Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

Lower Duwamish Waterway Remedial Investigation

QUALITY ASSURANCE PROJECT PLAN: POREWATER SAMPLING OF LOWER DUWAMISH WATERWAY

FINAL

For submittal to:

The US Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

May 31, 2005

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TITLE AND APPROVAL PAGE
LDW POREWATER SAMPLING
QUALITY ASSURANCE PROJECT PLAN

Windward Project Manager

	Name	Date

Windward QA Manager

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EPA Project Manager

	Name	Date

EPA QA Manager

	Name	Date

Ecology Project Manager

	Name	Date

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Acronyms

Acronym	Definition
ACG	analytical concentration goal
AOC	area of concern
ARI	Analytical Resources, Inc.
bgs	below ground surface
COC	chain of custody
DCE	dichloroethene

Acronym	Definition
DO	dissolved oxygen
DQI	data quality indicator
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
FC	field coordinator
GPS	global positioning system
GWI	Great Western International
HSP	health and safety plan
KCSPCL	King County South Park Custodial Landfill
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
MDL	method detection limit
MLLW	mean lower low water
MHHW	mean higher high water
NAD83	North American datum 1983
ORP	oxidation-reduction potential
OSHA	Occupational Safety and Health Administration
PCE	tetrachloroethene
PM	project manager
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RI	Remedial Investigation
RL	reporting limit
RM	river mile
RPD	relative percent difference
SDG	sample delivery group
SRI	Supplemental Remedial Investigation
SWMU	solid waste management unit
TCE	trichloroethene
TM	task manager
TRV	toxicity reference value
VC	vinyl chloride
VOC	volatile organic compound
WBZ	water-bearing zone
Windward	Windward Environmental LLC

1.0 Introduction

This quality assurance project plan (QAPP) describes the quality assurance (QA) objectives, methods, and procedures for collecting and analyzing porewater samples collected in the Lower Duwamish Waterway (LDW) study area. These data will be used to support the source evaluation and the benthic risk assessment in the LDW remedial investigation (RI) as described in the Phase 2 work plan (Windward 2004b). Section 3.1.9 of the Phase 2 work plan presented a preliminary study design for collecting and chemically analyzing porewater samples, to provide all stakeholders with a common understanding of the objectives, background, and general study design of the porewater study. This QAPP presents the study design, including details on project organization, field data collection, laboratory analyses, and data management.

US Environmental Protection Agency (EPA) guidance for QAPPs was followed in the preparation of this project plan (EPA 2002b). This plan is organized into the following sections:

- Section 2 – project management
- Section 3 – data generation and acquisition
- Section 4 – assessment and oversight
- Section 5 – data validation and usability
- Section 6 – references

Appendix A is a health and safety plan (HSP) designed to protect on-site personnel from physical, chemical, and other hazards posed by the field sampling effort. Appendix B contains porewater data collection forms. Appendix C presents the risk-based analytical concentration goals (ACGs) and compares the ACGs to laboratory reporting limits (RLs). Appendix C also contains a list of all chemicals that will be analyzed, including both the laboratory method detection limits (MDLs) and RLs. Appendix D presents the predicted tide levels for the LDW during the sampling period in May 2005.

2.0 Project Management

This section describes the overall management of the project, including project organization, key personnel, problem definition and background, project description and summary, quality objectives and criteria, special training requirements and certification, and documents and record keeping.

2.1 PROJECT ORGANIZATION

The overall project organization and the individuals responsible for the various tasks required for the porewater sample collection and analysis are shown in Figure 2-1. Responsibilities of these individuals are described in the following sections.

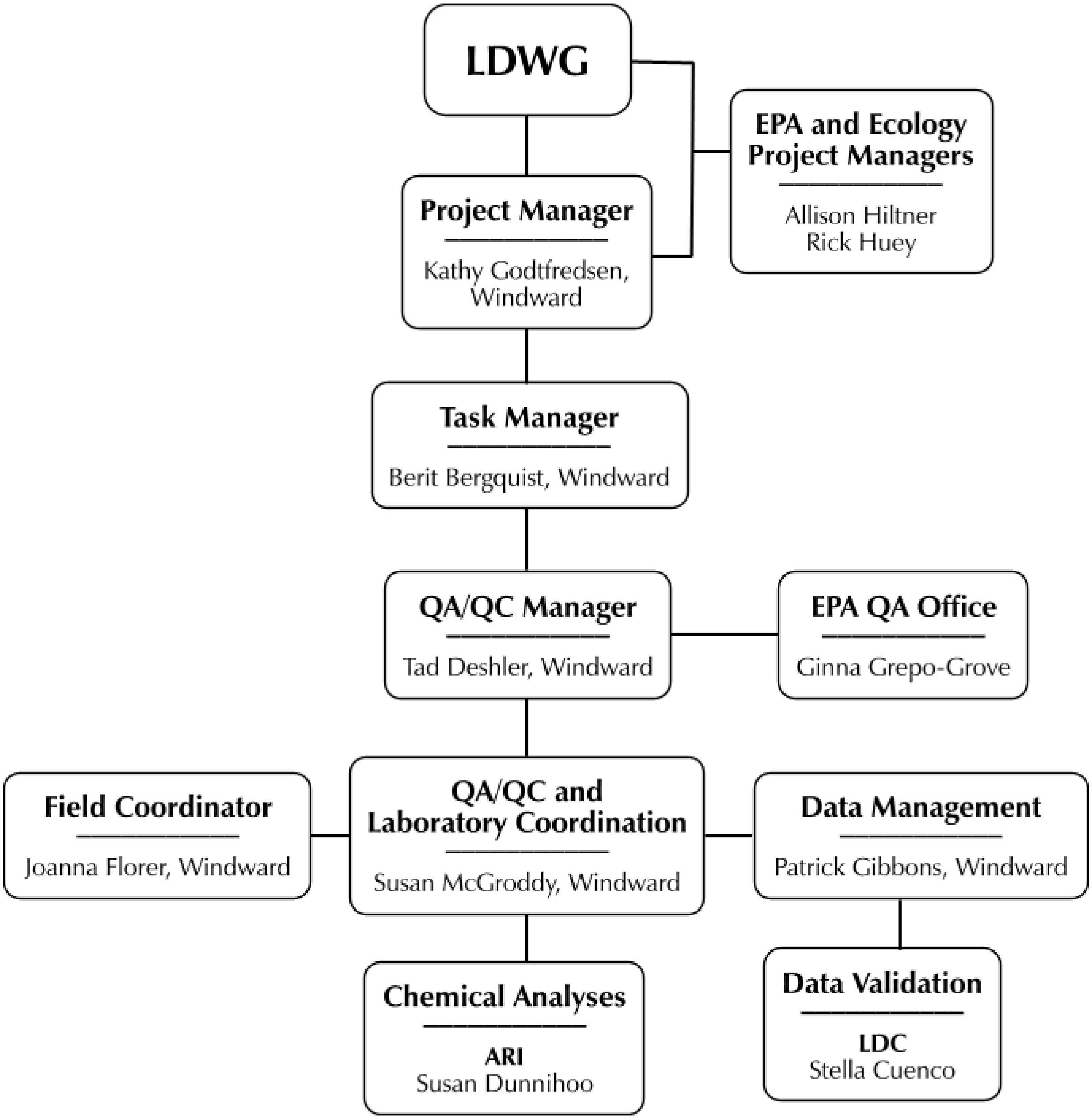

Figure 2-1. Project organization

2.1.1 Project management

The Lower Duwamish Waterway Group (LDWG), EPA, and the Washington Department of Ecology (Ecology) will be involved in all aspects of this project, including discussion, review, and approval of the QAPP, and interpretation of the results of the investigation. EPA and Ecology will be represented by their Project Managers (PMs) for this project, Allison Hiltner and Rick Huey, respectively.

Kathy Godtfredsen will serve as the PM for Windward Environmental LLC (Windward). The PM is responsible for overall project coordination and provides oversight on planning and coordination, production of work plans, production of all project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. She will also be responsible for coordinating with LDWG, EPA, and Ecology on schedule, deliverables, and other administrative details. Dr. Godtfredsen can be reached as follows:

Kathy Godtfredsen
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1283
Facsimile: 206.217.0089
Email: kathyg@windwardenv.com

Berit Bergquist will serve as the Windward Task Manager (TM). The TM is responsible for project planning and coordination, production of work plans, production of all project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. The TM is responsible for communicating with the PM on progress of project tasks and on any deviations from the QAPP. Significant deviations from the QAPP will be further reported to LDWG, EPA, and Ecology. Ms. Bergquist can be reached as follows:

Berit Bergquist
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1291
Facsimile: 206.217.0089
Email: beritb@windwardenv.com

2.1.2 Field coordination

Joanna Florer will serve as the Windward Field Coordinator (FC). The FC is responsible for managing the field sampling activities and general field and quality assurance/quality control (QA/QC) oversight. She will ensure that appropriate protocols for sample collection, preservation, and holding times are observed and will oversee delivery of environmental samples to the designated laboratories for chemical analyses. Deviations from this QAPP will be reported to the Windward TM and PM for consultation. Significant deviations from the QAPP will be further reported to representatives of LDWG, EPA, and Ecology. Ms. Florer can be reached as follows:

Joanna Florer
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1294
Facsimile: 206.217.0089
Email: joannaf@windwardenv.com

2.1.3 Quality assurance/quality control

Tad Deshler of Windward will oversee QA/QC for the project. As the QA/QC manager, he will provide oversight for both the field sampling and laboratory programs, and will supervise data validation and project QA coordination, including coordination with the EPA QA officer, Ginna Grepo-Grove.

Mr. Deshler can be reached as follows:

Tad Deshler
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1285
Facsimile: 206.217.0089
Email: tad@windwardenv.com

Ms. Grepo-Grove can be reached as follows:

Ginna Grepo-Grove
US Environmental Protection Agency, Region 10
1200 6th Avenue
Seattle, WA 98101
Telephone: 206.553.1632
Email: grepo-grove.gina@epa.gov

Susan McGroddy will serve as Windward's QA/QC and laboratory coordinator. The QA/QC and laboratory coordinator will ensure that samples are collected and documented appropriately and will coordinate with the analytical laboratories to ensure that QAPP requirements are followed. Dr. McGroddy can be reached as follows:

Susan McGroddy
Windward Environmental LLC
200 W. Mercer St., Suite 401
Seattle, WA 98119
Telephone: 206.577.1292
Facsimile: 206.217.0089
Email: susanm@windwardenv.com

Independent third-party data review and validation will be provided by Stella Cuenco of Laboratory Data Consultants, Inc. (or a suitable alternative). Ms. Stella Cuenco can be reached as follows:

Stella Cuenco
Laboratory Data Consultants, Inc.
7750 El Camino Real, Suite 2C
Carlsbad, CA 92009-8519
Telephone: 760.634.0437
Facsimile: 760.634.1674
Email: scuenco@lab-data.com

2.1.4 Laboratory project management

Susan McGroddy of Windward will serve as the laboratory coordinator. Analytical Resources, Inc. (ARI) will perform chemical analyses on the porewater samples. The laboratory PM at ARI can be reached as follows:

Susan Dunnihoo
Analytical Resources, Inc.
4611 S. 134th Place, Suite 100
Tukwila, WA 98168-3240
Telephone: 206.695.6207
Email: sue@arilabs.com

The analytical laboratory will accomplish the following:

- adhere to the methods outlined in this QAPP, including those methods referenced for each analytical procedure
- adhere to documentation, custody, and sample logbook procedures
- implement laboratory QA/QC procedures defined in this QAPP
- meet all reporting requirements
- deliver electronic data files as specified in this QAPP
- meet turnaround times for deliverables as described in the QAPP
- coordinate with EPA and the QA/QC contractor to perform laboratory and data audits

2.1.5 Data management

Patrick Gibbons of Windward will oversee data management to ensure that analytical data are incorporated into the LDWG database with appropriate qualifiers following acceptance of the data validation. QA/QC of the database entries will ensure accuracy for use in Phase 2.

2.2 PROBLEM DEFINITION/BACKGROUND

The LDW Phase 1 RI (Windward 2003a) presented a summary of current LDW conditions using information gathered from previous studies. Based on the Phase 1 RI, the data needs memorandum (Windward 2003c) identified the need to collect porewater samples for analysis of volatile organic compounds (VOCs), which are difficult to detect in bulk sediment because they are not readily adsorbed onto sediment, to assess risk to benthic invertebrates. To address this need, the Phase 2 work plan (Windward 2004b) stated that porewater samples would be collected in areas where VOCs have been historically detected in groundwater, and from which VOCs are thus are more likely to be currently discharging to the LDW. This section presents the objective, conceptual site model, and background information to address this sampling effort and to select sites for porewater sampling. An overview of the study components and schedule is presented in Section 2.3, and a detailed study design is presented in Section 3.1.

2.2.1 Objective

VOCs may be present in sediment porewater in areas associated with groundwater discharge to the LDW if there is a continuing source of VOC-contaminated groundwater (Chadwick et al. 1999; Church et al. 2002). VOCs do not have a high affinity for sediment because of their generally low organic carbon/water partition coefficients (K_{OC}) (Mabey et al. 1982). Therefore, the exposure of sediment-dwelling organisms (i.e., benthic invertebrates) to VOCs is most appropriately assessed through analysis of sediment porewater rather than bulk sediment.

The purpose of the porewater study is to characterize VOC concentrations in sediment porewater at locations where groundwater discharging to the LDW is expected to have the highest concentrations of VOCs, and where benthic organisms may thus potentially be exposed. It is assumed that exposure in these areas would be higher than exposure in areas where groundwater VOC concentrations are lower or non-detected, or where upland VOC plumes do not extend to the LDW. Concentrations of VOCs in porewater from these worst-case areas will be compared to available toxicological effects data for invertebrate species (see Appendix C for a listing of available effects data). LDWG and EPA/Ecology will discuss the results of this comparison to determine whether any additional porewater sampling is required. Thus, the objective of collecting porewater from areas with the highest potential VOC concentrations is to assess worst-case exposure of benthic invertebrates to VOCs. If no significant risks to benthic invertebrates are identified at the sampled areas, then other locations with lower VOC concentrations should pose even lower risks to these organisms.

2.2.2 Conceptual site model

This section describes a general conceptual site model for the potential interaction of groundwater and sediment porewater in the LDW.

Porewater, or interstitial water, is defined as the water occupying the spaces between sediment particles. Because porewater may be in contact with sediment surfaces for relatively long periods of time, it can become contaminated as a result of partitioning of chemicals from the surrounding sediments. Porewater may also reflect the groundwater/surface water transition zone in upwelling or downwelling areas. In upwelling areas, porewater chemistry might reflect groundwater chemistry, whereas in downwelling areas porewater chemistry might reflect chemistry of the overlying water column at the site. Depending on the origin of the porewater, factors such as flow, residence time, and other physicochemical factors (e.g., pH, temperature, redox potential, organic carbon, sulfides, carbonates, mineralogy) can have varying influences in determining whether interstitial waters are contaminated.

The LDW is a well-stratified, salt-wedge-type estuary that is influenced by river flow and tidal effects. The typical tidal range in the LDW is approximately 11 ft, based on the difference between mean higher high water (MHHW) of 5.1 ft above sea level and mean lower low water (MLLW) of 6 ft below sea level. Groundwater from upland areas generally flows toward the LDW (Booth and Herman 1998; Booth and Crowser 1998). However, tidal action can increase the variability of the groundwater flow patterns. High tides can cause an apparent groundwater flow reversal, with surface water temporarily flowing inland, although the net groundwater flow direction is towards the LDW (Booth and Herman 1998; Booth and Crowser 1998). Tidal changes in the LDW are reflected in groundwater levels in wells adjacent to the river. Because of these tidal fluctuations, porewater chemistry in LDW sediment may reflect either surface water or groundwater, depending on tidal conditions.

In the LDW, freshwater moving downstream overlies a tidally driven saltwater wedge. These conditions result in the occurrence of saline water in the groundwater zone beneath the LDW. Less dense, fresh groundwater will not mix or migrate readily into these saline zones. As a result, fresh groundwater migrating beneath upland areas is likely to discharge upwards primarily into shallower areas of the LDW when it meets the saline groundwater wedge located directly beneath the LDW, as shown conceptually in Figure 2-2. Therefore, sediment porewater in shallower, nearshore areas is more likely to reflect upland groundwater chemistry than is porewater in deeper areas of the LDW. This edge-focused discharge of fresh groundwater, as shown in the conceptual model, is based on an evaluation of Boeing Plant 2 hydrogeology and bathymetry data, as discussed in Section 3.1.3.2. However, there is some uncertainty associated with this conceptual model because site-specific data are not available to confirm the exact shape and slope of the freshwater/saline interface that defines the saline groundwater wedge.

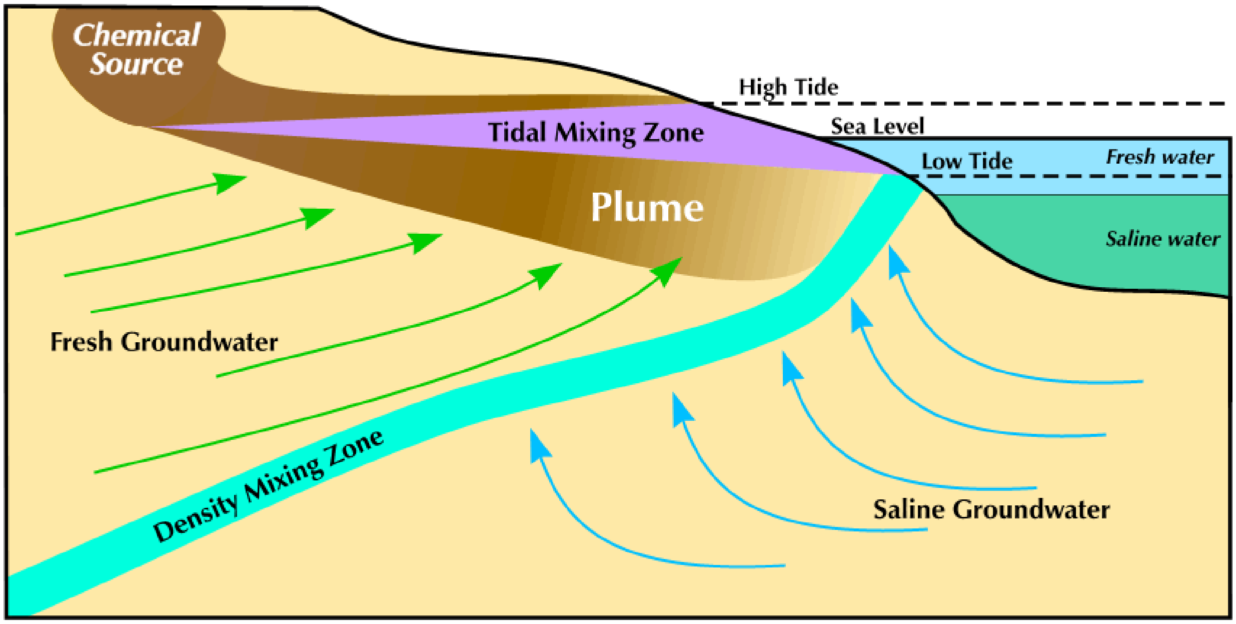

Figure 2-2. Generalized groundwater conceptual site model

Figure adapted from Slide 3 of *RITS Spring 2003: Coastal Contamination Migration Monitoring*, accessed at http://enviro.nfesc.navy.mil/erb/erb_a/support/rits/presentations/2003-04-ccm.pdf, April 28, 2005; the original figure represented marine conditions, although in principle, the same features should apply to a salt-wedge estuary. Figure not to scale. The configuration of the density mixing zone is site-specific, and may be broader than shown.

2.2.3 Historical data

This section presents available data on VOCs in groundwater from 10 of the 12 upland sites that were identified by EPA and Ecology in the LDW Phase 1 RI (Windward 2003a) as preliminary sites of interest in the LDW (Figure 2-3). Groundwater VOC data are not available for two of these 12 sites (Boeing Isaacson and Terminal 117/Malarkey). These two sites are thus not discussed further in this section. This section presents data on an additional site that was not previously identified by EPA and Ecology in the LDW Phase 1 RI as a preliminary site of interest – the Boeing Electronics Manufacturing Facility (EMF). Therefore, a total of 11 sites are discussed in this section, as listed in Table 2-1.

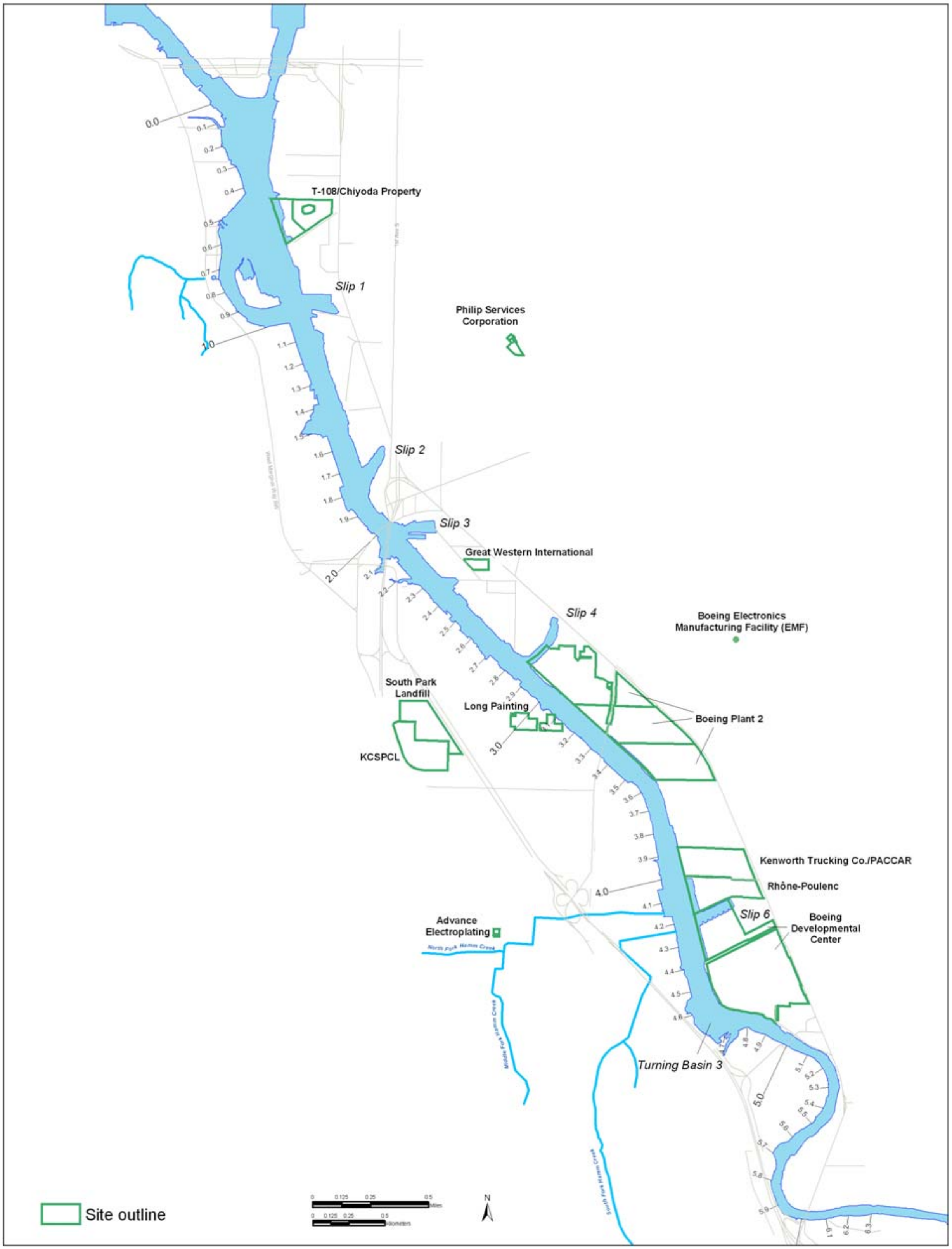

Figure 2-3. Upland sites along the LDW evaluated as potential porewater sampling locations

Table 2-1. Summary of VOCs in groundwater and approximate distance from LDW for upland sites of interest along the LDW

SITE	APPROXIMATE DISTANCE FROM LDW TO CLOSEST MONITORING WELLS (ft)	VOCS IN GROUNDWATER AT MONITORING WELLS CLOSEST TO THE LDW AT EACH SITE[a]	REFERENCES
Advance Electroplating	2,500	Moderate concentrations of 1,1,1-trichlororethane, 1,2-dichloroethene, and trichloroethene	Cutler (1999); Ecology & Environment (1997)
Boeing Developmental Center[b]	700 to 1,200	Low concentrations of VOCs, except for naphthalene, which was detected at a relatively high concentration in an area about 700 ft from the LDW	Landau (2001, 2002)
Boeing Electronics Manufacturing Facility (EMF)	50	Moderate concentrations of vinyl chloride	Boeing (Bach 2005)
Boeing Plant 2	50 to 100	Relatively high concentrations of cis-1,2-dichloroethene and vinyl chloride in groundwater adjacent to the LDW at RM 3.6 east;[c] also a smaller vinyl chloride plume adjacent to the LDW at about RM 3.0 east	Weston (Weston 1998, 2001a, b, c, d, 2002)
Great Western International (GWI)	50	Relatively high concentrations of cis-1,2-dichloroethene and vinyl chloride in groundwater adjacent to the LDW	Terra Vac and Floyd & Snider (2000)
Long Painting	60	1,1,1-trichloroethane and tetrachloroethene detected at low concentrations	Kleinfelder (2000)
Kenworth Trucking Co./PACCAR	700	Relatively low concentrations of 13 VOCs	GeoEngineers and Kennedy/Jenks (1990)
Plume at RM 1.5 east downgradient from Philip Services	50	Relatively high trichloroethene concentrations	PSC (2001, 2002a, b, c)
Rhône-Poulenc	50	Relatively high toluene concentrations in groundwater	GeoEngineers (1995; 1996); Rhône-Poulenc (2002)
South Park Landfill/King County South Park Custodial Landfill (KCSPCL)	2,000	Low concentrations of chlorobenzene, 1,2-dichloroethene, and vinyl chloride	Holmes (2000); King County (2000); Onsite (1992)
T-108/Chiyoda Property	400	Low concentrations of benzene, ethylbenzene, toluene, and xylene	AGI (1992)

na – not applicable

RM – river mile

[a] General descriptive terms for groundwater VOC concentrations (i.e., low, moderate, high) are used as a qualitative comparison of contamination among sites

[b] There are several solid waste management units (SWMUs) or areas of concern (AOCs) at Boeing Developmental Center. The data summarized in this table are from the wells closest to the LDW at each of the SWMUs or AOCs.

[c] The groundwater wells with the highest VOC concentrations are located on Jorgensen Forge property

Groundwater data presented in this section for the 10 upland sites of concern identified by EPA and Ecology as preliminary sites of interest were obtained from the groundwater pathway assessment of the LDW Phase 1 RI (Windward 2003a, Appendix G). Recent groundwater data for the Boeing Electronics Manufacturing Facility (EMF) site were obtained from Boeing (Bach 2005). Existing seep data are also presented because these data indicate concentrations of VOCs at the point of groundwater discharge to intertidal areas of the LDW. These groundwater and seep data are used in Section 2.2.4 of this QAPP to select sites for porewater sampling.

Table 2-1 lists the 11 upland sites of concern, presents information on the distance from the LDW of each site's potentially contaminated groundwater plume, and discusses the extent of VOC contamination in groundwater at each site. Figure 2-4 see Map Folio) shows the regional groundwater flow direction, as well as site-specific flow information, based on available potentiometric data. In general, groundwater flow moves towards the LDW on both a site-specific and regional basis.

Table 2-2 presents the highest concentrations of VOCs detected in groundwater monitoring wells located closest to the LDW at sites listed in Table 2-1. These data were presented in the LDW Phase 1 RI (Windward 2003b). More recent data from the plume at river mile (RM) 1.5 east (PSC 2001, 2002a, b, c) and from Boeing Plant 2 (Weston 1998, 2001a, b, c, d, 2002) are also included in Table 2-2. In addition, the most recent data from the monitoring well closest to the LDW within the Boeing EMF plume were added in Table 2-2 (Bach 2005).

Table 2-2. Maximum concentrations of VOCs in groundwater monitoring wells closest to the LDW at each site

VOC	Maximum Concentration (µg/L)[a]							
	Advance Electroplating	Boeing Developmental Center[b]	Boeing EMF[c]	Boeing Plant 2		GWI	Long Painting	Kenworth Trucking/ Paccar
				2001/2002	2004			
1,1,1-Trichloroethane	470	1.0 U	na	15 U	50 U	500 U	0.63	260
1,1,2-Trichloroethane	1.5	1.0 U	na	15 U	50 U	100 U	0.2 U	1.0
1,1-Dichloroethane	21	1.0 U	na	2.5	1.1	170	0.2 U	100
1,1-Dichloroethene	77	1.0 U	na	10	50 U	100 U	0.2 U	38
1,2-Dichloroethane	nav	5.0 U	na	15 U	50 U	100 U	0.2 U	4.7
Acetone	0.82	5.0 U	na	22	250 U	5,000 UB	5.0 U	5.0 U
Benzene	nav	1.0	na	29	50 U	100 U	0.2 U	2.1
Carbon disulfide	nav	1.0 U	na	1.6	50 U	100 U	0.2 U	1.0 U
Carbon tetrachloride	nav	5.0 U	na	2.2	50 U	100 U	0.2 U	1.0 U
Chlorobenzene	nav	1.0 U	na	41	50 U	100 U	0.2 U	nav
Chloroethane	18 U	2.0 U	na	1.8	50 U	100 U	0.2 U	54
Chloroform	97	1.0 U	na	5.1	50 U	100 U	0.2 U	1.6
Chloromethane	15	1.0 U	na	48	50 U	100 U	0.2 U	2.0 U
cis-1,2-Dichloroethene	180[d]	2.8	20 U	26,000	2,200	21,000	0.2 U	110
Ethylbenzene	nav	1.0 U	na	92	50 U	100 U	0.2 U	1.0 U
Methylene chloride	14	5.0 U	na	30 U	100 U	500 U	1.0 U	2.0 U
Naphthalene	nav	840	na	na	na	2,000 U	1.0 U	nav
Tetrachloroethene	84	1.0 U	na	15 U	50 U	130	0.92	1.8
Toluene	nav	1.0 U	na	680	50 U	100 U	0.2 U	1.0 U
trans-1,2-Dichloroethene	180[d]	1.0 U	20 U	380	16	100	0.2 U	1.7
Trichloroethene	2,600	1.0 U	20 U	31	50 U	5.7	0.2 U	160
Vinyl chloride	nav	2.0	820	16,000	7,000 J	23,000	0.2 U	190
m,p,-xylene	nav	1.0 U	na	80	50 U	200 U	0.4 U	1.0 U
o-Xylene	nav	1.4	na	76	50 U	100 U	0.2 U	1.0 U

Table 2-2, continued

VOC	Maximum Concentration (µg/L)[a]				
	Plume at RM 1.5 East (downgradient from Philip Services)		Rhône Poulenc	South Park Landfill/KCSPCL	T-108/ Chiyoda
	1998-2002	2003			
1,1,1-Trichloroethane	nav	1 U	1.0 U	0.20 U	nav
1,1,2-Trichloroethane	nav	0.5 U	1.0 U	0.20 U	nav
1,1-Dichloroethane	nav	1 U	1.0 U	0.20 U	nav
1,1-Dichloroethene	nav	1 U	1.0 U	0.20 U	nav
1,2-Dichloroethane	nav	1 U	1.0 U	0.20 U	nav
Acetone	nav	25 U	5.0 U	4.0 UB	nav
Benzene	nav	0.5 U	5.0	0.20 U	0.6
Carbon disulfide	nav	0.5 U	1.0 U	0.20 U	nav
Carbon tetrachloride	nav	1 U	1.0 U	0.20 U	nav
Chlorobenzene	nav	1 U	1.0 U	0.6	nav
Chloroethane	nav	1 U	1.0 U	0.20 U	nav
Chloroform	nav	1 U	1.0 U	0.20 U	nav
Chloromethane	nav	2.5 U	1.0 U	0.20 U	nav
cis-1,2-Dichloroethene	139	11.1	1.0 U	1.7	nav
Ethylbenzene	nav	1 U	2.8	0.20 U	0.4
Methylene chloride	nav	5 U	2.0 U	0.20 U	nav
Naphthalene	nav	0.5 U	5.0 U	2.8 U	10 U
Tetrachloroethene	nav	1 U	1.0 U	0.20 U	nav
Toluene	nav	1 U	3,900	0.20 U	0.9
trans-1,2-Dichloroethene	nav	1 U	1.0 U	0.35 J	nav
Trichloroethene	6,580	1 U	1.0 U	0.20 U	nav
Vinyl chloride	21.3	115	1.0 U	1.5	na
m,p,-xylene	nav	2 U	11	0.20 U[e]	1.0[e]
o-Xylene	nav	1 U	1.0 U	0.20 U[e]	1.0[e]

na – not analyzed   nav – data not readily available   U – undetected   UB – undetected; suspected laboratory contamination

[a] If chemical was not detected, the maximum reporting limit is shown

[b] The concentration shown is the maximum concentration of each chemical from wells closest to the LDW at each of the SWMUs or AOCs

[c] Analytes previously detected in groundwater in the Boeing EMF plume are cis-1,2-dichloroethene and vinyl chloride; current analytical constituents are cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride.

[d] The laboratory was unable to resolve the cis- and trans- isomers of dichloroethene. The result reported is the total of the two isomers.

[e] Total xylenes

VOCs have been analyzed in seep water at three sites along the LDW as part of site-specific investigations conducted between 1995 and 2003: Rhône-Poulenc, Boeing Plant 2, and Great Western International (GWI). In addition, during the Phase 2 RI seep sampling event, two of the 16 seep samples analyzed for VOCs were collected in the vicinity of sites listed in Table 2-2: seep 80 is located near the plume at RM 1.5 east and seep 48 is located near Long Painting (Windward 2004a). These Phase 2 RI seep water samples were collected by withdrawing seep water directly from the sediment using mini-piezometers. The only VOC detected in either of these two seeps was carbon disulfide at a concentration of 1.1 µg/L at seep 80. No VOCs were detected in the water sample from seep 48. The only other seep sample collected during the Phase 2 RI sampling that contained a detectable VOC concentration was from seep 54 located at RM 2.2 west; this sample had a chlorobenzene concentration of 6.5 µg/L and a carbon disulfide concentration of 2.4 µg/L. An unfiltered water sample collected from seep 54 was also analyzed for semivolatile organic compounds. This sample had detected concentrations of 1,2-dichlorobenzene (2.9 µg/L), 1,3-dichlorobenzene (58.3 µg/L), and 1,4-dichlorobenzene (40.2 µg/L).

Table 2-3 presents the maximum concentrations of VOCs detected in seep water at Boeing Plant 2 and GWI. At Boeing Plant 2, intertidal seep water samples were collected for VOC analyses from 18 seeps throughout the shoreline as part of the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) in 1995. Concentrations of VOCs in the seep samples ranged from 2.2 µg/L (concentration of benzene in a seep downgradient of the Jorgensen Forge property near RM 3.5 east) to 40 µg/L (concentration of cis-1,2-dichloroethene in a seep approximately 1,400 ft north of the Building 2-66 sheet pile wall).

Table 2-3. Maximum concentrations of VOCs detected in seep water at Boeing Plant 2 and GWI

VOC	CONCENTRATION (µg/L)	
	BOEING PLANT 2	GWI
1,1,1-Trichloroethane	1 U	1
1,1,2-Trichloroethane	1 U	20 U
1,1-Dichloroethane	1 U	88
1,1-Dichloroethene	1 U	27
1,2-Dichloroethane	1 U	27
Acetone	5 U	6.4
Benzene	2.2	40
Carbon disulfide	1 U	20 U
Carbon tetrachloride	1 U	20 U
Chlorobenzene	1 U	8.9
Chloroethane	2 U	20 U
Chloroform	1 U	20 U
Chloromethane	2 U	20 U
cis-1,2-Dichloroethene	40	5,400
Ethylbenzene	1 U	20 U

VOC	CONCENTRATION (µg/L)	
	BOEING PLANT 2	GWI
Methylene chloride	2 U	100 U
Naphthalene	1 U	50 U
Tetrachloroethene	1 U	760
Toluene	1 U	3.4
trans-1,2-Dichloroethene	1 U	110
Trichloroethene	13	480
Vinyl chloride	36	3,500
m,p,-Xylene	1 U	2 U
o-Xylene	1 U	2.8

At GWI, 12 seeps were sampled during a series of sampling events occurring from 1994 to 1999 from throughout the S. Myrtle St. embayment where the plume is located. The VOCs with the highest detected concentrations were cis-1,2-dichloroethene (5,400 µg/L), tetrachloroethene (760 µg/L), trichloroethene (480 µg/L), and vinyl chloride (3,500 µg/L).

At Rhône-Poulenc, seep data were available for the only detected VOC, formaldehyde, which was detected in one sample at a concentration of 24 µg/L. Reporting limits for VOCs that were not detected in seep water were not available. It should be noted that with the exception of the Phase 2 seep water samples at seeps 80 and 54, which were collected using a mini-piezometer, the seep samples discussed in this section were collected by capturing surface flow seeping from the sediment surface. This method results in the collection of samples that have been exposed to air, resulting in the potential loss of VOCs that may have been present in the water prior to its discharge to the surface. Thus, these concentrations may underestimate concentrations within sediment porewater where contaminated groundwater is discharging.

2.2.4 Site selection

Historical data presented in Section 2.2.3 were reviewed to determine which sites have the highest potential for VOC concentrations in porewater, and should therefore be included in the porewater sampling described in this QAPP. Primary considerations for site selection included concentrations of VOCs in groundwater beneath the adjacent upland parcel and the likelihood of contaminated groundwater discharging to the LDW. The following factors were considered in selecting sites for porewater sampling:

- concentrations of VOCs, and consistency of elevated concentrations of VOCs, in groundwater adjacent to the site relative to those at other LDW sites
- concentrations of VOCs in groundwater, distance of groundwater VOC concentrations from the LDW, and potential for VOC discharge to the LDW
- whether VOCs are considered chemicals of potential concern at the site (i.e., whether VOCs have been previously monitored or detected in site groundwater)

- whether porewater data are already available at the site (i.e., Rhône-Poulenc)

Based on these considerations, GWI and Boeing Plant 2 at the Jorgensen Forge boundary were selected for porewater sampling, for the reasons summarized in Table 2-4. The Boeing Plant 2 porewater sampling location is referred to in this QAPP as Boeing Plant 2/Jorgensen Forge because it is adjacent to both sites. Six sites (Boeing EMF, Long Painting, Kenworth Trucking Co./PACCAR, plume at RM 1.5 east (downgradient from Philip Services), South Park Landfill/ King County South Park Custodial Landfill (KCSPCL), and T-108/Chiyoda) were not selected because groundwater VOC concentrations were low or moderate relative to other sites.[1] For example, the highest groundwater concentrations of vinyl chloride and cis-1,2-dichloroethene at any of these six sites were 820 µg/L and 11 µg/L, respectively, whereas the highest concentrations of these VOCs at GWI were 16,000 µg/L and 26,000 µg/L, respectively, and at Boeing Plant 2/Jorgensen Forge were 7,000 and 2,200 µg/L, respectively, in the most recent monitoring events. In addition, the groundwater containing VOCs associated with the Boeing EMF plume is in the deeper B-level of the aquifer, which is the same groundwater discharge scenario that is already selected for further study at the GWI site. The groundwater containing VOCs at the Boeing Plant 2/Jorgensen Forge property boundary is in the shallower A-level of the aquifer and will yield information regarding interaction of shallower groundwater with the LDW.

Advance Electroplating and the Boeing Developmental Center were not selected because although VOCs were detected in groundwater at those sites, the plumes are not likely to extend to the LDW (Landau 2001, 2002; Windward 2003a). At Rhône-Poulenc, recent porewater sampling has been conducted. In addition, groundwater cleanup was initiated in 2003, consisting of a subsurface grout containment wall and a system to pump and treat contaminated groundwater. This work is expected to stop or minimize the migration of contaminated groundwater from the Rhône-Poulenc property (EPA 2002a).

Table 2-4. Site selection for porewater samples

SITE	SELECTED AS SITE FOR SAMPLING?	RATIONALE[a]
Advance Electroplating	no	VOCs in groundwater, but plume is not expected to extend to the LDW (Windward 2003a)
Boeing Developmental Center	no	naphthalene in groundwater, but plume is not expected to extend to the LDW (Landau 2001, 2002)
Boeing EMF	no	lower VOC concentrations in groundwater compared to concentrations in the plume located at approximately RM 3.6 at Boeing Plant 2/Jorgensen Forge

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[1] This comparison is based on the most recent data in Table 2-2 for the plume at RM 1.5 (2003) and Boeing Plant 2 (2004).

SITE	SELECTED AS SITE FOR SAMPLING?	RATIONALE[a]
Boeing Plant 2/Jorgensen Forge	yes	VOCs in groundwater adjacent to the LDW; detected VOCs in seeps
GWI	yes	VOCs in groundwater adjacent to the LDW; detected VOCs in seeps
Long Painting	no	low groundwater VOC concentrations; no VOCs detected in Seep 48
Paccar	no	low groundwater VOC concentrations
Plume at RM 1.5 E down-gradient from Philip Services	no	low groundwater VOC concentrations in most recent data
Rhône-Poulenc	no	porewater data recently collected at this site
South Park Landfill/KCSPCL	no	low groundwater VOC concentrations
T-108/Chiyoda	no	low groundwater VOC concentrations

[a] See Table 2-1 for site-specific references with more detailed information.

2.3 PROJECT/TASK DESCRIPTION AND SCHEDULE

This section provides an overview of the sampling and analysis activities and schedule for the studies designed to address the data needs outlined in Section 2.2. Samples from two areas in the LDW will be collected using piezometers and peepers, and will be analyzed for VOCs to assess the potential for adverse effects on benthic invertebrates. A detailed study design is presented in Section 3.1. If VOCs are detected at concentrations exceeding relevant ecological toxicity reference values (TRVs) at piezometer locations, then peepers will also be deployed at those locations. TRVs will be compiled for VOCs that may be detected in porewater at each of the locations and presented in a separate technical memorandum to EPA and Ecology, as discussed in Sections 3.1.2.3 and 3.1.3.3. The draft memorandum will be submitted to EPA and Ecology on June 3, 2005, and the final memorandum will be approved by EPA and Ecology no later than July 15, 2005, prior to deployment of peepers the week of July 18, 2005.

A reconnaissance effort will be conducted the week of June 6, 2005 (following the approval of the QAPP) to test the field equipment. Water samples will be collected with piezometers during the week of June 20, 2005. The samples will be analyzed at ARI for VOCs as specified in Section 3.4.1, with a rapid turnaround time of 48 hours. The preliminary, unvalidated data will be provided to EPA and Ecology on July 6, 2005, and the need for any additional peeper locations will be agreed upon by LDWG, EPA, and Ecology by July 15, 2005.

Peeper deployment will occur the week of July 18, 2005, and peepers will be retrieved during the week of August 1, 2005. The samples will be analyzed at ARI for VOCs as specified in Section 3.4.1, with a turnaround time of three weeks. Chemical data will be validated within three weeks of receiving data packages from ARI. A draft data and analysis report with the results of the validated chemical analyses will be submitted to EPA and Ecology December 2, 2005. This report is termed a data and analysis report because in addition to presenting data from the field event, this report will also compare the results to relevant toxicity data to allow a more expedient determination of whether any additional porewater sampling is warranted in the LDW.

2.4 QUALITY OBJECTIVE AND CRITERIA FOR CHEMICAL DATA

The overall data quality objective for this project is to develop and implement procedures that will ensure the collection of representative data of known, acceptable, and defensible quality. Parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. These parameters are discussed in detail in Section 3.4.2, along with specific data quality indicators (DQIs) for porewater laboratory analyses.

2.5 SPECIAL TRAINING/CERTIFICATION

The Superfund Amendments and Reauthorization Act of 1986 required the Secretary of Labor to issue regulations through the Occupational Safety and Health Administration (OSHA) providing health and safety standards and guidelines for workers engaged in hazardous waste operations. Regulation 29CFR1910.120 requires training to provide employees with the knowledge and skills enabling them to perform their jobs safely and with minimum risk to their personal health. All sampling personnel will have completed the 40-hour HAZWOPER training course and 8-hour refresher courses, as necessary, to meet the requirements of the OSHA regulations. Commercial divers will be certified and will comply with OSHA Regulation 29CFR1910 subpart T.A diver safety manual and a site specific dive plan will be on the boat.

2.6 DOCUMENTATION AND RECORDS

This section describes documentation and records kept during field activities and laboratory analyses. In addition, the data reduction process and contents of the data and analysis report are described.

2.6.1 Field observations

All field activities will be recorded in a field logbook maintained by the FC. The logbook will provide a description of all field activities, conferences associated with field activities, field personnel, weather conditions, and a record of all modifications to the procedures and plans identified in this QAPP and the HSP (Appendix A). The field logbook will consist of bound, numbered pages. All entries will be made in indelible ink. The field logbook will provide sufficient data and observations to enable participants to reconstruct events that occurred during the sampling period.

The following information will be recorded on the Peeper Deployment Form and the Porewater Collection form (Forms 1 and 2, respectively, Appendix B):

- project name and task designation

- date and time of sample collection and name of person filling out form
- names of crew members
- weather conditions
- location ID number
- sampling method
- location - global positioning system (GPS) coordinates
- general description of substrate, including indications of the possible presence of anthropogenic fill or waste material
- description of porewater sampling location
- photograph ID numbers (non-submerged or shallow locations only)
- conventional water quality parameter results

Any deviations from the field procedures specified in this QAPP will be documented on the protocol modification form (Form 3, Appendix B).

2.6.2 Laboratory records

The laboratory will be responsible for internal checks on sample handling and analytical data reporting, and will correct errors identified during QA review. Any corrective actions that are required by the laboratory will be documented on the corrective action form (Form 4, Appendix B). Close communication will be maintained with the laboratory to resolve any QC problems in a timely manner. The laboratory data package will include the following:

- **Project narrative**: This summary, in the form of a cover letter, will present any problems encountered during any aspect of analysis. The summary will include, but not be limited to, discussion of quality control, sample delivery, sample storage, and analytical difficulties. Any problems encountered, whether actual or perceived, and their resolutions will be documented in as much detail as necessary. In addition, instrument operating conditions used for the VOC analysis, and definitions of laboratory qualifiers, will be provided.
- **Records**: Legible copies of the chain-of-custody (COC) forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory also will be documented.
- **Sample results**: Data packages will be submitted for both full and summary data validation. The full data validation packages will include all raw data. The summary data package will summarize the results for each sample analyzed. The summary will include the following information, when applicable:

  - field sample identification code and the corresponding laboratory identification code
  - sample matrix
  - date of sample extraction
  - date and time of analysis
  - weight and/or volume used for analysis, including final dilution volumes or concentration factor for the sample
  - identification of the instruments used for analysis
  - method reporting and quantitation limits
  - all data qualifiers and their definitions
- **QA/QC summaries:** These summaries will contain the results of all QA/QC procedures. Each QA/QC sample analysis will be documented with the same information required for the sample results (see above). The laboratory will make no recovery or blank corrections. The required summaries are listed below; additional information may be requested.
  - Calibration data summary will contain the concentrations of the initial calibration and daily calibration standards and the date and time of analysis. The response factor, percent relative standard deviation (%RSD), percent difference, and retention time for each analyte will be listed, as appropriate. Results for standards to indicate instrument sensitivity will be reported.
  - Performance summary report for each instrument will contain a list of the samples for which the performance checks are applicable.
  - Internal standard area summary will report the internal standard areas, as appropriate.
  - Method blank analysis summary will report the method blank analysis associated with each sample and the concentrations of all compounds of interest identified in these blanks.
  - Surrogate spike recovery summary will report all surrogate spike recovery data for VOC analyses. The names and concentrations of all compounds added, percent recoveries, and QC limits will be listed.
  - Matrix spike recovery summary will report the matrix spike or matrix spike/matrix spike duplicate recovery data for analyses, as appropriate. The names and concentrations of all compounds added, percent recoveries, and QC limits will be included in the data package. The relative percent differences (RPDs) for all matrix spike and matrix spike duplicate analyses will be reported.

  - Matrix duplicate summary will report the RPDs for all matrix duplicate analyses. The quality control limits for each compound or analyte will be listed.
  - Laboratory control analysis summary will report the results of the analyses of laboratory control samples. The QC limits for each compound or analyte will be included in the data package.
- **Original data:** Electronic copies of the original data generated by the laboratory will be provided, including the following:
  - sample refrigerator temperature logs
  - sample extraction and preparation logs
  - instrument specifications and analysis logs for all instruments used on days of calibration and analysis
  - reconstructed ion chromatograms for all samples, standards, blanks, calibrations, spikes, replicates, and laboratory control samples
  - raw and enhanced spectra of detected compounds with associated best-match spectra for each sample
  - printouts and quantitation reports for each instrument used, including reports for all samples, standards, blanks, calibrations, spikes, and replicates
  - original data quantitation reports for each sample

The contract laboratories for this project will submit data electronically, in delimited-text format. Guidelines for electronic data deliverables for chemical data are as follows:

- Each row of data will contain only one analyte for a given sample. Therefore, one complete sample will require multiple rows.
- If a comma separated value file format has been used, all fields must have quotations around each entry to avoid field value confusion. For example, "Indeno(1,2,3-cd)pyrene".
- Each result, reporting limit, and detection limit must show the proper significant figures and sensitivity.
- If a result for an analyte is below the detection limit, the laboratory qualifier will be U, and the value in the result column will be the reporting limit.
- Analytical results of laboratory samples for QA/QC will be included and clearly identified in the sample type code field.
- If replicate analyses are conducted on a submitted field sample, they too will be included and clearly identified in the sample type code.

- Wherever possible, all analytes and replicates for a given sample will be grouped together.
- If an analyte is not detected then the laboratory qualifier will be U, and the value in the result column will be the sample-specific reporting limit. Quantified results between the detection limit and the reporting limit will be laboratory J-qualified.

The electronic data deliverable (EDD) format for chemical data is provided in Table 2-5.

Table 2-5. Electronic data deliverable format for chemical data

FIELD	REQUIRED OR OPTIONAL
Project code	required
Event ID	required
Sample name	required
Sample date time	required
Analysis location	required
Lab name code	required
Parent sample name	optional
Lab sample ID	required
Sample type code	required
Sample delivery group	required
Standard analytical method name	required
Lab analytical method name	optional
CAS number	optional
Chemical name	required
Result value	required
Result unit	required
Lab flag	optional
Validator flag	optional
Result type code	required
Detect flag	required
Reporting detection limit	required
Dilution factor	required
Sample matrix code	required
Total or dissolved	required
Basis	required
Analysis date time	required
Method detection limit	required
Lab prep method name	required
Prep date time	required
Test batch ID	required
Result error delta	optional

FIELD	REQUIRED OR OPTIONAL
Tic retention time	optional
Result comment	optional
QC original concentration	optional
QC spike added	optional
QC spike measured	optional
QC spike recovery	optional
QC duplicate original concentration	optional
QC duplicate spike added	optional
QC duplicate spike measured	optional
QC duplicate spike recovery	optional
QC RPD	optional
QC spike LCL	optional
QC spike UCL	optional
QC RPD CL	optional
Lab analytical method description	optional
Lab flag description	optional

2.6.3 Data reduction

Data reduction is the process by which original data (analytical measurements) are converted or reduced to a specified format or unit to facilitate analysis of the data. Data reduction requires that all aspects of sample preparation that could affect the test result, such as sample volume analyzed or dilutions required, be taken into account in the final result. It is the laboratory analyst's responsibility to reduce the data, which are subjected to further review by the Laboratory PM, the Windward PM, the Project QA/QC Coordinator, and independent reviewers. The data will be generated in a form amenable to review and evaluation. Data reduction may be performed manually or electronically. If performed electronically, all software used must be demonstrated to be true and free from unacceptable error.

2.6.4 Data and analysis report

A data and analysis report, as described in Section 2.3, will be prepared by Windward documenting all activities associated with the collection, handling, and analysis of samples. At a minimum, the following will be included in the data and analysis report:

- summary of all field activities, including deviations from the approved QAPP
- porewater sampling locations reported in latitude and longitude to the nearest one-tenth of a second and in northing and easting to the nearest foot
- plan view of the project showing actual sampling locations
- summary of the QA/QC review of the chemical data
- copies of field logs (appendix)

- data validation report (appendix)
- tables of all raw data (appendix)
- results from the analyses of porewater samples, both as summary tables in the main body of the report and appendices with data forms submitted by the laboratories and as cross-tab tables produced from Windward's database
- comparison of porewater VOC concentrations to relevant toxicological effects data for invertebrates

Chemical data packages will be received from the laboratories no later than three weeks after the last sample was submitted. Chemical data will be validated within three weeks of receiving data packages from the laboratory. The draft data and analysis report, including electronic versions of the data, will be submitted to EPA and Ecology December 2, 2005. A draft final version of the data and analysis report will be submitted for approval approximately four weeks after receiving comments on the draft version.

3.0 Data Generation and Acquisition

This section describes the methods that will be used to collect porewater samples for VOC analysis. Elements include sampling design, porewater sampling methods, sample handling and custody requirements, decontamination procedures, analytical methods, quality assurance/quality control, instrument/equipment testing, inspection and maintenance, instrument calibration, supply inspection/acceptance, and data management.

3.1 STUDY DESIGN

This section presents the rationale and design for the placement of porewater sampling devices in the LDW adjacent to the two sites selected for sampling, GWI and Boeing Plant 2/Jorgensen Forge. The study design requires the porewater samplers to be placed in areas where contaminated groundwater is most likely to discharge to the LDW. Section 3.1.1 describes the overall conceptual site model for groundwater discharge in the LDW, Section 3.1.2 fine-tunes this discussion for the GWI site and discusses the site-specific rationale for sampling locations, and Section 3.1.3 presents a similar discussion for the Boeing Plant 2/Jorgensen Forge location.

3.1.1 Groundwater flow and discharge to the LDW

The following discussion is compiled from the Lower Duwamish Pathways Study (Booth and Herman 1998), from the draft Corrective Measures Study Hydrological Description for Boeing Plant 2 (see, for example, Environmental Partners et al. 2004), and from the supplemental remedial investigation and feasibility study (SRI/FS) for GWI (Terra Vac and Floyd & Snider 2000).

The LDW is located within the Lower Duwamish Valley, a flat valley filled with alluvial sediments between higher glacial hillsides. The valley has been present through many glacial cycles, and has filled with alluvial sediments through both glacial and non-glacial periods. Deeper sediments within the valley are fine-grained, and several marine layers exist where Puget Sound's marine waters historically extended upstream to Kent and beyond. Many of these deeper layers are filled with essentially connate water that was trapped in the formation during deposition and that experiences limited mixing with overlying, more recent groundwater. Shallower, more recent sediment deposits are more permeable, and groundwater moves through them considerably faster, eventually discharging to the LDW.

The deeper portion of the LDW is a marine salt-water wedge that is tidally connected to Elliott Bay. The salt wedge is always present at GWI, and present more than 80% of the time at the Boeing Plant 2/Jorgensen Forge property boundary. The height and extent of the salt wedge is controlled by the daily tides and by the degree of river flow. A layer of fresh water flows down the river on top of this saline water wedge. The thickness of the fresh water layer depends on tides, fresh river water discharge controlled by Howard Hansen Dam, and local rainfall.

Density differences between the salt water wedge in the bottom portion of the LDW and fresh groundwater result in displacement of the fresh groundwater by the overlying saline surface water. This displacement creates a wedge of saline groundwater beneath the LDW. The spatial orientation of the fresh water/saline water interface is controlled by the relative densities of the two liquids, recharge to the aquifer, and the hydraulic conductivity of the aquifer as described by the Dupuit-Ghyben-Herzberg model. Based on this model, it would be expected that the saline water wedge in the LDW extends into the groundwater system from its location in the waterway downward until it connects with the deeper connate groundwater (present from the time of sedimentation), which is brackish. The saline groundwater wedge is denser than the fresh, non-saline groundwater, thereby limiting the interchange between these two water-bearing zones.

Groundwater in the Lower Duwamish Valley generally flows from the sides of the valley to the waterway, entering the waterway with a flow direction that is almost perpendicular to the length of the waterway. The dominant groundwater flow direction is virtually horizontal, with a minor downward flow component in the uplands. As groundwater approaches its discharge zone in the LDW, the groundwater flow becomes forced upwards (Booth and Herman 1998). Given the flat topography and the predominantly horizontal flow, this means that contamination at 30 ft below ground surface (bgs) and 1,000 ft from the waterway is still approximately 30 ft bgs when it is within 100 ft of the waterway.

As the groundwater nears the waterway, however, the flow lines generally begin to curve upward in response to the denser saline groundwater wedge beneath the LDW (see Figure 2-2). When fresh groundwater encounters the denser saline groundwater wedge, it will flow above it ("ride over the top"), especially if it is also approaching a discharge zone (such as the waterway). For example, at GWI, groundwater contamination that had approached the waterway at –20 to –30 ft MLLW, appears to discharge from seeps located at approximately-3 ft MLLW.

In front of the Jorgensen Forge facility, just upstream of Boeing Plant 2, sediment grain size data exist for both the surface (0-10 cm), and the upper two 1-ft intervals. Sediments in this area are a silty sand and sandy silt. There is no significant difference between the sediment samples collected from 1-2 ft below mudline and the surface samples; however, the sediments nearer the shore contain more sands and gravels than do the sediments located closer to the channel. These nearshore sandier sediments will be more permeable than the sediment located farther offshore. As a result , groundwater that discharges near the shoreline in order to enter the waterway over the saline wedge would be expected to discharge nearer to the shore, through sediments with the highest permeability. Sediment conditions in this area are expected to be generally representative of conditions in the LDW, although site-specific differences may occur, such as in slips or embayments. Sediment conditions off the Boeing Plant 2/Jorgensen Forge site may not represent conditions in the Myrtle Street Embayment near GWI.

Identification of the areas where contaminated groundwater is potentially discharging at the two target sites is critical to the successful design of the porewater sampling program. The following sections discuss the site-specific sampling design and rationale for sampling locations at each of the two selected sites.

3.1.2 GWI

This section discusses the location of groundwater contamination and groundwater discharge areas at the GWI site. Based on this information, a study design for collection of porewater samples at the site is presented in Sections 3.1.2.3 and 3.1.2.4.

3.1.2.1 Location of contamination

Groundwater contamination has been identified in two zones in the alluvial aquifer (Terra Vac and Floyd & Snider 2000). The two zones are separated by a thin and discontinuous silt layer that has a profound effect on groundwater geochemistry and contaminant fate and transport, but little hydrologic impact. Figure 3-1 (see Map Folio), which is taken directly from the SRI/FS (Terra Vac and Floyd & Snider 2000), summarizes the characteristics of the two water-bearing zones at GWI.

The upper water-bearing zone (first WBZ) extends from the water table at 7-10 ft bgs (+5 ft MLLW) to the silt zone at approximately 15 ft bgs (0 ft MLLW) (Figure 3-1). It has been impacted by several different releases, contains low dissolved oxygen concentrations, and is dominated by parent products (tetrachloroethene and trichloroethene) rather than degradation products (dichloroethene and vinyl chloride). Concentrations in groundwater wells near the LDW are generally below 1,000 µg/L for tetrachloroethene and trichloroethene. In seeps, the highest concentrations were detected in seep S-2, downgradient from the NW Corner plume (Figure 3-2; see Map Folio).

The lower water-bearing zone (second WBZ) extends from the base of the silt layer to approximately 45 ft bgs (–30 ft MLLW), where another silt layer is encountered (Figure 3-1). The second WBZ is an anaerobic zone where trichloroethene has been actively degraded to dichloroethene, vinyl chloride, and to non-toxic species. Although dichloroethene and vinyl chloride are actively degrading in this zone, they are still present at high concentrations in groundwater near the LDW. The highest concentrations of dichloroethene and vinyl chloride (21,000 µg/L and 23,000 µg/L, respectively) in the most recent groundwater sampling conducted in 1999 were detected in well B-35, approximately 50 ft from the LDW. It appears likely that groundwater from this area discharges at seep S-13, where dichloroethene was detected at a concentration of 5,400 µg/L, and vinyl chloride was detected at a concentration of 1,600 µg/L (Figure 3-3; see Map Folio).

3.1.2.2 Groundwater discharge areas

Groundwater generally flows from the GWI site to the southwest toward the Myrtle Street embayment of the LDW, which is the shortest pathway to the LDW. The gradient of discharge into the LDW is highly dependent on the tides—at high tides, flow is from the LDW into the groundwater system; at lower tides the gradient is from the land to the LDW. Figure 3-2 shows the net groundwater flow directions for the first WBZ. This figure is a composite of a series of figures in Chapter 5 of the SRI/FS (Terra Vac and Floyd & Snider 2000). The "extent of contamination" was defined using groundwater and seep data and tidal studies defining groundwater gradients. Figure 3-3 shows the equivalent information for the second WBZ and is based on the same report. Note that although both zones are expected to discharge into the embayment, they will discharge at different elevations.

The top of the first WBZ discharges into an area along the bank that is strongly affected by bank storage/recharge – the tidally influenced filling and draining of the bank area. During the SRI, two seeps located at approximately –1 ft MLLW were also identified as discharging water from the first WBZ. The association of these seeps to the first WBZ was based on the presence of intermediate redox conditions, the dominance of tetrachloroethene and trichloroethene, and the comparability of geochemical and chemical concentrations.

The Myrtle Street Embayment Study was performed to determine whether there were other seeps or a seep face from which the first WBZ was discharging, and to identify where the second WBZ was discharging. This study consisted of three phases. The study used Gore-Sorber modules that were placed 12 to 18 inches (30 to 45 cm) below the mudline, attached to rebar stakes driven by hand into the sediments. These modules are passive sampling devices consisting of sorbant material surrounded by Gore-Tex tubing that prevents water from contacting the sorbant material. The modules absorb organic compounds and allow for a qualitative evaluation of the presence of VOCs based on the amount of compound adsorbed; actual concentrations in porewater are not obtained from this method. As part of Phase 1, Gore-Sorbers placed near known seeps were found to saturate (exceed their ability to detect higher concentrations) within 72 hours of placement.

In Phase 2, 43 Gore-Sorbers were deployed at 41 locations on a 50-ft grid (Figure 3-4) throughout the embayment for 48 hours to identify additional seeps and discharge areas. The eight Gore-Sorbers installed in the LDW at the depth of the shipping channel failed because of hydrostatic pressure rupturing the liner. The mass of each compound adsorbed onto the Gore-Sorber modules is shown in Table 3-1. Measurable amounts of tetrachloroethene and its degradation products were found in only two modules, indicating that the detections were very localized. The module located adjacent to seep S-1 contained cis- and trans-1,2-dichloroethene, vinyl chloride, 1,1-dichloroethene, and 1,1-dichloroethane. The module located at seep S-2 contained cis-1,2-dichloroethene. No VOCs were found in the module located at seep S-13 during this phase. The Gore-Sorbers located at seeps S-1 and S-2 were located within 3 ft of the known seeps; the Gore-Sorber at seep S-13 was 5 to 10 ft away and at a lower elevation. The other 32 Gore-Sorbers located between the shallow near shore seeps and the deeper shipping channel were successfully recovered, but contained no detectable VOCs.

In Phase 3, a series of Gore-Sorbers were deployed between seeps S-13 and S-1 to confirm that the discharge was occurring along a seep face over a very narrow elevation range, as shown in Figure 3-5. Several of these Gore-Sorbers were placed closer to seep S-13 and at a more similar elevation than in Phase 2. These Gore-Sorbers contained 1,1,2-trichloroethane, dichloroethane, tetrachloroethene, trichloroethene, dichloroethene, and vinyl chloride. The very strong dominance of dichloroethene in the Gore-Sorbers near seep S-13, plus the slightly deeper elevation of these Gore-Sorbers, indicates that these units likely detected discharge from the second WBZ, rather than the first WBZ where dichloroethene concentrations are much lower.

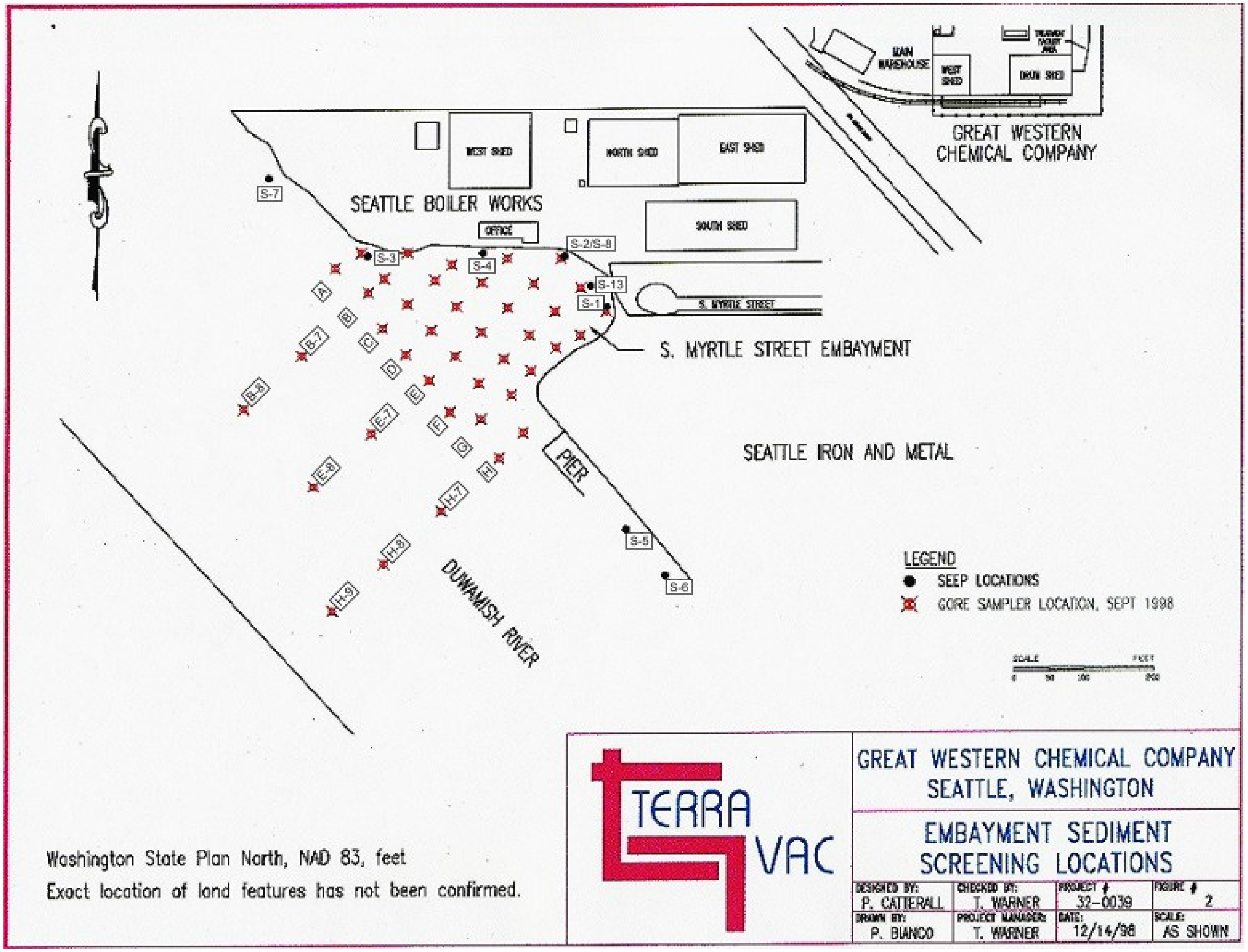
Results of Phases 2 and 3 indicated that the Gore-Sorbers were very effective at identifying seeps if they were within approximately 3 ft of the seep.

The key findings of the Myrtle Street Embayment Study are as follows:

- Groundwater discharge to the LDW at the Myrtle Street Embayment was found to occur as seep discharges. Generalized groundwater upwelling was not observed in the Myrtle Street Embayment based on the Gore-Sorber study using VOCs as chemical markers.
- The seeps identified during the SRI were also identified during this investigation as discrete seeps.
- Tetrachloroethene and/or its degradation products were also detected in Gore-Sorber modules placed in seep-face sediments along the eastern edge of the

Myrtle Street embayment. This seep face was further delineated in a second sampling event, and found to have a moderately long horizontal extent, but a very limited vertical extent (Table 3-1).

- No seeps were found to occur between the nearshore seeps and the edge of the embayment down to at least –15 ft MLLW; the study failed to gather information from elevations lower than 15 ft MLLW because of hydrostatic failure of the devices deployed at these deeper depths.
- In summary, the extent of groundwater discharge containing the chemical markers from the GWI site was delineated both vertically and horizontally using both sediment porewater screening and collection of seep grab samples. The extent was bounded to the north by seep S-2 and to the south by seep S-1. The seeps also were bounded in elevation (vertical extent) and found to occur between approximately -1 and -3 ft MLLW.



Washington State Plan North, NAD 83, feet
Exact location of land features has not been confirmed.

Figure 3-4. Seep and Gore-Sorber sampling locations during the Phase 2 embayment study (from Terra Vac and Floyd & Snider 2000)

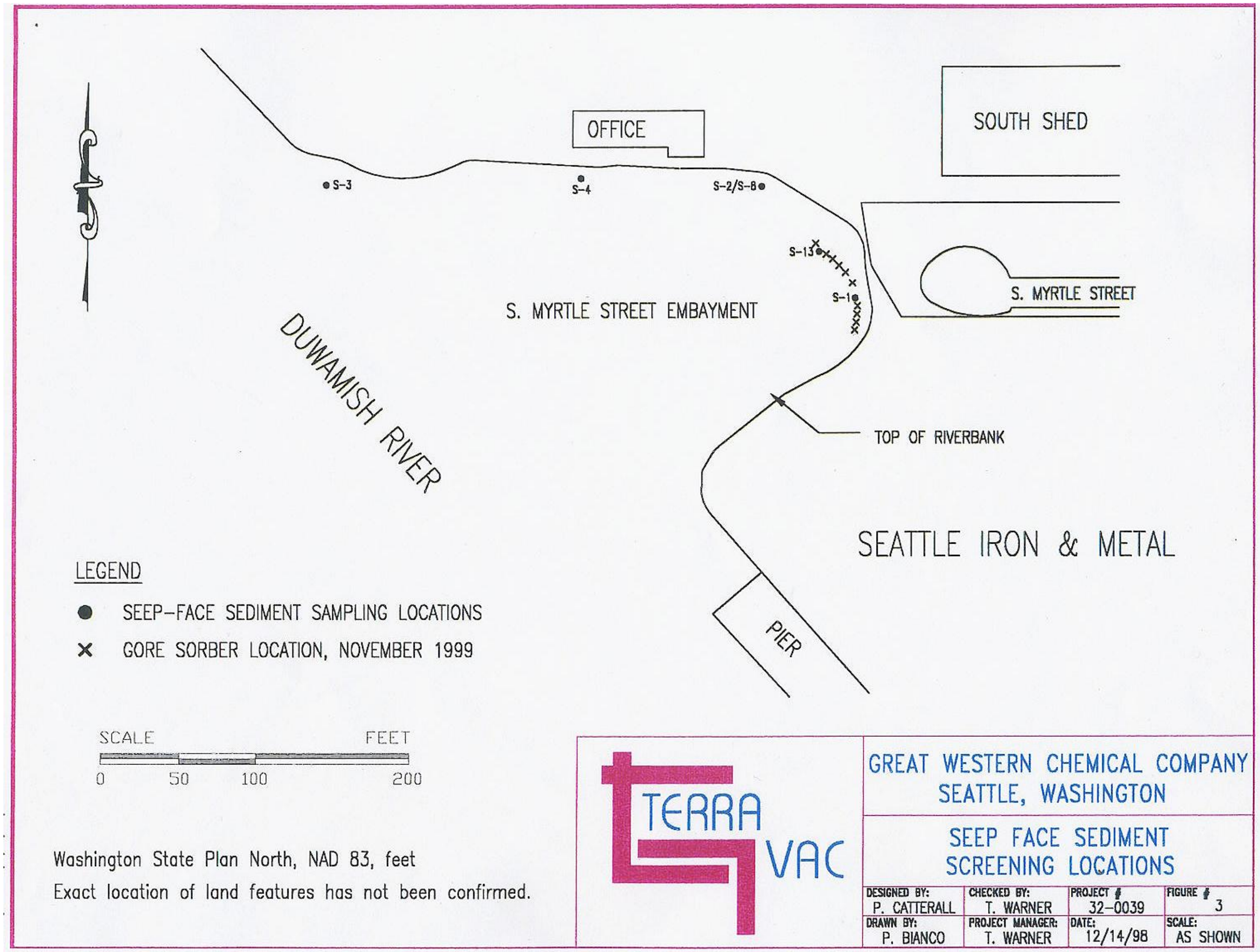


Figure 3-5. Gore-Sorber sampling locations for Phase 3 embayment study (from Terra Vac and Floyd & Snider 2000)

Table 3-1. Results of Gore-Sorber sampling at GWI during Phases 2 and 3

	Phase 2 Embayment Study (µg)[a]		Phase 3 Seep-face Study (µg)[a]									
Analyte	E-1[b]	G-1[c]	2'N of S-13	2'S of S-13	5.5'S of S-13	10.5'S of S-13	15.5'S of S-13	20.5'S of S-13	6'S of S-1	11'S of S-1	16.5'S of S-1	22'S of S-1
1,1,2-Trichloroethane	nd	nd	0.92	0.45	0.15	0.27	0.17	0.22	nd	nd	nd	nd
1,1-Dichloroethane	nd	0.58	1.98	12.48	6.76	7.59	6.47	8.36	nd	5.61	2.78	1.91
1,1-Dichloroethene	nd	0.33	1.5	4.15	2.08	1.24	1.24	0.94	0.41	nd	nd	nd
1,2-Dichloroethane	nd	nd	0.43	1.01	0.46	0.38	0.28	0.24	0.08	nd	nd	nd
cis-1,2-Dichloroethene	0.12	27.46	341.94	305.3	330.41	229.97	143.41	123.31	42.75	1.06	0.1	0.05
Tetrachloroethene	nd	nd	0.92	0.45	0.15	0.27	0.17	0.22	nd	nd	nd	nd
trans-1,2-Dichloroethene	nd	0.21	7.11	6.81	3.46	2.54	2.17	2.51	0.83	0.06	nd	nd
Trichloroethene	nd	nd	1.76	1.55	0.48	0.61	0.46	0.58	0.11	nd	nd	nd
Vinyl chloride	nd	42.05	38.57	27.9	51.75	62.86	44.96	47.58	103.94	7.71	nd	nd

[a] Units are reported as µg, not µg/L, because the sampling method measures the amount of chemical adsorbed onto the Gore-Sorbers rather than a concentration of the chemical in porewater.

[b] E transect started at seep S-2 (see Figure 3-4)

[c] G transect started at seep S-1 (see Figure 3-4)

nd - not detected

3.1.2.3 Piezometer sampling at GWI

Two seeps (S-1 and S-2) were found to represent maximum discharge areas for the first WBZ, and an extended seep face (S-13) was found to represent the maximum discharge area for the second WBZ. These seeps are located between –1 and –3 ft MLLW. None of the Gore-Sorbers located below –5 ft MLLW contained VOCs; therefore, it is believed that the second WBZ discharges at elevations above –5 ft MLLW, with the only documented discharge occurring at –3 ft MLLW. A series of piezometers will be installed in the embayment as part of this LDW Phase 2 study to confirm these results. Piezometers will also be installed in these deeper areas beyond the embayment to verify that, if groundwater is upwelling in these areas, VOC concentrations are not elevated.

Two transects of piezometers will be installed in the Myrtle Street embayment. One transect extends from seep S-2 and one transect extends from a point between seeps S-1 and S-13, each along a line parallel to the known flow gradient. Piezometers will be placed along these transects at the –5 ft, -10 ft, and –15 ft MLLW elevations (Figure 3-6; see Map Folio). The piezometer installed at the deepest bathymetric contour (-15 ft MLLW) is located outside of the embayment in the LDW.

Each piezometer will be deployed so that its screen is at least 1 ft below the mudline. The depth will be determined based on the results of the field reconnaissance conducted during the week of June 6, 2005 and conditions encountered during the piezometer sampling. After positioning the piezometers, a water sample will be collected as described in Section 3.2.3, and submitted to the laboratory for analysis of VOCs, by EPA 8260B with a rapid turn-around-time. A total of six samples will be collected from the embayment using the piezometers.

The concentrations of VOCs in water collected from the piezometers will be compared to relevant TRVs. Prior to field sampling, TRVs will be derived for those chemicals previously detected in seeps, Gore-Sorbers, or in the closest groundwater wells to the LDW (Tables 2-2, 2-3, and 3-1). These chemicals include acetone, benzene, chlorobenzene, cis-1,2-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, tetrachloroethene, trans-1,2-dichloroethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethene, toluene, vinyl chloride, and xylene. The specific TRV for each VOC will be determined in consultation with EPA and Ecology, presented in a technical memorandum, and agreed upon prior to collecting the water samples from the piezometers. If another VOC is detected in water sampling with the piezometers, a TRV will also be derived for this chemical, in consultation with EPA and Ecology.

If the concentrations of detected VOCs are less than the TRVs, then no additional sampling is required at those locations. If the detected concentration of any of the VOCs is above the TRV, a peeper will be placed in the same location as the piezometer with a VOC concentration in water above the TRV (but at a depth of 10 cm below the mudline). If needed, these peepers would be deployed at the same time as the peepers described in the following section.

3.1.2.4 Porewater sampling of discharge areas at GWI

Peepers will be installed at eight locations within the embayment, in areas expected to be subject to the greatest discharge, as shown in Figure 3-6:

- One peeper within 2 ft of seep S-2 (PE-01)
- One peeper approximately 20 ft southwest of S-2, between mudline elevations of 0 and –2 ft MLLW (PE-02)
- Two peepers channelward from the S-13 peepers, between mudline elevations of –3 and –5 ft MLLW (PE-03 and PE-04)
- Two peepers at either end of seep face S-13 (PE-05 and PE-06)
- One peeper approximately 5 ft northwest of S-1, between mudline elevations of 0 and –2 ft MLLW (PE-07)
- One peeper within 2 ft of seep S-1 (PE-08)

Peepers will not be placed directly within areas of higher active flow (e.g., rivulets) discharging from seeps. As discussed in Section 3.1.2.3, if VOCs are detected at concentrations above the TRVs in the water samples collected at any of the piezometer locations, then peepers will be added at those locations in addition to the eight peepers discussed above.

The top of each peeper will be placed at a depth of approximately 10 cm below the mudline. At one of the eight locations (PE-06), an additional two peepers will be deployed to assess variability, for a total of 10 peepers at GWI, as summarized in Table 3-2. Sampling location coordinates for piezometers and peepers are shown in Table 3-3. The locations of sampling transects for piezometers and peepers were chosen based on the conceptual site model and expected areas of groundwater discharge.

Table 3-2. Number of water samples

SAMPLE TYPE	GWI	BOEING PLANT 2/JORGENSEN
Piezometer samples	6	6
Peeper samples, including 2 field replicates	10	10
Potential peeper samples at piezometer locations	up to 6	up to 6

Table 3-3. Porewater sampling location coordinates

Sample Location ID	X Coordinate [a]	Y Coordinate [a]	Latitude [b]		Longitude [b]		Elevation relative to MLLW (ft) [c]
GWI sampling locations							
LDW-PW-G-PZ-01	1271176.15	200359.95	47	32.367	122	19.699	(-5)
LDW-PW-G-PZ-02	1271018.03	200283.93	47	32.354	122	19.737	-10
LDW-PW-G-PZ-03	1270936.63	200219.23	47	32.343	122	19.756	-15
LDW-PW-G-PZ-04	1271247.25	200313.52	47	32.359	122	19.681	-5
LDW-PW-G-PZ-05	1271102.32	200184.82	47	32.338	122	19.716	-10
LDW-PW-G-PZ-06	1271063.72	200123.69	47	32.327	122	19.725	-15
LDW-PW-G-PE-01	1271184.76	200393.91	47	32.372	122	19.697	(0 to -2)
LDW-PW-G-PE-02	1271180.94	200378.58	47	32.370	122	19.698	(0 to -2)
LDW-PW-G-PE-03	1271241.35	200390.42	47	32.372	122	19.683	-4
LDW-PW-G-PE-04	1271233.66	200337.15	47	32.363	122	19.685	-4
LDW-PW-G-PE-05	1271276.99	200364.50	47	32.368	122	19.674	(0 to -2)
LDW-PW-G-PE-06	1271263.19	200355.34	47	32.366	122	19.678	(0 to -2)
LDW-PW-G-PE-07	1271290.30	200324.77	47	32.361	122	19.671	(0 to -2)
LDW-PW-G-PE-08	1271279.98	200303.81	47	32.358	122	19.673	(0 to -2)
Boeing sampling locations							
LDW-PW-B-PZ-07	1275710.61	195751.75	47	31.623	122	18.576	-5
LDW-PW-B-PZ-08	1275690.90	195746.21	47	31.622	122	18.581	-10
LDW-PW-B-PZ-09	1275663.95	195739.46	47	31.621	122	18.587	-15
LDW-PW-B-PZ-10	1275750.19	195716.22	47	31.618	122	18.566	-5
LDW-PW-B-PZ-11	1275731.67	195704.41	47	31.616	122	18.571	-10
LDW-PW-B-PZ-12	1275701.61	195685.10	47	31.612	122	18.578	-15
LDW-PW-B-PE-09	1275752.24	195780.01	47	31.628	122	18.566	0
LDW-PW-B-PE-10	1275718.38	195765.29	47	31.625	122	18.574	-2
LDW-PW-B-PE-11	1275774.07	195762.17	47	31.625	122	18.561	0
LDW-PW-B-PE-12	1275746.90	195748.92	47	31.623	122	18.567	-3
LDW-PW-B-PE-13	1275782.77	195739.34	47	31.621	122	18.558	0
LDW-PW-B-PE-14	1275765.81	195730.86	47	31.620	122	18.562	-2
LDW-PW-B-PE-15	1275792.46	195719.78	47	31.618	122	18.556	0
LDW-PW-B-PE-16	1275776.28	195708.42	47	31.616	122	18.560	-3

[a] Coordinates are in Washington State Plane N, NAD83, US ft

[b] Coordinates are in degrees and decimal minutes, NAD83

[c] Elevations are based on bathymetry data, except those in parentheses, which are estimates because bathymetry data were not available

3.1.3 Boeing Plant 2/Jorgensen Forge

This section discusses the location of groundwater contamination and projected groundwater discharge areas near the property boundary of Boeing Plant 2 and Jorgensen Forge. Based on this information, a study design for collection of porewater samples at the site is presented in Sections 3.1.3.3 and 3.1.3.4.

3.1.3.1 Location of contamination

Significant historical releases of trichloroethene occurred near Building 2-66 at the south end of Boeing Plant 2. Approximately 90% of the resulting contaminated groundwater was enclosed within a sheet pile containment structure in 1994. However, the footprint of this structure was constrained by buildings and property lines, and a portion of the plume remains outside the sheetpile structure near well PL2-JF01AR (Figure 3-7; see map folio). This well is actually located on the Jorgensen Forge property, and is downgradient of portions of both Boeing Plant 2 and Jorgensen Forge. Chlorinated solvent and hydrocarbon releases have also been identified on the Jorgensen Forge property upgradient to this well; however, it is not known to what extent well sampling results from PL2-JF01AR reflect Jorgensen Forge releases. This well is located within approximately 50 ft of the LDW; the majority of the groundwater contamination is located within the upper part (A-level) of the aquifer at this location, based on analytical results from groundwater samples collected from three levels of the aquifer.

3.1.3.2 Groundwater flow and discharge to the LDW

The aquifer beneath the Boeing Plant 2 site occurs at approximately 10 ft bgs and consists of a sequence of sands and silt, with a thickness of about 80-90 ft. For comparative purposes, the MLLW level is approximately 18 ft bgs in the LDW adjacent to Boeing Plant 2. This aquifer has been divided into three levels—an upper level (referred to as the A-level of the aquifer at 10-30 ft bgs), an intermediate level (referred to as the B-level of the aquifer from 30-60 ft bgs), and a deeper level (referred to as the C-level of the aquifer from 60 to approximately 100 ft bgs), as shown in Figure 3-8. These divisions reflect the aquifer's hydrogeologic characteristics. The sand sequence increases in silt content with depth, and the deeper zone (C-level) contains saline water that is thought to be connate groundwater (present from the time of sedimentation). The base of the aquifer contains a distinctive low-permeability silt layer that acts as an aquitard at approximately 90-100 ft bgs.

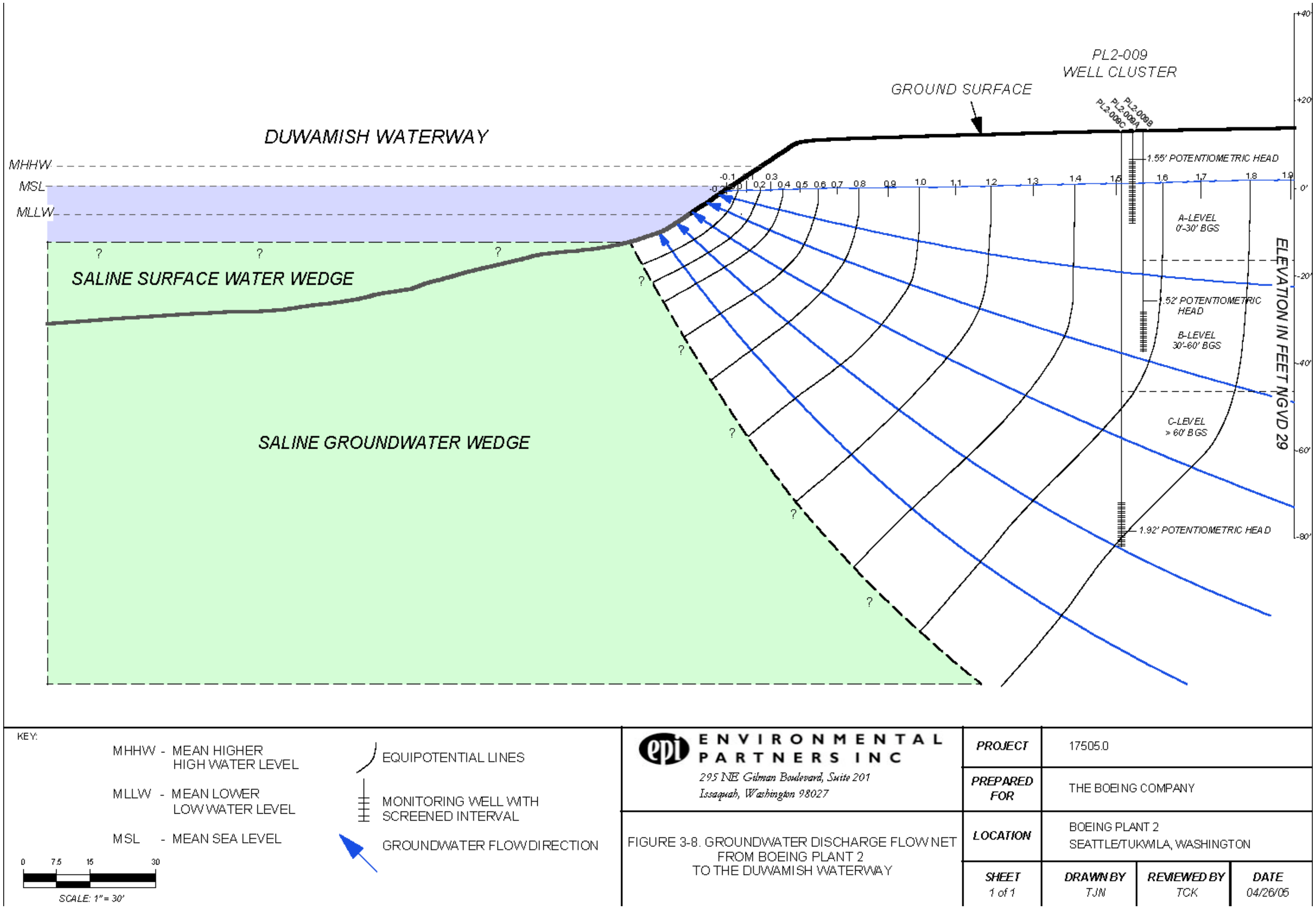


Figure 3-8. Groundwater discharge flow net from Boeing Plant 2 to the Duwamish Waterway

Note: Question marks indicate that the exact location and extent of the saline/freshwater interface is unknown. The actual interface is most likely a broad transition zone of brackish water.

Shallow groundwater beneath the facility migrates from east to west, ultimately discharging to the LDW. General groundwater elevation contours and horizontal groundwater flow directions are shown in Figure 2-4.[2] Tidal fluctuations can cause temporary horizontal groundwater gradient direction reversals near the LDW, but the measurable extent of tidal influence becomes negligible roughly 300 to 600 ft inland from the LDW.

A saline groundwater wedge and mixing zone occurs beneath the LDW, which causes fresh groundwater migrating beneath the site to discharge upwards to the LDW. Groundwater from the A-level of the aquifer primarily discharges within the shallow areas of the LDW near the shoreline (Figure 3-8).

The area where groundwater containing VOCs is most likely to discharge can be estimated using site-specific hydrogeologic and bathymetric data to create a flow net diagram, as shown in Figure 3-8. The physical features used to create this flow net were derived from site-specific bathymetric and topographic data to define sediment and land surface elevations upgradient and downgradient of the PL2-009 well cluster, which contains three wells, each in one of the A, B, or C levels of the aquifer. The PL2-009 well cluster location was selected for the flow net cross section because of the availability of appropriate net water level data for this well cluster. In addition, the PL2-009 well cluster is only 140 ft north of the JF01 well cluster (which also contains three wells, each in one of the A, B, or C aquifer levels); the hydrogeologic processes and conditions with respect to groundwater discharge at both locations should be similar.

Net water level elevation data for the PL2-009 well cluster were obtained using water level data collected at 5-minute intervals over a 72-hour period. The water level data were normalized to remove tidal effects using the method described by Serfes (1991). Density effects were also removed to yield net "environmental heads" for each of the three wells in the cluster. The resulting environmental heads show a net upward vertical gradient direction at the PL2-009 well cluster. This outcome was expected based on the cluster well location near a regional discharge zone and the known presence of a saline wedge in the aquifer beneath the LDW.

Because the saline wedge is significantly denser than the overlying fresh groundwater and the interface between the two dissimilar waters acts as a no-flow boundary, groundwater flow is forced upward as it approaches the waterway. These hydraulic effects are represented graphically in the cross section flow net presented in Figure 3-8, which shows the effect of the upward vertical gradient on horizontal groundwater flow as it approaches the LDW. The shape of the saline wedge was estimated using the

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[2] These elevation contours were derived from a series of groundwater elevation contour maps depicting flow during a variety of seasonal and tidal conditions, and thus are intended to represent mean elevation contours.

Ghyben-Herzberg principle (Fetter 1980); however, no site-specific data are available to confirm the exact shape and slope of the freshwater/saline interface that defines the saline wedge. Because of the uncertainty regarding the slope and location of the saline wedge, sampling with piezometers will be conducted beyond the discharge zone predicted by the conceptual groundwater flow model, as described below in Section 3.1.3.3. This sampling will provide an additional level of confidence that the areas being sampled with peepers are the likely areas of groundwater discharge.

The horizontal gradient used to establish the vertical equipotential lines in the flow net figure is based on an average horizontal gradient value calculated from several net groundwater elevation contour maps presented in the RFI for Boeing Plant 2 (Weston 1996). The horizontal gradient becomes steeper closer to the waterway, which is reflected in more closely spaced equipotential lines as groundwater approaches the LDW.

Groundwater in the A-level of the aquifer is of interest for porewater sampling because analytical data indicate that higher concentrations of VOCs are present only in the A-level well in the JF01 cluster, as discussed below. The cross section flow net, which is based on site-specific empirical data, indicates that the combined effects of the upward component of groundwater flow and the saline groundwater wedge will cause A-level groundwater to seep from the LDW sediments at a location close to the shoreline (i.e., no farther than approximately the -3 ft MLLW bathymetric contour).

The groundwater monitoring wells that consistently and most recently contained the highest concentrations of VOCs at Boeing Plant 2 are located near the former Building 2-66, just north of the property boundary between Jorgensen Forge and Boeing Plant 2 (Figure 3-7). In 1994, a sheet pile wall was placed around the area of highest VOC concentrations to contain approximately 90% of the contaminant mass at that location. Currently, VOCs within the sheet pile wall are being extracted by an active Density Driven Convection (DDC) remediation system that uses in-well air sparging combined with soil-vapor extraction methods. Long-term monitoring of groundwater is conducted in wells along the Boeing Plant 2/Jorgensen Forge shoreline. The highest concentrations of VOCs outside of the sheet pile structure in the August 2004 monitoring event were found in the sample from monitoring well JF01AR, located on Jorgensen Forge property outside of the containment wall in the A-level (0-30 ft bgs), as shown in Figure 3-7. Figure 3-7 shows that groundwater VOC concentrations are significantly lower or non-detect in the four monitoring wells to the north of JF01AR and in the deeper co-located wells JF01B and JF01C.

3.1.3.3 Piezometer sampling at Boeing Plant 2/Jorgensen Forge

The curvature of the flow lines and the occurrence of the groundwater contamination, primarily in the A level of the aquifer, indicate that discharge of contaminated groundwater is likely occurring near the shoreline in a fairly shallow area, likely within approximately 50 ft of the shoreline and no deeper than –3 ft MLLW. To confirm this assumption, two transects of piezometers will be installed and sampled.

The transects will extend from either side of well PL2-JF01AR toward the channel along a line parallel with the likely net groundwater flow directions. Piezometers will be installed at mudline elevations of –5, -10, and –15 ft MLLW along each transect (Figure 3-7).

Each piezometer will be placed so that its screen is at least 1 ft below the mudline. The depth will be determined based on the results of the field reconnaissance conducted during the week of June 6, 2005 and conditions encountered during the piezometer sampling. After positioning the piezometers, a water sample will be collected as described in Section 3.2.3, and submitted to the laboratory for analysis of VOCs by EPA 8060B with a rapid turn-around time. Six samples will be collected using the piezometers.

The concentrations of VOCs in water collected from the piezometers will be compared to relevant TRVs. Prior to field sampling, TRVs will be derived for chemicals previously detected in seeps or in the closest groundwater wells to the LDW sampled in 2004 (Tables 2-2 and 2-3). These chemicals include 1,1-dichloroethane, benzene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, trichloroethene, and vinyl chloride. As described in Section 3.1.2.3, the concentrations of these VOCs, or additional VOCs detected in water collected from the piezometers, will be compared to relevant TRVs. If the concentrations of detected VOCs are less than the TRVs, then no additional sampling is required at those locations. If the detected concentration of any of the site-specific VOCs is above the TRV, a peeper will be placed in the same location as the piezometer with a VOC concentration above the TRV (but at a depth of 10 cm below the mudline), at the same time as the peepers are placed in nearshore areas.

3.1.3.4 Porewater sampling of discharge areas at Boeing Plant 2/Jorgensen Forge

Peepers will be installed at eight locations within the 0 to -4 ft MLLW bathymetric contour lines, in areas expected to be subject to the greatest discharge from the A-level of the aquifer (Figure 3-7). Peepers will not be placed directly within areas of higher active flow (e.g., rivulets) discharging from seeps. In addition, at one of the eight locations (PE-11), an additional two peepers will be deployed to assess variability, for a total of 10 peepers in the 0 to -4 ft MLLW zone (Table 3-2).

As discussed in the above section, if VOCs are detected at concentrations above the TRVs in the water samples collected at any of the piezometer locations, then additional peepers will be added at those locations.

The top of each peeper will be placed at a depth of 10 cm below the mudline. Sampling location coordinates for piezometers and peepers are shown in Table 3-3. The locations of sampling transects for piezometers and peepers were chosen using best professional judgment based on the conceptual site model and expected areas of groundwater discharge.

3.2 SAMPLING METHODS

The methods for sampling porewater are described in this section. All field activities will be performed under the direction of the Windward FC or other oversight personnel, as determined by LDWG, EPA, and Ecology. Dr. Allen Burton of Wright State University will provide peepers, and will assist with peeper deployment and retrieval. Windward will obtain the piezometers and will have scuba diving assistance from Research Support Services, Inc.

3.2.1 Sample identification

Each porewater sampling location will be assigned a unique alphanumeric sample ID number. The first three characters of the location ID are "LDW" to identify the Lower Duwamish Waterway project area. The next two characters are "PW" to identify the medium sampled (porewater), followed by "PZ" or "PE" to signify piezometer or peeper, followed by "G" or "B" to identify GWI or Boeing Plant 2/Jorgensen Forge. The last two characters are consecutive numbers, beginning with 01, to identify the specific location within the LDW area for each collection device. For example, the sample ID of the first peeper sample, which will be collected at GWI, is LDW-PW-PE-G-01. Field QA/QC samples will be assigned modified sample IDs as described below:

- Field replicates will be identified using sample numbers starting with 201. For example, the first field replicate sample collected with a peeper at GWI will be identified as LDW-PW-PE-G-201.
- Identifiers for VOC trip and equipment blanks will contain the prefix "LDW-PW," followed by a unique numeric identifier and the letters "TB" or "EB" to designate trip or equipment blank, respectively. For example, the first trip blank submitted to the laboratory would be LDW-PW-01-TB. The peeper equipment blank would be LDW-PW-PE-01-EB.

3.2.2 Location positioning

Sampling locations will be located by GPS. The GPS unit will receive signals from satellites to produce positioning accuracy to within 1 m. Washington State Plane Coordinate System North coordinates in North American Datum 1983 (NAD83) will be used for the horizontal datum and North American Vertical Datum of 1988 (NAVD88) will be used for the vertical datum.

3.2.3 Porewater sample collection

This section describes the methods to be used to collect samples from both piezometers and peepers.

3.2.3.1 Piezometers

At locations to be sampled with piezometers, one of two types of piezometers will be used: a stainless steel PushPoint mini-piezometer designed by MHE products or an EPA-designed piezometer.

Mini-piezometers are made of small diameter 316 stainless steel and have a screened zone which consists of a series of interlaced machined slots (Figure 3-9). They are inserted so the top of the screen is at least 1 ft below the mudline. Once the desired depth is reached, an internal guard-rod is removed from the probe body. A syringe and tubing is attached to the top of the mini-piezometer to extract the sample from above the water surface.

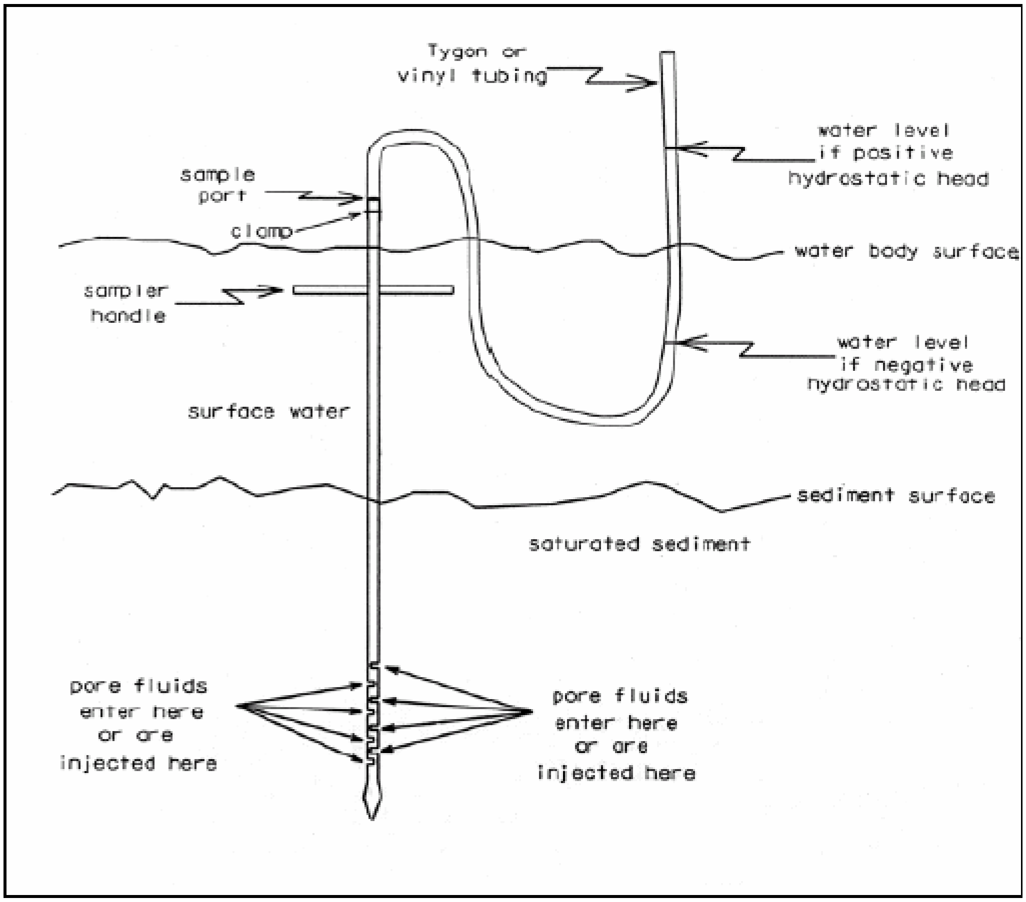

Figure 3-9. Mini-piezometer from MHE (2001)

The other piezometer is an EPA design used in the Hylebos Waterway (EPA and Ecology 2004). This piezometer is installed by inserting a section of steel pipe with a removable tip, so that the screened depth is at least one ft into the sediment. A short section of plastic tubing with six inches of perforations (of approximately 0.01 inches each) at the bottom end and an attached coupling at the other end is then inserted into the pipe (Figure 3-10). The tubing is inserted until the perforated portion is at least 1 ft within the sediment. The pipe is then removed and the inner tubing is connected to a longer section of tubing, which is brought to the surface. A syringe is attached to the tubing to extract the sample from the piezometer. Both types of piezometers can be used in intertidal or subtidal areas. If necessary in deeper areas, piezometers will be deployed from a boat (if possible) and aided by divers. If the shallower locations (5 ft below MLLW) are sampled at low tide, the boat and divers may not be needed.

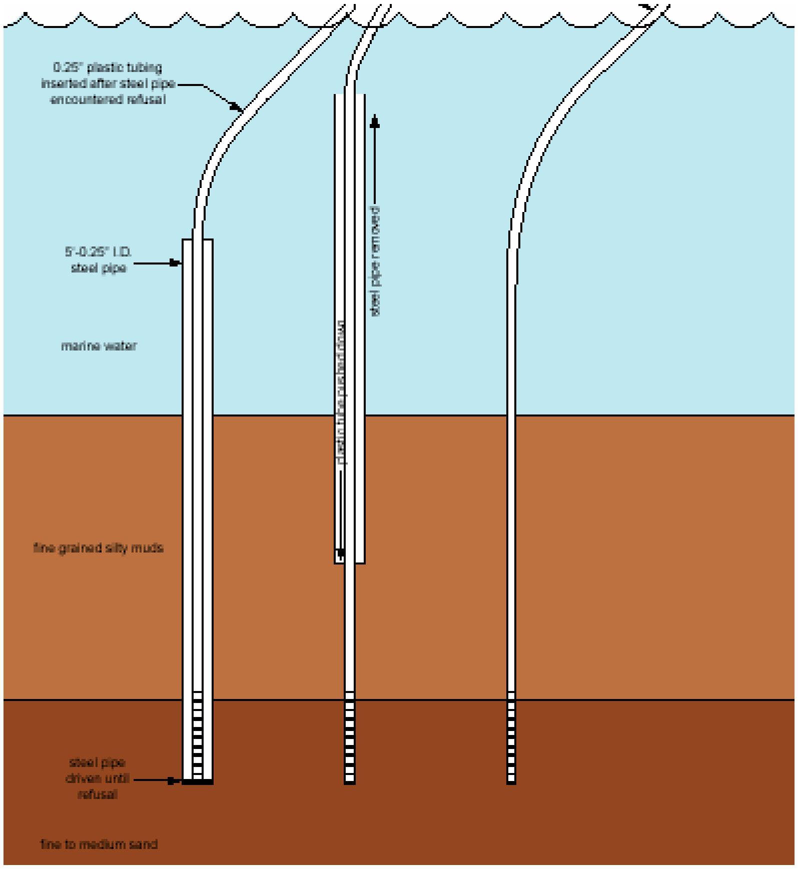

Figure 3-10. EPA-designed piezometer (EPA and Ecology 2004)

A reconnaissance will be conducted the week of June 6, 2005 to test the field equipment and to probe the target locations. Piezometer sampling will be conducted during the week of June 20, 2005, during the four hours encompassing the latter half of a falling tide, when groundwater discharge is expected to be the greatest. It is expected that each site will take one day to sample, but it may be necessary to conduct piezometer sampling over two days at each site. Appendix D shows predicted tide levels in the LDW for June 2005.

The reconnaissance in early June will determine which type of piezometer will be used to collect the sample, and the best method to collect a sample 1 ft below the mudline, or as shallow as possible below 1 ft, if a 1-ft deep sample is not retrievable. Trials of both diver-assisted and deployment-by-boat methods will be conducted during the reconnaissance. In addition, various methods will be tested to collect incrementally deeper samples to a maximum depth of 6 ft. The results of the reconnaissance will be summarized in a brief technical memorandum to document the methods to be used and general targeted depths at which samples will be retrievable during the sampling event the week of June 20, 2005. The targeted depths may need slight modifications during the sampling event to collect a sample at a depth as shallow as possible, but at least 1 ft below the mudline.

Tubing from the piezometer will first be attached to a peristaltic pump to collect sufficient water volume to measure conventional water quality parameters (turbidity, conductivity, pH, dissolved oxygen, temperature, oxidation-reduction potential) prior to collecting the VOC sample. Once the turbidity readings measured with a turbidity meter indicate that the initial turbid water has been flushed, the other water quality parameters will be recorded using a Hydrolab. After measurement of the water quality parameters on samples withdrawn using the peristaltic pump, the VOC sample will be collected using a pre-cleaned syringe attached to the tubing, if possible, to minimize the incorporation of air into the sample. If the sample cannot be collected with a syringe, the peristaltic pump will be used. A minimum of 120 mL of water will be collected from each sampling location described in Section 3.1, and the sample will be handled as described in Sections 3.2.3.3 and 3.3.1.

3.2.3.2 Peepers

Samples will also be collected using "peepers," which are small chambers with polypropylene or nylon screen walls (Figure 3-11). The type of peeper that will be used for this study is based on a design by Dr. Allen Burton of Wright State University. The peeper consists of a cylindrical tube made of cellulose acetate butyrate or Eastman Tenite Butyrate with polyethylene end caps, creating a chamber (Figure 3-11). Windows covered with 40 - 80 µm polypropylene or nylon mesh screen are attached with silicone on the side of the peeper to allow porewater, but not sediment, to enter the chamber.

Porewater samples will be collected by filling the peepers with deionized water, burying them in sediments and allowing dissolved chemicals to diffuse through the screen wall into the peeper. The time needed for VOCs to equilibrate with water in peepers can be as little as 3 days under steady state conditions, but a deployment period of one to two weeks is more common in the field (Ehlke et al. 2002; EPA 2001). This "equilibration" method is preferred because it is representative of porewater conditions over time, incorporating various tidal stages, in contrast to direct sampling methods, which are only indicative of conditions at the time of sampling. However, it is acknowledged that as a result of the tidal influence in the LDW, the concentrations of chemicals in the porewater and the peeper may never reach a true equilibrium condition.

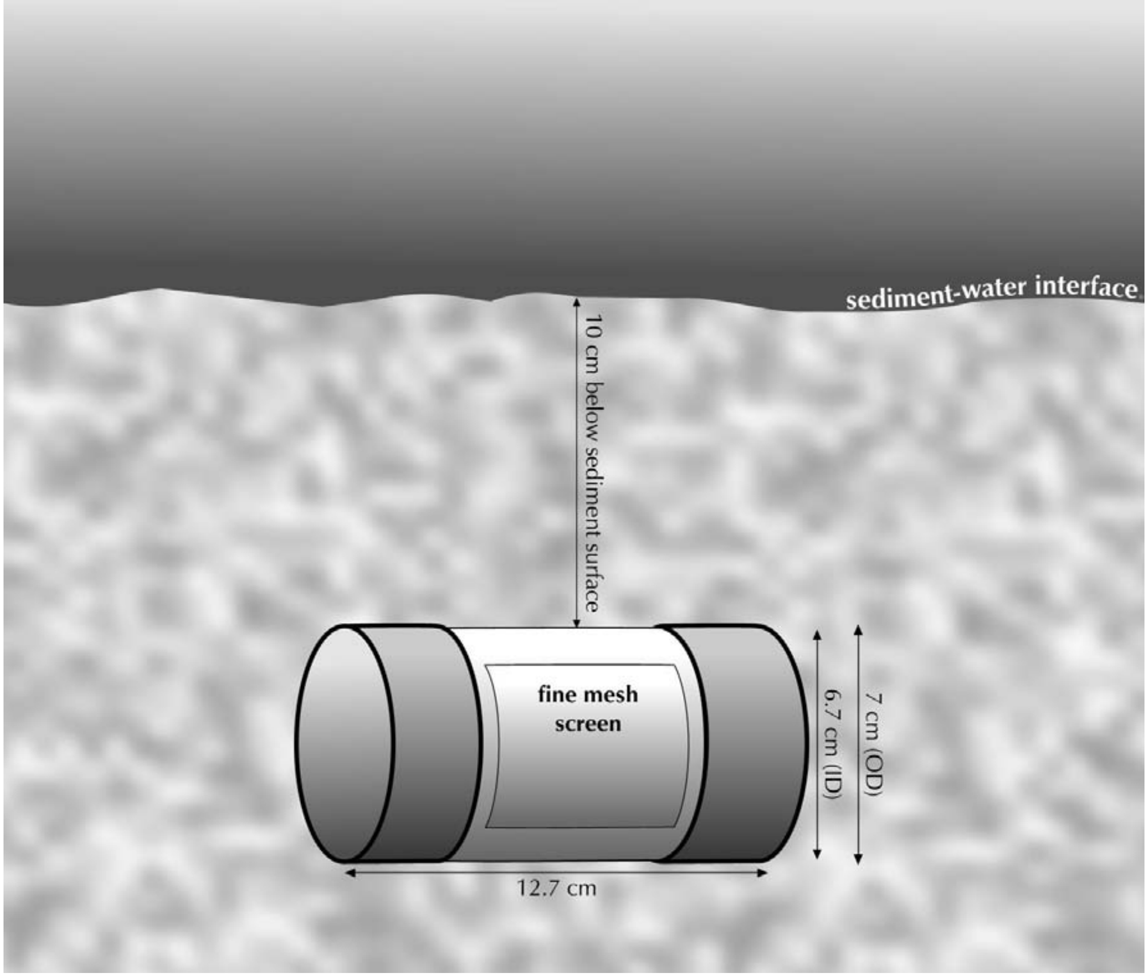

Figure 3-11. Diagram of peeper in place for collecting porewater samples

Peepers will be placed at the 16 sampling locations described in Section 3.1. Peepers will be placed so the top of the peeper is 10 cm below the sediment-water interface by pushing them directly into the sediment to the desired depth in soft sediment, or by digging a hole with a hand-held shovel and then covering the peeper with sediment in harder sediment. Peepers will be placed at low tide when the mudflat is exposed, with as little disturbance to the sediment as possible.

The volume of each peeper is approximately 450 mL. One peeper will have sufficient water volume for withdrawing a sample for VOC analyses (120 mL), with the remaining water volume in the peeper to be used for measurement of conventional water quality parameters (pH, dissolved oxygen, temperature, conductivity, oxidation- reduction potential, and salinity) At one location at each of the two sites, two additional peepers will be deployed adjacent to the first peeper for the collection of triplicate samples for VOC analysis and measurement of conventional parameters. The three peepers will be placed approximately 30 cm apart horizontally.

Each peeper will be secured to an anchored line that will extend across the sediment surface along a transect. The line will be attached to a short stake with flagging at the first peeper at the nearshore end of each transect. At the time of retrieval, the other peepers will be found by following the line. A stake marking the beginning of each transect will also be placed on the shoreline (but not attached to the line).

Peepers will be deployed during a time period surrounding low tide at the two sites the week of July 18, 2005 and will be retrieved approximately two weeks after deployment, during the week of August 1. Appendix D shows predicted tide levels in the LDW for July and August 2005. Field personnel in waders will deploy and retrieve peepers by foot. A diver may be used to deploy and retrieve the peepers if the water is too deep for deployment and retrieval above water. Upon retrieval, peepers will be unburied and a syringe will be inserted through the end of the peeper cap to extract the porewater immediately.

If a diver is needed to retrieve the peepers, the diver will remove the peepers from the sediment and place them into slightly larger container with lids that will be screwed shut. The diver will immediately bring the container to the surface. The crew on the boat will pour off the water from the outer container[3] and insert a syringe through the end of the peeper cap to extract the porewater.

3.2.3.3 Porewater handling

The porewater collected in the syringe from either the piezometer or the peeper will be dispensed into three 40-mL vials with septa caps (pre-preserved with hydrochloric acid). Care will be taken to avoid the entrapment of air bubbles into the sample. The sample vial will be filled from the bottom to the top leaving no headspace, and will be checked to ensure that no air bubbles are trapped in the vial.

Conventional water quality parameters will be measured in the field using a Hydrolab Series 4a Minisonde probe, which will be immersed in a container containing approximately 330 mL of the porewater withdrawn from the peepers after removal of porewater for VOC analysis. The probe will be allowed to equilibrate before taking measurements of conductivity, temperature, dissolved oxygen, pH, salinity, and oxidation-reduction potential. These parameters will also be measured in the LDW at each site just above the sediment surface by lowering the probe to the sediment surface and then raising it just enough so it is no longer in contact with the sediment. The same conventional measurements will then be made just below the water surface. Porewater deployment and collection forms (see Forms 1 and 2, Appendix B) will be completed at each porewater sampling location, as described in Section 2.6.1.

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[3] Dilution of porewater in the peeper with water from the larger container should be insignificant because of low water flow through the 40-80-µm screen and the short time period between peeper retrieval and porewater extraction from the peeper.

3.2.4 Field equipment

The items needed in the field for porewater sampling are identified in Table 3-4. The FC will check that all equipment is included and in working order each day before sampling personnel go in the field. The diver and tender/safety diver will be responsible for their own equipment.

Table 3-4. Porewater sampling field equipment

FIELD EQUIPMENT	
QAPP	Stakes
Health and safety plan	40-mL vials with septa cap and HCl
Field sample collection forms	Trip blanks
Field notebooks (Rite in the Rain®)	Hydrolab
Chain-of-custody forms	Squirt bottle with distilled water
Pens, pencils, Sharpies	Extra membranes for Hydrolab DO probe
GPS (w/ extra batteries)	Gloves
Digital camera	Rubber boots
Cellular phone	Rain gear
Garbage bags	Re-sealable sandwich bags
Coolers	Waders
Ice (wet)	Syringes
LDW maps including property boundaries	Peepers
Porewater location coordinates	Shovel
Property access notification letters	Anchor line
Scuba equipment (supplied by diver)	Diver Safety Manual
Dive plan	Flagging tape
Mini-piezometers and EPA-designed piezometers	Alconox
Tubing	Peristaltic pump

3.2.5 Decontamination procedures

The piezometers will be decontaminated between stations following Puget Sound Estuary Program (PSEP) (1997) guidelines, as follows:

1. Rinse with LDW water until free of sediment
2. Wash with phosphate-free detergent
3. Rinse with distilled water

During collection of porewater, decontamination of tubing, peepers, and syringes is not needed because pre-cleaned equipment will be used at each location. Peepers will require a lengthy cleaning process before use because the potential exists for leaching of certain chemicals from the peeper materials. An equipment blank will be collected and analyzed as described in Section 3.5.1.3 prior to peeper deployment to determine the potential for VOC contamination of the porewater samples from peeper materials.

Acid or solvent washes will not be used in the field because of safety considerations and problems associated with rinsate disposal and sample integrity. Specifically:

- Use of acids or organic solvents may pose a safety hazard to the field crew
- Disposal and spillage of acids and solvents during field activities pose an environmental concern
- Residues of solvents and acids on sampling equipment may affect sample integrity for chemical testing

Any sampling equipment that cannot be cleaned to the satisfaction of the FC will not be used for further sampling activity.

3.2.6 Field-generated waste disposal

All disposable sampling materials and personal protective equipment used in sample processing, such as gloves and paper towels, will be placed in heavyweight 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 as solid waste.

3.3 SAMPLE HANDLING AND CUSTODY

This section describes how individual samples will be processed, labeled, tracked, stored, and transported to the laboratory for analysis. In addition, this section describes sample custody procedures and shipping requirements. Sample custody is a critical aspect of environmental investigations. Sample possession and handling must be traceable from the time of sample collection, through laboratory and data analysis, to delivery of the sample results to the recipient.

3.3.1 Sample handling procedures

After porewater samples are placed in three 40-mL glass vials with septa caps, each vial will be sealed and completely labeled. The vials will be placed in a re-sealable plastic bag by location and placed in a cooler with wet ice. One trip blank will be included in each cooler. Each sample label will contain the project number, sample identification, preservation technique, analyses, date and time of collection, and initials of the person(s) preparing the sample. Sample labels will be filled out as completely as possible prior to the field event. Once completed, the sample label will be affixed to each sample container and covered with clear tape.

3.3.2 Sample custody procedures

Samples are considered to be in custody if they are: 1) in the custodian's (e.g., field or laboratory personnel's) possession or view, 2) retained in a secured place (under lock) with restricted access, or 3) placed in a container and secured with an official seal(s) such that the sample cannot be reached without breaking the seal(s). Custody procedures will be used for all samples throughout the collection, transport, and analytical process, and for all data and data documentation whether in hard copy or electronic format. Custody procedures will be initiated during sample collection. A COC form will accompany samples to the analytical laboratory. 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. Minimum documentation of sample handling and custody will include:

- sample location, project name/task, and unique sample number
- sample collection date and time
- any special notations on sample characteristics or problems
- initials of the person collecting the sample
- date sample was delivered to the laboratory

The FC will be responsible for all sample tracking and custody procedures for samples in the field and for final sample inventory, as well as for maintaining sample custody documentation. The FC will also complete COC forms prior to removing samples from the sampling area. At the end of each day, and prior to transfer, COC entries will be made for all samples. Information on the labels will be checked against sample log entries, and sample tracking forms and samples will be recounted. COC forms will accompany all samples. The COC forms will be signed at each point of transfer. Copies of all COC forms will be retained and included as appendices to the data and analysis report.

The laboratory will ensure that COC forms are properly signed upon receipt of the samples and will note questions or observations concerning sample integrity on the COC forms. The laboratory will contact the project QA/QC Coordinator immediately if discrepancies are discovered between the COC forms and the sample delivery upon receipt.

3.3.3 Shipping requirements and receipt

Sample coolers containing samples for chemical analyses will be hand-delivered to ARI at the end of each day. The temperature of the samples will be checked upon receipt of the coolers with an infrared thermometer. The laboratory will specifically note any coolers that do not contain ice packs or that are not sufficiently cold (4°C ± 2°C) upon receipt.

Each sample will be assigned a unique laboratory number using ARI's Laboratory Information Management System, which is used to match the sample ID with a laboratory ID and to print bottle labels, which are affixed to each sample. After the samples are labeled, a second person will confirm that the sample ID matches the laboratory ID. The laboratory will ensure that a sample-tracking record follows each sample through all stages of laboratory processing. The sample-tracking record must contain, at a minimum, the name/initials of responsible individuals performing the analyses, dates of sample extraction/preparation and analysis, and the type of analysis being performed.

All samples will be handled so as to prevent contamination or loss of any sample. Samples will be assigned a specific storage area within the laboratory and will be kept there until analyzed. The laboratory will not dispose of the environmental samples or sample extracts for this project until notified in writing by the Windward PM.

3.4 ANALYTICAL METHODS REQUIREMENTS

This section provides the selected analytical methods, sample handling requirements, and data quality indicators for laboratory and field water quality analyses.

3.4.1 Analytical methods and laboratory sample handling

The methods of chemical analysis and associated laboratory sample handling requirements are identified in Table 3-54.

Table 3-5. Laboratory analytical methods and sample handling requirements

PARAMETER	ANALYTICAL METHOD	CONTAINER	FILTRATION	SAMPLE PREPARATION METHOD	CLEANUP METHOD	HOLDING TIME	LABORATORY
VOCs	Purge & trap GC/MS (EPA 8260B)	3 40-mL vials w/septa cap, preserved with hydrochloric acid	none	EPA SW5030B	none	14 days	ARI

GC/MS – gas chromatography/mass spectrometry

3.4.2 Data quality indicators

The parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. Table 3-6 lists DQIs for analysis of VOCs. The MDL and RL values for each analyte are presented in Appendix C.

Table 3-6. Summary of DQIs for laboratory analyses

PARAMETER	UNITS	SENSITIVITY		PRECISION[a]	ACCURACY[b]	COMPLETENESS
		MDL	RL			
VOCs	µg/L	0.18-1.26	1-200	±30%	75-125%	95%

[a] Precision is assessed by laboratory duplicate analyses (duplicate samples, matrix spike duplicates, LCS duplicates)

[b] Accuracy is assessed by the percent recoveries of matrix spikes, laboratory control samples, and surrogates

3.4.2.1 Precision

Precision is the measure of the reproducibility among individual measurements of the same property, usually under similar conditions, such as multiple measurements of the same sample. Precision is assessed by performing multiple analyses on a sample and is expressed as an RPD when duplicate analyses are performed and as a percent relative standard deviation when more than two analyses are performed on the same sample (e.g., triplicates). Precision is assessed by laboratory duplicate analyses (duplicate samples, matrix spike duplicates, laboratory control sample duplicates) for all parameters. Precision measurements can be affected by the nearness of a chemical concentration to the MDL, where the percent error (expressed as either percent relative standard deviation or RPD) increases. The equations used to express precision are as follows:

$$\text{RPD} = \frac{\left|\text{measured conc} - \text{measured duplicate conc}\right|}{(\text{measured conc} + \text{measured duplicate conc}) \div 2} \times 100 \qquad \textbf{Equation 1}$$

$$\%\text{RSD} = (\text{SD}/\text{D}_{\text{ave}}) \times 100 \qquad \textbf{Equation 2}$$

where:

$$\text{SD} = \sqrt{\left(\frac{\Sigma(\text{D}_n - \text{D}_{\text{ave}})^2}{(n-1)}\right)}$$

D = sample concentration
D_{ave} = average sample concentration
n = number of samples
SD = standard deviation

3.4.2.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Accuracy may be expressed as a percent recovery for surrogates, matrix spike analyses, and laboratory control sample analyses. The equation used to express accuracy for spiked samples is as follows:

$$\text{Percent recovery} = \frac{\text{spike sample result} - \text{unspiked sample result}}{\text{amount of spike added}} \times 100 \qquad \textbf{Equation 3}$$

3.4.2.3 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent an environmental condition. The sampling approach was designed to address the specific objective described in Section 2.2.1.

3.4.2.4 Comparability

Comparability expresses the confidence with which one data set can be evaluated in relation to another data set. Therefore, the sample collection and chemical and physical testing will adhere to the most recent PSEP QA/QC procedures (EPA 1999; PSEP 1997) and EPA and PSEP analysis protocols.

3.4.2.5 Completeness

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. Completeness will be calculated as follows:

$$\text{Completeness} = \frac{\text{number of valid measurements}}{\text{total number of data points planned}} \times 100 \qquad \textbf{Equation 4}$$

The DQI for completeness for all components of this project is 95%. Data that have been qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that have been qualified as rejected will not be considered valid for the purpose of assessing completeness.

3.4.2.6 Sensitivity

Analytical sensitivity is a measure of both the ability of the analytical method to detect the analyte and the concentration that can be reliably quantified. The minimum concentration of the analyte that can be detected is the MDL. The minimum concentration that can be reliably quantified is the reporting limit (RL). ARI uses both MDLs and RLs for reporting analyte concentrations. For this study, MDLs and RLs will be used as measures of sensitivity for each analysis. Nondetected results will be reported at the RL. Detected concentrations between the MDL and RL will be qualified as estimated by the laboratory (J qualifier).

Appendix C presents an evaluation of whether, for those VOCs that have previously been detected in groundwater or seeps, RLs for porewater VOC analyses are sufficiently sensitive to meet risk-based water concentrations for the protection of benthic invertebrates for all chemicals. Based on that evaluation, the methods are sufficiently sensitive to meet the needs of the porewater evaluation.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

3.5.1 Field quality control samples

Although data validation guidelines have not been established for field quality control samples, the data resulting from the analysis of field QA/QC samples is useful in identifying possible problems resulting from sample collection or sample processing in the field. All field quality control samples will be documented in the field logbook and verified by the project QA/QC Coordinator or a designee.

Field QA/QC samples will be used to evaluate the efficiency of collection equipment cleaning procedures, and variability attributable to sample handling conditions. Three types of field QA/QC samples will be collected during each sampling event: field replicates, trip blanks, and equipment blanks. These sample types are further described below. Locations for collection of field QA/QC samples will be selected in the field by the FC.

3.5.1.1 Field replicate samples

Field replicate porewater samples will be collected from three separate peepers deployed at one location at each site, and submitted for VOC analysis. The purpose of the field replicate (triplicate in this case) is to evaluate variability attributable to field conditions and sample handling.

3.5.1.2 Trip blanks

Trip blanks will be used to determine whether VOCs are introduced to samples during holding, shipping, or storage prior to analysis. Trip blanks will consist of deionized water sealed in a VOC sample container by the analytical laboratory. Trip blanks will be transported from the laboratory to the field, will remain in the cooler during sampling, and then will be returned to the laboratory unopened for analysis. One trip blank will be included in each cooler.

3.5.1.3 Equipment blank

One equipment blank will be collected to determine the potential for VOCs to leach from peeper materials into porewater samples. This sample will be collected by placing a peeper in a capped decontaminated glass jar filled with deionized water. After at least 48 hours, a water sample will be withdrawn from the jar using a syringe, and analyzed for VOCs.

3.5.2 Chemical analyses

Before analyzing the samples, the laboratory must provide written protocols for the analytical methods to be used, calculate MDLs for each analyte in each matrix of interest, and establish an initial calibration curve for all analytes. The laboratory must demonstrate their continued proficiency by participation in interlaboratory comparison studies and through repeated analysis of certified reference materials, calibration checks, laboratory reagent blanks, and spiked samples.

3.5.2.1 Determination of MDLs

The MDL is defined as the lowest concentration of an analyte or compound that a method can detect in either a sample or a blank with 99% confidence. The laboratory determines MDLs using standard procedures outlined in 40CFR§136. In summary, seven replicate samples will be fortified at 1 to 5 times (but not to exceed 10 times) the expected MDL concentration. The MDL is then determined by calculating the standard deviation of the replicates and multiplying by a factor of 3.14.

3.5.2.2 Sample delivery group

Project- and/or method-specific quality control measures such as matrix spikes and matrix spike duplicates will be analyzed per sample delivery group (SDG) or sample batch. An SDG is defined as no more than 20 samples or a group of samples received at the laboratory within a two-week period. Although an SDG may span two weeks, all holding times specific to each analytical method will be met for each sample in the SDG.

3.5.2.3 Laboratory quality control criteria

The analyst will review results of QC analyses (described below) from each sample group immediately after a sample group has been analyzed. The QC sample results will then be evaluated to determine whether control limits have been exceeded. If control limits are exceeded in the sample group, the project QA/QC Coordinator will be contacted immediately, and corrective action, such as method modifications followed by reprocessing of the affected samples, will be initiated before processing a subsequent group of samples.

All primary chemical standards and standard solutions used in this project will be traceable to the National Institute of Standards and Technology, Environmental Resource Associates, National Research Council of Canada, or other documented, reliable, commercial sources. The accuracy of the standards will be verified by comparison with an independent standard. Laboratory QC standards are verified in a multitude of ways. Second-source calibration verifications are run (i.e., same standard, two different vendors) for calibrations. New working standard mixes (calibrations, spikes, etc.) are verified against the results of the original solution and must be within 10%. Newly purchased standards are verified against current data. Any impurities found in the standard will be documented. The following sections summarize the procedures that will be used to assess data quality throughout sample analysis. Table 3-7 summarizes the QC samples to be analyzed by the laboratory. The associated control limits for precision and accuracy are summarized in Table 3-6.

Table 3-7. Laboratory quality control sample analysis summary

ANALYSIS TYPE	INITIAL CALIBRATION	CONTINUING CALIBRATION	MATRIX SPIKES	MATRIX SPIKE DUPLICATES	METHOD BLANKS	SURROGATE SPIKES	LABORATORY CONTROL SAMPLES
VOCs	prior to analysis	daily	1 per batch or SDG	1 per batch or SDG	each batch or SDG	each sample	1 per batch or SDG

Matrix Spikes and Matrix Spike Duplicates

The analysis of matrix spike samples provides information on the efficiency of the purge and trap method and how it may be biased by the sample matrix. By performing duplicate matrix spike analyses, information on the precision of the method is also provided for organic analyses. A minimum of one matrix spike and matrix spike duplicate will be analyzed for each sample group or for every 20 samples, whichever is more frequent, when possible.

Surrogate Spikes

All project samples analyzed will be spiked with appropriate surrogate compounds as defined in the analytical methods. Surrogate recoveries will be reported by the laboratory; however, no sample results will be corrected for recovery using these values.

Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. A minimum of one method blank will be analyzed for each extraction batch or for every 20 samples, whichever is more frequent.

Laboratory Control Samples

Laboratory control samples are analyzed as a measure of the accuracy of the analyses. Laboratory control sample recoveries will be reported by the laboratories; however, sample results will not be corrected for recovery using these values.

3.6 FIELD AND LABORATORY INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

The FC will be responsible for overseeing the testing, inspection, and maintenance of all field equipment. Prior to each field event, measures will be taken to test, inspect, and maintain all field equipment. All equipment used, including the GPS unit, digital camera, and Hydrolab, will be tested for use before leaving for the field event.

The laboratory PM will be responsible for ensuring that laboratory equipment testing, inspection, and maintenance requirements are met. The calibration methods used in calibrating the analytical instrumentation are described in the following section.

3.7 INSTRUMENT CALIBRATION AND FREQUENCY

Multipoint initial calibration will be performed on each instrument at the start of the project, after each major interruption to the analytical instrument, and when any continuing calibration does not meet the specified criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibrations will be performed daily for VOC analyses.

Field equipment will be calibrated according to the manufacturer's procedures presented in the user's manuals on each day of sampling prior to use in the field. Calibration will be checked no less frequently than called for by the instrument manuals for the types of measurement being made and the conditions. Calibration information will be recorded in the field notebook. Equipment will be handled according to manufacturer's recommendations. Unusual or questionable readings will be noted and duplicate readings made. Precision will be assessed by comparing the results from duplicate measurements, as discussed in Section 3.4.2.1.

Calibration of analytical equipment used for chemical analysis includes instrument blanks or continuing calibration blanks, which provide information on the stability of the baseline established. Continuing calibration blanks will be analyzed immediately after the continuing calibration verification at a frequency of one blank for every 12 hours for VOC analyses. If the continuing calibration does not meet the specified criteria, the analysis must stop. Analysis may resume after corrective actions have been taken to meet the method specifications. All project samples analyzed by an instrument found to be out of compliance must be reanalyzed.

3.8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

The field team leaders for each sampling effort will have a checklist of supplies required for each day in the field (see Section 3.2.4). The FC will gather and check these supplies daily for satisfactory conditions before each field event. Batteries used in the GPS unit and the digital camera will be checked daily and recharged as necessary. Sample containers will be inspected to ensure that they are the correct size and quantity and were not damaged in shipment.

3.9 DATA MANAGEMENT

All data will be recorded on field forms, which will be checked by the FC at the end of each field day. After sampling efforts are completed, all data from field forms will be entered into a Microsoft Excel® spreadsheet. A QC check will be done to ensure that all data were properly transferred from the field form to the spreadsheet (see Section 5.1). This spreadsheet will be kept on the Windward network drive, which is backed up daily. Field forms will be archived in the Windward library.

Analytical laboratories are expected to submit data in an electronic format as described in Section 2.6.2 and Table 2-5. The laboratory PM should contact the project QA/QC coordinator prior to data delivery to discuss specific format requirements.

A library of routines will be used to translate typical electronic output from laboratory analytical systems and to generate data analysis reports. The use of automated routines ensures that all data are consistently converted into the desired data structures and that operator time is kept to a minimum. In addition, routines and methods for quality checks will be used to ensure that such translations are correctly applied.

Written documentation will be used to clarify how field and laboratory duplicates and QA/QC samples were recorded in the data tables and to provide explanations of other issues that may arise. The data management task will include keeping accurate records of field and laboratory QA/QC samples so that project team members who use the data will have appropriate documentation. Data management files will be stored on a secure computer.

4.0 Assessment and Oversight

4.1 COMPLIANCE ASSESSMENTS AND RESPONSE ACTIONS

EPA, Ecology, or other management agencies may observe field activities during each sampling event, as needed. If situations arise where there is an inability to follow QAPP methods precisely, the Windward PM will determine the appropriate actions or consult EPA and Ecology if the issue is significant.

4.1.1 Compliance assessments

Laboratory and field performance assessments consist of on-site reviews (conducted by EPA) of QA systems and equipment for sampling, calibration, and measurement. EPA personnel may conduct a laboratory audit prior to sample analysis. Any pertinent laboratory audit reports will be made available to the project QA/QC coordinator upon request. The laboratory is required to have written procedures addressing internal QA/QC; these procedures will be submitted for review by the Project QA/QC coordinator to ensure compliance with the QAPP. The laboratory and QA/QC coordinators are required to ensure that all personnel engaged in sampling and analysis tasks have appropriate training.

4.1.2 Response actions for field sampling

The FC or a designee will be responsible for correcting equipment malfunctions throughout the field sampling effort and resolving situations in the field that may result in nonconformance or noncompliance with the QAPP. All corrective measures will be immediately documented in the field logbook, and Protocol Modification Forms will be completed (Form 3, Appendix B).

4.1.3 Corrective action for laboratory analyses

The laboratory is required to comply with the standard operating procedures previously submitted to the project QA/QC coordinator. The laboratory PM will be responsible for ensuring that appropriate corrective actions are initiated as required for conformance with this QAPP. All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data.

4.2 REPORTS TO MANAGEMENT

Progress reports will be prepared by the FC for LDWG following the sampling event. The project QA/QC coordinator will also report to LDWG after the sampling is completed and the samples have been submitted for analysis, when information is received from the laboratory, and when analysis is complete. The status of the samples and analysis will be indicated with emphasis on any deviations from the QAPP. A data and analysis report will be written after validated data are available, as described in Section 2.6.4.

5.0 Data Validation and Usability

5.1 DATA VALIDATION

Data are not considered final until validated. Data validation will be conducted following EPA (1999) guidance.

The data validation process begins in the laboratory. The laboratory analyst is responsible for ensuring that the analytical data are correct and complete, that appropriate procedures have been followed, and that QC results are within the acceptable limits. In addition, laboratory supervisory personnel or QA specialists review and evaluate data.

The project QA/QC coordinator is responsible for ensuring that all analyses performed by the laboratories are correct, properly documented, and complete, and that they satisfy the data quality objective for this project, as specified in this QAPP.

Independent third-party data review and summary validation of the analytical chemical data will be conducted by Stella Cuenco of Laboratory Data Consultants, Inc. (or a suitable alternative). The first SDG submitted to the laboratory will undergo full data validation. Full data validation parameters include:

- quality control analysis frequencies
- evaluation of chain of custody and sample handling procedures
- analysis holding times
- laboratory blank contamination
- instrument calibration
- surrogate recoveries
- LCS recoveries
- matrix spike recoveries
- matrix spike/matrix spike duplicate RPDs
- compound identifications – verification of raw data with the reported results (10% of samples)
- compound quantitations – verification of calculations and reporting limits (10% of samples)
- instrument performance check using ion abundances
- internal standard areas and retention time shifts

If no discrepancies are found between reported results and raw data in the set that undergoes full data validation, then the validation of the subsequent SDGs will proceed as a summary validation, including an evaluation of all the summary forms for calibrations, instrument performance, and internal standard summaries. Data verification and validation will be conducted in accordance with EPA guidance (EPA 2002c), as well as the project's specified DQIs (Table 3-5), the technical specifications of the methods indicated in Table 3-4, and EPA (1999; EPA 2002d) guidance for organic data review. The EPA PM may have EPA peer review the third-party validation or perform data assessment/validation on a percentage of the data.

All discrepancies and requests for additional, corrected data will be discussed with the laboratory prior to issuing the formal data validation report. All contacts with the laboratory will be documented in a communication report. Review procedures used and findings made during data validation will be documented on worksheets. Laboratory Data Consultants, Inc. will prepare a data validation report that will list the samples (using LDW sample numbers and corresponding laboratory numbers) and the suite of parameters evaluated, and will provide a brief discussion of each data validation parameter, focusing on exceedances, out-of-control QC results, and their effects on the quality of the data reported. Only validated data with appropriate qualifiers will be released for general use.

5.2 RECONCILIATION WITH DATA QUALITY OBJECTIVES

Data quality assessment will be conducted by the project QA/QC coordinator in consultation with EPA guidelines. The results of the third-party independent review and validation will be reviewed and cases in which the project DQIs were not met will be identified. The usability of the data will be determined in terms of the magnitude of the DQI exceedance.

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Map Folio

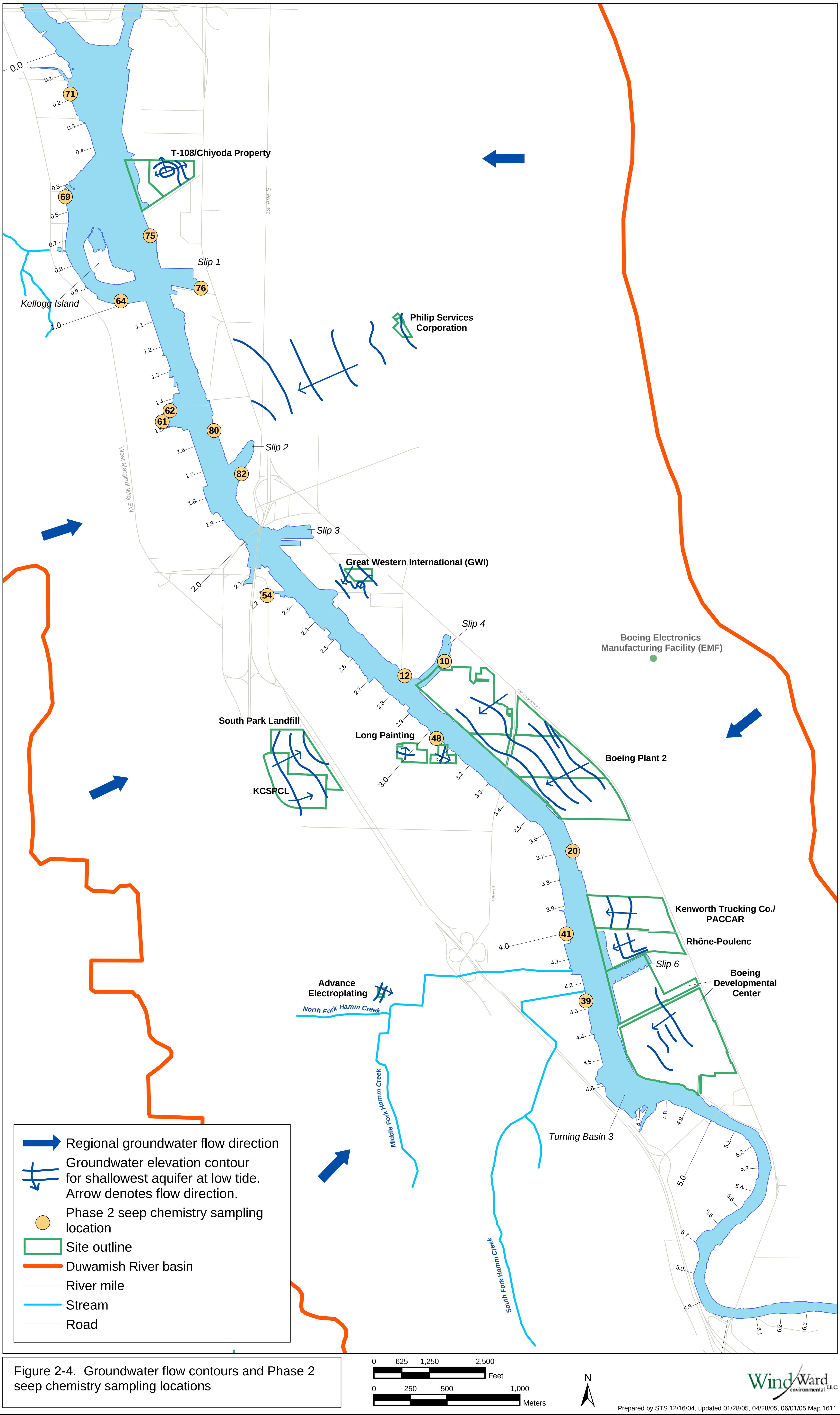

Figure 2-4. Groundwater flow contours and Phase 2 seep chemistry sampling locations

Prepared by STS 12/16/04, updated 01/28/05, 04/28/05, 06/01/05 Map 1611

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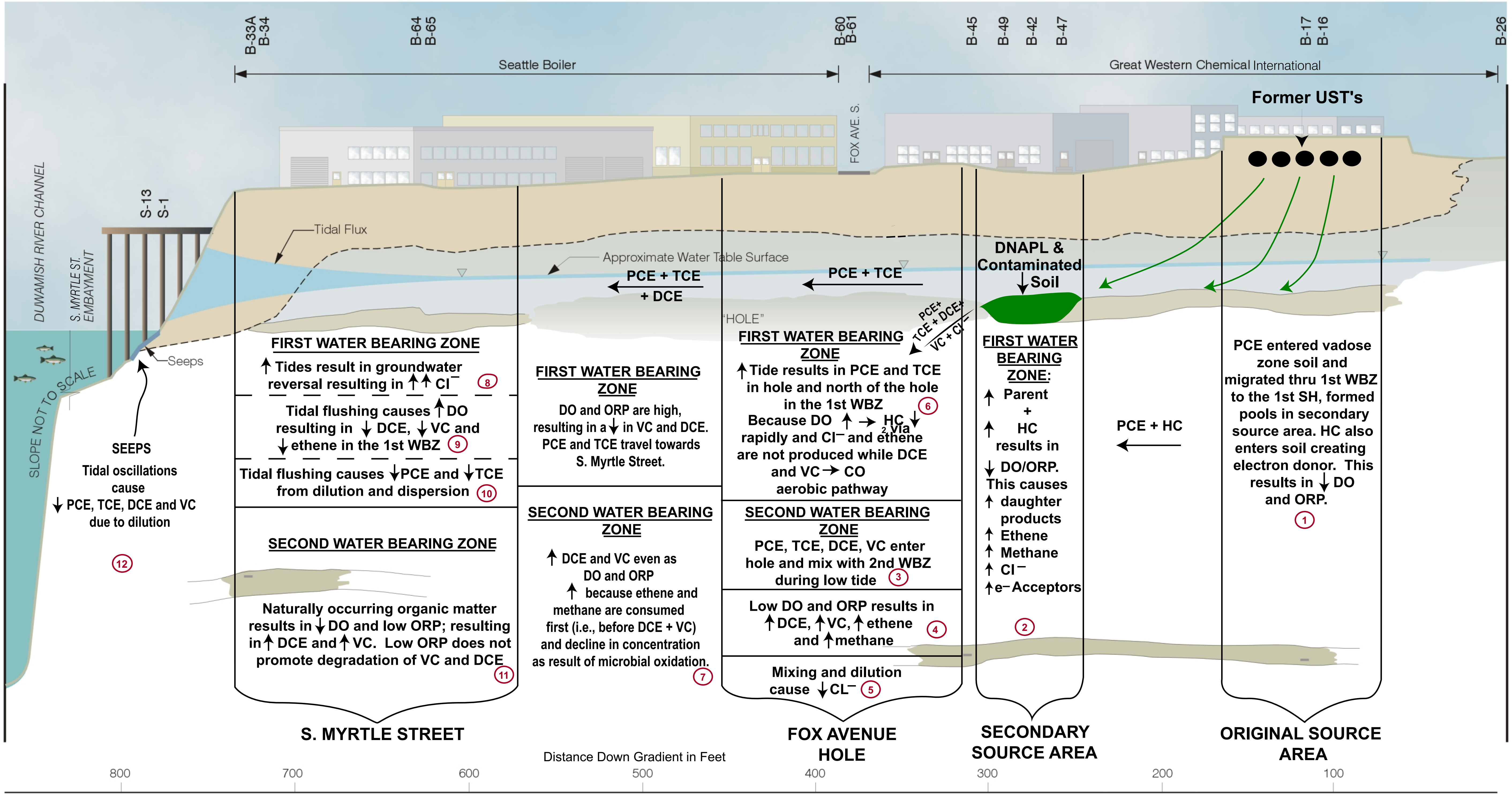


SEEPS
Tidal oscillations cause ↓ PCE, TCE, DCE and VC due to dilution ⑫

FIRST WATER BEARING ZONE

↑ Tides result in groundwater reversal resulting in ↑↑ Cl^- ⑧

Tidal flushing causes ↑ DO resulting in ↓ DCE, ↓ VC and ↓ ethene in the 1st WBZ ⑨

Tidal flushing causes ↓ PCE and ↓ TCE from dilution and dispersion ⑩

SECOND WATER BEARING ZONE

Naturally occurring organic matter results in ↓ DO and low ORP; resulting in ↑ DCE and ↑ VC. Low ORP does not promote degradation of VC and DCE ⑪

S. MYRTLE STREET

FIRST WATER BEARING ZONE

DO and ORP are high, resulting in a ↓ in VC and DCE. PCE and TCE travel towards S. Myrtle Street.

SECOND WATER BEARING ZONE

↑ DCE and VC even as DO and ORP ↑ because ethene and methane are consumed first (i.e., before DCE + VC) and decline in concentration as result of microbial oxidation. ⑦

FIRST WATER BEARING ZONE

↑ Tide results in PCE and TCE in hole and north of the hole in the 1st WBZ ⑥
Because DO ↑ → HC ↓ $_2$ via rapidly and Cl^- and ethene are not produced while DCE and VC → CO aerobic pathway

SECOND WATER BEARING ZONE

PCE, TCE, DCE, VC enter hole and mix with 2nd WBZ during low tide ③

Low DO and ORP results in ↑ DCE, ↑ VC, ↑ ethene and ↑ methane ④

Mixing and dilution cause ↓ CL^- ⑤

FOX AVENUE HOLE

FIRST WATER BEARING ZONE:

↑ Parent
+
↑ HC
results in
↓ DO/ORP.
This causes
↑ daughter products
↑ Ethene
↑ Methane
↑ Cl^-
↑ e− Acceptors
②

SECONDARY SOURCE AREA

PCE entered vadose zone soil and migrated thru 1st WBZ to the 1st SH, formed pools in secondary source area. HC also enters soil creating electron donor. This results in ↓ DO and ORP. ①

ORIGINAL SOURCE AREA

① See Sections 2.3.3.4, 4.3.1.1, 5.1.2 and 5.3.1
② See Sections 2.3.3.4, 4.2.1, 4.3.2, 4.4, 5.2.3, 5.2.4.1 and 5.3.2.1
③ See Sections 2.3.3.4, 2.4.2.2, 2.4.2.3, 2.4.4.4 and Appendix C
④ See Sections 4.4.1, 5.2.4, 5.2.5.2 and Appendix G
⑤ See Sections 2.4.2.3, 2.4.4.4, 4.4.2.1 and Appendix C
⑥ See Sections 2.4.2.2, 2.4.4, 4.4, 5.2.4 and Appendices C and G
⑦ See Sections 4.4., 5.2.3, 5.2.5, and Appendices G and J
⑧ See Sections 2.4.4, 2.4.5, 4.4.2.1, and Appendix C
⑨ See Sections 2.4.4, 4.4.1.1, 5.2.3, 5.2.4 and Appendix J
⑩ See Sections 2.4.4, 4.2.2, 4.2.3, 4.3.1.4 and Appendix D
⑪ See Sections 2.3.3, 2.4.3, 2.5, 4.4.1, 5.2.4 and Appendices C and D
⑫ See Sections 2.4.4, 4.2.3, 4.3.1.4, 5.1.1 and Appendices B, D and G

LEGEND
→ Means not increasing or decreasing
↑ Means increase or increasing
↓ Means decrease or decreasing
e− acceptor = electron acceptor
ORP = oxidation/reduction potential
HC = Hydrocarbon

Horizontal Scale in Feet
0 60 120
0 10 20
Vertical Scale in Feet
Vertical Exaggeration: 6X

Floyd & Snider Inc.

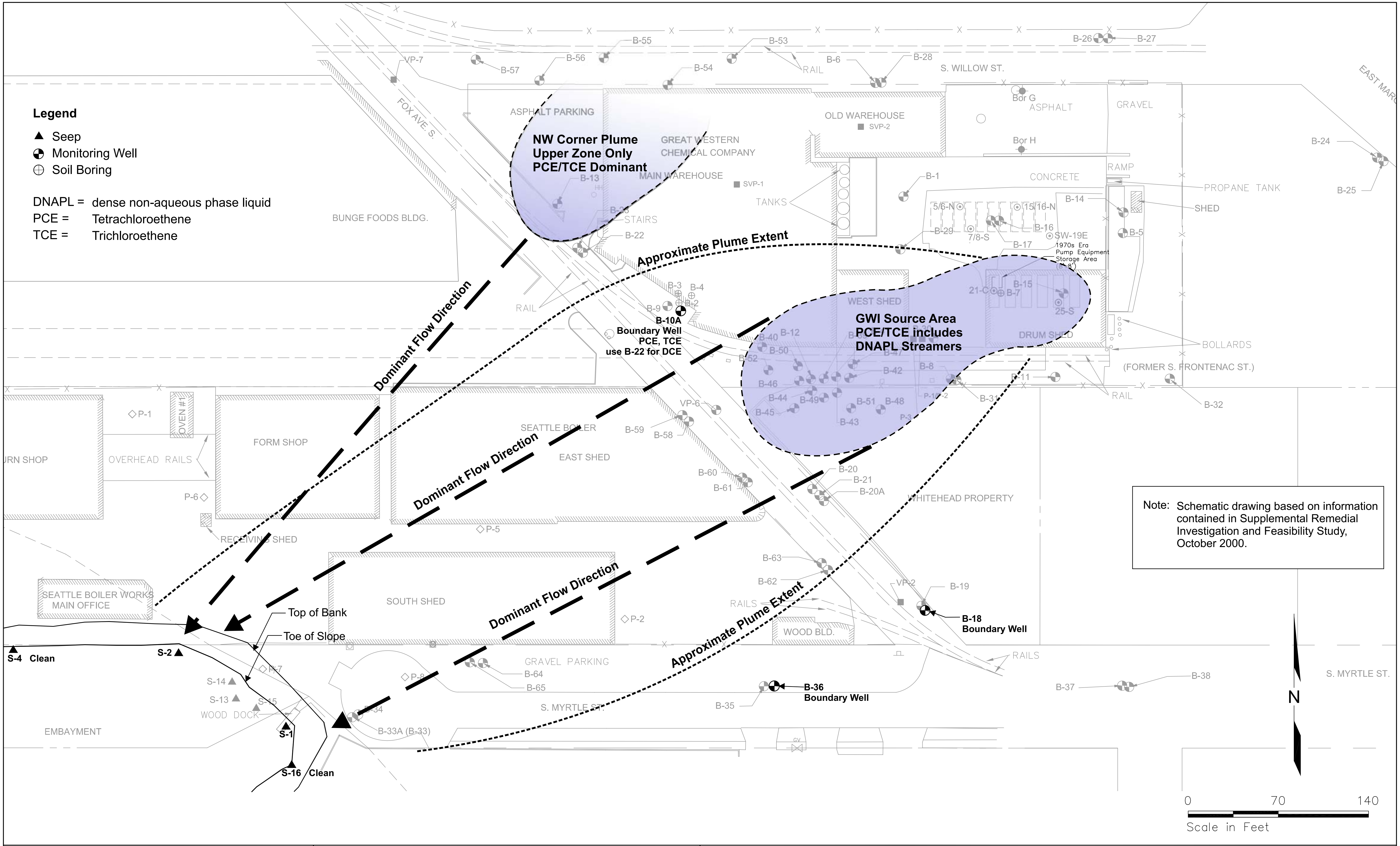
TERRA VAC

Great Western
Chemical Company
Seattle, Washington

Figure 3.1
Site Conceptual Model for
the Degradation of Chlorinated Ethenes

Figure reproduced from Figure 5.15 (Terra Vac and Floyd & Snider 2000)

pce1a.ai 10/18/2000



Note: Schematic drawing based on information contained in Supplemental Remedial Investigation and Feasibility Study, October 2000.

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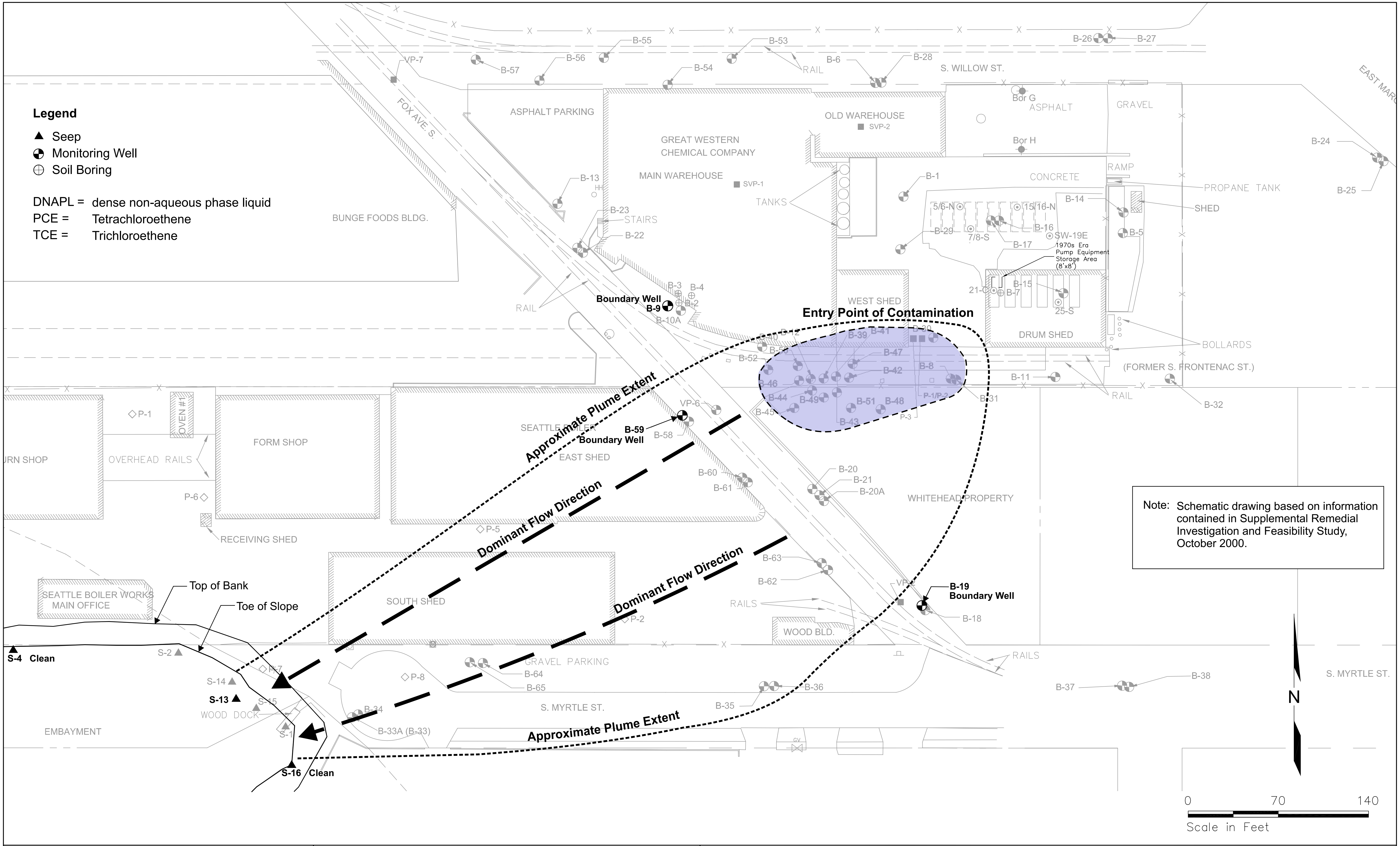
Figure 3-2
Primary Plumes and Discharge Areas
1st Water-Bearing Zone



Legend

▲ Seep
◕ Monitoring Well
⊕ Soil Boring

DNAPL = dense non-aqueous phase liquid
PCE = Tetrachloroethene
TCE = Trichloroethene

Note: Schematic drawing based on information contained in Supplemental Remedial Investigation and Feasibility Study, October 2000.

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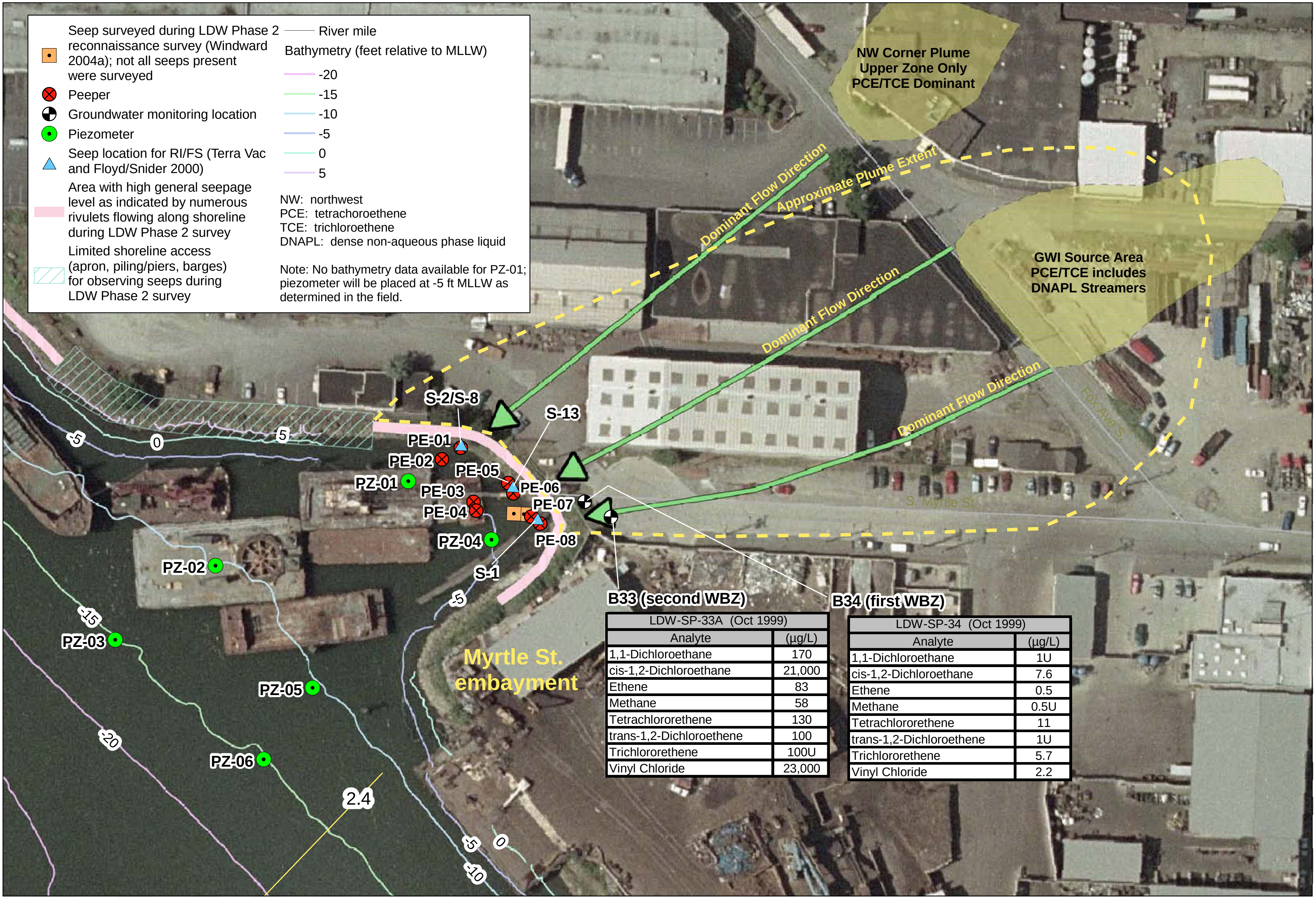
Figure 3-3
Primary Plumes and Discharge Areas
2nd Water-Bearing Zone



LDW-SP-33A (Oct 1999)	
Analyte	(µg/L)
1,1-Dichloroethane	170
cis-1,2-Dichloroethane	21,000
Ethene	83
Methane	58
Tetrachlororethene	130
trans-1,2-Dichloroethene	100
Trichlororethene	100U
Vinyl Chloride	23,000

LDW-SP-34 (Oct 1999)	
Analyte	(µg/L)
1,1-Dichloroethane	1U
cis-1,2-Dichloroethane	7.6
Ethene	0.5
Methane	0.5U
Tetrachlororethene	11
trans-1,2-Dichloroethene	1U
Trichlororethene	5.7
Vinyl Chloride	2.2

Figure 3-6. Phase 2 porewater sampling locations shown in relation to GWI groundwater monitoring wells and seeps

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Prepared by STS 04/04/05, updated 06/01/05 Map 1780

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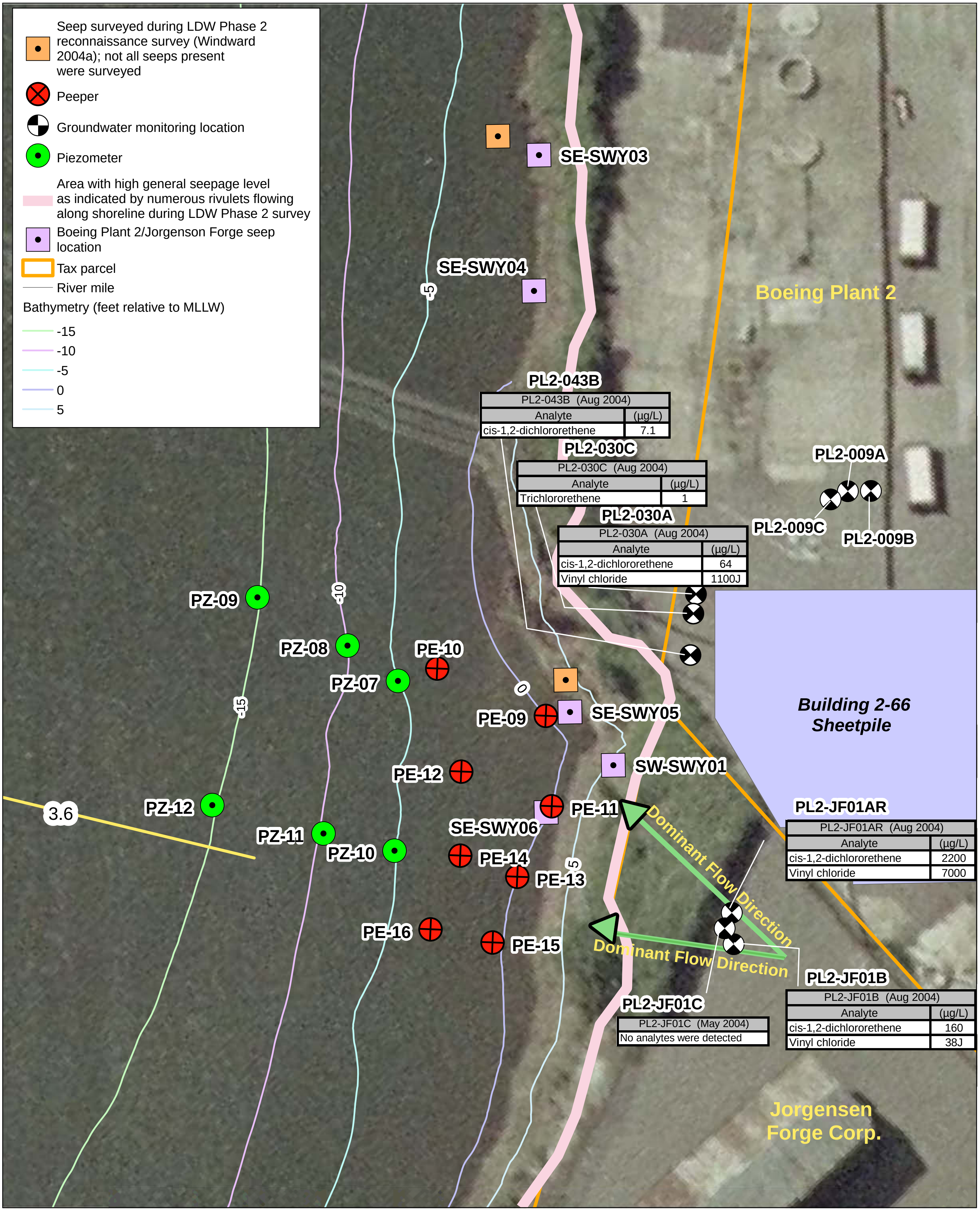

PL2-043B (Aug 2004)	
Analyte	(µg/L)
cis-1,2-dichlororethene	7.1

PL2-030C (Aug 2004)	
Analyte	(µg/L)
Trichlororethene	1

PL2-030A (Aug 2004)	
Analyte	(µg/L)
cis-1,2-dichlororethene	64
Vinyl chloride	1100J

PL2-JF01AR (Aug 2004)	
Analyte	(µg/L)
cis-1,2-dichlororethene	2200
Vinyl chloride	7000

PL2-JF01B (Aug 2004)	
Analyte	(µg/L)
cis-1,2-dichlororethene	160
Vinyl chloride	38J

PL2-JF01C (May 2004)
No analytes were detected

Figure 3-7. Phase 2 porewater sampling locations shown in relation to Boeing groundwater monitoring wells and seeps

Windward environmental LLC

Prepared by STS 04/04/05, updated 06/01/05 Map 1781

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