10	0.09	0.10	0.10	0.09	0.09	0.01	0.13	0.11			

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. I(t)/I(0)

Quality Control Steps:

1. Is control final mean output greater than 72% control initial mean output?

   $I_{(5)}$: $F_{c(mean)}/I_{c(mean)}$=95%

   $I_{(15)}$: $F_{c(mean)}/I_{c(mean)}$=85%

Control results are acceptable

2. Does the reference final mean exceed 80% of control final mean?

Ref 1 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=53% Ref 2 $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=83%

$I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=59% $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=84%

Ref 1 is not acceptable. Ref 2 is acceptable to be used in statistical analyses.

3. Is the reference initial mean > 80% of control initial mean?

   Ref 1: $I_{R(mean)}/I_{C(mean)}$=54% Ref 2: $I_{R(mean)}/I_{C(mean)}$=82%

Ref 1: Use control initial mean to calc. Change in final light readings

Ref 2: Use control initial mean to calculate change in light readings at $I_{(5)}$ and $I_{(15)}$ for reference site.

4. Are test initial mean values > 80% of control initial mean values?

   S54: $I_{T(mean)}/I_{C(mean)}$=46%, use control initial mean to calculate change in light readings.

   SB52: $I_{T(mean)}/I_{C(mean)}$=9%, use control initial mean readings to calculate change in light readings.

APPENDIX B

WATER QUALITY RESULTS

HYALELLA AZTECA

Appendix Table B-1. 10-Day Amphipod Survival Test (*Hyalella azteca*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 20 February 2004

Control

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.8	8.9	7.62	281	NT	<1.0	<0.01	0.02
1	19.6	8.3	7.48	274	---	---	---	---
2	19.6	8.1	7.04	306	---	---	---	---
3	19.7	8.3	7.51	304	---	---	---	---
4	19.6	8.5	7.58	319	---	---	---	---
5	19.2	8.4	7.80	372	---	---	---	---
6	19.5	8.9	7.74	421	---	---	---	---
7	19.9	8.6	8.08	409	---	---	---	---
8	19.7	8.7	7.92	415	---	---	---	---
9	19.8	8.6	7.87	410	---	---	---	---
10	19.8	8.9	7.97	477	4.7	5.5	<0.01	<0.01

AQT-REF1-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.6	8.8	7.63	248	1.4	1.6	<0.01	<0.01
1	19.6	8.2	7.33	217	---	---	---	---
2	19.7	8.0	7.12	229	---	---	---	---
3	19.6	8.6	7.35	214	---	---	---	---
4	19.6	8.5	7.38	236	---	---	---	---
5	19.4	8.3	7.68	289	---	---	---	---
6	19.4	8.9	7.43	254	---	---	---	---
7	19.5	8.4	7.84	303	---	---	---	---
8	19.7	8.5	7.81	292	---	---	---	---
9	19.8	8.4	7.82	305	---	---	---	---
10	19.6	8.1	7.84	334	6.1	4.9	<0.01	<0.01

AQT-REF2-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.8	8.8	7.68	249	<1.0	2.1	<0.01	<0.01
1	19.7	8.1	7.44	226	---	---	---	---
2	19.8	8.0	7.23	243	---	---	---	---
3	19.7	8.6	7.41	228	---	---	---	---
4	19.7	8.6	7.49	244	---	---	---	---
5	19.3	8.6	7.69	301	---	---	---	---
6	19.5	8.8	7.56	260	---	---	---	---
7	19.5	8.0	7.71	317	---	---	---	---
8	19.7	8.2	7.71	310	---	---	---	---
9	19.8	8.1	7.82	311	---	---	---	---
10	19.6	8.1	7.75	315	4.8	6.3	<0.01	<0.01

NT-Not Tested

Appendix Table B-1 (cont). 10-Day Amphipod Survival Test (*Hyalella azteca*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 20 February 2004

AQT-QB4-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	20.0	8.8	7.70	245	3.5	1.8	<0.01	0.02
1	19.8	8.1	7.50	217	---	---	---	---
2	19.9	8.5	7.39	232	---	---	---	---
3	19.8	8.8	7.44	214	---	---	---	---
4	19.7	8.8	7.54	229	---	---	---	---
5	19.1	8.4	7.73	289	---	---	---	---
6	19.5	8.8	7.60	251	---	---	---	---
7	19.5	8.6	7.84	301	---	---	---	---
8	19.7	8.7	7.77	295	---	---	---	---
9	19.7	8.6	7.85	297	---	---	---	---
10	19.5	8.6	8.04	301	5.2	5.2	<0.01	<0.01

AQT-SB52-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.8	8.9	7.65	233	2.2	1.7	<0.01	<0.01
1	19.7	8.2	7.49	236	---	---	---	---
2	19.7	9.0	7.42	242	---	---	---	---
3	19.5	9.1	7.24	219	---	---	---	---
4	19.8	9.0	7.36	231	---	---	---	---
5	19.2	8.6	7.69	292	---	---	---	---
6	19.6	8.8	7.31	237	---	---	---	---
7	19.1	8.8	7.73	311	---	---	---	---
8	19.5	8.7	7.67	302	---	---	---	---
9	19.8	8.6	7.72	305	---	---	---	---
10	19.7	8.2	7.69	305	5.4	5.1	<0.01	<0.01

AQT-S54-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.7	8.9	7.63	240	1.8	1.9	<0.01	0.01
1	19.6	8.5	7.52	237	---	---	---	---
2	19.7	9.0	7.44	246	---	---	---	---
3	19.5	9.1	7.26	227	---	---	---	---
4	19.8	9.0	7.33	234	---	---	---	---
5	19.4	8.6	7.77	309	---	---	---	---
6	19.5	8.7	7.30	243	---	---	---	---
7	19.4	8.5	7.87	316	---	---	---	---
8	19.7	8.4	7.85	302	---	---	---	---
9	19.8	8.4	7.87	305	---	---	---	---
10	19.6	8.5	7.84	322	5.9	5.3	<0.01	<0.01

Appendix Table B-1 (cont). 10-Day Amphipod Survival Test (*Hyalella azteca*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 20 February 2004

AQT-VS27-SS								
Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L)		Sulfides (mg/L)	
					Interstitial	Overlying	Interstitial	Overlying
0	19.5	8.9	7.70	249	1.7	2.2	<.01	0.13
1	19.6	8.2	7.52	248	---	---	---	---
2	19.6	9.0	7.45	266	---	---	---	---
3	19.5	9.0	7.33	250	---	---	---	---
4	19.6	9.0	7.39	256	---	---	---	---
5	19.0	8.6	7.76	298	---	---	---	---
6	19.5	8.7	7.36	271	---	---	---	---
7	19.5	8.6	7.57	284	---	---	---	---
8	19.4	8.6	7.52	287	---	---	---	---
9	19.7	8.7	7.54	288	---	---	---	---
10	19.5	8.7	7.62	298	7.2	5.1	<.01	NT

CHIRONOMUS TENTANS

Appendix Table B-2. 20-Day Midge Larvae Survival and Growth Test (*Chironomus tentans*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 19 February 2004

Control

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.7	9.2	7.44	291	NT	<1.0	<0.01	0.02
1	19.6	8.2	7.23	259	---	---	---	---
2	19.7	8.7	7.43	273	---	---	---	---
3	19.6	9.1	7.53	303	---	---	---	---
4	19.9	8.4	7.38	313	---	---	---	---
5	19.6	8.7	7.61	324	---	---	---	---
6	19.8	8.4	7.68	355	---	---	---	---
7	20.0	8.6	7.75	370	---	---	---	---
8	19.8	8.2	7.79	394	---	---	---	---
9	19.7	8.1	7.80	377	---	---	---	---
10	19.8	8.0	7.82	382	---	---	---	---
11	19.6	7.9	7.76	423	---	---	---	---
12	19.5	8.2	7.84	463	---	---	---	---
13	20.0	8.2	7.91	500	---	---	---	---
14	19.4	8.3	7.88	462	---	---	---	---
15	19.5	7.7	7.90	496	---	---	---	---
16	19.7	8.4	7.97	525	---	---	---	---
17	19.6	8.1	8.01	539	---	---	---	---
18	19.5	7.8	7.94	573	---	---	---	---
19	19.3	8.2	8.04	564	---	---	---	---
20	19.8	8.1	8.05	572	16.1	6.2	0.13	<0.01

AQT-REF1-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.5	9.3	7.58	251	1.4	1.0	<0.01	<0.01
1	19.5	8.6	7.53	242	---	---	---	---
2	19.7	8.7	7.48	230	---	---	---	---
3	19.8	8.9	7.45	244	---	---	---	---
4	19.9	8.5	7.27	233	---	---	---	---
5	19.9	8.7	7.41	243	---	---	---	---
6	19.9	8.5	7.37	255	---	---	---	---
7	20.0	8.8	7.29	265	---	---	---	---
8	19.4	8.6	7.35	281	---	---	---	---
9	19.7	8.6	7.31	282	---	---	---	---
10	19.8	8.5	7.37	285	---	---	---	---
11	19.6	8.5	7.63	312	---	---	---	---
12	19.0	8.5	7.68	310	---	---	---	---
13	19.5	8.9	7.83	320	---	---	---	---
14	19.8	8.6	7.76	325	---	---	---	---
15	20.0	8.2	8.01	343	---	---	---	---
16	19.8	8.1	8.01	351	---	---	---	---
17	19.8	8.2	8.10	349	---	---	---	---
18	19.7	7.9	8.03	364	---	---	---	---
19	19.7	8.5	8.16	367	---	---	---	---
20	20.3	8.3	8.17	372	8.8	4.6	0.12	<0.01

NT-Not Tested

Appendix Table B-2 (cont). 20-Day Midge Larvae Survival and Growth Test (*Chironomus tentans*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 19 February 2004

AQT-REF2-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.6	9.0	7.60	246	<1.0	<1.0	<0.01	<0.01
1	19.6	8.7	7.62	249	---	---	---	---
2	19.7	8.7	7.52	244	---	---	---	---
3	19.6	9.0	7.49	259	---	---	---	---
4	19.7	8.7	7.30	259	---	---	---	---
5	19.7	8.9	7.59	278	---	---	---	---
6	19.9	8.6	7.64	303	---	---	---	---
7	20.0	8.8	7.70	313	---	---	---	---
8	19.8	8.2	7.77	324	---	---	---	---
9	19.7	8.1	7.78	322	---	---	---	---
10	19.8	8.2	7.81	327	---	---	---	---
11	19.7	8.3	7.96	336	---	---	---	---
12	19.1	8.6	8.03	329	---	---	---	---
13	20.0	8.8	8.14	335	---	---	---	---
14	19.7	8.8	8.00	321	---	---	---	---
15	19.4	8.6	8.12	328	---	---	---	---
16	19.7	8.8	8.17	332	---	---	---	---
17	19.7	8.3	8.18	330	---	---	---	---
18	19.7	8.3	8.06	341	---	---	---	---
19	19.7	8.5	8.06	337	---	---	---	---
20	20.5	8.5	8.05	324	1.1	1.1	0.03	<0.01

AQT-QB4-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.5	9.2	7.62	241	3.5	1.6	<0.01	0.03
1	19.5	8.6	7.72	269	---	---	---	---
2	19.5	8.7	7.74	264	---	---	---	---
3	19.5	8.9	7.68	288	---	---	---	---
4	19.5	8.9	7.51	282	---	---	---	---
5	19.5	9.1	7.69	295	---	---	---	---
6	19.1	8.8	7.69	320	---	---	---	---
7	20.0	8.7	7.80	338	---	---	---	---
8	19.2	8.8	7.82	355	---	---	---	---
9	19.5	8.7	7.81	357	---	---	---	---
10	19.7	8.6	7.83	358	---	---	---	---
11	19.7	8.6	8.00	385	---	---	---	---
12	19.0	8.7	8.06	368	---	---	---	---
13	19.4	8.8	8.20	389	---	---	---	---
14	19.6	8.8	8.06	361	---	---	---	---
15	19.8	8.7	8.19	374	---	---	---	---
16	19.7	8.8	8.20	378	---	---	---	---
17	19.6	8.4	8.25	374	---	---	---	---
18	19.6	8.4	8.16	384	---	---	---	---
19	19.6	8.7	8.18	384	---	---	---	---
20	20.2	8.6	8.20	392	1.6	2.0	0.03	<0.01

Appendix Table B-2 (cont). 20-Day Midge Larvae Survival and Growth Test (*Chironomus tentans*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 19 February 2004

AQT-SB52-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.5	9.0	7.60	237	2.2	<1.0	<0.01	0.02
1	19.4	8.5	7.65	243	---	---	---	---
2	19.6	8.8	7.58	228	---	---	---	---
3	19.5	9.0	7.54	242	---	---	---	---
4	19.5	8.9	7.34	232	---	---	---	---
5	19.5	8.9	7.50	241	---	---	---	---
6	19.5	8.8	7.32	249	---	---	---	---
7	19.9	8.8	7.50	260	---	---	---	---
8	19.9	8.7	7.42	266	---	---	---	---
9	19.5	8.7	7.48	262	---	---	---	---
10	19.7	8.8	7.51	268	---	---	---	---
11	19.6	8.6	7.65	297	---	---	---	---
12	19.0	8.8	7.77	286	---	---	---	---
13	19.8	8.6	7.97	286	---	---	---	---
14	19.6	8.8	7.83	288	---	---	---	---
15	19.2	8.5	8.04	287	---	---	---	---
16	19.7	8.9	8.03	293	---	---	---	---
17	19.5	8.6	8.08	292	---	---	---	---
18	19.5	8.2	8.07	309	---	---	---	---
19	19.3	8.5	8.03	315	---	---	---	---
20	19.8	8.5	8.10	325	5.3	5.1	0.05	<0.01

AQT-S54-SS

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.6	9.2	7.59	243	1.8	<1.0	<0.01	<0.01
1	19.3	8.3	7.57	250	---	---	---	---
2	19.5	8.8	7.56	240	---	---	---	---
3	19.4	9.0	7.41	251	---	---	---	---
4	19.3	8.4	7.25	246	---	---	---	---
5	19.5	9.0	7.44	259	---	---	---	---
6	19.0	8.8	7.27	269	---	---	---	---
7	20.0	8.7	7.45	275	---	---	---	---
8	19.9	8.6	7.41	283	---	---	---	---
9	19.8	8.7	7.42	285	---	---	---	---
10	19.7	8.7	7.45	287	---	---	---	---
11	19.6	8.6	7.63	319	---	---	---	---
12	19.0	8.4	7.79	304	---	---	---	---
13	19.9	8.7	7.95	304	---	---	---	---
14	19.6	8.7	7.85	300	---	---	---	---
15	19.6	8.5	7.99	305	---	---	---	---
16	19.8	8.9	8.02	313	---	---	---	---
17	19.5	8.7	8.07	310	---	---	---	---
18	19.6	8.6	8.02	326	---	---	---	---
19	19.3	8.9	8.01	328	---	---	---	---
20	19.5	8.8	8.07	342	1.4	1.1	0.07	<0.01

Appendix Table B-2 (cont). 20-Day Midge Larvae Survival and Growth Test (*Chironomus tentans*)
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Initiated 19 February 2004

AQT-VS27-SS								
Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Total NH3 (mg/L) Overlying	Sulfides (mg/L) Interstitial	Sulfides (mg/L) Overlying
0	19.6	9.2	7.60	253	1.7	2.1	<0.01	0.01
1	19.5	8.5	7.63	246	---	---	---	---
2	19.6	8.5	7.62	238	---	---	---	---
3	19.5	8.9	7.45	238	---	---	---	---
4	19.5	8.6	7.20	243	---	---	---	---
5	19.6	8.8	7.38	253	---	---	---	---
6	19.1	8.7	7.27	264	---	---	---	---
7	20.0	8.5	7.47	276	---	---	---	---
8	19.9	8.5	7.48	286	---	---	---	---
9	19.7	8.4	7.45	285	---	---	---	---
10	19.7	8.5	7.47	287	---	---	---	---
11	19.8	8.6	7.88	313	---	---	---	---
12	19.0	8.6	7.86	294	---	---	---	---
13	19.5	8.4	7.99	291	---	---	---	---
14	19.6	8.6	7.95	289	---	---	---	---
15	19.5	8.3	8.03	288	---	---	---	---
16	19.7	8.7	7.97	284	---	---	---	---
17	19.8	8.3	7.92	271	---	---	---	---
18	19.8	7.8	7.78	269	---	---	---	---
19	19.8	8.4	7.80	250	---	---	---	---
20	20.2	8.1	7.78	231	0.7	1.4	0.08	<0.01

MICROTOX

Appendix Table B-3. Microtox Results
Port Quendall Terminals Project
Anchor Environmental
Water Quality Data

Test Date 25 February 2004

Site	Initial Salinity (ppt)	Final Salinity (ppt)	Initial D.O. (mg/L)	Final D.O. (mg/L)	Initial pH (units)	Final pH (units)	Final Porewater Conc.	Total NH_3 (mg/L)
Control	0.0	20.5	8.1	8.1	8.12	8.12	100%	NT
AQT-REF1-SS	0.0	19.4	8.5	8.5	7.91	7.91	100%	1.4
AQT-REF2-SS	0.0	19.2	8.4	8.4	7.63	8.19	99.6%	<1.0
AQT-QB4-SS	0.0	20.4	8.5	8.5	7.29	8.02	99.6%	3.5
AQT-SB52-SS	0.0	20.3	8.3	8.3	7.10	8.13	99.4%	2.2
AQT-S54-SS	0.0	19.3	8.3	8.3	7.60	8.04	99.8%	1.8
AQT-VS27-SS	0.0	20.6	8.3	8.3	7.46	8.08	99.6%	1.7

NT-Not Tested

APPENDIX C

REFERENCE TOXICANT TESTS

HYALELLA AZTECA

Appendix Table C-1. Reference Toxicant Data*
96-hr *Hyalella azteca* Survival
Initiated 24 February 2004

$CuCl_2$ Concentration	Rep	Temp. (°C) 0	24	48	72	96	D.O. (mg/L) 0	24	48	72	96	pH (units) 0	24	48	72	96	Cond (umhos/cm) 0	24	48	72	96	Survival 0	96
Control	1	20.1	20.0	20.0	20.0	19.8	8.2	8.2	8.2	8.2	8.2	7.89	7.63	7.62	7.61	7.60	339	295	302	312	313	10	9
	2																					10	10
	3																					10	9
	4																					10	10
187.5 µg/L	1	20.0	20.0	20.0	20.0	19.8	8.2	8.2	8.1	8.3	8.2	7.89	7.68	7.62	7.70	7.63	300	305	308	315	315	10	8
	2																					10	10
	3																					10	10
	4																					10	8
375 µg/L	1	20.1	19.9	20.0	19.8	19.8	8.2	8.5	8.5	8.4	8.3	7.88	7.77	7.76	7.79	7.78	299	294	298	303	307	10	7
	2																					10	9
	3																					10	6
	4																					10	8
750 µg/L	1	20.2	19.9	20.0	19.9	19.9	8.1	8.5	8.4	8.4	8.2	7.84	7.77	7.79	7.77	7.78	300	295	298	304	305	10	4
	2																					10	7
	3																					10	4
	4																					10	7
1500 µg/L	1	20.1	20.0	20.0	20.0	19.8	8.2	8.6	8.6	8.2	8.3	7.64	7.75	7.76	7.78	7.79	299	300	304	309	311	10	4
	2																					10	3
	3																					10	2
	4																					10	2
3000 µg/L	1	20.1	19.7	20.0	19.8	19.8	8.3	8.6	8.7	8.5	8.4	7.33	7.57	7.70	7.70	7.72	299	294	297	303	305	10	2
	2																					10	0
	3																					10	0
	4																					10	0

* Test conducted with organisms from population used in 10-day Amphipod test initiated 20 February 2004.

CHIRONOMUS TENTANS

Appendix Table C-2. Reference Toxicant Data*
96-hr *Chironomus tentans* Survival
Initiated 27 February 2004

$CuCl_2$ Concentration	Rep	Temp. (°C) 0	24	48	72	96	D.O. (mg/L) 0	24	48	72	96	pH (units) 0	24	48	72	96	Cond (umhos/cm) 0	24	48	72	96	Survival 0	96
Control	1	20.0	19.8	19.4	19.9	19.9	8.2	8.1	8.1	8.3	8.6	7.80	7.81	7.82	7.85	7.82	273	275	277	280	284	10	8
	2																					10	9
	3																					10	10
	4																					10	9
250 µg/L	1	20.3	19.7	19.2	20.0	19.9	8.6	8.2	8.0	8.3	8.7	7.61	7.65	7.62	7.75	7.83	268	270	275	278	281	10	5
	2																					10	2
	3																					10	2
	4																					10	5
500 µg/L	1	20.2	19.7	19.4	19.8	19.8	8.5	8.2	8.0	8.5	8.7	7.65	7.67	7.64	7.77	7.88	271	271	272	278	283	10	2
	2																					10	2
	3																					10	3
	4																					10	3
1000 µg/L	1	20.4	19.4	19.5	19.9	19.9	8.6	8.3	7.9	8.4	8.6	7.63	7.64	7.62	7.74	7.83	271	275	276	275	276	10	1
	2																					10	0
	3																					10	3
	4																					10	1
2000 µg/L	1	20.3	19.5	19.5	19.9	19.9	8.5	8.2	8.1	8.5	8.5	7.57	7.61	7.61	7.82	7.81	278	280	281	282	285	10	0
	2																					10	0
	3																					10	0
	4																					10	1
4000 µg/L	1	20.6	19.5	19.5	19.9	19.9	8.6	8.2	8.0	8.6	8.5	7.43	7.47	7.44	7.73	7.81	275	277	281	278	278	10	0
	2																					10	0
	3																					10	0
	4																					10	0

*** Test conducted with organisms from population used in 20-day Chironomus test initiated 19 February 2004.**

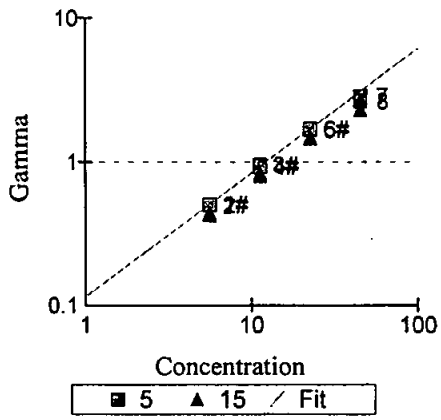
MICROTOX

MicrotoxOmni Test Report

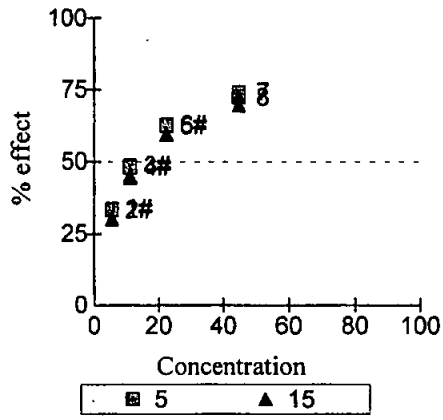
Date: 02/25/2004 03:05 PM

Test Protocol: Basic Test
Sample: 102 mg/L Phenol
Toxicant: 102 mg/L Phenol
Reagent Lot no.: 3J6034 Exp 9/05
Test description: Reference Toxicant
Test name: RT022504VF
Database file: C:\Program Files\MicrotoxOmni\Phenol.mdb

Plot of Gamma vs Concentration



Plot of %Effect vs Concentration



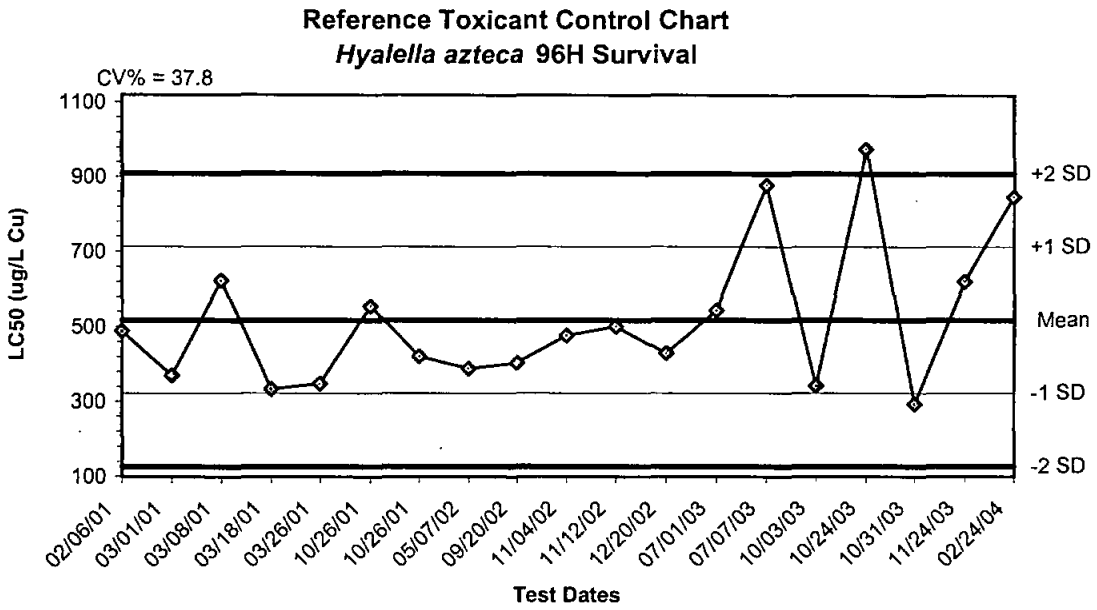
		5 Mins Data:				15 Mins Data:		
Sample	Conc	Io	It	Gamma	% effect	It	Gamma	% effect
Control	0.000	94.97	80.44	0.8470 #		80.60	0.8487 #	
Control	0.000	134.43	106.88	0.7951 #		102.53	0.7627 #	
1	5.625	127.40	69.43	0.5065 #	33.62%	71.95	0.4266	29.90%
2	5.625	133.52	73.03	0.5011 #	33.38%	74.78	0.4386 #	30.49%
3	11.25	131.22	55.40	0.9447 #	48.58%	58.06	0.8209 #	45.08%
4	11.25	119.09	50.81	0.9244 #	48.03%	53.42	0.7961 #	44.33%
5	22.50	132.62	41.02	1.654 #	62.33%	43.64	1.448 #	59.16%
6	22.50	133.91	40.98	1.683 #	62.73%	43.77	1.465 #	59.43%
7	45.00	129.22	27.62	2.841	73.97%	28.86	2.607	72.28%
8	45.00	130.12	29.57	2.613	72.32%	31.95	2.281	69.52%

- used in calculation; * - invalid data; D - deleted from calcs.
Autocalc has been used.

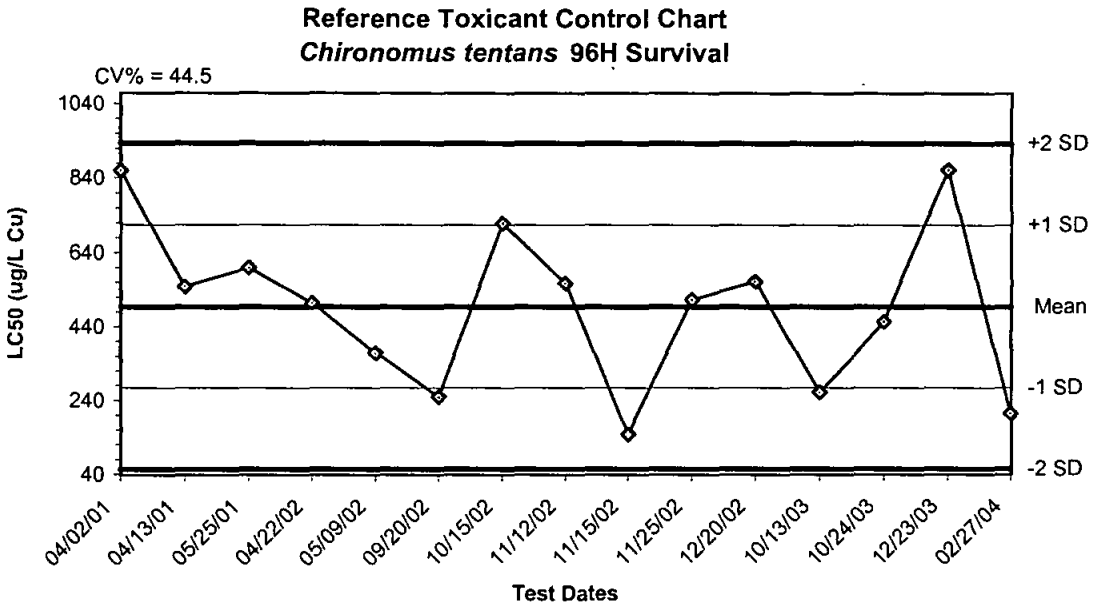
Calculations on 5 Mins data:
EC50 Concentration:12.35% (95% confidence range: 12.10 to 12.60)
95% Confidence Factor: 1.020
Estimating Equation:LOG C =1.157 x LOG G +1.092
Coeff. of Determination (R^2):0.9994
Slope: 0.8638
Correction Factor: 0.8210

Calculations on 15 Mins data:
EC50 Concentration:14.50% (95% confidence range: 14.13 to 14.87)
95% Confidence Factor: 1.026
Estimating Equation:LOG C =1.157 x LOG G +1.161
Coeff. of Determination (R^2):0.9993
Slope: 0.8636
Correction Factor: 0.8057

REFERENCE TOXICANT CONTROL CHARTS



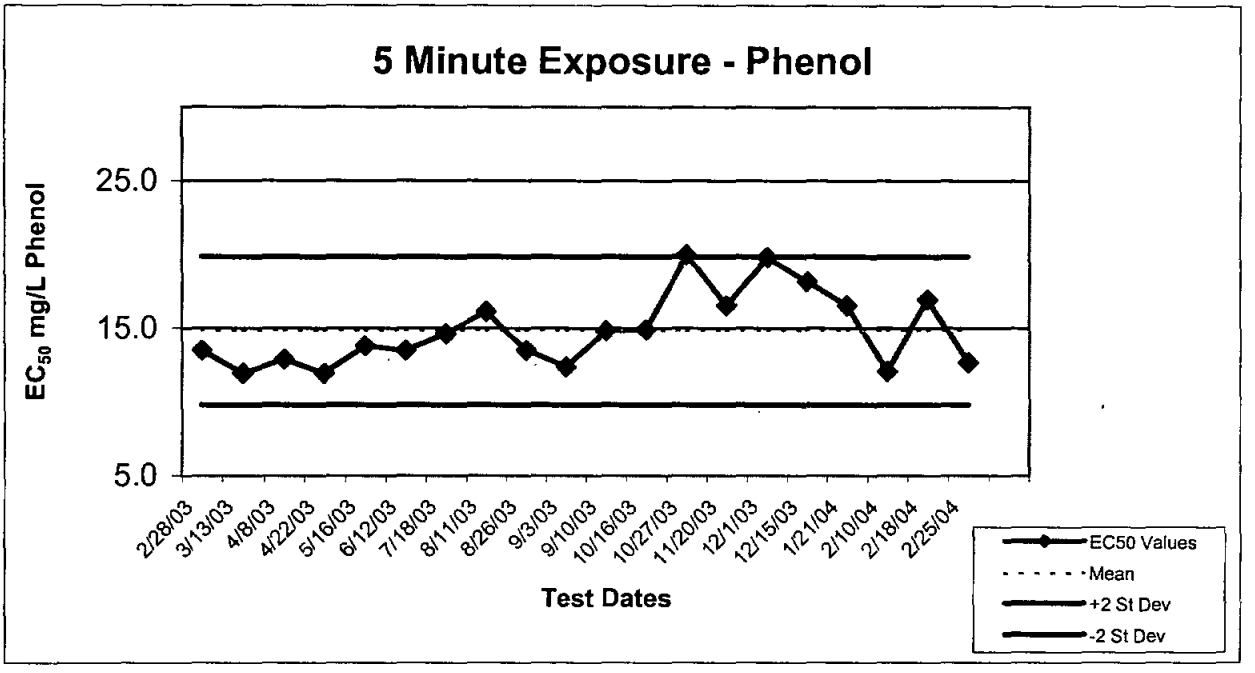
Dates	Values	Mean	-1 SD	-2 SD	+1 SD	+2 SD
02/06/01	487.9825	517.1293	321.5047	125.8800	712.7540	908.3787
03/01/01	369.3743	517.1293	321.5047	125.8800	712.7540	908.3787
03/08/01	622.8646	517.1293	321.5047	125.8800	712.7540	908.3787
03/18/01	332.8283	517.1293	321.5047	125.8800	712.7540	908.3787
03/26/01	347.4598	517.1293	321.5047	125.8800	712.7540	908.3787
10/26/01	553.1055	517.1293	321.5047	125.8800	712.7540	908.3787
10/26/01	420.4106	517.1293	321.5047	125.8800	712.7540	908.3787
05/07/02	387.5000	517.1293	321.5047	125.8800	712.7540	908.3787
09/20/02	402.7778	517.1293	321.5047	125.8800	712.7540	908.3787
11/04/02	475.2931	517.1293	321.5047	125.8800	712.7540	908.3787
11/12/02	500.0000	517.1293	321.5047	125.8800	712.7540	908.3787
12/20/02	428.5714	517.1293	321.5047	125.8800	712.7540	908.3787
07/01/03	542.4136	517.1293	321.5047	125.8800	712.7540	908.3787
07/07/03	878.1261	517.1293	321.5047	125.8800	712.7540	908.3787
10/03/03	341.2267	517.1293	321.5047	125.8800	712.7540	908.3787
10/24/03	975.3029	517.1293	321.5047	125.8800	712.7540	908.3787
10/31/03	292.7254	517.1293	321.5047	125.8800	712.7540	908.3787
11/24/03	620.2026	517.1293	321.5047	125.8800	712.7540	908.3787
02/24/04	847.2922	517.1293	321.5047	125.8800	712.7540	908.3787



Dates	Values	Mean	-1 SD	-2 SD	+1 SD	+2 SD
04/02/01	860.2941	494.4447	274.3391	54.2335	714.5503	934.6558
04/13/01	549.1071	494.4447	274.3391	54.2335	714.5503	934.6558
05/25/01	600.0000	494.4447	274.3391	54.2335	714.5503	934.6558
04/22/02	505.1020	494.4447	274.3391	54.2335	714.5503	934.6558
05/09/02	369.3182	494.4447	274.3391	54.2335	714.5503	934.6558
09/20/02	250.0000	494.4447	274.3391	54.2335	714.5503	934.6558
10/15/02	718.7500	494.4447	274.3391	54.2335	714.5503	934.6558
11/12/02	557.6923	494.4447	274.3391	54.2335	714.5503	934.6558
11/15/02	147.6459	494.4447	274.3391	54.2335	714.5503	934.6558
11/25/02	513.5731	494.4447	274.3391	54.2335	714.5503	934.6558
12/20/02	562.5000	494.4447	274.3391	54.2335	714.5503	934.6558
10/13/03	262.0790	494.4447	274.3391	54.2335	714.5503	934.6558
10/24/03	453.5630	494.4447	274.3391	54.2335	714.5503	934.6558
12/23/03	862.5000	494.4447	274.3391	54.2335	714.5503	934.6558
02/27/04	204.5455	494.4447	274.3391	54.2335	714.5503	934.6558

Reference Toxicant Control Chart
Microtox

CV% = 17.0

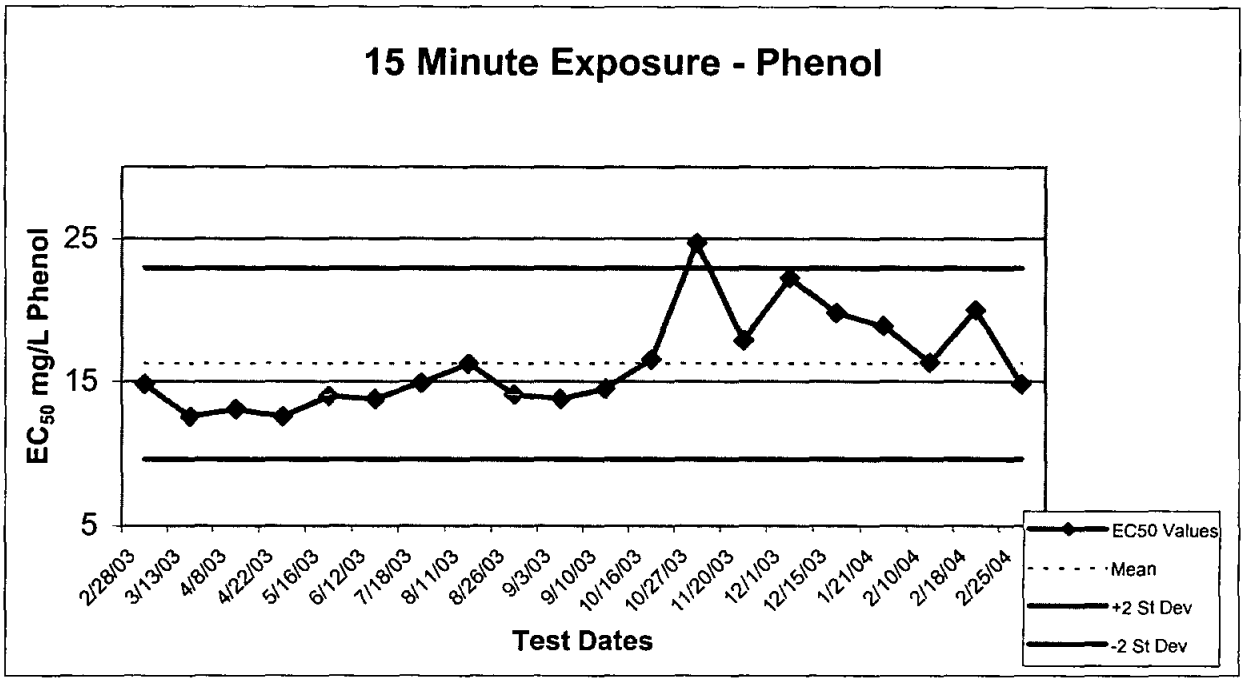


Date	Time	EC50 %	EC50 mg/L Phenol [a]	Mean	StDev	-2 SD	+2 SD
2/28/03	1459	13.2	13.5	14.8	2.52	9.8	19.8
3/13/03	1517	11.7	11.9	14.8	2.52	9.8	19.8
4/8/03	1645	12.6	12.9	14.8	2.52	9.8	19.8
4/22/03	1523	11.7	11.9	14.8	2.52	9.8	19.8
5/16/03	1503	13.5	13.8	14.8	2.52	9.8	19.8
6/12/03	1540	13.2	13.5	14.8	2.52	9.8	19.8
7/18/03	1635	14.3	14.6	14.8	2.52	9.8	19.8
8/11/03	1225	15.8	16.1	14.8	2.52	9.8	19.8
8/26/03	1612	13.2	13.5	14.8	2.52	9.8	19.8
9/3/03	1739	12.1	12.4	14.8	2.52	9.8	19.8
9/10/03	1746	14.5	14.8	14.8	2.52	9.8	19.8
10/16/03	1642	14.6	14.9	14.8	2.52	9.8	19.8
10/27/03	1735	19.6	20.0	14.8	2.52	9.8	19.8
11/20/03	1530	16.2	16.5	14.8	2.52	9.8	19.8
12/1/03	1535	19.4	19.8	14.8	2.52	9.8	19.8
12/15/03	1113	17.8	18.2	14.8	2.52	9.8	19.8
1/21/04	1723	16.2	16.5	14.8	2.52	9.8	19.8
2/10/04	1549	11.8	12.0	14.8	2.52	9.8	19.8
2/18/04	1522	16.6	16.9	14.8	2.52	9.8	19.8
2/25/04	1505	12.4	12.6	14.8	2.52	9.8	19.8

a - Highest concentration of Phenol is 102 mg/L

Reference Toxicant Control Chart
Microtox

CV% = 20.5



Date	Time	EC50 %	EC50 mg/L Phenol [a]	Mean	StDev	-2 SD	+2 SD
2/28/03	1459	14.5	14.8	16.3	3.34	9.6	22.9
3/13/03	1517	12.3	12.5	16.3	3.34	9.6	22.9
4/8/03	1645	12.8	13.1	16.3	3.34	9.6	22.9
4/22/03	1523	12.3	12.5	16.3	3.34	9.6	22.9
5/16/03	1503	13.7	14.0	16.3	3.34	9.6	22.9
6/12/03	1540	13.5	13.8	16.3	3.34	9.6	22.9
7/18/03	1635	14.6	14.9	16.3	3.34	9.6	22.9
8/11/03	1225	15.9	16.2	16.3	3.34	9.6	22.9
8/26/03	1612	13.8	14.1	16.3	3.34	9.6	22.9
9/3/03	1739	13.5	13.8	16.3	3.34	9.6	22.9
9/10/03	1746	14.2	14.5	16.3	3.34	9.6	22.9
10/16/03	1642	16.2	16.5	16.3	3.34	9.6	22.9
10/27/03	1735	24.2	24.7	16.3	3.34	9.6	22.9
11/20/03	1530	17.5	17.9	16.3	3.34	9.6	22.9
12/1/03	1535	21.8	22.2	16.3	3.34	9.6	22.9
12/15/03	1113	19.4	19.8	16.3	3.34	9.6	22.9
1/21/04	1723	18.5	18.9	16.3	3.34	9.6	22.9
2/10/04	1549	16.0	16.3	16.3	3.34	9.6	22.9
2/18/04	1522	19.6	20.0	16.3	3.34	9.6	22.9
2/25/04	1505	14.5	14.8	16.3	3.34	9.6	22.9

a - Highest concentration of Phenol is 102 mg/L

APPENDIX D

CHAIN-OF-CUSTODY FORM

Chain of Custody

amec Earth & Environmental
AMEC Northwest Bioassay Laboratory
5009 Pacific Highway East, Suite 2
Fife, WA 98424
Phone: 253-922-4296 FAX: 253-922-5814

Date 2/13/04 Page 1 of 1

COMPANY Anchor/D. Henessey
ADDRESS 1423 3rd Ave #300
CITY Seattle STATE WA ZIP 98101
PHONE NO. 206 287 9130

D. Henessey
PROJECT MANAGER
J. Keithly
SAMPLERS (SIGNATURE)
206 915 5217
PHONE NUMBER

ANALYSIS REQUIRED

SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	20-d chironomus	10-d hyalella	Microtox 100% porewater											CONCENTRATIONS/COMMENTS	NUMBER OF CONTAINERS
AQT-QB4-SS	2/13/04		S	P	X	X	X					AQT-QB4-SS						SED04-0001	
AQT-QSB52-SS	2/13/04		S	P	X	X	X					AQT-SB52-SS						SED04-0002	
AQT-S54-SS	2/13/04		S	P	X	X	X					AQT-S54-SS						SED 04-0003	
~~AQT-SV~~												AQT-VS27-SS							
AQT-VS27-SS	2/13/04		S	P	X	X	X					AQT-REF1-SS						SED 04-0004	
AQT-REF1-SS	2/13/04		S	P	X	X	X					AQT-REF2-SS						SED 04-0005	
AQT-REF2-SS	2/13/04		S	P	X	X	X											SED 04-0006	

Sample id confirmed w/ James 2/19/04 NF

PROJECT INFORMATION	SAMPLE RECEIPT	
CLIENT	TOTAL NO. OF CONTAINERS 6	6
P.O. NO.	CHAIN OF CUSTODY SEALS	N
SHIPPED VIA:	RECEIPT TEMP	9.3
	CONFORMS TO RECORD	Y

SPECIAL INSTRUCTIONS/COMMENTS:

RELINQUISHED BY	RELINQUISHED BY
(Signature) [signature] 2/13/04 1420 (Time)	(Signature) [signature] 1520 (Time)
(Printed Name) J. Keithly (Date)	(Printed Name) ERIC PARKER (Date) 2/13/04
(Company) Anchor	(Company) ANCHOR ENV.

RECEIVED BY	RECEIVED BY (LABORATORY)
(Signature) [signature] 2/13/04 1420 (Time)	(Signature) Eric Tollefson 15:20 (Time)
(Printed Name) ERIC PARKER (Date)	(Printed Name) ERIC TOLLEFSON 2/13/04 (Date)
(Company) Anchor	AMEC Bioassay Lab Log-in No. 04-0001 - 04-0006

Additional disposal charges may apply.

DISTRIBUTION: WHITE, CANARY - AMEC Bioassay Lab, PINK - Originator

APPENDIX C

SUPPLEMENTAL SURFACE SOIL STUDY

A surface soil investigation was performed at the Quendall Terminals Site (Site) to provide additional data in assessing the potential risks associated with human health and ecological exposures, as well as to support the identification and evaluation of remedial alternatives. Twenty-two soil samples were collected from the Site on February 27 and March 1, 2004, and eleven of these were analyzed for VOCs by EPA Method 8260B and eleven were analyzed for SVOCs by EPA Method 8270C. Soil sample collection and analysis was performed in accordance with the Sampling Analysis Plan (Aspect 2004), with the following exceptions:

- At three sampling locations, large cobbles (2 to 6 inches in diameter) prevented sample collection to the specified 3-foot depth. Sample locations and refusal depths were as follows:
  - SS-BH9 (2 feet);
  - SS-HC8 (2.1 feet); and
  - SS-HC2 (2.3 feet).
- At several other locations, large gravel and cobbles were encountered but were removed using a post hole digger, pickaxe, and/or shovel. All excavation equipment was decontaminated between sample locations.

Sample locations are shown on Figure 1 of the Sampling and Analysis Plan, and soil sampling logs are provided in Attachment 1. A summary of chemical analytical results is provided in Table 1. Laboratory certificates of analysis are available upon request.

Attachments:

Table C-1 – Chemical Analytical Results

Attachment 1 – Surface Soil Sampling Logs

Data Quality Review

Twenty-two soil samples were collected on February 27 and March 1, 2004 at the Quendall Terminals site. The samples were submitted to Columbia Analytical Services of Kelso, Washington for analysis of one of the following:

- Volatile Organics (EPA Method 8260B); and
- Semivolatile Organics (EPA Method 8270C).

The following quality assurance/quality control parameters were evaluated in the standard validation process for applicable analyses:

- Holding Times;
- Method Blanks;
- Surrogate Recoveries;
- Matrix Spike/Matrix Spike Duplicates Relative Percent Differences (RPD);
- Blank Spike/Laboratory Control Spike Recoveries; and
- Reported Detection Limits.

Based on our review of these QA/QC parameters, we believe the soil quality data collected during this surface soil investigation are acceptable for defining the nature and extent of contamination and evaluating site risks. A detailed evaluation is provided in the laboratory case narrative (attached). In summary, the following actions were taken:

- During the analysis of sample SS-TP4-1.5 for VOCs, the internal standard control criteria were exceeded. The sample was reanalyzed within the holding time and met the control criteria. The results of the reanalysis were reported without qualification.
- During the analysis of samples SS-TP2-1.5 and SS-BH7-1.5 for VOCs, the internal standard control criterion was exceeded. Reanalysis of these samples was performed 3 days after the holding time limit and met control criteria. The results of the initial analysis and reanalysis in both cases were comparable; however, because in one instance the internal standard control criterion was exceeded and in the other the holding time limit was exceeded, the highest detected concentration of each analyte was reported and the result flagged 'J' to indicate an estimated value.
- Reporting limits were elevated due to dilution or matrix interferences on several samples. Detected concentrations below the method reporting limit were flagged 'J'. Detection limits for non-detected analytes with method reporting limits above those

specified in the Sampling and Analysis Plan were reported to the method detection limit and flagged 'UJ'.

- Methylene chloride was detected in the method blank and in two samples at a concentration less than 5 times the detected method blank concentration. Therefore, methylene chloride concentrations were reported as non-detect at the MRL.

Table C-1
Analytical Results of Surface Soil Samples-SVOCs
Detected Constituents and COPCs

General Location	Former May Creek Channel		Quendall Pond				South Sump		North Sump		Still House											
Sample Number	SS-HC7-0/3		SS-BH19-0/3		SS-TP4-0/3		SS-BH7-0/3		SS-HC2-0/2.3		SS-HC5-0/3		SS-HC8-0/2.1		SS-BH9-0/2		SS-BH27-0/3		SS-TP2-0/3		SS-TP5-0/3	
Sample Depth in Feet	0 to 3		0 to 3		0 to 3		0 to 3		0 to 2.3		0 to 3		0 to 2.1		0 to 2		0 to 3		0 to 3		0 to 3	
Sample Date	3/1/2004		3/1/2004		3/1/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		2/27/2004		3/1/2004	
Analyte																						
SVOCs by EPA Method 8270C (Concentrations in mg/kg)																						
PAHs																						
Naphthalene	**0.052**	**J**	**2.3**		**0.027**	**J**	**0.075**	**J**	**0.094**	**J**	**37**		**0.057**	**J**	**270**		**0.18**	**J**	**0.22**	**J**	0.81	U
2-Methylnapthalene	**0.041**	**J**	**0.83**		0.39	U	**0.056**	**J**	**0.045**	**J**	**14**		**0.025**	**J**	**57**		**0.089**	**J**	**0.14**	**J**	0.81	U
Acenaphthylene	0.34	U	**0.16**		0.39	U	**0.034**	**J**	0.45	U	**0.78**		0.34	U	**2.1**		0.55	U	**0.045**	**J**	0.81	U
Acenaphthene	**0.042**	**J**	**1.2**		0.39	U	**0.037**	**J**	**0.072**	**J**	**18**		**0.02**	**J**	**49**		**0.27**	**J**	**0.4**	**J**	0.81	U
Fluorene	**0.063**	**J**	**0.90**		**0.021**	**J**	**0.084**	**J**	**0.050**	**J**	**19**		**0.023**	**J**	**47**		**0.13**	**J**	**0.35**	**J**	0.81	U
Phenanthrene	**0.29**	**J**	**7.4**		**0.14**	**J**	**0.72**		**0.51**		**44**		**0.16**	**J**	**110**		**1.6**		**3.6**		**0.15**	**J**
Anthracene	**0.52**		**2.5**		**0.053**	**J**	**0.16**	**J**	**0.16**	**J**	**46**		**0.065**	**J**	**88**		**0.4**	**J**	**0.86**		**0.052**	**J**
Fluoranthene	**0.23**	**J**	**6.0**		**0.18**	**J**	**0.61**		**0.57**	**J**	**28**		**0.12**	**J**	**74**		**1.5**		**3.0**		**0.2**	**J**
Pyrene	**0.33**	**J**	**9.6**		**0.21**	**J**	**0.67**		**0.81**		**32**		**0.17**	**J**	**88**		**2.4**		**3.9**		**0.23**	**J**
Benz[a]anthracene	**0.17**	**J**	**5.4**		**0.12**	**J**	**0.39**		**0.46**		**10**		**0.092**	**J**	**37**		**1.0**		**2.5**		**0.15**	**J**
Chrysene	**0.27**	**J**	**6.7**		**0.17**	**J**	**0.49**		**0.67**		**14**		**0.14**	**J**	**54**		**1.3**		**3.2**		**0.25**	**J**
Benzo[b]fluoranthene	**0.16**	**J**	**5.0**		**0.11**	**J**	**0.33**	**J**	**0.56**	**J**	**7.4**		**0.10**	**J**	**29**		**1.1**		**2.5**		**0.18**	**J**
Benzo[k]fluoranthene	**0.17**	**J**	**4.0**		**0.11**	**J**	**0.34**	**J**	**0.38**	**J**	**8.9**		**0.094**	**J**	**32**		**0.88**		**1.9**		**0.19**	**J**
Benzo[a]pyrene	**0.19**	**J**	**6.4**		**0.13**	**J**	**0.36**	**J**	**0.65**	**J**	**9.4**		**0.13**	**J**	**35**		**1.3**		**2.9**		**0.18**	**J**
Indeno[1,2,3-cd]pyrene	**0.14**	**J**	**4.3**		**0.098**	**J**	**0.23**	**J**	4.5	U	**6.7**		**0.092**	**J**	**24**		**0.89**		**2.2**		**0.13**	**J**
Dibenz[a,h]anthracene	**0.041**	**J**	**1.0**		0.038	UJ	**0.067**	**J**	0.44	UJ	**1.7**		0.032	UJ	**7.4**		**0.22**	**J**	**0.54**	**J**	0.071	UJ
Benzo[g,h,i]perylene	**0.13**	**J**	**5.1**		**0.098**	**J**	**0.15**	**J**	**0.60**	**J**	**7.1**		**0.1**	**J**	**24**		**0.98**		**1.9**		**0.13**	**J**
Total cPAHs - B[a]P Equivalent	**0.27**		**8.7**		**0.19**		**0.52**		**1.4**		**14**		**0.18**		**51**		**1.8**		**4.1**		**0.28**	
Total PAHs	**3.2**		**69**		**2.7**		**4.8**		**11**		**304**		**1.8**		**1,028**		**15**		**30**		**6.0**	
Nitroaromatics																						
n-Nitroso-di-phenylamine	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	0.34	U	0.34	U	0.71	U	0.55	U	0.54	U	0.81	U
Phenolics																						
Phenol	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	**0.23**	**J**	0.34	U	**0.47**	**J**	0.55	U	0.047	J	0.81	U
2-Methylphenol	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	**0.098**	**J**	0.34	U	**0.23**	**J**	0.55	U	0.54	U	0.81	U
4-Methylphenol	0.34	U	**0.046**	**J**	**0.074**	**J**	**1.2**		**0.048**	**J**	**0.38**		0.34	U	**1.8**		**0.082**	**J**	0.12	J	**0.21**	**J**
2,4-Dimethylphenol	0.34	U	0.77	U	0.39	U	0.46	U	0.45	U	**0.13**	**J**	0.34	U	**1.3**		0.55	U	0.54	U	0.81	U
Pentachlorophenol	0.16	UJ	0.29	UJ	0.18	UJ	0.21	UJ	0.2	UJ	1.5	UJ	0.15	UJ	0.27	UJ	0.25	UJ	0.25	UJ	0.32	UJ
Phthalates																						
Bis(2-ethylhexyl)phthalate	0.34	U	0.77	U	0.39	U	**0.035**	**J**	0.45	U	0.34	U	**0.047**	**J**	7.1	U	0.55	U	0.05	J	0.81	U
Di-n-octylphthalate	0.34	U	0.77	U	0.39	U	0.46	U	4.5	U	3.4	U	0.34	U	7.1	U	0.55	U	0.54	U	0.81	U
Miscellaneous																						
Benzoic Acid	2.1	U	4.7	U	2.4	U	**0.41**	**J**	2.7	U	2.1	U	2.1	U	4.3	U	3.4	U	3.3	U	4.9	U
Dibenzofuran	**0.020**	**J**	**0.19**		0.39	U	**0.053**	**J**	**0.021**	**J**	**12**		0.34	U	**33**		0.036	U	**0.12**	**J**	0.81	U

Note:
U Not detected at indicated detection limit
J Estimated value
Bold indicates detected compound

LOG OF SOIL PROBE NO. SS-BH19

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Grass
						Medium dense, moist, brown to dark brown, SAND, with silt, few gravel. Fine-to-coarse grey brown gravel grades fine.
	VOC		8.6 ppm			
						Bottom of Hole: 3'.
						One sample for VOC collected at a depth of 1.5 feet. One sample for SVOC composited from a depth of 0 to 3 feet.
						0 to 3 feet composite sample. PID: 8.6 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

PQUENDALL QUENDALL HAND AUGERS.GPJ May 25, 2004

LOG OF SOIL PROBE NO. SS-BH27

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose to medium dense, moist, red brown to dark brown SAND with wood chips and fragment organics, little silt. Fine-to-coarse sand, fine gravel.
	VOC		13.1 ppm			
						Becomes very dense.
						Bottom of Hole: 3.0'
						One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 3 feet.
						0-3' composite sample. PID: 13.1 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

PQUENDALL QUENDALL HAND AUGERS.GPJ May 25, 2004

LOG OF SOIL PROBE NO. SS-BH7

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose, brown, moist, silty, organic SAND with frequent roots and wood fibers. Fine-to-coarse sand, predominately fine-to-medium sand.
	VOC					Dense silty SAND with gravel.
						Medium dense, olive gray, moist, SAND, little silt and gravel. Fine-to-coarse sand, fine gravel.
						Bottom of Hole: 3.0' One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 3 feet.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

LOG OF SOIL PROBE NO. SS-BH9

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose, moist-to-wet, dark brown, silty SAND with organics and wood fragments.
			30.1 ppm			Very dense, moist, brown to dark brown, GRAVEL with cobbles, few sand, little silt. Fine-to-coarse sand, fine-to-coarse gravel. Bulk composition is >50% 3-8" cobbles, scattered organics.
	VOC					
						Refusal at 2'. One soil sample collected for VOC analysis at a depth of 1.5'. One soil sample collected for SVOC analysis composited from a depth of 0 to 2 feet. 0-2' composite sample. PID: 30.1 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

PQUENDALL QUENDALL HAND AUGERS.GPJ May 25, 2004

LOG OF SOIL PROBE NO. SS-HC2

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose, moist, brown to red brown, silty SAND with frequent organics, wood and roots. Fine-to-coarse sand.
	VOC		10.6 ppm			Dense to very dense, moist brown, sandy GRAVEL with 40-60% cobbles, crushed rock base, and cement. Fine-to-coarse sand, fine-to-coarse gravel.
						Refusal at 2.3' One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 3 feet. 0 to 3' composite sample. PID: 10.6 ppm

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

LOG OF SOIL PROBE NO. SS-HC5

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose, wet, dark brown, silty, sandy, ORGANICS and wood fragments.
						Dense, moist, olive gray, silty SAND with gravel. Fine-to-coarse sand, fine gravels.
	VOC		20.7 ppm			Medium dense to dense, moist, brown, silty SAND with fine gravel, scattered organic fragments. Cobbles frequent below 2'.
						Bottom of Hole: 3.0' Soil sample collected for VOC analysis at a depth of 1.5' Soil sample collected for SVOC analysis composited from a depth of 0 to 3 feet. 0-3' composite sample. PID: 20.7 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

PQUENDALL QUENDALL HAND AUGERS.GPJ May 25, 2004

LOG OF SOIL PROBE NO. SS-HC7

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplification of actual conditions encountered. **DESCRIPTION**
	SVOC			▼		Dense, moist, dark brown GRAVEL with sand, little silt, frequent cobbles organics. Fine-to-coarse sand, fine-to-coarse gravel. Wet at 0.5'.
	VOC		1.0 ppm			Medium dense, wet, green gray SAND with gravel, fine-to-coarse sand, fine-to-coarse gravel, rounded gravels.
						Bottom of Hole: 3'. One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 3 feet. 0 to 3' composite sample. PID: 1.0 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

LOG OF SOIL PROBE NO. SS-HC8

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Medium dense, moist, brown, silty SAND with gravel. Fine-to-coarse sand, fine to coarse gravel with organics.
	VOC					Dense to very dense, moist, olive gray to brown, GRAVEL with sand, little silt. Fine-to-coarse sand, fine-to-coarse gravel. Frequent cobbles.
						Refusal at 2.1'. One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 2.1 feet.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

LOG OF SOIL PROBE NO. SS-TP2

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Medium dense, dark brown, moist, silty, organic SAND with few gravel, frequent wood. Fine-to-coarse sand, fine-to-coarse gravel.
	VOC		4.1 ppm	▼		Wet below 1.5'.
						Bottom of Hole: 3.0'. One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 3 feet. 0-3' composite sample. PID: 4.1 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

PQUENDALL QUENDALL HAND AUGERS.GPJ May 25, 2004

LOG OF SOIL PROBE NO. SS-TP4

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose, moist, dark brown, silty SAND, frequent wood chips and organics. Fine-to-coarse sand.
	VOC		2.6 ppm			
						Medium dense, green-gray, moist, SAND with silt and gravel. Fine-to-coarse sand, fine-to-coarse gravel, predominately fine-to-medium sand. Grades to SILT with sand.
						Bottom of Hole: 3'. One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis compisted from a depth of 0 to 3 feet. 0 to 3 foot composite sample. PID: 2.6 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

PQUENDALL QUENDALL HAND AUGERS.GPJ May 25, 2004

LOG OF SOIL PROBE NO. SS-TP5

Location: Renton, Washington

Depth, ft	Samples collected for lab analysis	Sample Type	PID	Remarks	Graphic Symbol	This log is part of the report prepared by Aspect Consulting, LLC, for the named project and should be read together with that report for complete interpretation. This summary applies only to the location of this boring at the time of installation. Subsurface conditions may change at this location with the passage of time. The data presented are a simplfication of actual conditions encountered. **DESCRIPTION**
	SVOC					Loose, moist, dark brown, silty SAND, fine-to-coarse sand, frequent (~30-40%) wood chips, fragments, organics.
	VOC		2.2 ppm			
				▼		Water at 2'.
						Bottom of Hole: 3' One sample collected for VOC analysis at a depth of 1.5 feet. One sample collected for SVOC analysis composited from a depth of 0 to 3 feet. 0 - 3' composite sample. PID: 2.2 ppm.

Sampler Type (ST): **3-inch-diameter Hand Auger**

▼ **Water Level (ATD)**

Project No. **020027**

Aspect consulting
IN-DEPTH PERSPECTIVE

APPENDIX D

RESTORATION TIMEFRAME

CONTAMINANT MASS BALANCE CALCULATIONS

Site contaminants can be actively remediated to address potential exposure pathways to site receptors via reuse, destruction, immobilization, off-site containment, and on-site containment. Estimating the percentage of contaminant mass actively remediated in each remedial alternative provides a basis for comparative analysis of the restoration time frame. The assumptions and methods used to estimate contaminant mass remediation are described below.

Total Contaminant Mass

The total mass of DNAPL at the site was calculated using the following assumptions:

- The majority of mass is in free-phase product (DNAPL).
- The areas of the site containing DNAPL are as follows:
  - North Sump and Quendall Pond: 2.5 acres
  - May Creek: 0.9 acres
  - Still House: 1.6 acres

- The average thickness of DNAPL in soil is 2 feet in the North Sump, Quendall Pond, and Still House areas, and 3 feet in the May Creek area.
- The average oil-filled porosity of DNAPL-containing soil is 0.067, based on:
  - Average concentration of total PAHs in DNAPL-containing soil samples is 20,000 ppm; and
  - Average percentage of total PAHs in product samples is 30% by weight.

- The density of DNAPL is 65.52 pounds per cubic foot.

The estimated DNAPL mass at the site is 2,100,000 pounds.

Mass Reused

For this evaluation, it is assumed that recovered DNAPL may not be economically recycled or reused. Therefore, for all alternatives, the percent mass of VOC and SVOC COPCs recycled/reused is 0%.

Under Alternatives 4, 5, and 6, all woodwaste-affected sediments would be removed and beneficially used on site in upland areas. Therefore, the percent mass of woodwaste recycled/reused for these alternatives is 100%.

Mass Destroyed

It is assumed that all DNAPL recovered by pumping will be destroyed through treatment. The mass of DNAPL recovered under each alternative was calculated using the following assumptions:

- The rate of DNAPL mass removal (removal efficiency) will diminish over time.
- Assuming a 5-year recovery program (actual operation timeframe will depend on effectiveness of system optimization over time), the average DNAPL recovery rate at each well = 50 gallons per year (based on results of the pilot DNAPL recovery test to date).
- The upland areas over which a DNAPL recovery program will be applied for each of the alternatives, as shown in Chapter 9, are assumed as follows:
    - Alternative 2: 70,000 square feet (approximately 1.6 acres)
    - Alternative 3: 49,000 square feet (approximately 1.1 acres)
    - Alternative 4: 84,000 square feet (approximately 1.9 acres)
    - Alternative 5: 42,000 square feet (approximately 1.0 acres)

The area of influence (based on a vertical recovery well) is estimated to be on the order of 1,400 square feet (actual area of influence may be higher for recovery trenches). The resulting mass recovered and destroyed under each alternative, and the percentage of the total mass, is estimated at 110,000 pounds (5%) for Alternative 2, 80,000 pounds (4%) for Alternative 3, 130,000 pounds (6%) for Alternative 4, and 65,000 pounds (3%) for Alternative 5.

Contaminant mass (residual) left in place, particularly within groundwater media, would also be destroyed over the long term by biodegradation and, in Alternatives 4 and 5, by reactive caps or walls. In situ biodegradation rates are discussed in more detail in Section 4 of the accompanying RI/FS Report.

Mass Contained Off Site

Under Alternatives 5 and 6, soil and sediment would be excavated and transported to an off-site containment facility. Under Alternative 5, only nearshore contaminated sediments and soils will be removed. Under Alternative 6, all accessible sediments and soils exceeding cleanup levels will be removed. For the purposes of this evaluation, it is assumed that

excavation to the maximum depth of DNAPL occurrences is technically feasible. The maximum observed depth of DNAPL for the majority of the site is approximately 16 feet, with limited areas that may have DNAPL to 20 feet. These depths occur below the shallow groundwater level, necessitating the need for dewatering during removal activities. The estimated total areas to be excavated/dredged, and the resulting percentages of mass removal, are as follows:

- Alternative 5: 0.7 acres in the Quendall Pond area (13%); and
- Alternative 6: all DNAPL-containing areas (100%).

Mass Contained On-Site

In Alternatives 2 through 5, the contaminant mass that is not reused, destroyed, or contained off site is assumed to be contained on site. The mechanism of containment, and the percentage of mass estimated to be contained on site, as follows:

- Alternative 2: Upland capping and natural attenuation (95%)
- Alternative 3: Upland capping, cutoff wall, and sediment capping (96%)
- Alternative 4: Upland capping, sediment capping (94%)
- Alternative 5: Upland capping, treatment wall (84%)

Under Alternative 3, 100 percent of woodwaste-affected sediments are contained on site.

RESTORATION TIME FRAME

For the purposes of this evaluation, restoration time frame is considered to be the time to achieve prospective cleanup levels at the conditional points of compliance at the site, as defined in Section 5. The restoration time frame for media addressed by active remedial measures, as discussed in Section 10, is a function of the design, permitting, and implementation schedule of those measures. For media addressed by natural attenuation processes (e.g., groundwater and sediment quality in selected alternatives), the restoration time frame depends on the rate at which site contaminants are attenuated. Alternatives which include active remedial measures that remove, treat, or contain contaminant mass (e.g., DNAPL recovery) in conjunction with natural attenuation will, in general, have faster projected restoration time frames than alternatives that rely solely on natural attenuation alone.

The conditional point of compliance for groundwater for this evaluation is porewater in sediment 10 cm below mudline. Benzene and naphthalene concentrations in sediment

porewater have been detected that exceed the prospective cleanup standards for these compounds. Under Alternatives 1 (no mass removal) and 2 (mass removal by DNAPL recovery, the concentration of benzene and naphthalene will decrease over a long period of time, and ultimately achieve the prospective cleanup standards, as natural attenuation processes reduce the mass of contaminant at the site. Assumptions used to estimate the restoration time frame to achieve the prospective cleanup standards for groundwater under these alternatives are discussed below.

Predictive modeling of the rate of natural attenuation processes (see Chapter 4) indicates that dissolved-phase COPCs in groundwater, in equilibrium with free-phase DNAPL, will attenuate to below cleanup levels over a flow path of approximately 50 feet (see Chapter 4). Consequently, based on this rate of natural attenuation, exceedences of COPCs at the groundwater conditional point of compliance is attributed to the presence of DNAPL occurrences located within 50 feet of the point of groundwater discharge into Lake Washington.

Restoration time frame was estimated using the methodology described in 'Methodology for Estimating Times of Remediation Associated with Monitored Natural Attenuation' (USGS 2003). This methodology was the basis for Natural Attenuation Software (NAS) developed by the USGS (http://www.cee.vt.edu/NAS). The NAS model can be used to estimate remediation time for NAPL occurrences. Applying the model for benzene-containing NAPL at the Quendall site resulted in an estimated remediation time frame of greater than 100 years. An estimate of the relative restoration timeframe was also derived by utilizing the underlying assumptions of the NAS model and applying a simplified spreadsheet analysis. A mass balance was constructed around the 50-foot nearshore area assuming that the time frame is dependent on the rate of dissolution of benzene and naphthalene from DNAPL in this area (which assumes that contaminants undergo biodegradation only in the dissolved phase). The mass of benzene and naphthalene in the subsurface was calculated using the following assumptions:

- DNAPL is present at an average depth of 2 feet in the Quendall Pond area and 3 feet in the former May Creek channel area;
- The oil-filled porosity in DNAPL areas is 0.07, based on the concentration of total PAHs detected in DNAPL areas, and the percent by weight of PAHs in product samples;
- Product in the Quendall Pond area contains an average of 0.6% benzene and 15% naphthalene by weight, based on analysis of product from BH-5 and RW-QP-1; and

- Product in the former May Creek area contains no benzene and 6% naphthalene by weight, based on analysis of product from BH-21A.

Based on these assumptions, roughly 2,400 pounds of benzene and 63,200 pounds of naphthalene are present in the subsurface within 50 feet of the Lake Washington shoreline.

The removal rates of benzene and naphthalene were estimated by calculating the advective mass flux of benzene and naphthalene through the source area, utilizing the following assumptions:

- Source area width (perpendicular to groundwater flow) is 400 feet in the Quendall Pond area and 200 feet in the May Creek area;
- Groundwater plume depth is 30 feet;
- Average groundwater flow velocity is 50 feet per year;
- Average and maximum naphthalene concentrations in Quendall Pond and May Creek areas are 10 mg/L (average of WP-19A, WP-19B, WP-20B, and WP-21C) and 19 mg/L (WP-19B), respectively, and the maximum naphthalene concentration at the conditional point of compliance is 0.37 mg/L;
- Average and maximum benzene concentrations in the Quendall Pond area are 8 mg/L (WP-19A, WP-19B, WP-20B) and 12 mg/L (WP-19A), respectively, and the maximum benzene concentration at the conditional point of compliance is 0.55 mg/L;
- The attenuation factor between the maximum concentrations of benzene and naphthalene in the source area and the conditional point of compliance is constant.

The rate of advective mass removal is assumed to depend directly on the mass remaining in place; therefore, as the total remaining mass declines, the average concentration in groundwater declines, and the rate of removal declines as well.

Applying the above assumptions and performing a step-wise calculation of mass removal, the estimated time to reach the proposed cleanup standards at the conditional point of compliance in Alternative 1 is 140 years for benzene and 380 years for naphthalene.

For Alternative 2, the total mass of benzene and naphthalene in the source area would be reduced through DNAPL recovery. To calculate restoration time frame in this scenario, the

mass of benzene and naphthalene removed by DNAPL recovery was estimated using the following simplifying assumptions:

- The number of DNAPL recovery wells (or trench equivalent) located less than 50 feet from the Lake Washington shoreline = 15;
- The average DNAPL recovery rate at each well = 50 gallons per year; and
- The DNAPL recovery program will operate for 5 years (actual operation will depend on optimization effectiveness).

An estimated 7% of the DNAPL located within 50 feet of the shoreline would be recovered by pumping, leaving an estimated 2,200 pounds of benzene and 59,000 pounds of naphthalene in place. Applying the attenuation assumptions listed above (and adjusting the average starting source-area benzene and naphthalene concentrations, based on the reduction in mass, to 7.4 and 9.3 mg/L, respectively), the estimated time to reach the prospective cleanup levels at the conditional point of compliance is 135 years for benzene and 340 years for naphthalene.

Table D-1
Relative Percentage of Contaminant Mass Actively Remediated

Alternative	Percent of Total Estimated Mass Remediated by Method				
	Reuse	Destruction	Immobilization	Off Site Containment	On Site Containment
1 - No Action	0%	0%	0%	0%	0%
2 - Source Control with Monitored Natural Recovery	0%	5%	0%	0%	95%
3 - In-Place Containment	0%	4%	0%	0%	96%
4 - Source Control, Woodwaste Dredging/Reuse, and Reactive Sediment Cap	0%	6%	0%	0%	94%
5 - Woodwaste Dredging, Sediment Dredging, and DNAPL Recovery	0%	3%	0%	13%	84%
6 - Soil and Sediment Removal and Disposal	0%	0%	0%	100%	0%

APPENDIX E

DNAPL RECOVERY PILOT STUDY

DNAPL RECOVERY PILOT TEST

This appendix documents the results of the DNAPL Recovery Pilot Test conducted at Quendall Terminals site from November 2003 to May 2004. The Pilot Test was performed as specified in the April 2003 RA/FS Work Plan, except as follows:

- Eight geoprobe borings were advanced instead of seven, to provide additional delineation of DNAPL occurrences in the Quendall Pond area;
- Two new recovery wells and one existing well containing product were used for the product recovery pilot test, rather than installing three new wells;
- In addition to the laboratory analyses specified in the Work Plan, product samples were also analyzed for BTEX by EPA Method 8021B; and
- A three-month extension to the product recovery pilot test was conducted from February to May 2004, to better analyze the potential long-term effectiveness of this technology.

PILOT TEST TIMELINE

The pilot test consisted of the following activities:

- **November 6 and 7, 2003.** Advancing eight direct-push borings (SP-1 through SP-8) in locations of potential DNAPL occurrences. Locations are shown on the Site and Exploration Plan. Continuous soil samples were collected to identify intervals of DNAPL occurrences and the thickness of the underlying confining layer. Soil boring logs are attached.
- **November 13 and 14, 2003.** Installing two product recovery wells based on the direct-push boring results. DNAPL was observed in each boring location; recovery well locations were selected on their potential for recovering product and to investigate recovery from potentially different DNAPL occurrences. Recovery locations were selected as follows:
    - Recovery well RW-NS-1 was installed in the North Sump area next to boring SP-5 because at this location in the North Sump area there was both the greatest thickness of soil containing free product (6 feet) and the underlying silty peat layer was greater than 5 feet thick, allowing installation of a 5-foot-deep sump. The total depth of this well (including sump) is 21.5 feet, with a screened interval 6.5 to 16.5 feet deep.

- Recovery well RW-QP-1 was installed in the Quendall Pond area next to boring SP-3. This location was close to the Lake Washington shoreline and had the greatest thickness of DNAPL in this area (2 feet). Because the underlying silty peat layer was only 3 feet thick, a 2.5-foot-deep sump was installed at this location. The total depth of this well (including sump) is 21 feet, with a screened interval 8.5 to 18.5 feet deep.

- **November 26 to December 18, 2003.** Measuring product thickness and removing product from three wells: the two new recovery wells (RW-NS-1 and RW-QP-1) and an existing monitoring well containing free product (BH-21A). These three wells are located in three areas with DNAPL from potentially different sources: BH-21A is located in the former May Creek Channel, RW-NS-1 is located in the North Sump area, and RW-QP-1 is located in the Quendall Pond area. BH-21A and RW-QP-1 are also located close to the Lake Washington shoreline, and therefore product mobility in these areas is a primary concern. At the conclusion of this period, a sample of accumulated product from each well was collected and submitted for laboratory analysis.
- **February 7 to May 3, 2004.** Continuing the product recovery pilot test at the two wells identified with recoverable product: BH-21A and RW-QP-1. Product in each well was measured and removed weekly to evaluate long-term recovery potential at these locations. Well RW-NS-1 was inspected monthly for the presence of product but none was observed.

Below we describe the results of DNAPL recovery and product analysis.

DNAPL RECOVERY RESULTS

Measured product thickness and estimated recovered volumes for each site visit are provided in Table 1. Accumulated product volume recovered from each well is shown on Figure 1. During the initial 3-week pilot test, 13 gallons of DNAPL were recovered from well RW-QP-1, 7 gallons were recovered from BH-21A, and 1 gallon was recovered from RW-NS-1. Observations at each well included the following:

- **RW-QP-1.** Product from this well was black and had a relatively lower viscosity than product from other wells. It was easily removed with a peristaltic pump. Product recovered to this well at a moderate rate, returning to 60% of its original thickness

within 3 days of pumping at the beginning of the pilot test. Pumping product from this well would create a product-water-air emulsion. When a sample of product removed from this well was placed in a jar of water, it separated into a sinking phase and a floating phase. Over the course of 2 hours, the floating phase (apparently the air-water-product emulsion) separated out, forming sinking product droplets, until only a thin film was left on the surface. No floating product was observed in the recovery well.

- **BH-21A.** Product from this well was black and appeared to be more viscous than product from RW-QP-1, but was still easily removed with a peristaltic pump. Product recovered to this well relatively quickly, returning to 90% of its original thickness within three days of pumping throughout the pilot test. When a sample of product was placed in a jar of water, the product immediately sank to the bottom and no emulsion was observed. No floating product was observed in the recovery well.
- **RW-NS-1.** Only 1 gallon of product was removed from this well on the initial site visit, and no product was observed in this well for the duration of the recovery test. The product when removed was black and extremely viscous. Closer observation revealed that silt and fine sand was entrained in the product, creating a viscous sludge. After 3 weeks, approximately 500 ml of less-viscous free product had separated from the soil-product sludge, and this was collected and submitted for laboratory analysis. No floating product was observed in the recovery well.

During the extended pilot test, DNAPL continued to rapidly recharge to well BH-21A, but the rate of removal declined because of the less frequent removal schedule (weekly as opposed to every 2 to 3 days, during the initial test). The rate of DNAPL removal measured at this well was 110 gallons per year during the initial 3-week test and 31 gallons per year during the extended test. However, during both periods, DNAPL recovery at BH-21A appeared limited by well construction (2-inch diameter well with no collection sump) and by the frequency of pumping. It is likely that the potential initial rate of DNAPL removal at this location is at least 100 gallons per year.

The rate of recovery also slowed during the extended pilot test at well RW-QP-1, from 210 gallons per year during the initial 3-week test period to 40 gallons per year during the extended test. The rate of recovery at this well appeared limited by the mobility of DNAPL in the formation rather than the well construction or pumping frequency. In fact, the rate of

accumulation in the well between the initial and extended test periods was 34 gallons per year over a 6 week period, which was almost the same as the rate of recovery during the extended period with weekly pumping.

The collected data were not sufficient to allow accurate calculation of the area of influence of DNAPL recovery. The negligible decrease in DNAPL thickness at well BH-21A (measured to be 1 inch after removing 18 gallons of product) indicates that the radius of influence is greater than 10 feet. Based on the available data and professional judgment, a likely range for the radius of influence of DNAPL recovery at the Quendall Site is between 10 and 30 feet; however, this value could vary significantly based on localized geological characteristics. A longer pilot test would be necessary to provide a more precise estimate of the area of influence.

PRODUCT ANALYTICAL RESULTS

Analytical results are summarized in Table 2. Laboratory certificates of analysis are available on request from Ecology. Analytical results from product samples collected in 1996 are provided in Table 2 for comparison. Of particular note are the following observations:

- Product from well BH-21A (Former May Creek Area) contains very low concentrations of BTEX, with no detected benzene. This is consistent with groundwater chemistry observed in this area.
- Product from well RW-QP-1 (Quendall Pond Area) contains relatively high concentrations of BTEX, consistent with groundwater chemistry in this area and with product chemistry from well BH-5A, located along the upland shore of Quendall Pond.
- Product from well RW-NS-1 (North Sump Area) has a slightly higher viscosity, higher density, higher total PAH content, higher flashpoint, and much lower BTEX content than product from RW-QP-1. The chemical and physical properties of North Sump product indicate it is likely less mobile than Quendall Pond product, consistent with field observations.
- All three product samples contained carbazole, consistent with these products originating from a coal source rather than a petroleum source. In addition, the laboratory noted that although they reported diesel-range and residual-range petroleum hydrocarbon concentrations from the NWTPH-Dx analysis, the chromatogram suggested that these samples were not petroleum products.

CONCLUSIONS

Field observations and laboratory results indicate the following:

- DNAPL present in the Former May Creek Channel (near BH-21A) and in the Quendall Pond area is amendable to product recovery. In spite of its higher viscosity, product at BH-21A recovered quickly, likely due to the greater thickness (approximately 5 feet) of DNAPL in this location. Boring logs indicate that DNAPL is present in the Quendall Pond area at several different depth intervals separated by potentially discontinuous silty peat confining layers. Supplemental subsurface characterization is necessary to support design of an effective DNAPL recovery program using vertical wells or trenches
- DNAPL in the North Sump area does not appear to be recoverable. In addition to the lack of recoverable product at RW-NS-1, measurable product has not been observed at well BH-23, also located within the DNAPL product area of the North Sump. It is likely that DNAPL observed while drilling in these areas occurs in non-continuous, isolated NAPL 'ganglia' that are not mobile, typical of DNAPL occurrences at or below residual saturation.
- DNAPL recovery rates during the long-term pilot test ranged from 30 gallons per year at BH-21A to 40 gallons per year at RW-QP-1; however, it is likely that a greater recovery rate at BH-21A would be possible using a well constructed for DNAPL recovery rather than groundwater monitoring.
- Product chemistry at BH-21A and RW-QP-1 are consistent with groundwater chemistry in these areas.
- Product chemistry at all three wells indicates that although all the DNAPL appears to originate from a coal source, the three areas contain products with different physical characteristics and chemical composition. The differences may indicate different sources for the DNAPL occurrences or be the result of differential weathering and/or transport in the subsurface. The product composition at BH-21A is consistent with creosote (very low levels of BTEX), whereas the product compositions in the Quendall Pond and North Sump areas are consistent with coal tar (higher levels of BTEX). Quendall Pond product is differentiated from North Sump product by its higher BTEX composition and lower flash point.

- DNAPL in the Quendall Pond area has the potential to form a floating air-water-product emulsion when disturbed. This may need to be considered when designing remedial alternatives that include disturbing subsurface soil and/or sediments.

ATTACHMENTS

Table 1 – Product Recovery Measurements

Table 2 – Summary of Analytical Results

Figure 1 – Cumulative Product Recovery

Boring Logs and Well Construction Details

Table E-1
Product Recovery Measurements

Date	Time	Elapsed Time of Test (Days)	Product Thickness in Inches (Before Pumping)			Product Volume Recovered in Gallons		
			BH-21A	RW-NS-1	RW-QP-1	BH-21A	RW-NS-1	RW-QP-1
11/13/2003	1600	0	--	--	0	0	0	0
11/14/2003	1600	0	--	0	15	0	0	0
11/24/2003	1500	0	66	--	44	0	0	0
11/26/2003	1400	0.0	66	18 (1)	44	0.9	1	4.0
11/29/2003	1000	2.9	60	0	28	0.8	0	1.3
12/2/2003	1300	6.0	64	0	37	0.9	0	2.2
12/5/2003	1100	9.0	64	0	25	0.9	0	1.2
12/8/2003	1500	12.1	62	0	34	0.8	0	1.6
12/10/2003	1500	14.1	62	0	16	0.8	0	0.7
12/15/2003	1000	18.9	64	0	29	0.8	0	1.0
12/18/2003	1100	22.0	62	0	15	0.6	0	0.7
2/7/2004	1400	85.9	63	0	58	0.9	0	6.0
2/11/2004	1200	89.8	62	0	17	0.8	0	0.8
2/23/2004	1000	101.8	66	0	30	0.9	0	1.7
3/1/2004	1300	108.9	62	--	11	0.7	0	0.6
3/9/2004	1400	116.9	61	--	13	1.4	0	0.8
3/16/2004	1100	123.8	62	0	11	0.9	0	0.7
3/24/2004	1100	131.8	65	--	13	1.4	0	1.0
4/1/2004	1100	139.8	61	--	12	1.8	0	0.9
4/8/2004	1100	146.8	62	--	13	1.2	0	0.9
4/13/2004	1100	151.8	62	--	10	1.2	0	0.8
5/3/2004	1500	172.0	65	--	23	0 (2)	0	1.1
Total Recovered Product						**17.8**	**1.0**	**28.0**

Notes:

-- not measured

(1) Interface meter did not provide reproducible measurement at well RW-NS-1.
Product thickness calculated from sump dimensions and volume product recovered.

(2) No product recovered due to dead pump battery.

Table E-2
Summary of Analytical Results

	Location	Former May Creek Channel				Quendall Pond				North Sump	
	Well Number	BH-21A				BH-5		RW-QP-1		RW-NS-1	
	Sample Date	1/19/1996		12/18/2003		1/19/1996		12/18/2003		12/18/2003	
Analysis											
TPH (Concentrations in mg/kg)											
	Analysis Method	*WTPH-HCID*		*NWTPH-Dx*		*WTPH-HCID*		*NWTPH-Dx*		*NWTPH-Dx*	
	Gasoline Range Organics	59,000		--		510,000		--		--	
	Diesel Range Organics	640,000		860,000	Z	330,000		500,000	Z	610,000	Z
	Residual Range Organics	200,000		260,000	Z	210,000		330,000	Z	240,000	Z
BTEX by EPA Method 8020 or 8021B (Concentrations in mg/kg)											
	Benzene	50	U	5	U	9,900		2,100		550	
	Toluene	50	U	29		20,000		19,000		1,300	
	Ethylbenzene	850		470		6,500		6,000		1,000	
	m,p-Xylenes	1,100		670		20,000		21,000		2,000	
	o-Xylene	430		280		7,400		19,000		1,500	
	Total BTEX	2,480		1,454		63,800		67,100		6,350	
SVOCs by EPA Method 8270 or 8270C (Concentrations in mg/kg)											
	Naphthalene	70,000		52,000		180,000		130,000		140,000	
	2-Methylnapthalene	32,000		27,000		48,000		32,000		39,000	
	Acenaphthylene	420		200		8,500		6,200		4,500	
	Acenaphthene	22,000		16,000		5,600		3,600		17,000	
	Dibenzofuran	9,100		7,400		4,000		3,000		6,600	
	Fluorene	14,000		13,000		6,300		4,400		11,000	
	Phenanthrene	61,000		48,000		18,000		9,700		34,000	
	Anthracene	10,000		7,100		4,100		2,500		7,800	
	Fluoranthene	28,000		17,000		9,000		7,200		16,000	
	Pyrene	27,000		14,000		9,700		10,000		16,000	
	Benz[a]anthracene	8,100		6,900		5,400		6,300		4,900	
	Chrysene	6,300		5,300		8,600		7,200		5,200	
	Benzo[b]fluoranthene	5,600		5,200		7,100		11,000		6,200	
	Benzo[k]fluoranthene	5,600		4,000		7,600		6,900		3,900	
	Benzo[a]pyrene	6,600		5,100		8,900		11,000		6,800	
	Indeno[1,2,3-cd]pyrene	2,400		2,100		4,300		5,700		5,200	
	Dibenz[a,h]anthracene	970		720		1,600		1,800		1,300	
	Benzo[g,h,i]perylene	2,800		2,100		6,400		6,700		6,300	
	9H-Carbazole	3,200		2,200		2,000		1,100		3,600	
	Total cPAHs	35,570		29,320		43,500		49,900		33,500	
	Total PAHs	311,890		233,120		343,100		265,200		331,700	
Flash Point by EPA Method 1020 (Temperature in Degrees Celsius)											
	Flash Point	--		>200		--		112		>200	
Specific Gravity by ASTM D-1298											
	Specific Gravity	1.043		1.08		1.09		1.04		1.07	
Kinematic Viscosity in Centistokes											
	Viscosity (Measured)	10.2	@104F	7.4	@122F	3.41	@104F	4.22	@122F	4.51	@122F
	Viscosity at 55 F (Calculated)	23.9		23.9		7.98		9.88		10.6	

Note:

Viscosity at 55 F calculated based on temperature-viscosity relationship of naphthalene

-- Not measured

U Not detected at indicated detection limit

Z Laboratory noted that the product fingerprint did not resemble a petroleum product.

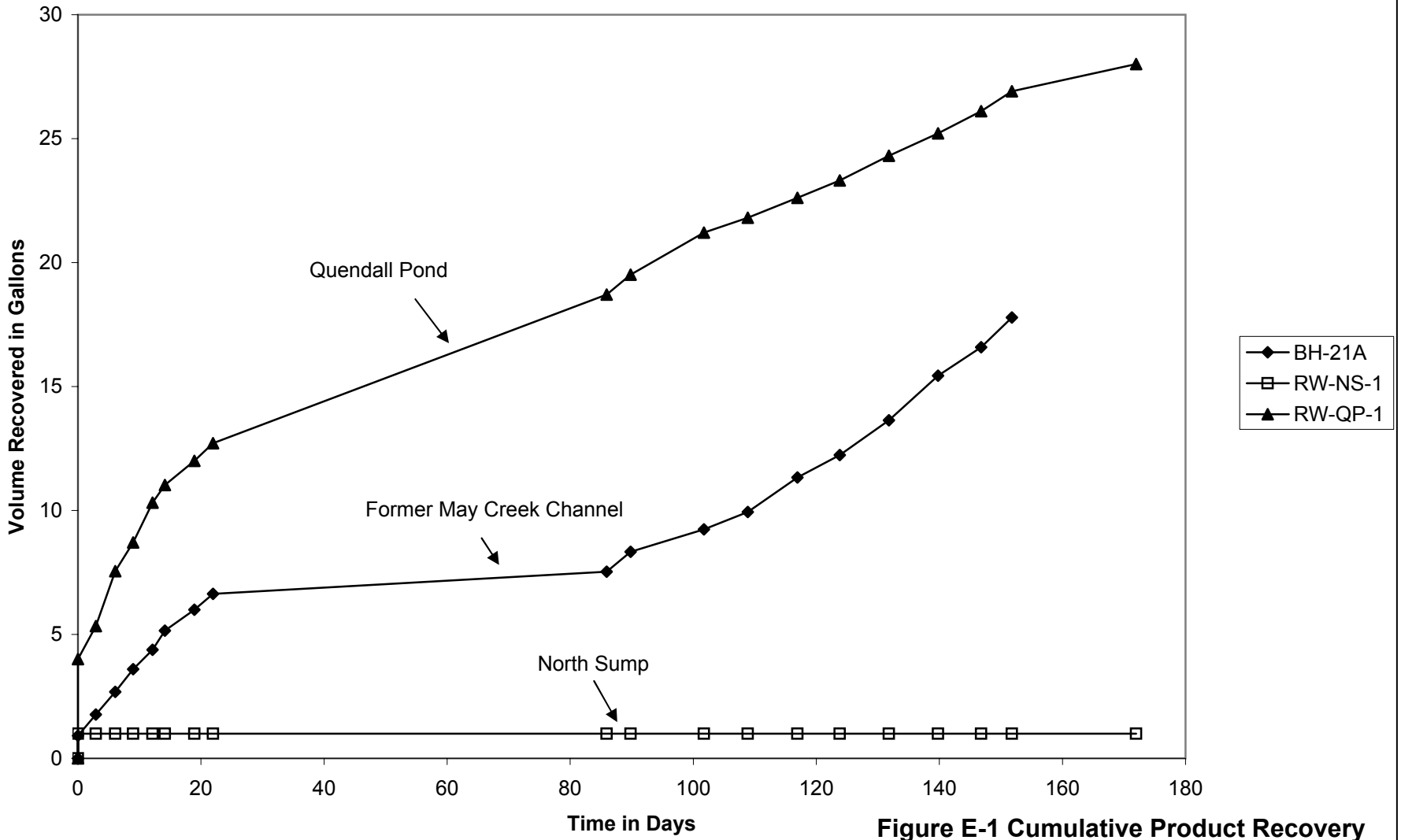


Figure E-1 Cumulative Product Recovery

Geologic & Monitoring Well Construction Log

Aspect consulting — IN-DEPTH PERSPECTIVE

Project Number	Well Number	Sheet
020027	RW-NS-1	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	27.20'
Location	Renton, Washington	Depth to Water (ft bgs)	
Drilling Method	10" HSA ; Holt	Start Date	November 14, 2003
Sampling Method	18" SS	Finish Date	November 14, 2003

Depth feet	Well Construction	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
								NOTE: FOR DETAILED SOIL LOG, SEE SP-5.
1		Concrete surface seal						
2								
3		Bentonite						
4		Riser: 4-inch diameter, stainless steel, schedule 0.5S.						
5		10/20 Silica sand						
6								
7		Well screen: 4-inch diameter, stainless steel, 50-slot.						
8		No recovery - 2" rock in shoe.	○	18/12/7		S-1		
9								
10		Pea gravel filter pack.		9/8/16	65	S-2		Wood debris.
11		Strong sheen, odor, yellow-brown oil.						Medium dense, wet, grey SAND.
12								
13				4/3/2	33	S-3		Finer SAND.
14		In area of coarser sand, no product.						Coarser SAND.
15				4/4/3	549	S-4		
16		Dark yellow-brown oil.						Peaty SILT (Sampled from cuttings. Depth based on drill action).
17								
18		Sump: 4-inch diameter, stainless steel.		5/4/3		S-5		
19		(Slough)						
20		(Slough) Bentonite		6/5/3		S-6		
21								
22								Bottom of boring: 21.5'.
23								
24								
25								
26								
27								
28								
29								

Sampler Type (ST):

- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler

PID - Photoionization Detector

- Water Level (ATD)
- Static Water Level

Logged by: JJP

Approved by: JJP

Figure No. 1- 1

MW_GEOLG-QUENDALL QUENDALL.GPJ May 25, 2004

Geologic & Monitoring Well Construction Log

Aspect consulting — IN-DEPTH PERSPECTIVE

Project Number	Well Number	Sheet
020027	RW-QP-1	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	19.71
Location	Renton, Washington	Depth to Water (ft bgs)	
Drilling Method	10" HSA ; Holt	Start Date	November 13, 2003
Sampling Method	18" SS	Finish Date	November 13, 2003

Depth feet	Well Construction	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
								NOTE: FOR DETAILED SOIL LOG, SEE SP-3.
1		Concrete						
2		Riser: 4-inch diameter, stainless steel, schedule 05S.						
3		Bentonite						
4								
5		10/20 Silica sand						
6								
7		Screen: 4-inch diameter, stainless steel, 50-slot.						
8				9/11/6	26.6	S-1		Medium dense, wet, brown, very silty fine SAND with abundant organics.
9		Hydrocarbon odor.						Loose, wet, grey, slightly silty fine-to-medium SAND.
10		Creosote odor.		3/2/1	32.2	S-2		
11								Mostly fine SAND.
12		Pea gravel filter pack						
13				2/1/1	16.3	S-3		
14		Creosote odor.			383			Soft, brown, slightly sandy organic SILT.
15				3/4/6	88	S-4		Loose, wet, grey, fine-to-medium SAND with silty SAND layers.
16		Creosote odor. Sheen. Slightly stiffer drilling at 16'.						Soft, wet, dark brown, slightly sandy SILT with interbedded very silty SAND layers.
17		Bentonite						
18		Sump: 4-inch diameter, stainless steel.		5/5/6		S-5		
19								Bottom of boring: 19'.
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								

Sampler Type (ST):

- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler

PID - Photoionization Detector

- Water Level (ATD)
- Static Water Level

Logged by: JJP

Approved by: JJP

Figure No. 1- 2

Geologic & Boring Log

Aspect consulting — IN-DEPTH PERSPECTIVE

Project Number	Well Number	Sheet
020027	SP-1	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	
Location	Renton, Washington	Depth to Water (ft bgs)	
Drilling Method	GeoProbe	Start Date	November 6, 2003
		Finish Date	November 6, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
	No sheen/odor.				S-1		(Loose) moist dark brown, silty SAND with gravel, abundant wood debris, few coal pieces.
1							
2					S-2		
3							
4							
5	No sheen/odor.						(Medium dense) moist, brown to grey, sandy silty GRAVEL, some organic material.
6					S-3		(Medium dense) moist, brown, silty SAND, abundant organics.
7							
8							
9							(Medium stiff) moist, grey, sandy SILT with wood and organics.
10	Sheen; black, viscous oil, stain, yields oil material when squeezed (9.2' to 9.8').				S-4		(Medium dense) moist to wet, dark grey, slightly gravelly silty SAND.
11	Sheen/odor.						(Medium dense) wet, grey, medium SAND. Coarse SAND with gravel, 11.7-12.2'.
12	Sheen/odor.						
13							(Medium dense) wet, brown, silty SAND with silt layer 12.5-12.7'
14							(Medium stiff) wet, brown, slightly sandy organic SILT.
15	Sheen/odor.				S-5		(Medium dense) wet, grey fine-to-medium SAND.
16							
17							
18					S-6		
19							(Soft) wet, brown, organic SILT.
20							
21							Becomes medium stiff, light brown.
22					S-7		
23							1" wood and 2" fine-to-medium SAND layer at 22.8'.
24	Very slight sheen.						(Medium dense) wet, grey, slightly silty fine-to-medium SAND with interbedded 0.5" SILT laters.
25							
26							Bottom of boring: 26'.
27							
28							
29							

Sampler Type (ST):

- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector

- Water Level (ATD)
- Static Water Level

Logged by: JJP

Approved by: JJP

Figure No. 1- 3

MW_GEOLG_QUENDALL_QUENDALL-SP.GPJ May 25, 2004

Geologic & Boring Log

Aspect consulting — IN-DEPTH PERSPECTIVE

Project Number	Well Number	Sheet
020027	SP-2	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	
Location	Renton, Washington	Depth to Water (ft bgs)	
Drilling Method	GeoProbe	Start Date	November 7, 2003
Sampling Method	4' Dual Tube	Finish Date	November 7, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Loose) moist, brown, silty SAND with abundant organics.
1							(Loose) moist, brown to black, slightly silty sandy GRAVEL with occasional coal chips.
2					S-2		(Medium dense) moist, brown to grey, slightly silty fine-to-medium SAND.
3							
4							Very silty SAND layer 3.9-4.0'
5							Very silty SAND layer 4.8-5.0'.
6					S-3		Dark brown organics and wood 5.8'-5.9'.
7							(Medium dense) moist, brown, silty SAND with trace gravel, abundant organics.
8							
9							9-9.3' sandy SILT layer.
10	no odor, no sheen.				S-4		(Medium dense) moist to wet, grey, medium-to-fine SAND.
11							Wood layer 10.7-10.9'.
12							Coarsens with depth 11' to 12' to primarily medium SAND. Slightly silty medium-to-fine SAND, abundant organics 12-13'.
13							(Medium stiff) wet, brown, slightly sandy organic SILT.
14					S-5		
15							(Medium dense) wet, grey, slightly silty medium-to-fine SAND with some wood debris.
16							Becoming clean SAND at 16'.
17							(Medium dense) wet, grey, fine-to-medium SAND.
18	Heaving SAND.				S-6		
19							
20	Product staining, free oil, odor 21.8'-22'						
21							
22							Bottom of boring: 22'. Refusal.
23							
24							
25							
26							
27							
28							
29							

Sampler Type (ST):
- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector
- Water Level (ATD)
- Static Water Level

Logged by: JJP
Approved by: JJP
Figure No. 1- 4

MW_GEOLG_QUENDALL_QUENDALL-SP.GPJ May 25, 2004

Aspect consulting
IN-DEPTH PERSPECTIVE

Geologic & Boring Log

Project Number	Well Number	Sheet
020027	SP-3	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	
Location	Renton, Washington	Depth to Water (ft bgs)	
Drilling Method	GeoProbe	Start Date	November 7, 2003
Sampling Method	4' Dual Tube	Finish Date	November 7, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Loose) moist, brown silty SAND, abundant organics.
1	Iron oxide staining 0.9'-1.7', no odor.						(Loose) wet, grey, fine-to-medium SAND.
2					S-2		
3							Becomes silty at 3'.
4							Very silty 3.5'-4' organics and wood at 4'-4.3'.
5							(Soft) wet, brown, sandy SILT with organics.
6					S-3		
7	No sheen/no odor.						(Loose) wet, grey, slightly silty fine-to-medium SAND.
8							Interbedded 1-2" organic silty, wood layers 8'-10.5'.
9							
10					S-4		
11							(Soft) wet, brown, organic SILT (peaty layers 13'-13.6').
12							
13							
14	Dark brown product 14'-16'.				S-5		(Medium dense) wet, brown, medium SAND (interbedded layers of medium-to-fine SAND).
15							
16	No product.						(Medium stiff) wet, brown, organic SILT.
17							
18							Becomes light brown to grey 17.5'.
					S-6		(Medium dense) wet, grey and brown, interbedded SAND and silty SAND (1"-2" layers).
19							18.1'-19.2' interbedded 2"-3" layers slightly sandy SILT and silty fine SAND.
20	Slight sheen.						(Medium dense) wet, grey, SAND (coarser than usual).
21							Becomes slightly silty medium-to-fine SAND.
							(Medium stiff) wet, light brown slightly sandy SILT.
22					S-7		(Medium dense) wet, grey, fine-to-medium SAND.
23							
	Heaving SAND.						
24	No sheen, odor.						
25							(Medium stiff) wet, brown, SILT with organics. Dark brown peat at 25.3'-25.4'.
26							Grey, wet, SAND layer 25.6'-25.7'.
							Bottom of boring: 26'.
27							
28							
29							

Sampler Type (ST):
- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector
- Water Level (ATD)
- Static Water Level

Logged by: JJP
Approved by: JJP
Figure No. 1- 5

MW_GEOLG_QUENDALL QUENDALL-SP.GPJ May 25, 2004

Geologic & Boring Log

Aspect consulting — IN-DEPTH PERSPECTIVE

Project Number	Well Number	Sheet
020027	SP-4	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	
Location	Renton, Washington	Depth to Water (ft bgs)	5.5
Drilling Method	GeoProbe	Start Date	November 7, 2003
Sampling Method	4' Dual Tube	Finish Date	November 7, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Soft) moist, dark brown, sandy SILT with organics.
1	No odor.						
2					S-2		(Loose) moist, dark brown, silty SAND with trace gravel, some organics.
3							Abundant coal chips 1.8'-2'.
4							(Loose) wet, dark grey to black, silty, gravelly SAND.
5 ▽							Becomes dark brown, very silty SAND.
6					S-3		(Medium dense) wet, grey, fine-to-medium SAND.
7	Strong sheen, creosote odor.						Becomes medium-to-fine SAND.
8	Few areas of yellow-brown product staining; 6.8'-7' and						
9	8.3'-9.0' (at contacts with finer SAND).						Silty sand with wood 8.7'-9'.
10					S-4		
11							Becomes fine-to-medium sand at 10.5'.
12	Yellow-brown product at 11.5'-12.5', Dark brown 11.6'-11.8'.						Silty medium-to-fine SAND at 12'.
13	Sheen, odor.						(Medium stiff) wet, brown, sandy organic SILT. Becomes slightly sandy at 13'.
14					S-5		Slightly clayey, SILT at 14'.
15							
16							Fine sandy SILT at 15.5'.
17							
18							Mottled with dark brown peat.
19	No sheen/odor				S-6		(Medium dense) wet, brown to grey, silty SAND with organics.
20							
21							(Medium stiff) wet, brown, slightly sandy SILT.
22	No sheen/odor						(Medium dense) wet, grey silty fine-to-medium SAND.
23							Bottom of boring: 22'.
24							
25							
26							
27							
28							
29							

Sampler Type (ST):

- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector

- Water Level (ATD)
- Static Water Level

Logged by: JJP

Approved by: JJP

Figure No. 1- 6

MW_GEOLG_QUENDALL_QUENDALL-SP.GPJ May 25, 2004

Aspect consulting
IN-DEPTH PERSPECTIVE

Geologic & Boring Log

Project Number	Well Number	Sheet
020027	SP-5	1 of 1

Project Name: Quendall Terminals
Location: Renton, Washington
Drilling Method: GeoProbe

Top of Casing Elev. (ft mllw):
Depth to Water (ft bgs):
Start Date: November 6, 2003
Finish Date: November 6, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Loose) moist, dark brown, silty SAND with gravel, abundant organic materials.
1	No odor.						
2					S-2		
3							
4							
5							(Loose) moist-to-wet, grey and tan, slightly silty, slightly gravelly SAND.
6	Slight creosote odor, no sheen.				S-3		(Loose) moist, grey, silty SAND.
7							
8	No recovery 6'-10'.						
9							
10					S-4		(Medium dense) wet, grey, fine-to-medium SAND.
11							
12	Dark brown free product 10'-16'.						
13							
14					S-5		
15							(Medium dense) wet, brown, silty medium-to-fine SAND.
16	Odor, sheen.						(Soft) wet, brown, organic SILT to slightly sandy SILT.
17							
18					S-6		
19							
20							
21							
22							Bottom of boring: 22'.
23							
24							
25							
26							
27							
28							
29							

Sampler Type (ST):
- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector
- Water Level (ATD)
- Static Water Level

Logged by: JJP
Approved by: JJP
Figure No. 1- 7

MW_GEOLG_QUENDALL_QUENDALL-SP.GPJ May 25, 2004

Aspect consulting
IN-DEPTH PERSPECTIVE

Geologic & Boring Log

Project Number	Well Number	Sheet
020027	SP-6	1 of 1

Project Name: Quendall Terminals
Location: Renton, Washington
Drilling Method: GeoProbe

Top of Casing Elev. (ft mllw):
Depth to Water (ft bgs):
Start Date: November 6, 2003
Finish Date: November 6, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Loose) moist, brown to dark brown, silty SAND with wood debris and organics.
1							
2	Slight creosote odor.				S-2		(Loose) moist, grey and tan, very gravelly SAND.
3							
4							
5							(Loose) wet, grey and tan, silty gravelly SAND 5'-5.5'
6					S-3		Wood debris 5.8'-6.0'.
7	Sheen test negative; no creosote odor.						
8							Wood debris.
9	Strong odor, brown oil. Free product at 9.5'-13'.						(Medium dense) wet, grey, medium-to-fine SAND.
10					S-4		
11							
12							SAND becomes coarser at 12' primarily medium.
13							(Medium stiff) wet, brown organic SILT.
14					S-5		
15							
16	No sheen/odor.						Interbedded (medium dense) wet, brown to grey, very silty SAND and wet, grey, slightly silty medium-to-fine SAND.
17							
18							(Medium stiff) wet, dark brown, slightly sandy organic SILT.
							Bottom of boring: 18'.
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							

Sampler Type (ST):
- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector
- Water Level (ATD)
- Static Water Level

Logged by: JJP
Approved by: JJP
Figure No. 1- 8

Geologic & Boring Log

Aspect consulting — IN-DEPTH PERSPECTIVE

Project Number	Well Number	Sheet
020027	SP-7	1 of 1

Project Name	Quendall Terminals	Top of Casing Elev. (ft mllw)	
Location	Renton, Washington	Depth to Water (ft bgs)	
Drilling Method	GeoProbe	Start Date	November 6, 2003
Sampling Method	4' Dual Tube	Finish Date	November 6, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Loose) moist-to-wet, dark brown, silty, gravelly SAND with abundant wood debris and organics.
1							
2					S-2		
3							Wood debris.
4							2" loose, moist, grey, SAND.
							(Soft) moist, brown to grey sandy SILT with occasional coal chips.
5	Strong sheen, creosote odor.						Coal chips 4'-4.3'.
							(Medium stiff) wet, black, slightly sandy SILT.
	Becomes less sheen, dark grey at 5'.						5.2' (Medium dense) wet, grey, fine-to-medium SAND.
6	Strong creosote odor.				S-3		
7	Sheen at 6.5'						
8							
9							
10	Becomes oily, dark brown product 10'-13'.				S-4		
11							
12							
13	Sheen 13'-13.2'.						(Medium stiff) wet, brown to dark brown, SILT to slightly clayey SILT.
14					S-5		
15	Slight odor at 15'.						Becomes sandy SILT at 15.2'.
16							Wood (slightly decomposed).
17							(Medium stiff) wet, dark brown, organic SILT.
18	Brown oil in sand layer 17.6'-17.8'.				S-6		17.6'-17.8' (Medium dense) wet, grey-brown, fine-to-medium SAND.
19							
20							(Medium stiff) wet, grey, fine sandy SILT.
21							Grey to light brown slightly sandy SILT.
22							
23							Bottom of boring: 22' Sampler fractured.
24							
25							
26							
27							
28							
29							

Sampler Type (ST):

- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector

- Water Level (ATD)
- Static Water Level

Logged by: JJP

Approved by: JJP

Figure No. 1- 9

MW_GEOLG_QUENDALL_QUENDALL-SP.GPJ May 25, 2004

Aspect consulting
IN-DEPTH PERSPECTIVE

Geologic & Boring Log

Project Number	Well Number	Sheet
020027	SP-8	1 of 1

Project Name: Quendall Terminals
Location: Renton, Washington
Drilling Method: GeoProbe

Top of Casing Elev. (ft mllw):
Depth to Water (ft bgs):
Start Date: November 7, 2003
Finish Date: November 7, 2003

Depth feet	Tests\Remarks	ST	Blows/ 6"	PID	Sample ID	Mtl. Graphic	Description
					S-1		(Soft) moist, dark brown, very sandy SILT, abundant organics.
1							
2					S-2		(Soft) moist, dark brown, organic SILT.
3							
4							(Loose) wet, grey, fine-to-medium SAND.
5							
6					S-3		
7							
8							
9	Yellow-brown product stain 9.2'-10'.						
10					S-4		(Medium dense) wet, brown, silty SAND with wood and peat layers.
11							(Soft) wet, brown, peaty SILT.
12							
13							
14					S-5		
15							
16							(Medium dense) wet, brown, fine-to-medium SAND with wood and peat layers 17.5'-18'.
17	Brown product 16.6'-18'.						
18							Bottom of boring: 18'.
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							

Sampler Type (ST):
- 3.25" OD D & M Split-Spoon Ring Sampler
- No Recovery
- 2" OD Split-Spoon Sampler
- 1.3" O.D. Dual-Tube

PID - Photoionization Detector
- Water Level (ATD)
- Static Water Level

Logged by: JJP
Approved by: JJP
Figure No. 1- 10

MW_GEOLG_QUENDALL QUENDALL-SP.GPJ May 25, 2004

APPENDIX F

GROUNDWATER VERTICAL PERMIABILITY AND VERTICAL HEAD STUDY

The following documents the results of the vertical hydraulic head and vertical permeability field tests conducted at Quendall Terminals site in December 2003. These tests were performed in accordance with the November 4, 2003 Work Plan Addendum, with the following exceptions:

- In addition to vertical hydraulic head measurements at existing well points, measurements of the vertical hydraulic head in shallow sediments were also collected at the same location and depth that vertical permeability tests were conducted. This was done to minimize error from subsurface heterogeneities when combining vertical head and vertical permeabilities to estimate groundwater velocities. To measure the subtle differences in hydraulic head in shallow sediments, an oil-water manometer was used.
- Vertical permeabilities were measured in two of the three potential areas mentioned in the Work Plan Addendum: near WP-20A and near WP-19A. Three measurements were made in each area at locations that potentially provided a range of permeabilities.
- Vertical hydraulic head measurements could not be measured at the following well point locations: WP-18A, WP-18B, WP-20A, and WP-28A. Water could not be pumped from these well points without introducing gas bubbles, which cause inaccurate manometer readings. This was presumably because these well points are screened in low-permeability sediment layers.

Permeability measurements and well-point hydraulic head measurements were made on December 11, 2003, and shallow sediment hydraulic head measurements were made on December 14, 2003. Results are provided in Table 1. Table 1 includes calculated groundwater velocities at each measurement location using the equation:

$$v = K_v * \Delta h / \theta$$

with: v = seepage velocity (ft/day)

K_v = vertical permeability (ft/day)

Δh = vertical hydraulic head (ft/ft)

Θ = effective porosity

At locations without directly measured hydraulic head and permeability data, the following assumptions were made:

- **WP-21A and WP-21B**. At these locations, hydraulic head was measured between the well points (screened 5 to 7 feet below mudline) and the lake. Vertical permeability of the sediments was not measured. Field observations and sediment core logs indicated

the sediments in the upper 6 feet consist of relatively homogeneous fine-to-medium sand with very little silt content, similar to areas near WP-19A. Therefore, the highest vertical permeability measured near WP-19A was used to calculate velocities in the WP-21A and WP-21B area.

- **Low Permeability Layers at WP-19A.** Near WP-19A, shallow vertical permeability and hydraulic head were measured directly. Vertical hydraulic head at well points WP-19A, WP-19B, and WP-19C were also measured; however, sediment core logs indicated that these well points were screened below low-permeability silt or peat layers. Groundwater velocities through these layers were calculated as follows:
  - The vertical hydraulic head across the layer was determined by calculating what the head would be above the layer, based on the measured gradient in the shallow sediments and the thickness of the shallow sediments, subtracting it from the head measured at the well point, and applying this gradient across the thickness of the low permeability layer (estimated from nearby sediment core logs).
  - The vertical permeability for the silty peat layer from the calibrated groundwater model (Retec 1998) was used.

RESULTS

Results are included in Tables 1 through 4. Results are summarized as follows:

- Average vertical gradients ranged from 0.0038 ft/ft across sandy materials to 0.10 ft/ft across low-permeability silt and peat layers. These gradients are consistent with those calculated by the calibrated groundwater model (Retec 1998).
- Average vertical permeabilities ranged from 16 to 55 ft/day in shallow sediments, consistent with the visual characterization of these sediments as sand and silty sand. The vertical permeability used for low-permeability silt and peat layers (from the calibrated groundwater model (Retec 1998)) was 0.06 ft/day.
- Average seepage velocities ranged from 0.028 feet per day (3.1 meters per year) through low-permeability layers to 1.4 feet per day (160 meters per year) through shallow sandy sediments, based on an assumed effective porosity of 0.20 at the well points. Note that seepage velocities depend directly on the effective porosity of the sediments, and field measurements indicate that the actual sediment porosity increases in the uppermost sediment layer, ranging from 0.39 at WP-19C to 0.86 at WP-20B. Taking the average of the assumed porosity at the well point (0.20) and the measured porosity of the shallow

sediment at locations with porosity data, effective porosities range between 0.30 and 0.53. Seepage velocities based on average effective porosities range between 1.6 meters per year (at WP-19B) and 70 meters per year.

Table F-1
Calculation of Sediment Vertical Permeability

Location	Sediment Description	Measured Hydraulic Head (1)	Gradient Probe Depth	Gradient Induced by Pumping	Cross-Sectional Area of Flow	Pumping Flowrate	Calculated Vertical Permeability	
		cm water	cm	cm/cm	cm2	cm3/s	cm/s	ft/day
WP-19A No.1	Silty Sand	22	25	0.88	707	4.7	0.0076	22
WP-19A No.2	Silty Sand	39	25	1.52	707	2.8	0.0026	7.3
WP-19A No.3	Sand	18	25	0.69	707	5.6	0.011	32
WP-20A No.1	Silty Sand	21	31	0.69	707	5.3	0.011	31
WP-20A No.2	Silty Sand	58	31	1.91	707	3.1	0.0023	6.4
WP-20A No.3	Sand	13	31	0.43	707	8.3	0.028	78

Notes:

WP-19A No.1, 2, and 3 were performed at 3 different locations within 15 feet of well point WP-19A.

WP-20A Nos. 1, 2, and 3 were performed at 3 different locations within 20 feet of well point WP-20A.

(1) Hydraulic head between Lake Washington surface and gradient probe measured with an air-water manometer.

Table F-2
Vertical Gradients

Measured Vertical Gradients in Sediments

Location	Sediment Description	Measured Hydraulic Head cm water	Average Screen Depth cm	Calculated Vertical Gradient cm/cm	Notes if Not Measured
Sediments between Well Points to Lake Washington (Measured with Air-Water Manometer)					
WP-18A		--	155	--	gas bubbles
WP-18B		--	152	--	not located
WP-19A	sand and silt layers	5.1	149	0.034	
WP-19B	sand and silt layers	5.8	149	0.039	
WP-19C	sand and silt layers	5.6	146	0.038	
WP-20A		--	168	--	gas bubbles
WP-20B		--	152	--	not located
WP-28A		--	152	--	not steady
WP-21A	sand	0.51	219	0.0023	
WP-21B	sand	0.76	183	0.0042	
Sediments between Shallow Temporary Probes and Lake Washington (Measured with Oil-Water Manometer)					
WP-19A No.1	silty sand	0.19	25.4	0.0074	
WP-19A No.2	silty sand	0.19	25.4	0.0074	
WP-19A No. 3		--	--	--	gas bubbles
WP-20A No.2A	silty sand	0.37	30.5	0.0123	
WP-20A No.2B	silty sand	0.40	30.5	0.0130	
WP-20A No.3	sand	0.15	30.5	0.0048	

Calculated Gradient Across Lower Permeability Sediment Unit

		Overlying Sand Unit			Low Permeability Unit		
Location	Sediment Description	Thickness in cm (1)	Gradient in cm/cm (2)	Calculated Vertical head loss in cm	Head across Unit in cm (3)	Thickness in cm (1)	Calculated Gradient in cm/cm
WP-19B	sandy silt	74	0.0074	0.5	5.3	76	0.070
WP-19C	peaty silt	109	0.0074	0.8	4.8	41	0.117

Notes:

-- not measured

(1) From nearby sediment core logs

(2) Measured in shallow sediment at WP-19A Nos.1 & 2

(3) Calculated by subtracting head loss in overlying unit from overall measured hydraulic head at WP-19B and WP-19C

Table F-3
Calculated Flow Velocity

Location	Sediment Type	Depth of Sediment Layer	Gradient (See Table 2)	Vertical Permeability			Assumed Porosity	Calculated Velocity (4)
		Inches	cm/cm	cm/s	ft/day	Source	effective	ft/day
Velocity from Well Points to Lake Washington - No Stratification								
WP-21A	Sand	0 to 60	0.0023	0.028	78	(1)	0.2	0.9
WP-21B	Sand	0 to 60	0.0042	0.028	78	(1)	0.2	1.6
Velocity from Well Poinits to Lake Washington - Stratified Sediments								
Overlying, High-Permeablity Sediment Layer								
WP-19A No. 1	Silty Sand	0 to 10	0.0074	0.0076	22	(2)	0.2	0.80
WP-19A No. 2	Silty Sand	0 to 10	0.0074	0.0026	7.3	(2)	0.2	0.27
WP-19A No. 3	Sand	0 to 10	0.0074	0.0114	32.3	(2)	0.2	1.19
WP-20A No. 2	Silty Sand	0 to 12	0.013	0.0023	6.4	(2)	0.2	0.40
WP-20A No. 3	Sand	0 to 12	0.0048	0.0277	78	(2)	0.2	1.9
Underlying, Low-Permeablity Sediment Layer								
WP-19C	Peaty Silt	14 to 18, 44 to 56	0.12	0.000021	0.06	(3)	0.2	0.035
WP-19B	Sandy Silt	18 to 48	0.070	0.000021	0.06	(3)	0.2	0.021

Notes:

(1) From calculated permeability of sand at WP-20A No.3. Field observations indicated similar grain size and fines content.

(2) Calculation shown in Table 1 from Vertical Permeability Measurements.

(3) From calibrated groundwater model (Retec 1998)

(4) Based on assumed porosity at well point. See text for discussion.

Table F-4
Summary of Average Hydraulic Parameters by Sediment Type

Sediment Type	Vertical Gradient ft/ft	Vertical Permeability ft/day	Effective Porosity	Velocity in ft/day (3)	
				See Note 1	See Note 2
Sand	0.0038	55	0.2	1.04	1.40
Silty Sand	0.010	16	0.2	0.82	0.49
Sandy/Peaty Silt	0.093	0.06	0.2	0.028	0.028

Notes:

(1) Average velocity calculated from average gradient, permeability, and effective porosity

(2) Average velocity from Table 3 for each sediment type.

(3) Based on assumed porosity at well point. See text for discussion.