DRAFT
REMEDIAL INVESTIGATION REPORT

UNOCAL EDMONDS BULK FUEL TERMINAL

EDMONDS, WASHINGTON

Prepared for

UNOCAL Corporation

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EXECUTIVE SUMMARY

The UNOCAL Edmonds Bulk Fuel Terminal comprises approximately 47 acres of land on and adjacent to the northern slope of a hillside and lies within approximately 1,000 feet of the Puget Sound Shoreline. The site is underlain by fill, alluvium, and a sequence of glacial and pre-glacial deposits. Groundwater is primarily found in one site-wide aquifer, at depths generally less than 8 feet below ground surface (bgs) in the lower yard, and 20 to 140 feet bgs in the upper yard. Groundwater flow is generally toward the north.

The Terminal, which operated from 1923 to 1991, was used for the bulk storage and distribution of petroleum fuels. The 22-acre lower yard consists of office buildings, former truck loading racks, aboveground piping, underground storage tanks (USTs) and vaults, detention basins, and an oil/water separator. Previous operations also included an air-blown asphalt plant, an asphalt packaging warehouse, and a railcar loading/unloading facility. The 25-acre upper yard consists of aboveground tanks, above-grade piping, and a garage and warehouse. All tanks and lines at the Terminal are empty.

The remedial investigation was performed between October 1994 and August 1996. Field investigations included 31 surface soil samples, 120 shallow soil borings, installation of 39 additional monitoring wells and 9 piezometers, over 375 soil samples, 17 basin sediment/soil samples, 15 upland sediment samples, 3 test pits, and 4 test trenches. Four quarters of groundwater samples were collected, twelve monthly rounds of water levels were measured, one round of surface water and storm water samples were collected, and aquifer characterization tests were performed.

The primary environmental impacts at the Terminal include free product on the groundwater table, related petroleum hydrocarbon chemicals in subsurface soil and groundwater, and paint/sand blast grit-related metals in the surface soil. Free product has been found in six lower yard plumes at the Terminal. These plumes are the result of releases during former Terminal operations. Approximately 9,500 gallons of product have been recovered from these plumes as of December 2000, and it is estimated that approximately 3,100 gallons of product remain in these plumes. Chemical analyses of recovered product indicate that the free product consists of gasoline-range, diesel-range, and oil-range hydrocarbons. Field observations indicate that much of the free product may be heavier-end hydrocarbons. Based on product thickness measurements over the last 13 years, product migration rates are low and are estimated at less than 5 feet per year.

Petroleum hydrocarbon constituents dissolved in groundwater were primarily found near free product plumes and in areas with free-phase product trapped in the vadose zone near the water table. These chemicals were not found in significant concentrations on the north side of Detention Basin No. 1, beneath and immediately downgradient of the upper yard, in deeper lower yard monitoring wells, or off site along the BNRR right of way.[1] Except for zinc, metals concentrations in groundwater were generally low, with the highest concentrations found in isolated locations around the Terminal. Zinc was the most frequently detected metal in groundwater. Non-BTEX volatile organic compounds were not found in groundwater at the Terminal.

High concentrations of petroleum hydrocarbons in soil were primarily found near free product plumes and in areas with free-phase product trapped in the vadose zone. High concentrations of petroleum hydrocarbons were also found in the material within Detention Basin No. 1. These chemicals were not found in significant concentrations along the west and north sides of Detention Basin No. 1, in most of the random lower yard soil borings, in random upper yard soil borings, or off site along the BNRR right of way. Non-BTEX volatile organic compounds and non-PAH semivolatile organic compounds were not found in significant concentrations in Terminal soil. Elevated metals concentrations were found in surface soil in areas of sand blast grit and paint chips which occur under pipe runs and manifolds, in isolated grit piles, and in certain tank basins. Leachable metals concentrations were low, indicating that leaching of metals from surface soil is not likely. Additionally, metals were not found in significant concentrations in subsurface soil.

Petroleum-related chemicals were detected in on-site storm water, primarily from the lower yard. Storm water metals concentrations were generally low. Non-BTEX volatile organic compounds, and oil and grease were not found in storm water. Similarly, these constituents were also not detected in surface water in Willow Creek and the tidal basin adjacent to the site, nor were total petroleum hydrocarbons in the gas, diesel or oil ranges. The highest metals concentrations, and elevated PAH concentrations, were found in surface water upgradient of the site. Upland sediment from 8 of 15 locations along the Terminal boundary, including the downstream tidal basin and sediment from Willow Creek adjacent to the marsh, passed all criteria for bioassay testing. At six locations, as well as the upstream location, limited toxic effects were exhibited in bioassay testing. No discernible pattern was identified that would point to a single sediment toxicity source.

The Model Toxics Control Act (MTCA) regulations of chapter 173-340 WAC provide methods for identifying cleanup levels for a site. For preliminary evaluation purposes in the remedial investigation phase, MTCA cleanup levels were used as screening levels to compare the Terminal remedial investigation data. The selection of MTCA-based

[1] For purposes of this Executive Summary, insignificant concentrations means the chemical was not detected, detected at concentrations near the method detection limit, detected within the range of background values, and/or detected in the part per billion range.

screening levels for comparative purposes is not meant to imply that these levels will be the ultimate cleanup levels for the site. Final cleanup levels for the site will be selected in the cleanup action plan.

MTCA cleanup actions must comply with MTCA cleanup standards as well as other state and federal regulatory standards. Some of these other standards are encompassed in the development of MTCA Method A, B, or C cleanup levels; for example, Method B cleanup levels for the protection of surface water incorporate state and federal ambient water quality criteria. For purposes of this remedial investigation evaluation, a comparison of data to cleanup levels beyond these MTCA methods and other MTCA methods (for example, soil cleanup levels to protect against exposure to vapors) was not performed, except for a comparison of sediment results to the Sediment Management Standards of chapter 173-204 WAC. A complete evaluation of applicable, or relevant and appropriate requirements (ARARs) will be provided in the feasibility study report for the site.

Indicator hazardous substances (IHSs) were selected as part of a baseline exposure assessment of the site. Selected lower and upper yard soil IHSs were total petroleum hydrocarbons (TPH), benzene (lower yard only), chrysene, antimony, and arsenic. Groundwater IHSs were TPH, benzene, chrysene, lead, zinc, and, tentatively, arsenic and copper. Zinc was identified as a surface/storm water IHS, and TPH/oil and grease were retained as surface water IHSs. The reasonable maximum exposure scenario for site soil is considered to be residential exposure, based on the upper yard’s potential use for residential purposes. Based on the flow of groundwater to nearby surface water, the reasonable maximum exposure for groundwater is based on potential exposure to surface water. Groundwater is not currently used for drinking water and is not likely to be used for drinking water in the future. However, the Department of Ecology has determined that the site-wide aquifer as it exists beneath the upper yard portion of the site is a potential drinking water resource. Based on this determination, the reasonable maximum exposure scenario for this portion of the aquifer is human exposure to hazardous substances by drinking this water or through other domestic use. The reasonable maximum exposure scenario for surface water is exposure of aquatic organisms, and humans (by ingestion of aquatic organisms).

To characterize potential risks to the environment posed by the site, a qualitative environmental evaluation was performed by comparing groundwater, surface water, and storm water data collected at the site to existing federal and state ambient water quality criteria and sediment data to state sediment management standards. In addition, potential aquatic and terrestrial biota receptors were identified through a field survey. Four different vegetation communities are found at the Terminal, with disturbed upland and upland forest being the primary and secondary communities. The habitat value of these two communities is considered low to moderate. Bald eagle territory is located to the south of the Terminal and extends into the south end of the site. No other threatened species and no endangered species were identified as associated with the site, the adjacent Willow creek, or the adjacent marsh.

To assess residual risk to the environment that may be posed by the site, an ecological evaluation will be performed in conjunction with the feasibility study.

Free product occurs under the lower yard (including an area adjacent to the property boundary at the southwest part of the site), a number of petroleum-hydrocarbon-related chemicals and paint/sand blast grit-related metals have been identified as site IHSs, and groundwater and storm water have been identified as migration pathways. However, chemical concentrations in groundwater at the perimeter of the site and in surface water in the perimeter Willow Creek are relatively low. Additionally, upland sediment bioassay tests showed no toxic effects at the majority of the stations. These results indicate that chemical migration off site appears to be limited. Site hydrogeology, the termination of site operations, chemical and product characteristics, and product recovery operations contribute to limit chemical migration from the site.

1 INTRODUCTION

1.1 Purpose of Investigation

Union Oil Company of California, dba UNOCAL, entered into Agreed Order No. DE 92TC-N328 with the Washington Department of Ecology (Ecology) to conduct environmental investigations at the UNOCAL Edmonds Bulk Fuel Terminal located at 11720 Unoco Road in Edmonds, Washington (Figure 1-1). The scope of the Agreed Order, issued pursuant to the Model Toxics Control Act (MTCA), includes the following tasks: (1) a facility background history review, (2) a remedial investigation/feasibility study, and (3) an evaluation of an existing free petroleum product recovery system.

Specific to the remedial investigation, the Agreed Order requires UNOCAL to conduct an investigation of the existing Edmonds Bulk Fuel Terminal in accordance with the scope and contents specified in WAC 173-340-350. The terminal includes, but is not limited to, the tank farm, process area, former asphalt plant operation, and Detention Basin No. 1.

The facility background history review, the product recovery system evaluation, and a remedial investigation (RI) work plan were completed and reported to Ecology (EMCON, 1994a, 1994b, and 1995a, respectively). The RI work plan was approved by Ecology by letter dated September 5, 1995. Additional interim deliverables specified in the work plan have also been completed and submitted to Ecology: the upland sediments evaluation work plan (EMCON, 1995b), the laboratory quality assurance/quality control (QA/QC) plan (UNOCAL, 1995), the proposed monitoring well network (EMCON, 1995c), results of the drainage system inventory (EMCON, 1996a), and a combustible gas monitoring and evaluation (EMCON, 1996). A preliminary evaluation of the upper yard hydrogeology was also completed and reported to Ecology (EMCON, 1996c).

This report summarizes the RI work performed by EMCON and presents the results of the data obtained; major portions of this report are from a previous draft prepared by EMCON in 1998. In this report, references to the MTCA regulations of chapter 173-340 WAC do not include the revisions promulgated in February 2001. Results presented herein include soil laboratory data, groundwater quality data, groundwater levels, aquifer characterization test results, catch basin sediment data, storm water and surface water data, upland aquatic sediment data, and results of the wildlife and habitat survey.

1.2 Project Objectives

The RI was performed to provide information on soil, groundwater, surface water, storm water, and upland aquatic sediment quality, as well as soil and aquifer characteristics which may affect the fate and transport of indicator hazardous substances. The overall project data quality objectives (DQOs) were to (1) determine the nature and extent of contamination in soil, groundwater, surface water, and upland sediments, (2) perform a baseline exposure evaluation covering human health, natural resources, and ecology, and (3) assess compliance with MTCA and applicable, or relevant and appropriate requirements (ARARs).

The soil RI objectives were to (1) assess the nature and extent of potential surface and subsurface soil contamination from historic activities at the terminal, (2) assess the hydrogeology of the site, and (3) characterize the physical parameters (e.g., soil types and grain size).

The groundwater RI objectives were to (1) further delineate the extent and thickness of free petroleum product at the site, (2) assess the nature and extent of potential groundwater contamination at the terminal from historic activities, (3) further characterize the site hydrogeology (e.g., occurrence of groundwater and flow direction), and (4) determine the potential for on-site and off-site contaminant migration.

The surface water drainage system RI objectives were to (1) confirm location of existing storm drains at the site to identify contaminant transport pathways, (2) assess the nature and extent of contamination in on-site surface water, storm water runoff from the site, storm drain sediment, and Detention Basin No. 2 sediment, and (3) identify the volume of contaminated storm drain sediment for potential remediation purposes.

The upland aquatic sediment RI objectives were to (1) assess the nature and extent of sediment contamination, (2) evaluate the potential for adverse biological impacts, (3) determine potential impacts from off-site sources, and (4) evaluate potential migration pathways off site.

1.3 Report Organization

The report is organized as follows:

- Section 2 provides a description of the site and surrounding properties and provides a brief summary of previous investigations.
- Section 3 describes the environmental setting of the area, including climate, surface water hydrology, regional geology and hydrogeology, and area water supply wells.

- Section 4 summarizes the RI site investigations.
- Section 5 discusses the site physical and ecological characteristics, including air, topography and features, geology, hydrogeology, surface water hydrology, the storm water drainage system, upland sediment, wildlife, and habitat.
- Section 6 summarizes the nature and extent of chemicals in soil, groundwater, surface water, storm water, and upland sediment.
- Section 7 presents the results of the baseline exposure evaluation including both human health and environmental evaluations.
- Section 8 provides a conceptual site model, including contaminant sources and migration routes.
- Appendix A provides the underground storage tank (UST) decommissioning report.
- Appendix B contains the Sampling Alteration Checklists.
- Appendix C provides the lithologic logs, well development data, and soil physical data.
- Appendix D presents the soil and groundwater samples submitted for chemical analysis.
- Appendix E presents field sampling data sheets for groundwater, surface water, storm water, and upland aquatic sediments.
- Appendix F presents groundwater and surface water levels.
- Appendix G provides the tidal response study hydrographs and hydraulic conductivity test results.
- Appendix H provides the drainage system inventory report.
- Appendix I contains the wildlife and habitat survey report.
- Appendix J contains the data validation reports.
- Appendix K provides the gas monitoring and evaluation report.
- Appendix L contains the upland sediment statistical calculations.
- Appendix M provides the product volume calculations.

- Appendix N provides an analysis under Ecology's Interim TPH Policy.
- Appendix O contains correspondence regarding groundwater beneficial use.

2 SITE BACKGROUND

2.1 Site Description

2.1.1 Terminal

The Terminal comprises approximately 47 acres of land on and adjacent to the northern slope of a hillside and lies within approximately 1,000 feet of the Puget Sound shoreline. At its nearest point, (southwest corner of lower yard), the Terminal boundary is approximately 160 feet from the Puget Sound shoreline. The Terminal has two distinct areas, the upper yard (tank farm) area and the lower yard area (Figure 2-1 and Drawing No. 1 [in pocket]).

The lower yard is approximately 22 acres, lying east of the Burlington Northern Railroad right-of-way, south of Union Oil Marsh, west of the Deer Creek Salmon Hatchery, and north of the upper yard. The lower yard elevation ranges from approximately 10 to 25 feet above the mean lower low water datum (MLLW). The lower yard consists of office buildings, two former truck loading racks, aboveground piping, two underground (former vapor recovery) tanks, two underground vaults, Detention Basin No. 1, Detention Basin No. 2, and an oil/water separator. Previous operations also included an air-blown asphalt plant, an asphalt packaging warehouse, and a railcar loading/unloading facility.

The upper yard is approximately 25 acres located immediately south of the lower yard. Upper yard elevations range from approximately 25 to 150 feet (MLLW). The upper yard consists of 23 aboveground storage tanks, above-grade piping, a garage, and a warehouse.

UNOCAL operated the Terminal from 1923 to 1991. Detailed descriptions of the Terminal facilities and historic activities are presented in the Background History Report, (EMCON, 1994a). The facility is currently used only for office purposes. All tanks and lines at the Terminal are empty.

2.1.2 Land Use and Zoning

Properties surrounding the Terminal consist of various commercial, recreational, and residential sites. The Terminal is bound to the north by a property designated “open space." Further to the north is Harbor Square, a commercial development. The Town of Woodway corporate limit serves as the southern boundary of the Terminal. The Terminal is bounded on the east by State Route 104. The Deer Creek Salmon Hatchery is located on the southeast corner of the Terminal property, on the northwest corner of State Route 104 and Pine Street. The Terminal is bounded to the west by the Burlington Northern Santa Fe Railroad right-of-way, the Port of Edmonds marina, Marina Beach Park, and the Puget Sound shoreline.

The Terminal is currently zoned as commercial waterfront (CW). The property immediately north of the Terminal is designated open space (OS). Further to the north, Harbor Square is zoned commercial general (CG). Land use in the town of Woodway, to the south of the UNOCAL facility is primarily single-family residential. The property east of the Terminal, to the east of State Route 104, is zoned under public use (P), multi-family (RM-26), and single-family residential (RS) designations. The Burlington Northern Railroad right of way, the Port of Edmonds marina, Marina Beach Park, and the Puget Sound shoreline west of the Terminal are zoned commercial waterfront.

2.2 Previous Investigations

Tables 2-1 through 2-6 present existing data generated by previous investigations at the Terminal. Drawing No. 2 (in pocket) and Figures 2-2 and 2-3 show the locations where data were previously collected. Previous investigations are described in detail in the Background History Report (EMCON, 1994b).

Sampling locations were relatively evenly split between the upper and lower yards. Most of the analyses performed were soil TPH analyses. Little data on metals in soil, TPH in groundwater, or metals in groundwater were collected. Almost no PAH data were collected prior to the RI. All data generated previously at the Terminal provide useful qualitative indicators of sample contaminants. However, since some sample surrogate and spike compound recoveries were low, individual sample results may be biased low. Analytical results for previous work were therefore only used to provide relative comparisons of contaminant concentrations.

UNOCAL decommissioned five USTs at the site between October 25 and November 3, 1994: one 10,000-gallon diesel tank (UST 0200-3) located at the northwest corner of the maintenance garage; one 5,000-gallon diesel tank (UST 0200-9) located adjacent to the boiler; one 500-gallon diesel additive tank (UST 0200-10A) located at the east corner of the southern loading rack canopy; one 300-gallon waste oil tank (UST 0200-4) located at the southwest corner of the maintenance garage; and one 100-gallon gasoline tank (UST 0200-5) located south of the foam shed (Appendix A; EMCON, 1994a). Each UST was excavated and removed. Soil samples were collected from the excavation sidewalls and bottom (if above the water table). Drawing No. 2 shows the locations of the USTs, and Tables 2-7 and 2-8 present the laboratory results for sidewall and bottom samples.

3 ENVIRONMENTAL SETTING

3.1 Climate

Edmonds lies on the Puget Sound, approximately 100 miles inland from the Pacific Ocean coastline. The Puget Sound area is temperate with moderate precipitation and temperatures. The Olympic Mountains, lying between Edmonds and the ocean coast, form a significant barrier to on-shore wind flow, and wind and precipitation tend to be diverted to the north and south of the mountains. The Cascade Range, lying approximately 50 miles to the east, forms a steep topographic barrier to marine air flow and receives significant precipitation. The Cascade Range forms a barrier against westerly flow of colder and drier continental air masses.

Winds, storms, and temperatures are typically mild year-round in the Edmonds area. Occasionally, winter storms will bring heavy rainfall, strong winds, or snow fall. Average winter temperatures are typically in the 30s and 40s (°F), and summer temperatures commonly range from the 50s to 70s (°F). The average annual precipitation is approximately 34 inches, the majority falling as rain between October and March.

3.2 Surface Water Hydrology

The Terminal is located on the eastern side of Puget Sound. The site is bounded on the northwest and northeast by a drainage ditch which conveys Willow Creek and carries surface runoff from areas east of the site to Puget Sound. North of Willow Creek lies a 23-acre freshwater and brackish water marsh known as the Union Oil Marsh. The marsh is tidally influenced and also fed by Shellabarger Creek on the east side of the marsh. Small creeks and ditches drain the upland areas to the east of the Terminal. The closest lakes or ponds to the site are two unnamed ponds over 1 mile north up the shoreline and Chase Lake, located almost 2 miles to the east.

3.3 Regional Geology

The Edmonds area lies within the Puget Sound lowland, a tectonic/geomorphic depression between the Olympic Mountains and the Cascade Range. The north-south trending depression extends from Oregon to southwestern British Columbia. The depression is characterized by relatively thick accumulations of post-glacial and glacial deposits overlying Tertiary sedimentary and igneous rocks. The lowlands area has been influenced by at least five major advances and several lesser advances of Pleistocene continental ice. Glacial deposits consist of a complex sequence of lacustrine deposits, advance outwash, drift, till, and recessional deposits. A variety of river deposits characterize the interglacial periods. The Quaternary glacial and interglacial deposits range in thickness from 0 to 300 feet in the Terminal vicinity (Yount, et. al., 1985). The underlying bedrock consists primarily of Tertiary sedimentary and volcanic rocks.

The Terminal lies on and to the northwest of a bluff along Puget Sound and southwest of the city of Edmonds. The bluff consists primarily of interglacial deposits termed the “Whidbey Formation,” alluvial/lacustrine preglacial deposits termed “Transitional Beds” and “Advance Outwash,” and glacial deposits termed “till” (Minard, 1983). According to Minard (1983), the lower yard is bounded to the northeast by marsh deposits and to the north and northwest by “modified land” which has been dredged and filled. Site geology is discussed in Section 5.2.

3.4 Regional Hydrogeology

Groundwater flow in the Puget Sound region generally can be divided into regional, intermediate, and local flow systems. The regional and intermediate flow systems in the Edmonds vicinity are found in Pleistocene, unconsolidated, glacially derived sediment and in the underlying Tertiary marine sediment and volcanic rocks. The systems are recharged in areas where the units are exposed (i.e., in the uplands east of the Sound), and discharge groundwater into Puget Sound.

Local flow systems occur in the alluvial and lacustrine pre-glacial deposits, glacial sediment, postglacial alluvial deposits, and fill. They are influenced by surface topography and composition, precipitation patterns, and local surface water bodies. Local flow systems are recharged by precipitation and discharge from deeper flow systems. Discharge is primarily to adjacent surface water bodies.

3.5 Water Supply Wells

Based on a review of Ecology and Snohomish Health District files, two water supply wells exist within a 1-mile radius of the Terminal (Figure 3-1). One, the Deer Creek Hatchery well, is located at the hatchery about 800 feet east of the eastern boundary of the upper yard. The hatchery well has never been used, but may be used in the future to augment the hatchery surface water supply during periods of turbid runoff (Hjort, 1995). The other, a domestic supply well, is reportedly located about 0.85 miles south of the Terminal. It is not know if the domestic well, which was installed in 1980, still exists or is used. But based on its location, this well could not be affected by Terminal operations. Two abandoned test wells were also present within a 1-mile radius of the Terminal. One of the abandoned test wells, which was used for dewatering during construction of the Edmonds Wastewater Treatment Plant, is located about 0.4 miles northeast of the Terminal. The other abandoned test well, an Olympic View Water District test well, is located about 0.9 miles south of the Terminal.

4 SITE INVESTIGATION

Field work for the Terminal began in October 1994. The field work was performed by EMCON and included investigations of air, soil, basin sediment/soil, groundwater, surface water, storm water, upland aquatic sediment, catch basin sediment, free product, and aquifer characteristics.

Thirty-nine monitoring wells, 9 piezometers, and 120 shallow soil borings were drilled/installed; three test pits and four test trenches were excavated; 15 upland sediment samples were collected; over 375 subsurface soil samples, 31 surface soil samples, and 17 basin sediment/soil samples were collected for soil identification and chemical and physical analyses. In addition, 16 previously installed monitoring wells and 4 sumps were abandoned during the investigation by filling the well or sump with bentonite chips. The new monitoring wells were developed and surveyed. Four quarters of groundwater samples have been collected from select new and existing monitoring wells. The aquifer characterization study consisted of a week-long tidal response study, nine slug tests, and 12 monthly rounds of water level measurements. Physical analyses, including grain size, porosity, and vertical hydraulic conductivity, were performed on 23 soil samples from the site.

The RI work scope was described in the Final Remedial Investigation Work Plan (Work Plan; EMCON 1995a) and Work Plan Addendum (EMCON, 1995c). The Work Plan presented a conceptual site model and the sampling plan rationale, and described the sample types, frequency, and analyses. The Work Plan also defined procedures for RI activities, including: surface and subsurface soil sampling; groundwater, surface water, and product sampling and monitoring; vapor monitoring; collection of field QA samples; sample designation; drilling; well installation and development; boring and well abandonment; aquifer testing; waste handling and characterization; and surveying.

Work was performed consistent with the procedures described in the Work Plan and addendum, unless otherwise noted. Deviations from the general sampling procedures were brought to the attention of the EMCON project manager, and a Sample Alteration Checklist was completed. Copies of the checklists are provided in Appendix B.

4.1 Air

Based on site conditions and as described in the Work Plan, ambient air was not a field investigation component of the RI. However, due to the existence of floating product on the groundwater, vapor measurements were collected at locations throughout the site. A GasTech, Inc. Model NP-204 or a Gas Tech, Inc. Model 1939 OX combustible gas indicator was used to measure concentrations of vapors in select soil borings, all lower yard storm drain manholes, in shallow monitoring wells, and in all site buildings, as described in the Work Plan. Soil vapor was monitored at the tops of select soil borings during drilling.

The number of borings in which combustible gas measurements were made was based on the results of the first borings drilled in an area. If combustible gases were detected in the first boring drilled in an area, additional borings were monitored. If combustible gases were not detected in the first boring drilled in an area, the amount of additional monitoring in that area was reduced. Measurements were typically made the first time augers were opened for soil sample collection, allowing monitoring of combustible gases near the top of the vadose zone. Test pit measurements were made at various depths immediately after the backhoe bucket was removed from the pit.

The storm drain manholes in the lower yard were monitored for vapors in June 1996. Vapor measurements were taken at the top of each shallow network monitoring well in January and June 1996, and in all buildings on site in June 1996. Oxygen and combustible gas levels were measured in four monitoring wells and four catch basins located south of the northern truck loading rack in the lower yard in October 1996. Although the Work Plan specified that vapor measurements would be collected twice in the first four months in the lower yard shallow monitoring wells, the second round of measurements was delayed to wait for warmer weather.

4.2 Soil

Surface and subsurface soil samples were collected at the site. Subsurface soil samples were collected from shallow soil borings, monitoring well and piezometer boreholes, test pits, and test trenches. Subsurface soil samples were screened and logged consistent with the Work Plan. Boring logs, including screening results, are included in Appendix C.

Sampling locations generally were selected based on historic on-site uses and operations, data from previous investigations, the need to spatially distribute borings for statistical analyses, and the need to further characterized soil types and properties. Detailed rationale for soil sampling location, frequency, and analyses is described in the Work Plan. Soil sample, soil boring, monitoring well, piezometer, test pit, and test trench locations are shown on Drawing No. 2.

4.2.1 Surface Soil

Thirty-one surface soil samples were collected between the ground surface and a depth of 0.5 feet in selected locations at the site. The Work Plan presented sampling locations for 27 surface soil samples; these were collected consistent with the plan. Additionally, four surface soil samples were collected in accessible locations along the northern Detention Basin No. 1 berm as a measure of whether the detention basin may have historically overtopped the berm. Three near-surface (0.5 to 1.0-foot depth) samples were also collected to investigate the distribution of surface soil metals.

4.2.2 Subsurface Soil

Soil Borings. One hundred twenty (120) shallow soil borings were drilled up to approximately 15 feet (ft) below the ground surface (bgs). Eighty-eight (88) borings were drilled in the lower yard. The remaining 32 soil borings were drilled in the upper yard.

The Work Plan presented locations for 108 shallow soil borings. The following alterations to the Work Plan occurred (Appendix B):

- Only one soil sample was collected from soil boring (SB-208) due to the presence of perched water and difficulties in advancing the drill rig auger.

- Six sites (SB-122, SB-125, SB-130, SB-143, SB-159, and SB-167) were re-drilled to replace samples that, due to a laboratory error (missed holding times), had not been analyzed for polycyclic aromatic hydrocarbons (PAHs).

- One site (SB-104) was re-drilled to collect required samples below the water table.

- Seven borings (SB-176 through SB-182) were added to the investigation to investigate the extent of impacted soil observed in SB-165 and SB-166.

- Two borings (SB-234 and SB-235) were added to investigate the extent of impacted soil observed above 5 ft bgs in boring SB-207.

- Additional samples were collected below the water table in soil borings SB-170 through SB-175, to investigate the extent of impacted soil observed in the former asphalt plant area.

- Holes were hand augered to depths up to 2 feet on the northwest side of the Willow Creek conveyance ditch to investigate the extent of an asphalt coating applied to the edge of the ditch.

Soil borings were advanced using one of the following: (1) a 3.5-inch (in.)-diameter stainless steel hand auger; (2) a Mobile B59 hollow-stem auger drill rig with nominal 4-inch-inside-diameter (i.d.), 8-inch-outside-diameter (o.d.) auger; or (3) an electric Minuteman hollow-stem auger drill rig with nominal 4-inch o.d. auger. A hand auger was used to advanced 22 soil borings, a truck mounted rig was used to advance 84 soil borings, and a Minuteman rig was used to advance 15 borings.

The Work Plan specified drilling by hand auger or hollow-stem auger drill rig. A hollow-stem auger rig (truck-mounted or Minuteman) was used in place of the hand auger in locations where (1) hollow-stem auger drilling was necessary or significantly quicker than a hand auger due to dense soil, or (2) shallow perched water in the upper yard may have altered the chemistry of samples collected with a hand auger. In these cases, the Minuteman was used when access with a truck-mounted drill rig was not possible. Two lower yard soil borings and 13 upper yard soil borings were completed with the Minuteman rig rather than a hand auger. Four soil borings (SB-116, SB-117, SB-137, and SB-146) were advanced using a truck-mounted drill rig rather than a hand auger.

Soil samples were collected using a split barrel, split spoon, or Shelby tube sampler. Soil samples from the Minuteman drilled borings were collected using an 18-inch-long, 1.5-inch-o.d. split spoon sampler. The samplers were driven in advance of the drill bit using a 140 pound hammer dropped approximately 24 inches.

Twelve locations were sampled for basin sediments: eleven locations in Detention Basin No. 1 and one location in Detention Basin No. 2. The basin sediment samples were collected consistent with procedures described in the Work Plan. Two basin sediment sample sites (BSS-105 and BSS-110) were drilled using the electric Minuteman hollow-stem auger rig. Minuteman drilling and sampling was performed as described above.

Monitoring Well and Piezometer Boreholes. Thirty-nine monitoring well boreholes were drilled at the site: 32 shallow (approximately 15 feet deep), five intermediate (30 to 40 feet deep), and two deep (106 to 120 feet deep). Thirty of the boreholes were located in the lower yard, including 27 shallow and 3 intermediate depth boreholes. Five shallow boreholes were located off site adjacent to the lower yard in the Burlington Northern Railroad (BNRR) right of way. Four boreholes were located in the upper yard, including two intermediate and two deep boreholes.

The Work Plan describes drilling eighteen borings for monitoring well installation. The following alterations occurred:

- Three monitoring wells (MW-134, MW-135, and MW-136) were added in the southeast part of the lower yard

- Two monitoring wells (MW-137 and MW-138) were added across Willow Creek to the north of the site, on the Burlington Northern Santa Fe Railroad right-of-way

- One monitoring well (MW-139) was added at the northwest property boundary.

The monitoring wells were added to (1) further investigate the extent of impacted soil in the lower yard and (2) assess the quality of groundwater in the associated areas.

Monitoring well boreholes were advanced using one of the following: (1) a Mobile B59 hollow-stem auger drill rig with nominal 6-in.-i.d., 10-in.-o.d. auger; (2) an electric Minuteman hollow-stem auger drill rig with nominal 4-in.-o.d. auger; or (3) a cable tool dill rig with 6-in.-i.d. casing. Wells MW-108, MW-109, MW-135, and MW-136 were drilled using the Minuteman, and wells MW-120, MW-121, and MW-122 were drilled using the cable tool rig. Soil samples were collected as described above.

Three piezometer borings (P-201, P-202 and P-203) were drilled at the site in October 1994. The piezometers were drilled with an air percussion drilling rig using 6-in.-i.d. drill pipe. Piezometer borings were advanced to an elevation of 0 feet MLLW from 104 to 167 ft above MLLW for the installation of the piezometers. One piezometer boring was drilled to an elevation of -25 ft MLLW to allow investigation of lithology to an elevation consistent with the deep monitoring wells in the lower yard.

Test Pit and Test Trench Excavation. Subsurface soil samples were also collected in shallow test pits and test trenches excavated at the site using a backhoe. The Work Plan presented sampling of three lower yard and two upper yard test pits; two additional test trenches were excavated in the upper yard.

The lower yard test pits (TP-101, TP-102, and TP-103) were excavated to determine the vertical extent of a tar-like substance in the subsurface. One sample of the tar-like substance was collected from TP-101. A number of shallow hand auger borings were also completed on the northwest side of Willow Creek (on the west side of the lower yard) to determine the lateral extent of the tar layer.

Two upper yard trenches (T-203 and T-204) were excavated to investigate the area near a french drain. The two trenches which were added in the upper yard (T-201 and T-202) were excavated to investigate soil quality and lithology in the vicinity of two aboveground tanks. The four test trenches were approximately 2.5 feet wide and ranged from approximately 25 to 50 feet long and 4 to 8 feet deep. Two soil samples were collected from T-203, and one soil sample was collected from T-204.

4.2.3 Soil Sampling and Analyses

Sample types, sampling frequency, and analyses performed for each sample were specified in the Work Plan. Laboratory parameters were selected based on historic site activities and previously collected soil and groundwater data in the vicinity. Table D-1 in Appendix D lists the sample locations, depths, and laboratory numbers for each sample.

Three hundred seventy-six soil samples from the soil borings and monitoring well boreholes were submitted for analyses. Per the Work Plan, the majority of submitted samples were analyzed for benzene, toluene, ethylbenzene, xylenes, (BTEX), total petroleum hydrocarbons as gasoline (TPH-G), diesel (TPH-D), and oil (TPH-O), and PAHs. Approximately half the samples were submitted for metals analyses (cadmium, chromium, lead, and zinc). Select samples were analyzed for total organic carbon (TOC); volatile organic compounds (VOCs); semivolatile organic compounds (SVOCs); toxicity characteristic (TC) metals; antimony, arsenic, copper, and mercury; and the herbicide glyphosate, as described in the Work Plan. Samples collected from the test pit and test trenches were submitted to be analyzed for TPH-G, TPH-D TPH-O, PAHs, British thermal units (BTUs), TC SVOCs, and/or TC metals.

Thirty-one surface soil samples were submitted for analyses. Twenty-three samples were analyzed for WTPH-G and BTEX, 26 samples were analyzed for TPH-D, TPH-O, and PAHs, and 29 samples were analyzed for metals. In addition, three of the surface soil samples were analyzed for TC metals, three samples were analyzed for glyphosate, two samples were analyzed for TOC, and one sample was analyzed for VOCs and SVOCs.

Twenty-three soil samples were submitted for analyses of physical soil properties. Twenty samples were analyzed for grain size distribution, eleven were analyzed for porosity, nine were analyzed for Atterberg limits, and six were analyzed for vertical hydraulic conductivity.

Seventeen basin sediment/soil samples were submitted for analyses. All 17 samples were analyzed for TPH-G, TPH-D, TPH-O, BTEX, and PAHs, and 14 samples were analyzed for metals (antimony, arsenic, copper, cadmium, chromium, lead, mercury, and zinc). Antimony, arsenic, copper, and mercury were added to the standard metals list (cadmium, chromium, lead, and zinc).

4.3 Groundwater

4.3.1 Well and Piezometer Installation and Well Abandonment

Thirty-nine, single-completion (one well per borehole) monitoring wells were installed during RI activities: 32 shallow (less than 20 feet deep), five intermediate (20 to 45 feet deep), and two deep (95 to 106 feet deep) wells. Three triple-completion (three piezometers per borehole) piezometers were installed in the upper yard. Monitoring well locations were selected based on historic land uses, soil and groundwater quality data generated from previous studies, and the need to further characterize aquifer properties and groundwater quality. A summary of monitoring well construction details for the new and existing wells and piezometers is provided in Table 4-1. Table C-1 in Appendix C presents survey data and Table C-2 in Appendix C presents well development data.

Wells and piezometers were installed and developed consistent with procedures described in the Work Plan, except as follows:

- The wells located on the detention basin berm (MW-108 and MW-109) and wells located on a berm at the eastern end of the lower yard (MW-135 and MW-136) were constructed using nominal 1-in-diameter PVC instead of 2-inch-diameter PVC. For access reasons, the portable Minuteman rig was used to drill the boreholes, limiting the well size.

- The screen length in the lower yard well MW-120 was shortened from 10 ft to 5 ft to position the screen in a zone of coarser-grained soil.

The wells and piezometers were surveyed for horizontal and vertical elevations as described in the Work Plan. As previously noted, 16 existing wells and 4 sumps were abandoned consistent with procedures described in the Work Plan. Well abandonments were performed in accordance with the regulations and recommendations provided by Ecology (Rod Thompson, personal communication, April 6, 1995). WAC 173-160-560(1) states that “If it can be verified that a resource protection well was constructed in accordance with the regulations, it shall be abandoned by filling the casing from the bottom to the surface with grout or bentonite.” Since this was the case, the wells were abandoned by filling them with bentonite chips. Per Rod Thompson’s recommendations, the sump casings were removed and the holes filled with bentonite chips. BNRR monitoring well MW-27 was not abandoned as planned because the well was not found. It is believed to have been buried by BNRR personnel.

4.3.2 Groundwater and Product Monitoring

The network of monitoring wells used during groundwater monitoring and sampling activities was described in Existing Monitoring Well Assessment and Proposed Monitoring Well Network (Monitoring Well Assessment; EMCON, 1995d). The wells included in the groundwater sampling network were reviewed and approved by Ecology (Ecology, 1995).

Groundwater and floating product levels were measured monthly for one year in all existing and new monitoring wells. The wells were also checked for the presence of sinking product once near the beginning of the 12-month monitoring period

(January 1996) and once near the end of the 12-month monitoring period (December 1996).

4.3.3 Groundwater and Product Sampling and Analyses

Groundwater samples were collected in November 1995 and February, May, and August 1996. Sample types, sampling frequency, and analyses performed for each sample were specified in the Work Plan. Table D-2 in Appendix D lists the sample locations, dates, and laboratory numbers. Groundwater field sampling data sheets are presented in Appendix E; groundwater and surface water levels are presented in Appendix F.

Groundwater samples were collected from 37 to 42 monitoring wells during each sampling event, the number of wells sampled depending on the presence of free-phase product. All groundwater samples were analyzed for TPH-G, BTEX, TPH-D, TPH-O, PAHs, total and dissolved metals (cadmium, chromium, lead, mercury, and zinc), water quality parameters (total dissolved solids [TDS] and total suspended solids [TSS]), and field parameters (specific conductance, pH, temperature, dissolved oxygen, and turbidity). In accordance with the Work Plan, groundwater samples from five wells were analyzed for VOCs. During the second sampling event, groundwater samples from three wells also were analyzed for remedial parameters. During the fourth sampling event, all groundwater samples were also analyzed for antimony, arsenic, and copper. Groundwater samples were not collected from wells containing floating product.

Product samples were collected from five wells at the site (MW-5, MW-13, MW-113, MW-118, and MW-130). The product samples were collected in December 1995. Product samples were analyzed for PAHs, TPH, lead, viscosity, and specific gravity.

Groundwater and product samples were collected consistent with procedures described in the Monitoring Well Assessment and Work Plan, with the following modifications:

- Groundwater samples from wells MW-105, MW-106, MW-107, MW-137, MW-138, and MW-139 were collected one month after the initial round of sampling of the other wells because those six wells were not installed until December 1995.

- MW-113 was not sampled due to the presence of free product in the well. Instead, groundwater from MW-112 was sampled.

- Groundwater samples from MW-123 were also analyzed for VOCs.

4.4 Aquifer Characterization

4.4.1 Tidal Response Study

A tidal response study was conducted between January 17 and 24, 1996. This time period corresponded to the predicted maximum change in tidal levels for the winter months. Sixteen monitoring wells, the tidal basin, Willow Creek, Detention Basin No. 1, and Puget Sound were monitored (Appendix G). The sixteen wells that were monitored included 13 shallow wells (MW-7, MW-8, MW-20, MW-26, MW-101, MW-105, MW-109, MW-112, MW-115, MW-123, MW-124, MW-125, and MW-129) and 3 deep wells (MW-120, MW-121, and MW-122). The locations monitored were selected to provide a reasonably even spatial distribution across the lower yard. The creek locations monitored were selected to be adjacent to monitored wells.

Water levels for Puget Sound were monitored in a 1-inch-diameter PVC stilling well at the end of the UNOCAL dock. The monitored surface water stations consisted of a staff gauge and a 1-inch-diameter PVC stilling well attached to a steel fence post. Water levels at all monitored locations were referenced to a surveyed point. Water levels were monitored with pressure transducers and programmable data loggers. Measurements were collected every 6 minutes. One site-wide round of water levels was measured on January 18. Before and during the test, five rounds of measurements were completed by hand with an electric well probe. These measurements were used to calibrate the transducers and to check for transducer drift. No transducers were found to drift significantly. Equipment failure occurred at 3 of the 13 shallow wells preventing or limiting data collection: no usable data were collected at MW-101 and MW-125, and at MW-123, data collection stopped prematurely on January 19. This equipment failure did not affect the overall quality of the tidal response study data set. Product thickness fluctuations in the monitoring wells were not measured during the study. Section 5.3.5 discusses the tidal response study results.

4.4.2 Hydraulic Conductivity Tests

The horizontal hydraulic conductivity of the aquifer was estimated using the rising head slug test method. Six lower yard monitoring wells (MW-101, MW-112, MW-119, MW-120, MW-127, and MW-131) and three upper yard wells (MW-7U, MW-13U, and MW-203) were tested on March 11 and 12, 1996. The locations monitored were selected to provide (1) results from a variety of geologic materials and (2) a reasonably even spatial distribution across the site. Water levels were monitored with pressure transducers and programmable data loggers. Data from one deeper lower yard monitoring well (MW-120) was significantly influenced by tidal fluctuations. The data were corrected to remove the tidal effect prior to hydraulic conductivity analysis.

4.5 Surface Water

Surface water levels were monitored during groundwater monitoring events conducted in November/December 1995, February 1996, and May 1996. Eighteen surface water samples were collected during a storm event on April 23, 1996, from Willow Creek, the tidal basin, and Detention Basins No. 1 and 2, following procedures described in the Work Plan. Samples were collected in conjunction with storm water sampling. Sample and laboratory numbers are summarized in Appendix D, Table D-3. The six surface water sampling locations, designated SW-1 through SW-6 (Drawing No. 3), were selected after evaluation of the drainage system and were subsequently approved by Ecology (Ecology, 1996). SW-1 was located approximately 150 feet downstream of the point at which off-site drainage (from Pine Street/south residential area) is discharged into Willow Creek. During the storm event, surface water samples were collected commencing at upstream station SW-1 and proceeding sequentially through SW-4, at the tidal basin station. The sample at SW-1, which is unaffected by tides, was collected at high tide, and the samples at SW-2, SW-3, and SW-4 were collected during the subsequent falling tide. Site storm water was discharging from Outfall 001 when samples were collected from station SW-3 (located downstream of this outfall) and SW-4. Samples of impounded water were collected from Detention Basin No. 1 (SW-5) and Detention Basin No. 2 (SW-6).

Samples were analyzed for oil and grease, TPH-G, TPH-D, TPH-O, BTEX, PAHs, total and dissolved metals (As, Cd, Cr, Cu, Pb, Sb, Hg, Zn), VOCs, and TSS. Temperature, pH and conductivity were measured in the field.

The RI Work Plan specified that two surface water sampling events would be performed in conjunction with storm water sampling during one dry season event and one wet season event as schedule and weather allow. Schedule and weather did not allow collection of a dry season sampling event prior to the August 1996 submittal of the Draft RI Report. UNOCAL agreed to perform a second surface water sampling event in late 1997 if groundwater and surface water conditions acceptable to Ecology were met (no storm water discharge and groundwater elevations between about MW-20 and MW-103 higher than adjacent surface water elevations). UNOCAL measured groundwater and surface water elevations near low tide on September 19 and 26, October 17, November 12 and 14, and December 1, 1997. On each of these occasions, surface water elevations were above groundwater elevations, so a second surface water sampling event was not conducted.

4.6 Storm Water Runoff

A drainage system inventory was performed in November and December, 1995, as described in the Work Plan. Results of the inventory (EMCON, 1996a) are provided in full in Appendix H. Based on the inventory, three storm water sampling locations were selected and subsequently approved by Ecology (Ecology, 1996). Locations were selected considering drainage areas contributing to the location, and accessibility for sampling. The monitored locations were STW-U44, reflecting upper yard runoff; STW-L32, reflecting lower yard runoff; and the last chamber of the API separator (STW-API), reflecting the combined site runoff (Drawing No. 3). Storm water samples were collected at these locations during a storm event on April 23, 1996. Sample and laboratory numbers are summarized in Appendix D, Table D-3.

Storm water sampling commenced at 7:47 am on April 23, and was completed at 12:57 am on April 24. Approximately 0.9 inches of rain fell during the sampling period. Due to a malfunction of the autosampler stationed at STW-API, grab samples were not collected at this location. However, grab samples were collected at both the upper and lower yard stations and composite samples were successfully collected at STW-API.

Grab samples were analyzed for oil and grease, TPH-G, TPH-D, TPH-O, BTEX, total and dissolved metals (As, Cd, Cr, Cu, Pb, Sb, Hg, Zn), and VOCs. Composite samples were analyzed for TPH-G, TPH-D, TPH-O, BTEX, total and dissolved metals (As, Cd, CR, Pb, Sb, Hg, Zn), VOCs, PAHs, and TSS.

Based on spatial distribution, drainage areas, and volume of sediment in catch basins identified in the drainage system inventory, sediment sampling locations were selected and subsequently approved by Ecology (Ecology, 1996). Sediment samples were collected from the drainage system as described in the Work Plan. Three samples were collected from upper yard catch basins (CB-U11, CB-U19, and CB-U31), and three samples were collected from lower yard catch basins (CB-L6, CB-L26, and CB-L32). Following discussions with Ecology, a sample was also collected from CB-U46. Sampling locations are shown on Drawing No. 3. Catch basin sediment samples were analyzed for TPH-G, TPH-D, TPH-O, PAHs, and total and TC metals (As, Cd, Pb, Hg). The sample from U31 was also sampled for glyphosate. Sample and laboratory numbers are summarized in Appendix D, Table D-3.

4.7 Upland Aquatic Sediments

Fifteen upland sediment samples and two reference area samples were collected for bioassay and conventionals (i.e., grain size and TOC) testing. Samples were collected between June 12 and 18, 1995, following procedures specified in the Upland Sediments Work Plan. Sample locations are presented on Drawing No. 2. Two reference area samples were collected from a station in the Nisqually River delta (sample NISQ) and from Carr Inlet (sample CARR), and one of the upland sediment samples (sample US-15) was collected from an area near the upstream edge of the site in Willow Creek. Sample number, date collected, sampling interval, and laboratory sample numbers are presented in Appendix D, Table D-4. Sediment field sampling data sheets are presented in Appendix E, and laboratory reports are presented in Appendix L.

Acute and chronic biological toxicity testing and analysis of grain size and TOC were conducted on the upland sediment samples and reference area samples. Per the work plan, a field duplicate sample was analyzed for grain size and TOC, only. Biological testing included amphipod mortality using the test species *Eohaustarius estuarius*, bivalve larvae abnormality/mortality using the test species *Mytilus edulis*, and juvenile polychaete biomass using the test species *Neanthes arenaceodentata*. Ammonia and sulfides were also analyzed concurrent with the biological testing to evaluate potential toxicity of these compounds. All testing was conducted following protocols specified in the Upland Sediments Work Plan except for the amphipod bioassays. The control samples in the initial amphipod mortality testing showed mortality greater than control limits. The initial amphipod testing was terminated, and re-testing was conducted. Results for the re-test are reported.

4.8 Wildlife and Habitat

A wildlife and habitat study was performed to identify terrestrial or aquatic wildlife which may be affected by existing site conditions or future cleanup actions at the Terminal. The study area included the Terminal, the adjacent marsh, Shellabarger Creek west of State Route 104, and Willow Creek upstream to the Deer Creek Fish Hatchery. The wildlife and habitat study involved (1) a literature review, (2) database searches, (3) discussions with agency personnel, conservation group members, and botany and wildlife experts, and (4) a field study performed in April 1996. The background information sources are listed in the wildlife and habitat study report which is provided in full as Appendix I.

5 SITE CHARACTERISTICS

5.1 Surface Topography and Features

5.1.1 Topography

The lower yard elevation ranges from approximately 10 to 25 feet above the mean lower low water (MLLW) datum on Drawing No. 1. The lower yard is relatively flat and typically about 13 to 16 feet above MLLW, except in the north and east parts of the yard. In the north part of the lower yard, Detention Basins No. 1 and No. 2 form depressions approximately 6 feet and 4 feet deep, respectively. Detention Basin No. 1 is bounded to the northwest, northeast, and southeast by a man-made berm. The berm runs along the northern property boundary, adjacent to the marsh area. South of the berm in the east part of the lower yard, the ground surface is irregular and the elevation is approximately 4 feet higher than much of the lower yard.

Upper yard elevations range from approximately 25 to 170 feet above MLLW. The upper yard can be divided roughly into two areas: the main part of the upper yard (at the top of the bluff) and the garage area located in the north part of the upper yard (midway between the top of the bluff and the lower yard). The main part of the upper yard ranges from approximately 30 to 170 feet above MLLW, and the garage area ranges from about 25 to 30 feet above MLLW. The main part of the upper yard is separated topographically from the garage area and lower yard by a wooded hill slope. Topography in the upper yard is irregular.

5.1.2 Utilities/Easements

Underground utilities at the site consist of electrical and water lines. Former fire suppression lines are also located in the upper yard. Typically, these utilities are located within approximately 3 feet of ground surface. The sewer system at the facility consists of three separate septic tanks and drain lines. The two-story office building near the southern truck loading rack and the office building nearest the northern loading rack are connected to the same septic tank and drain lines, located in the lawn area to the northeast of the two-story office building. The second septic system is immediately west of the northernmost office building. The third septic system is located beneath the paved parking areas to the west of the maintenance garage south of Unoco Road. Each of the septic systems consists of a 500-gallon septic tank with 4-inch-diameter drain lines. The systems collect wastewater from employee sinks and restrooms in the offices and garage.

During construction of State Route 104 in the early 1970s, the Washington State Department of Highways obtained a drainage easement along Unoco Road and across the central portion of the lower yard to the tidal basin (Figure 5-1). The easement contains a large diameter steel pipe, with a starting pipe diameter and invert elevation of 48 inches and approximately 40 feet above MLLW, respectively, at Pine Street. The pipe diameter increases across the Terminal. As the drainage line departs the Terminal in the vicinity of the tidal basin, the diameter of the pipe and the invert elevation are 72 inches and approximately 0 feet (MLLW), respectively (Washington State Department of Highways, 1971). The site storm drain system is described in Section 5.4.

5.1.3 Structures and Product Piping

Three office buildings, an oil/water separator and a shed, two former truck loading racks, two underground vaults, and two underground (former vapor recovery) tanks are present in the lower yard (Figure 2-1, Drawing No. 2). A two-story office building is located at the toe of the hillside in the south-central part of the lower yard and houses environmental staffing offices. Two other office buildings are located in the central part of the lower yard. The oil/water separator and shed are located approximately 150 feet south of Detention Basin No. 2. One truck loading rack is located immediately west of the northernmost office buildings, and the other is located west of the two-story office building. The two former vapor recovery tanks are constructed of welded steel and are located west of the northern office buildings. The two steel storm water processing vaults are located west of the southern loading rack and on the east end of the northern loading rack.

A garage, warehouse, former foam sheds, and twenty-three aboveground storage tanks (ASTs) are present in the upper yard (Drawing No. 2). The garage and warehouse are located along Unoco Road near the entrance gate in the eastern part of the site. The garage building houses office space, a restroom, and three service bays which are currently not in use. The unused foam sheds are located along Pine Street, at the southern site boundary near the city limits of Woodway. The ASTs range in size from 9,726 to 3,491,754 gallons. All product storage tanks are made of welded or riveted steel and have either fixed or floating (interior or exterior) roofs. All tanks are empty and have been cleaned out.

Product pipelines at the Terminal consist of a series of aboveground lines which were used to move product between areas of receipt, storage tanks, and asphalt-facility tanks. The existing piping generally consists of 2-inch-diameter to 12-inch-diameter, steel, aboveground lines. All pipes are no longer in use and have been cleaned out. Ten product lines run above ground from the dock to the shoreline manifold area in the southwest corner of the lower yard. From the shoreline manifold area, the aboveground piping runs southeast up the hillside, into the southwest portion of the upper yard, and northeast along the toe of the hillside to the north central portion of the upper yard. Overhead pipelines to a former vapor recovery system and the northern truck loading rack exit the upper tank yard in the vicinity of the boiler, and run north toward the laboratory building. The vapor recovery system was located along the northwest property limit.

Former structures at the site included two railcar unloading areas, the air-blown asphalt plant (including piping and ASTs), an asphalt warehouse, a laboratory, and a boiler building. A detailed description of the current and former structures and piping at the Terminal is presented in the Background History Report.

5.1.4 Surface Cover

Pavement. Asphaltic pavement is present at the site on access roads in the lower and upper yards, access paths in the upper yard, in parking areas near the UNOCAL and Hemphill office buildings and garage, and lining some drainage ditches in the upper yard. Concrete slabs are present beneath the two former truck loading racks. Pavement and buildings (noted above) cover approximately 8 percent of the site surface.

Coating. An asphalt/tar/polyurethane emulsion coating was placed over parts of the upper yard surface to prevent soil erosion (Drawing No. 4). The coating is present mainly on the soil berms which surround the upper yard ASTs. The coating is also present on the north hill slope west of the garage area and the hill slope between the garage area and Unoco Road. In addition, the coating is present on the soil berm northwest of the former asphalt plant area. The coating covers approximately 17 percent of the site surface.

Tanks. Twenty-three ASTs in the upper yard cover approximately 5 percent of the site surface.

5.2 Site Geology

Five main geologic units were identified at the Terminal: two units in the lower yard and three units in the upper yard. Figures 5-2 through 5-6 present cross sections of the site. Drawing No. 2 provides the cross section locations. The five units are discussed below.

5.2.1 Lower Yard

Fill. The uppermost unit occurring in the lower yard is fill. Fill material is found across the entire lower yard, and generally varies from approximately 1 to 8 feet thick. Grade fill comprises the graveled areas of the lower yard. Grade fill is present from the surface up to about 3 feet bgs, and it consists primarily of sand and gravel mixtures, with small amounts of silt. The sand is gray to brown and fine to medium. The gravel is generally uniform, subangular crushed rock up to approximately 2.5 inches in diameter.

Finer-grained fill covers the ungraveled portion of the lower yard and underlies the grade fill. The finer-grained fill varies in composition, but generally consists of sand and silt mixtures with varying amounts of gravel, organic material, and miscellaneous debris (including wood, concrete, wire, and fabric fiber). Fill typically consists of gray to brown, fine to medium sand with few to some silt and trace to few gravel. Sand with silt and silty sand fill are also common. The silt is typically brown to gray-brown with low plasticity. Finer-grained fill may be comprised of reworked native soil, and delineation of the contact between the fill and the underlying native soil is difficult.

The fill was mapped as “modified land” and designated the youngest unit in the area by Minard (1983).

Alluvium. Native soil underlies the fill throughout the lower yard. The native soil is present from the base of the fill to the maximum explored depth of 41.8 feet bgs. The native soil typically consists of gray to brown-gray, fine to medium sand with trace to few silt, trace to few organic material, and trace gravel. Interbedded sand with silt is abundant, and interbedded silt and sandy silt are also frequent. Interbeds range in thickness from less than 1 inch to several feet, and appear to be laterally discontinuous.

The unit is interpreted to be alluvium, and may be part of either the Whidbey Formation or more recent marginal marine/estuarine deposits.

5.2.2 Upper Yard

Fill. The uppermost unit occurring in the upper yard is fill. Fill material occurs around most tank basins and along access roads throughout the upper yard. Except for the berms, the upper yard fill typically varies from less than one foot to approximately 3 feet thick. The upper yard fill consists primarily of gray to brown, fine- to medium-grained sand or silt and sand mixtures, with trace to some gravel.

Transitional Beds. Native material underlying the fill consists primarily of silt and silty sand. The silt and silty sand unit ranges from about 50 to 100 feet thick in the upper yard. In general, the unit consists of a silt layer underlain by a sandier layer with frequent silt interbeds or lenses (Figures 5-2 through 5-4). The upper silt layer ranges from approximately 30 to 100 feet thick, and the sand layer ranges from 30 to 70 feet thick. At least two extensive silt interbeds or lenses, ranging from approximately 5 to 30 feet thick, lie within the sand layer. The frequency and thickness of silt interbeds within the sand layer decreases toward the east. The silt fraction within the sand layer also decreases toward the east. Due to the variation in topography, the upper silt layer is absent in the northernmost portion of the upper yard (north of MW-5U).

The nonplastic to medium plasticity silt is typically brown to gray, with trace to some sand. Fractures were observed locally in the silt. The sand is typically brown to gray and fine- to medium-grained, with few to some silt. Both silt and sand layers contain occasional thin (less than 0.5-inch) laminations. Occasional gravel and rare elastic silt and medium- to high-plasticity clay interbeds, or lenses, are also present.

This unit is interpreted to be alluvial/lacustrine preglacial deposits of the Transitional Beds. The Transitional Beds were mapped by Minard (1983) in the central portion of the upper yard.

Whidbey Formation. A predominantly sand unit underlies the Transitional Beds to the maximum explored depth in the upper yard. The unit generally consists of medium- to coarse-grained sand, sand with gravel, gravel, and silty sand, with local silt interbeds or lenses. The maximum penetrated thickness was about 38 feet.

The sand unit is interpreted to be part of the Whidbey Formation, an interglacial formation mapped in the northern part of the upper yard by Minard (1983).

5.2.3 Physical and Chemical Soil Parameters

Select soil samples collected from the upper and lower yards were tested for physical and chemical parameters such as grain size, and vertical hydraulic conductivity. Results of physical parameters tests are summarized in Table 5-1, and the laboratory report, including the grain size distributions and plasticity chart, is provided in Appendix C. Vertical hydraulic conductivities of the site soils are discussed in Section 5.3.6.

5.3 Site Hydrology

5.3.1 Hydrostratigraphic Units

Four hydrostratigraphic units have been identified at the site: surficial fill, Transitional Beds silt, Transitional Beds sand, and alluvium/Whidbey Formation (Figures 5-2, 5-3, and 5-4).

Surficial Fill. As described in Sections 5.2.1 and 5.2.2, sand and gravel fill is found at the surface in all unpaved parts of the lower yard and around some tank basins in the upper yard. Typically, the fill is permeable and allows precipitation to infiltrate and penetrate to deeper units. The unit was unsaturated during the RI field work (September 1995 through June 1996). Following rainfall events, water ponded in a few areas underlain by less permeable materials, especially the eastern part of the lower yard.

Transitional Beds Silt. Outside of the tank basin berms, the uppermost unit in the upper yard is the Transitional Beds silt. The silt unit is found above an approximate elevation of 75 feet (MLLW datum) south of MW-5U and ranges in thickness from 15 feet to over 100 feet. The unit mostly contains silt, with local interbeds of silty sand and sand with silt. The unit is generally unsaturated. Local accumulations of perched water occur on top of the unit, and in fracture zones within the unit. As discussed below, the unit is of low permeability and serves as a barrier to downward groundwater flow. Two monitoring wells (HA-5, HA-12) and four piezometers (P-201S, P-201I, P-202S, and P-203S) are screened in this unit.

Transitional Beds Sand. This unit lies underneath the Transitional Beds silt and ranges from approximately 30 to 60 feet thick. It consists of silty sand, silt with sand, and sand, and contains two extensive silt interbeds. Since it underlies the low permeability silt unit, the Transitional Beds sand is generally unsaturated. The unit contains local accumulations of perched water in the northern part of the site (at MW-5U and on top of the basal silt layer between MW-10U and MW-11U). The sandier portions of the unit are of moderate permeability, but the two extensive silt interbeds limit the downward migration of groundwater flow. Three monitoring wells (MW-5U, MW-10, and MW-11U) and two piezometers (P-202I and P-203I) are screened within this unit.

Alluvium/Whidbey Formation. The alluvium/Whidbey Formation unit underlies the entire site. This unit primarily consists of fine to medium sand and gravel, with lesser amounts of silt. It occurs below a depth of approximately 3.5 feet bgs in the lower yard and below depths ranging from approximately 10 to 100 feet bgs in the upper yard. Saturated below an elevation of approximately 9 to 12 feet (relative to the MLLW datum), this hydrostratigraphic unit (termed the site-wide aquifer where saturated) is unconfined (water table aquifer), tidally influenced, and likely a regional aquifer. All lower yard monitoring wells, six upper yard monitoring wells (MW-7U, MW-13U, and MW-201 through MW-204), and three upper yard piezometers (P-201D, P-202D, and P-203D) are screened in the site-wide aquifer.

5.3.2 Groundwater Elevations

RI groundwater level measurements obtained from December 1995 through November 1996 are presented in Appendix F, Table F-1.

Lower Yard. During the period of measurement, depth to the unconfined groundwater surface (site-wide aquifer) in the lower yard ranged from 1.7 feet bgs at LM-3 in February 1996 to 21.7 feet bgs at MW-134 in December 1995. This variation is primarily due to surface topography variations. Groundwater depths beneath the majority of the lower yard ranged from 3.5 to 8 feet bgs.

Groundwater elevations during the period of measurement varied from 6.45 feet at MW-1 in November 1996 to 17.05 feet at MW-134 in April 1996 (relative to the MLLW datum). Groundwater elevations in the majority of the lower yard varied from 7 to 12 feet, with the highest elevations in the central part of the lower yard and the lowest elevations in the southwest part of the lower yard. The highest groundwater elevations occurred in January and February, and the lowest groundwater elevations generally occurred in June, July, and August. Figures 5-8 and 5-9 provide the groundwater elevations for January and August 1996, respectively. Groundwater elevation variations at a given well ranged from about 0.6 to 2.9 feet throughout the period of measurement.

It appears that the on-site storm drain invert downstream of catch basin L30 is below the water table, based on pipe invert elevations for catch basins L32 and L37 of 9.17 and 8.22 feet (MLLW), respectively. It is likely that the on-site storm drain lines between MW-117 and MW-131 are also below the water table. A qualitative estimate of the volume of groundwater that may be moving into the drainage system is provided by observations of the site supervisor for the past 13 years. He has observed that the American Petroleum Institute (API) pump rarely activates during dry weather (the drainage system cannot gravity-drain beyond the API pump station, and the buildup of water at this location will activate the pump as necessary). Similarly, no seepage has been observed into the API separator or Detention Basin No. 2 during dry weather. These observations indicate little groundwater flows into the system.

Based on a Washington State Department of Highways profile (Washington State Department of Highways, 1971), the Department of Transportation storm drain in the easement through the site (Figure 5-1) lies below the water table downstream (west) of the vicinity of MW-26.

Depth to groundwater in the deeper lower yard monitoring wells ranged from 4.5 feet bgs at MW-122 in January 1996 to 8.1 feet bgs at MW-121 in August 1996. Groundwater elevations in deeper wells MW-120 and MW-121 were generally slightly lower than groundwater elevations in adjacent shallow wells. Groundwater elevations in MW-122 were higher than in adjacent shallow well MW-129. The highest groundwater elevations occurred in January, and the lowest groundwater elevations occurred between June and September. During the period of measurement, groundwater elevation fluctuations at a given well ranged from about 1.2 to 2.5 feet throughout the period of measurement. The deeper wells appear to be screened in the same aquifer as the shallow wells, based on similar water levels, similar lithology, and the lack of a low permeability layer between the shallow and deeper zones.

Groundwater elevations at monitoring well MW-134 were 4 to 10 feet higher than groundwater elevations in the rest of the Terminal. MW-134 is screened about 6 feet higher in the alluvium/Whidbey Formation than the other Terminal monitoring wells. Based on the occurrence of silt interbeds at the bottom of the boring, the elevation of the well screen, and the anomalously high water elevation in the well, it appears that groundwater is perched above the site-wide aquifer at this location.

In summary, the groundwater table occurs at shallow depths beneath the lower yard, the highest elevations occur in the central portion of the lower yard, and the lowest elevations occur in the southwest part of the lower yard. The deeper wells appear to be screened in the same aquifer as the shallow wells and have similar water elevations.

Upper Yard. During the period of measurement, depth to groundwater in the site-wide aquifer beneath the upper yard ranged from 17.2 feet bgs at MW-13U in February 1996 to 143 feet bgs at P-201D in March 1996. This variation is due to surface topography variations.

Site-wide aquifer elevations ranged from 8.0 feet (MLLW) at MW-201 in September 1996 to 12.4 feet at P-201D February 1996. The highest elevations were in the south-central part of the upper yard, and the lowest elevations were in the west part of the upper yard. In general, the highest groundwater elevations occurred in January and February, and the lowest groundwater elevations occurred between June and September. Groundwater elevation fluctuations at a given well ranged from about 0.4 to 1.6 feet throughout the period of measurement.

Perched groundwater was monitored at eight locations (HA-5, HA-12, MW-5U, MW-10U, MW-11U, P-201S, P-202S, and P-203S). Depth to groundwater in the perched zones ranged from less than 3 feet bgs at HA-5 in February 1996 to more than 52 feet bgs at MW-11U in December 1995. Perched zone groundwater elevations ranged from about 29 feet at MW-10U in September 1996 to over 121 feet at HA-5 in February 1996. In general, the highest groundwater elevations occurred in January or February, and the lowest groundwater elevations occurred in August or September. Groundwater elevation fluctuations at a given well ranged from about 0.2 to 4.1 feet throughout the period of measurement.

In summary, groundwater is found in perched zones (from less than 3 feet to more than 52 feet bgs) and in the site-wide aquifer (from 17 to 143 feet bgs). The highest elevations in the site-wide aquifer occur in the south-central part of the upper yard, and the lowest elevations occur in the west part of the upper yard.

5.3.3 Surface Water

The Terminal is situated within 1,000 feet of Puget Sound. Tides in the Edmonds part of Puget Sound range from approximately -3 to 13 feet relative to MLLW. The Terminal is bounded on the northwest and northeast by an open and uncontrolled drainage ditch which conveys Willow Creek around this part of the site perimeter. The drainage ditch carries surface water (Willow Creek) into a tidal basin, where water is then conveyed beneath the Burlington Northern Santa Fe Railroad right-of-way via a 48-inch-diameter culvert and on to Puget Sound. A wetland area, the Union Oil Marsh, is located to the north of Willow Creek on the northeast side of the site. The marsh drains to Willow Creek.

The drainage ditch and the marsh are directly connected to Puget Sound and are tidally influenced (Section 5.3.5). During periods of high tide, flow reversal occurs in the ditch and the marsh partially fills with water. Based on salinity tests conducted in conjunction with the upland sediment evaluation, marine water intrusion appears to extend up to surface water station D-4 during high tide. During periods of low tide, the marsh completely drains. Surface water elevations in the drainage ditch (including at the downstream end of the marsh) varied from 8.53 to 10.98 feet between December 1995 and November 1996 (Appendix F, Table F-1). Figure 5-7 presents a longitudinal profile of the ditch showing the range in surface water elevations and adjacent groundwater elevations. The surface water elevation difference between the upstream surface water station (D-4) and the tidal basin (TB) was less than 0.5 feet. Groundwater elevations southeast of Detention Basin No. 1 were higher than adjacent surface water elevations. Surface water elevations in the ditch around and downstream of Detention Basin No. 1 were higher than groundwater elevations adjacent to the ditch in these areas.

Water intermittently ponds in low spots on site (e.g., near MW-133 and in former stockpile area) during prolonged rainfall. The ponded water either percolates into the ground or runs into the stormdrain system, through an oil/water separator, and into Willow Creek along the northwest property boundary. A detailed description of the stormdrain system, including the two detention basins, is presented below.

5.3.4 Detention Basins

Two detention basins, Detention Basin No. 1 and Detention Basin No. 2, are present on site. The detention basins are part of the on-site stormdrain system. Water elevations in Detention Basin No. 1 varied from 5.92 to 10.42 feet between December 1995 and November 1996 and for 10 of the 12 monthly basin water elevation measurements[2] were

[2] Except for May 10 and July 9, 1996. Based on a review of the rainfall records for the week proceeding the May 10 and July 9, 1996, water level measurement events, and a comparison of detention basin water levels to water levels in wells significantly upgradient (e.g., MW-3 and MW-133), it appears that the detention basin water levels on these two dates were erroneous.

lower than the surrounding groundwater and surface water elevations. Water elevations in Detention Basin No. 2, which is lined with plastic, were always higher than adjacent groundwater elevations and were typically higher than surface water elevations.

Observations and measurements made during the RI monthly water level monitoring (Section 5.3.2) and the tidal response study (Section 5.3.5) indicate that water levels in Willow Creek (as conveyed through the ditch) are higher than water levels in Detention Basin No. 1. During the storm that occurred when the tidal study was being conducted (January 18, 1996), the water level in the ditch was within 1 foot of the top of the detention basin. This unusual occurrence was partially due to the city of Edmonds Public Works Department discharging an estimated 7.5 million gallons of treated sewage per day into the wetlands during an outfall construction period. The highest water level recorded in Detention Basin No. 1 during the RI was about 3 feet below the top of the berm around the basin.

Several storms occurred during the winter 1995/1996, and in no case resulted in overtopping of the basin. Large storm events occurred on November 7, 1995 (approximately 1.9 inches of rain recorded in Seattle) and February 8, 1996 (approximately 3 inches of rain recorded in Seattle). Storm water was managed via the Terminal's on-site system during these and all rainfall events and no overtopping of the basin berm occurred. For comparative purposes, the 10-year, 24-hour storm for the Terminal area is approximately 2.1 inches of rain and the 50-year, 24-hour storm for the area is approximately 2.7 inches of rain (NOAA, 1973). These data indicate that it is not likely that water in Detention Basin No. 1 historically overtopped the berm.

5.3.5 Tidal Influence

A tidal response study was conducted between January 17 and 24, 1996. During the period of the study, Puget Sound tides, measured at the end of the UNOCAL dock, varied between -2.34 and 13.15 feet relative to the MLLW datum (Table 5-2). Groundwater elevations (MLLW datum) in the site-wide aquifer ranged from 7.43 feet at MW-120 to 11.74 feet at MW-109. Observed fluctuations in groundwater elevations in the eleven shallow monitoring wells ranged from 0.26 to 2.08 feet, and the observed fluctuations in groundwater elevations in the three deep monitoring wells varied from 1.06 to 2.52 feet. Detention basin and Willow Creek water elevations varied from 7.49 feet in Detention Basin No. 1 to 12.73 feet at surface water station D-3. Observed fluctuations in detention basin and Willow Creek water levels ranged from 1.92 to 3.05 feet.

Tidal response study hydrographs are presented in Appendix G. Based on a review of the hydrographs, it appears that groundwater levels in the site-wide aquifer wells are influenced by tidal fluctuations in Puget Sound and surface water fluctuations in the ditch and detention basin. Additionally, groundwater levels in the wells during the tidal response study were influenced by the infiltration of precipitation, with 2.4 inches of rain falling during the four days prior to the test and another 2.4 inches falling during the study. A figure showing daily rainfall during the tidal response study is presented in Appendix G.

Groundwater elevations at monitoring wells MW-8, MW-20, MW-115, MW-120, MW-121, MW-123, and MW-124 were primarily influenced by tidal fluctuations in Puget Sound. The hydrographs from these wells were similar to the overall shape and peak pattern (comparing the first daily peak to the second) of the Puget Sound hydrograph. Time lag (the length of time between a point on the Puget Sound hydrograph and a corresponding point on a well hydrograph) ranged from 2.1 days at MW-120 to 3.2 days at MW-115. Tidal efficiency (the ratio of well water level amplitude to tidal amplitude) varied from 5 to 12 percent.

Groundwater in wells closest to Willow Creek on the west side of the site (MW-8, MW-20, and MW-115) did not appear to be influenced by water level fluctuations in the creek and tidal basin. The hydrograph for the tidal basin showed a trough pattern characteristic of drainage from the marsh (delayed drainage due to the amount of time the marsh takes to drain). This trough pattern was not identified in any of the monitoring well hydrographs. It is likely that the diurnal ditch water level fluctuations (1 to 2 feet) were not great enough to induce a noticeable fluctuation in groundwater levels relative to those induced by the tidal fluctuations in Puget Sound (15 feet). Although the ditch bottom on the west side of the site is composed primarily of sand, a thin, surficial layer of low permeability sediment in the ditch, or a fine-grained layer beneath the ditch (as observed in SB-170 through SB-175), may also attenuate the influence of ditch water level fluctuations on nearby groundwater levels.

Groundwater at MW-109 and MW-122 was primarily influenced by surface water fluctuations in Willow Creek. The hydrographs from these two wells were well-matched with the surface water station D-3 hydrograph. The hydrograph from Detention Basin No. 1, showed an upward trend during the study, presumably due to storm water runoff.

The hydrographs from MW-7, MW-26, MW-105, MW-112, and MW-129 did not match the Puget Sound or creek hydrographs. It is likely that groundwater pressure waves generated by surface water fluctuating at multiple locations (Puget Sound, the drainage ditch, and Detention Basin No. 1) interfered with each other, creating more chaotic hydrographs. In general, these hydrographs showed an upward trend throughout the test, indicating an influence from the infiltration of precipitation.

The average (arithmetic mean) groundwater and surface water elevations were calculated for data collected on January 18. The elevations from shallow and deep wells are plotted on Figures 5-10 and 5-11, respectively. Shallow elevations at the lowest low tide and highest high tide on January 18 are also plotted on Figures 5-12 and 5-13. All groundwater contour patterns (i.e., average, low, and high) are similar and show that during the period of the test (1) the water elevation in the creek/ditch was higher than the water elevation in the wells nearest the creek/ditch, (2) the water elevation in Detention Basin No. 1 was consistently the lowest on site, and (3) groundwater flow was toward Detention Basin No. 1 in the north-central part of the site, and toward the northwest in the western part of the site.

5.3.6 Hydraulic Conductivity

Three methods were used to estimate the hydraulic conductivity (K) of geologic materials at the boring locations: (1) laboratory tests on core samples, (2) tidal response study calculations, and (3) short-term, in situ, rising head tests (slug tests). Tables 5-1, 5-2, and 5-3 summarize the laboratory K results, tidal response study K results, and slug test K results, respectively. Graphs of slug test data and calculations used to estimate K are presented in Appendix G.

Laboratory Permeameter Tests. Laboratory permeameter tests were performed on undisturbed core samples from six monitoring well borings (MW-120, MW-129, MW-131, MW-201, MW-202, and MW-204) to estimate the vertical K (permeability) of finer-grained interbeds in the alluvium and transitional beds. The vertical K of the lower yard alluvium varied from 1×10^{-7} centimeters per second (cm/sec) for a clay sample from MW-120 to 1×10^{-5} cm/sec for a silty sand sample from MW-129 (Table 5-1). The vertical K of the upper yard Transitional Beds ranged from 5×10^{-8} cm/sec for a clay sample from MW-201 to 4×10^{-5} cm/sec for a silty sand sample from MW-202. These values fall within the range of expected values for clay and silty sand materials (Freeze and Cherry, 1979; Wolff, 1982).

Tidal Response Study Calculations. Tidal response study data from six monitoring wells borings (MW-8, MW-20, MW-115, MW-120, MW-121, and MW-124) were used to estimate the average (arithmetic mean) horizontal K for the area between the wells and Puget Sound (Todd, 1980). In the calculations, a storativity (specific yield in an unconfined aquifer) of 15 percent was selected as a midpoint in the range of specific yields (8 to 23 percent) for sand and silt aquifers (Todd, 1980). Additionally, an aquifer thickness of 50 feet was selected as a conservative estimate of the thickness likely to have affected the wells measured during the tidal response study. The calculated horizontal K ranged from 2×10^{-3} to 5×10^{-3} cm/sec, with an average of 3×10^{-3} cm/sec (Table 5-2).

Slug Tests. Slug tests were performed on nine monitoring wells borings (MW-101, MW-112, MW-119, MW-120, MW-127, MW-131, MW-7U, MW-13U, and MW-203) to estimate the horizontal K of the site-wide aquifer. The horizontal K estimated from the slug tests ranged from 7×10^{-4} to 1×10^{-1} cm/sec, with an average of 2×10^{-2} cm/sec (Table 5-3). The estimated lower yard horizontal K varied from 7×10^{-4} to 2×10^{-2} cm/sec, with an average of 9×10^{-3} cm/sec. The estimated upper yard horizontal K ranged from 1×10^{-2} to 1×10^{-1} cm/sec, with an average of 5×10^{-2} cm/sec.

These values fall within the range of expected values for sand and silty sand aquifers (Freeze and Cherry, 1979; Wolff, 1982).

The hydraulic conductivity tests and calculations indicate that the most permeable part of the site-wide aquifer lies in the Whidbey Formation beneath the upper yard (K_hs from 1×10^{-2} to 1×10^{-1} cm/sec, with an average of 5×10^{-2} cm/sec). Based on the tidal response study calculations (representing the aquifer K between the wells and Puget Sound), the least permeable part of the site-wide aquifer appears to be between the site and Puget Sound (K_hs from 7×10^{-4} cm/sec at MW-120 to 2×10^{-2} cm/sec at MW-112, with an average of 9×10^{-3} cm/sec). The vertical K values determined by the laboratory permeameter tests indicate that the finer-grained interbeds in the lower yard (K_vs from 1×10^{-7} cm/sec for a clay sample from MW-120 to 1×10^{-5} cm/sec for a silty sand sample from MW-129) and within much of the transitional beds (K_vs from 5×10^{-8} cm/sec for a clay sample from MW-201 to 4×10^{-5} cm/sec for a silty sand sample from MW-202) provide a significant barrier to downward groundwater flow.

5.3.7 Groundwater Flow Directions

Site-Wide Aquifer. Figures 5-8 and 5-9 present shallow groundwater contour maps using site-wide aquifer data obtained during the monthly water level measurement rounds conducted on January 18 and August 12, 1996. Groundwater elevations from MW-134 were not included in the contour maps since groundwater appears to be perched at this location. Water levels on January 18 and August 12, 1996, were collected over 8-hour and 5.5-hour time periods, respectively. Collecting data over this period of time did not appear to significantly affect the groundwater contour maps, based on the similarity of the groundwater contour maps prepared using tidal response study data and the similarity of shallow groundwater contour maps prepared from data collected in all 12 months of the monitoring period. Groundwater contours generally match the ground surface contours. The principal exceptions to this are (1) near Willow Creek around and downstream of Detention Basin No. 1, (2) in the central and eastern parts of the upper yard, and (3) near MW-127 in the lower yard. Although portions of the on-site storm drain system and the Washington Department of Transportation storm drain line in the easement through the site (Figure 5-1) lie beneath the water table (see Section 5.3.2), groundwater elevations do not appear to be affected by their presence.

The estimated shallow groundwater flow directions are to the northwest in the western part of the Terminal, toward Detention Basin No. 1 in the central part of the lower yard, and to the northeast in the eastern part of the Terminal. Groundwater flows toward Willow Creek (to the north) in the northeast part of the Terminal, away from Willow Creek in the northern part of the Terminal, and radially into Detention Basin No. 1 (see Figures 5-8 and 5-9). Since water levels in Detention Basin No. 1 are artificially lowered by pumping, the detention basin serves as a groundwater sink, with groundwater being pulled toward the basin as it is pumped (see Section 5.4.2). The specific conductances of water samples collected in wells between Willow Creek and Detention Basin No. 1 also indicate flow from Willow Creek to the detention basin. During the RI, specific conductance in these wells (LM-2, MW-108, and MW-109) ranged from 1,400 to 22,000 µS/cm, similar to creek sediment pore water measurements (EMCON, 1995b). The creek upstream of the detention basin (southeast of MW-129) also serves as groundwater sink. Since Willow Creek water levels are higher than both on-site groundwater levels adjacent to the creek and water levels in Detention Basin No. 1, the creek around and downstream of the detention basin serves as a source, with groundwater flowing toward the site from the creek. This condition substantially controls the migration of contaminants in this area of the site (see additional discussion in Section 8.3).

Estimated horizontal groundwater gradients from the groundwater contour maps are 0.003 to 0.02 feet/foot across most of the site. Horizontal hydraulic gradients in the northeastern part of the Terminal range from 0.002 to 0.005 feet/foot. Horizontal hydraulic gradients between the ditch and Detention Basin No. 1 are up to 0.1 feet/foot. Horizontal hydraulic gradients south of Detention Basin No. 1 in the central part of the lower yard are approximately 0.003 feet/foot. Horizontal gradients in the southwestern part of the lower yard range from 0.004 to 0.005 feet/foot. Horizontal groundwater gradients range from less than 0.002 to 0.006 feet/foot in the central and eastern portion of the upper yard. Based on a comparison of groundwater elevations in adjacent shallow and deeper monitoring wells, the average vertical hydraulic gradients are 0.008 feet/foot downward at MW-120 (in the southwestern part of the lower yard), 0.012 feet/foot downward at MW-121 (adjacent to the ditch in the western part of the lower yard), and 0.024 feet/foot upward at MW-122 (on the south side of Detention Basin No. 1). Though slight downward gradients exist at MW-120 and MW-121, vertical hydraulic conductivities are typically 10 times lower than horizontal hydraulic conductivities (Todd, 1980; Freeze and Cherry, 1979), yielding shallow groundwater flow directions that are nearly horizontal at these locations.

The site-wide aquifer is recharged laterally from the south of the site and from Willow Creek at the north part of the site, vertically from infiltration of precipitation in the lower yard, and potentially vertically from perched zones in the upper yard. The site-wide aquifer discharges laterally to Willow Creek at the northeastern part of the site, to Detention Basin No. 1, and to Puget Sound.

Average groundwater and surface water elevations from the January 18, 1996, tidal response study are plotted on Figures 5-10 and 5-11. Water elevations at the lowest low tide and highest high tide on January 18 are also plotted on Figures 5-12 and 5-13. All four groundwater contour patterns are similar and show that during the period of the test (1) the water elevation in Willow Creek as conveyed through the ditch was higher than the water elevation in the wells nearest Willow Creek, (2) the water elevation in Detention Basin No. 1 was consistently the lowest on site, presumably due to pumping of the basin, (3) groundwater flow in the site-wide aquifer was toward Detention Basin

No. 1 in the north-central part of the site, and to the northwest in the western part of the site, and (4) although tidally-induced head variations occur along the western part of the site, the overall groundwater contours at the site are similar throughout the tidal cycle. Additionally, the groundwater contour maps prepared from the tidal response study data are similar to the contour maps prepared from the monthly groundwater monitoring events.

The horizontal groundwater flow rate (average linear velocity) for shallow groundwater was estimated using the following equation (Freeze and Cherry, 1979):

$$v = ki/n$$

where k = hydraulic conductivity (cm/sec),

i = gradient (feet/foot), and

n = porosity (dimensionless).

Based on an average porosity of 0.375 (Table 5-1), gradients from Figures 5-8 and 5-9, and hydraulic conductivities determined by slug testing in shallow wells (Table 5-3), the estimated groundwater flow rate varies from about 55 feet per year at MW-203 (in the eastern part of the site) to 220 feet per year at MW-112 (southwest of Detention Basin No. 2). For the northeastern part of the Terminal, using a porosity of 0.29 (Table 5-1, MW-203), gradients from Figures 5-8 and 5-9 (0.002 to 0.005 feet/foot), and a hydraulic conductivity of 0.01 cm/sec for MW-203 (Table 5-3), the estimated groundwater flow rate to the north varies from 71 feet per year to 160 feet per year. For the central part of the Terminal south of Detention Basin No. 1, using a porosity of 0.38 (Table 5-1, MW-131), gradients from Figures 5-8 and 5-9 (0.0026 to 0.0028 feet/foot), and a hydraulic conductivity of 0.01 cm/sec for MW-131 (Table 5-3), the estimated groundwater flow rate to Detention Basin No. 1 varies from 68 feet per year to 74 feet per year. For the western and southwestern part of the Terminal, using a porosity of 0.32 (Table 5-1, MW-124), gradients from Figures 5-8 and 5-9 (0.0038 to 0.0045 feet/foot), and a hydraulic conductivity of 0.003 cm/sec for MW-124 (Table 5-2), the estimated groundwater flow rate to the northwest varies from 36 feet per year to 42 feet per year. Using an average hydraulic conductivity from the tidal response study (0.002 cm/sec) and horizontal groundwater gradients typical for most of the site (0.003 to 0.02 feet/foot), the estimated groundwater flow rate varies from about 16 to 110 feet per year.

Perched Groundwater Zones. Based on groundwater elevations in the eight wells monitoring perched groundwater in the upper yard, only two wells appear to be monitoring the same perched unit. Soil samples from borings near the wells monitoring perched groundwater zones indicate that these zones are laterally discontinuous and surrounded by unsaturated soil. The volume of water in the perched zones beneath the upper yard was calculated by estimating the areal extent and thickness of each perched zone (using water level data from the upper yard soil boring logs, wells, and piezometers). Based on a comparison of the summed upper yard perched zone volumes and the estimated volume of the site-wide aquifer, it is estimated that the volume of the perched zones is 3 percent of the volume of the site-wide aquifer beneath the upper and lower yards. Given the lower permeability of the perched zones relative to the site-wide aquifer, the groundwater flux in the perched zones is probably considerably less than 3 percent of the groundwater flux in the site-wide aquifer. The perched zones are probably recharged when the tank containment areas are used as storm water detention basins. By design, each tank containment area stores all rain falling within its limits. The storm water collected from each area is not released into the stormdrain system until that area's drain valve is opened. The perched zones likely discharge water to surrounding unsaturated soil, to deeper perched zones, to the stormdrain system, or as seeps along steeper slopes.

Summary. Site-wide aquifer groundwater contours roughly follow ground surface contours and are similar seasonally. Groundwater flow does not appear to be influenced by the presence of subsurface utilities. Groundwater flows to the northwest in the western part of the Terminal, toward Detention Basin No. 1 in the central part of the lower yard, and to the northeast in the eastern part of the Terminal. Groundwater flows toward Willow Creek (to the north) in the northeast part of the Terminal, away from Willow Creek in the northern part of the Terminal, and radially into Detention Basin No. 1. Perched groundwater occurs beneath the upper yard in isolated, laterally discontinuous zones surrounded by unsaturated soil.

5.4 Storm Water Drainage System

This section discusses the on-site drainage system, summarizing the drainage system inventory which is provided in full in Appendix H.

5.4.1 System Description

The upper and lower yards at the Terminal are served by a stormdrain system which ultimately conveys storm water to the site's API oil/water separator (Drawing No. 3). The system includes a series of catch basins connected by underground concrete pipes, a sump with a pump, the two detention basins, and the API oil/water separator. The lower yard system can be subdivided into five parts: the southwest, southeast, west, east, and north lower yard. All but the west and north part drain into a sump located northeast of the API oil/water separator. The west part drains directly to the oil/water separator, and the north part discharges to Detention Basin No. 2.

During upper yard tank installation, earthen and concrete secondary containment structures were constructed around each tank or group of tanks. By design, each containment area stores all rain falling within its limits. The storm water collected from each area cannot be released until that area's drain valve is opened, allowing the stored water into the stormdrain system. These valves are normally closed and are only opened when the site's API oil/water separator can process the stored water. The majority of upper yard storm water originating from areas outside the containment structures is collected along an asphalt concrete ditch which flows west to east across the upper yard. Other storm water originating outside the containment structures sheet-flows to the toe of the slope where it is collected by the lower yard system.

A French drain reportedly exists in the upper yard to minimize the seepage of perched groundwater into the southernmost tank basins. According to UNOCAL personnel present during the French drain installation, the drain extends along the southern boundary of the upper yard from Tank 263 to Tank 3717 and connects to the storm drain system between catch basins U17 and U19 by running downhill between Tanks 2605 and 2911 (Drawing 3). Construction drawings are not available for the French drain, and the location of the drain could not be determined during site utility locating.

5.4.2 System Operation

The method of operation for the site's storm water system depends on storm event size and the tidal cycle in the drainage ditch to which the system discharges. Normal operating procedures during storm events are as follows. Storm flows from the lower yard are processed through the API oil/water separator either by gravity flow (from the area west of the API separator), or by pumping from the API pump (from the rest of the lower yard). Processed water flows by gravity from the API oil/water separator to Detention Basin No. 2 and is discharged by gravity to Willow Creek during low tide (Outfall 002). During high tide, processed water from the API oil/water separator either: (1) flows by gravity to Detention Basin No. 2, where it is stored and then released to Willow Creek during low tide; or (2) flows by gravity to the HC (Hydrocleaner) Pump and then is pumped into Willow Creek (Outfall 001).

After the lower yard storm volumes have been processed, storm water held in the upper yard containment areas is manually released. Storm water released from the upper yard drains to the API separator, except during large storm events when excess storm water is routed into Detention Basin No. 1. After the lower and upper yard storm water volumes have been processed, Detention Basin No. 1 storm water is then pumped to the API oil/water separator. To maintain the maximum storm water detention volume, Detention Basin No. 1 is routinely pumped. This storm water management practice prevents the need for personnel to be on site should a large storm event occur during evening or weekend hours. The detention basin is typically pumped daily to every other day in the winter and weekly to every other week in the summer, depending on weather.

5.4.3 Off-Site Drainage

Willow Creek collects runoff from off-site areas northeast and east of the site (wetlands area, hatchery, and SR 104) and from the southern off-site residential area which abuts the east half of the site's south edge. Willow Creek is also the recipient of all storm water discharged from the site. The creek flows west from the site's northwest edge into Puget Sound.

Pine Street borders the site along the east half of its south edge. A roadside ditch exists on the south side of Pine Street and this ditch drains the residential area to the south. The ditch flows to the intersection of Pine Street and the site entrance road where flow is piped under Pine Street and the site entrance road and outfalls to the ditch bearing northeast toward the neighboring fish hatchery.

A small swale exists between the site fence and the adjacent roadway along the west half of the site's south edge. The swale conveys flow from the residential area immediately to the south, west to the forested area located in the site's southwest corner. Runoff from this forested area of the site sheet-flows off site and is not conveyed to the site's stormdrain system.

A low-lying area exists along the south half of the site's northwest edge between the property line and the neighboring railroad tracks. This depression slopes gradually to the northeast until it drains into the large drainage ditch.

5.4.4 System Condition

The site drainage system appears to be in good working order. During the system inventory, one instance of a crushed or plugged pipe was noted (between catch basins L1 and L8), as well as high sediment accumulations in a few catch basins. At the time of the inventory, the total volume of sediment in the site stormdrain system was estimated at approximately 500 cubic feet. In the summer of 1995, UNOCAL had portions of the system cleaned: catch basins L29 through L37 and the drain lines between them. During cleaning of catch basin L26, a film of product was reportedly observed entering the brick-lined catch basin. Product was not observed in other catch basins. In the fall of 1994 the API oil/water separator, all catch basins closest to the separator, and drain lines out to about 250 feet from the separator were cleaned. U46 was not cleaned at this time. In March 1996 (not fall 1996, as stated in the drainage system inventory [Appendix H]) all but five of the lower yard catch basins were cleaned out. Additional catch basin cleaning has not been conducted since that time.

5.5 Upland Sediments

During a flood tide, the upland sediments are partially to fully inundated with water, and during an ebb tide the sediments on the banks of Willow Creek (as conveyed through the drainage ditch) and tidal basin are uncovered. Observations of the sediments in the bottom center of Willow Creek during field sampling indicated that these sediments are constantly submerged. The water covering the upland sediments was generally brackish (1 to 30 parts per thousand [ppt] salinity) as a result of the mixing of surface water runoff with salt water from tidal incursion. Upland sediment pore water salinities measured between 11 and 21 ppt in the top 10 centimeters.

Observations of upland sediment characteristics are reported on the sediment field sampling data forms included in Appendix E. Upland sediments observed along the northeast boundary of the Terminal were organic enriched, very soft to firm, olive brown to black sandy silts. Upland sediments that were at an elevation high enough to support perennial vegetation retained a peat-like structure. This peat-like structure was observed in sediment samples collected from stations US-08, US-09, US-10, US-12, and US-14. Sediments located in the bottom of Willow Creek and also along the northwest property boundary were generally loose olive gray to gray silty sands. Tidal basin sediments were loose gray to brown gravely sands. Reducing sediments indicative of anoxic conditions were observed at stations US-10 through US-14 along the northeast boundary of the Terminal. Amphipods were observed in the upland sediments from stations US-01 through US-04, US-08 through US-12, and at US-15.

6 NATURE AND EXTENT OF CONTAMINATION

6.1 Data Validation and Management

All sample data received from the analytical laboratories were reviewed to determine compliance with data quality objectives (DQOs) as specified in the Work Plan. Data were reviewed according to procedures in the Quality Assurance Project Plan, and following data validation guidelines in *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic and Organic Data Review* (USEPA, 1994a, b). Data that did not meet the validation criteria were assigned data qualifiers to restrict or modify appropriate uses. Results of the data validation process are presented in the data validation reports (Appendix J).

The laboratory assigned data qualifiers that were retained in the project database were as follows:

- < (a less than symbol) - The analyte was not detected at the method detection limit (MDL) shown
- J - Estimated quantity; value reported is between the MDL and 10x the MDL, the practical quantitation limit (PQL)
- X - Value is biased high by interference

Data qualifiers assigned during data validation review were as follows:

- E - The associated numerical value is an estimated quantity
- B - The analyte was also detected in an associated blank

Data were judged to meet quality assurance (QA) objectives for precision, accuracy, representativeness, and comparability. All sample analyses exceeded the QA objectives for completeness of 95 percent. Some of the data were assigned laboratory and data validation qualifiers. The data qualifier definitions are as defined above.

Data were entered into a personal-computer-compatible database with their assigned data qualifiers. Most of the data were transferred directly into the database from electronic deliverables provided by the laboratory, and some data were hand entered. A 100 percent check for accuracy was performed on data that were hand entered, and a minimum 10 percent accuracy check was performed on data that were entered by electronic transfer.

6.2 Data Evaluation Procedures

Data were evaluated using the procedures described in the Work Plan. The sampling design called out focused (biased) and random sampling locations. For purposes of evaluating the RI data, focused and random results were combined for the summary statistics (with upper yard data evaluated distinctly from lower yard data).

The lower and upper yard unsaturated (vadose zone) soil samples were evaluated separately by analytical method and compound. Due to timing, results from upper yard soil borings SB-212 and SB-216, collected in June 1996, were not included in the statistical analysis. Lower yard data included in the statistics were results from all SS-100 series locations; all SB-100 series locations; and all "upper yard" locations that are at an intermediate level: SB-201, SB-202, SB-203, SB-204, and SB-205. Data that were not included in the lower yard statistics were results from background locations SS-107 and SS-108; TP-101, because the sample included tar-like material; catch basin samples; all BSS samples, which were evaluated separately; and off-site locations MW-105, MW-106, MW-107, MW-137, and MW-138. Upper yard data included in the statistics were results from all SB-200 series locations (except those included in the lower yard evaluation); all SS-200 series locations; all MW-200 series locations; and all TP-200 series locations. Data that were not included in the upper yard statistics were results from background sample SS-208.

Thirty-four saturated soil samples were collected pursuant to the Work Plan. Because the results of saturated soil samples often do not allow differentiation between soil contamination and groundwater contamination, and because alternative methods were used to estimate contaminated soil volumes, saturated soil data were not included in the statistical summary of unsaturated soil data. At Ecology's request, UNOCAL ran summary statistics on the results of the 34 soil samples collected from below the water table.

The first, second, third, and fourth quarter groundwater results were evaluated separately, and by analytical method and compound. Data from off-site wells MW-105, MW-106, MW-107, MW-137, MW-138, and MW-28 were not included in the groundwater statistics. The sample data from November for MW-20 were also omitted from the analysis based on a film of product observed during sampling.

Soil and groundwater data were summarized by maximum detection, frequency of detection above a specified screening level, and percent detected above that screening level.

6.3 Cleanup Levels and Other Regulatory Standards

The MTCA regulations of chapter 173-340 WAC provide methods for identifying cleanup levels for a site. For preliminary evaluation purposes in the remedial investigation phase, MTCA cleanup levels were used as screening levels to compare the Terminal RI data as follows: upper yard soil data were compared to pertinent Method B residential cleanup levels and the lower yard soil data were compared to pertinent Method C industrial cleanup levels.[3] This approach was identified by Ecology and UNOCAL as appropriate for preliminary evaluation purposes, based on an assumption that future upper yard use may be residential in nature and future lower yard use may be industrial in nature. However, for the lower yard data evaluation, the Method A industrial cleanup level for lead was used as a screening level because a Method C cleanup level is not available for this compound. For the upper yard data evaluation, a Method B (residential) TPH cleanup level was calculated as a screening level, as Method A does not provide a mechanism for this. Soil data from the lower yard were also compared to groundwater-protection-based soil screening values.

There are currently no MTCA regulatory procedures to develop cleanup levels that reflect the soil-to-air (vapor) pathway; the soil screening levels used in the RI do not reflect this pathway.[4]

Similarly, groundwater data from the site-wide aquifer and surface/storm water data were compared to Method B, surface water-protection-based screening levels.[5] Groundwater data collected from the site-wide aquifer beneath the upper yard were also compared to Method B, drinking-water-based screening levels, as described further below.

The selection of MTCA-based screening levels for comparative purposes in the RI is not meant to imply that these levels will be the ultimate cleanup levels for the site. Final cleanup levels for the site will be selected in the cleanup action plan and will include consideration for the soil-to-vapor pathway.

6.3.1 Soil

Soil screening levels for the lower and upper yards are provided in Tables 6-1a and 6-1b, respectively. For the lower yard, human health (direct contact)-based values are listed, as well as groundwater protection-based values for TPH. Direct contact-based soil screening levels reflect the assumptions noted above; i.e., the Method C industrial assumptions of WAC 173-340-745 for the lower yard comparison and the Method B residential assumptions of WAC 173-340-740 for the upper yard comparison. The Method B- and C-based screening levels reflect the direct contact pathway only.

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[3] This evaluation was performed prior to the February 2001 revisions to chapter 173-340 WAC.
[4] Ibid.
[5] Ibid.

Groundwater-protection-based screening levels for TPH are discussed below. Groundwater-protection-based soil screening levels were not used for assessment of the upper yard soil data because of a) the depth to groundwater (generally greater than 50 feet), b) the thickness of low permeability silt above the water table (generally greater than 30 feet), and c) the extensive unsaturated sand and silt units beneath the upper yard.

For TPH, Method B (residential) and Method C (industrial) human-health-based screening levels were calculated for the direct contact pathway using *Interim Interpretive and Policy Statement, Cleanup of Total Petroleum Hydrocarbons (TPH)* (Interim TPH Policy; Ecology, 1997a) and fractionated soil data collected at the site in January 1998 (EMCON, 1998b). These data were collected pursuant to procedures of a Sampling and Analysis Plan addendum (EMCON, 1997b). The fractionated results of the lower yard soil sample and upper yard soil sample which yielded the most conservative TPH screening level were used: SB-187 in the lower yard and SB-238 in the upper yard. The percent aliphatics and percent aromatics associated with these samples resulted in human-health (direct contact)-based TPH screening levels of 143,043 milligrams per kilogram (mg/kg) for the lower yard and 3,443 mg/kg for the upper yard. Data summaries and the procedures used to derive these values are provided in Appendix N.

The human-health (direct contact)-based TPH screening level for the lower yard (143,043 mg/kg) is greater than the residual saturation concentration for petroleum hydrocarbons. As such, the residual saturation concentration becomes an upper limit to a human-health-based soil screening level.

The residual saturation concentration is dependent on soil and product type and is defined as the concentration above which petroleum product in soil is expected to flow downward under the force of gravity. A residual saturation concentration for the lower yard was initially estimated using American Petroleum Institute (API) Publication 1629 (API, 1993). This publication gives residual saturation values for five soil types, ranging from coarse gravel to silt, and three product types, gasoline, middle distillates, and fuel oil. Based on the lower yard soil type (fine sand with silt to silty fine sand) and product specific gravity data collected at the site (an average of 0.885), a residual saturation concentration of 28,800 mg/kg was calculated for use as a TPH screening level for the lower yard. Using Option 2 of the Interim TPH Policy, this concentration in soil (28,800 mg/kg) does not meet the criteria for individual concentration limits; i.e., the 28,800 mg/kg residual saturation screening level is predicted to cause an exceedance of the benzene screening level. (EMCON, 1998c; Appendix N).

A table of residual saturation values for a range of soil and product types was compiled by Ecology from a variety of sources (Ecology, 1998a; Appendix N). Ecology selected residual saturation values for the site that are reflective of petroleum hydrocarbons in coarse gravel. These values are 1,000 mg/kg for gasoline, 2,000 mg/kg for middle distillates (diesel), and 5,000 mg/kg for oil (Ecology, 1998d). These values are shown on Table 6-1a as the groundwater-protection-based soil screening levels for TPH in the lower yard. Because the lower yard soil is not comprised of coarse gravel, these values are conservative. On-site, vadose zone TPH concentrations exist above these values, indicating that residual saturation concentrations at some locations on the site are higher than the screening values selected by Ecology.

6.3.2 Groundwater and Surface/Storm Water

Screening levels for surface/storm water and groundwater are based on Method B, as Method B is the standard approach applicable to all sites (WAC 173-340-705).

To determine the most appropriate screening levels for groundwater, a groundwater potability analysis was performed for the site-wide aquifer (UNOCAL, 1998; Appendix O). Results of this analysis demonstrated that the highest beneficial use and reasonable maximum exposure scenario for groundwater beneath the Terminal is protecting beneficial uses of adjacent surface water, based on the following:

- Groundwater does not serve as a current source of drinking water (WAC 173-340-720[1]][a][i]).

- Groundwater is not a potential future source of drinking water (WAC 173-340-720[1][a][ii] and [c]) for the following reasons:

  – The city of Edmonds currently provides water to all residential, industrial, and commercial property owners in the area and plans to in the future. The city policy is to discourage the installation of wells and encourage the use of city water.

  – The Terminal is located in an urban area with little surrounding land left to be developed. The likelihood of any new development not wanting to use city water is extremely remote.

  – The aquifer beneath the Terminal is too shallow and too fine-grained for use as a large capacity water production system. Given the proximity of the Terminal to Puget Sound, the depth required for high capacity water production (if a suitable aquifer were available) would result in additional salt water intrusion, making the groundwater unusable without treatment.

- The site is located adjacent to Puget Sound and a tidally influenced marsh. Groundwater discharge at the site is to Puget Sound and the tidally influenced creek surrounding the site (WAC 173-340-720[1][c][i]), neither of which is a suitable domestic water supply source (WAC 173-340-720[1][a][ii]).[6]

- Due to the location of the site in a regional groundwater discharge area, any hazardous substances would not be transported to inland groundwater that is a current or potential future source of drinking water (WAC 173-340-720[1][c][i]).

- The cleanup action will include institutional controls to prevent the use of groundwater for drinking purposes (WAC 173-340-720[1][c][iv]).

- Under Ecology's recommended approach for developing groundwater cleanup standards, the aquifer beneath the Terminal meets the conditions for the second type of aquifer: groundwater near certain surface water (Ecology, 1997b and 1997c). The aquifer beneath the Terminal is sufficiently hydraulically connected to an undrinkable surface water body such that groundwater could not be used without treatment. The area is served by a public water system, and the local water purveyor has indicated that the use of groundwater as a source of drinking water is an extremely low probability (UNOCAL, 1998).

For these reasons, groundwater screening levels established for the protection of surface water were used to evaluate groundwater data. The comparison of groundwater data to Method B screening levels set for protection of surface water is discussed in Sections 6.5.7; screening levels are provided in Tables 6-2 and 6-3.

Ecology concurred with this approach for the site-wide aquifer beneath the lower yard, but not for the aquifer as it exists beneath the upper yard (Ecology, 1998b and 1998c). Ecology has identified the highest beneficial use of the groundwater in the site-wide aquifer as it exists beneath the upper yard as a drinking water resource and believes there is more than an extremely low probability that groundwater beneath the upper yard will be used as a future source of drinking water for the following reasons (Ecology 1998c):

- Groundwater in the site-wide aquifer beneath the upper yard qualifies as a potential drinking water resource according to WAC 173-340-720(1)(ii).

- The city of Edmonds does not have a requirement in the code that new developments hook up to city water; therefore, the city does not enforce the use

[6] Puget Sound and Willow Creek are classified in chapter 173-201A WAC as Class AA. Characteristic uses of Class AA surface waters are defined to include water supply for domestic use. However, the AA classification was not intended to indicate that marine water is suitable for domestic water supply. Marine water contains a TDS concentration of 30,000 mg/L, making use of this water for drinking not practicable. [Note: The TDS of ditch sediment pore water ranged from 24,000 to 30,000 mg/L during flood tide.] Furthermore, WAC 173-340-720(1)(a) defines groundwater containing TDS concentrations greater than 10,000 mg/L as not practicable for drinking.

of city water. However, by verbal policy, the city discourages the installation of wells and encourages the use of city water.

- A domestic well may pump at a rate much less than that which would result in salt water intrusion.

Based on this determination, RI data for groundwater beneath the upper yard were compared to Method B screening levels based on its use for drinking water (WAC 173-340-720). These screening levels are provided in Table 6-4 and the data comparison is discussed in Section 6.5.7.

Surface/storm water data were compared to Method B screening levels set for protection of surface water. The data comparison is discussed in Section 6.8.6. Screening levels are provided in Table 6-5.

6.3.3 Other Regulatory Standards

MTCA cleanup actions must comply with other state and federal regulatory standards, as well as with the substantive portions of local permitting requirements. Some of these are encompassed in the development of Method A, B, or C cleanup levels; for example, Method B cleanup levels for the protection of surface water incorporate state and federal ambient water quality criteria. For purposes of this RI evaluation, a comparison of data to cleanup levels beyond these MTCA methods was not performed, except for a comparison of sediment results to the Sediment Management Standards of chapter 173-204 WAC. A complete evaluation of applicable, or relevant and appropriate requirements (ARARs) will be provided in the feasibility study report for the site.

6.3.4 Indicator Hazardous Substances

Indicator hazardous substances (IHSs) are defined by MTCA as a subset of hazardous substances present at a site that are selected per WAC 173-340-708 for monitoring and analysis during any phase of remedial action, for the purpose of characterizing the site or establishing cleanup requirements for that site (WAC 173-340-200). A description of the process used to select these indicator substances is provided in Section 7.

6.4 Soil

Table 6-6 provides a statistical summary of the surface and subsurface (vadose zone) soil results, including number of samples analyzed, detections, MDLs, mean, and median. Table 6-7 provides a similar statistical summary for saturated soil samples. Tables 6-8 through 6-18 provide the analytical results for each soil sample, as well as the analytical results for the tar-like substance samples collected from the lower yard.

6.4.1 Surface Soil

Following is a discussion of the surface soil results by chemical class. A comparison of soil results to Method C industrial screening levels (lower yard) and Method B residential screening levels (upper yard) is provided in Section 6.4.5.

6.4.1.1 TPH/BTEX

Lower Yard. Fifteen lower yard surface soil samples for TPH and BTEX analysis were collected by focused sampling in the areas most likely to contain petroleum hydrocarbon impacts, and in areas requested by Ecology (SS-109 through SS-114). Elevated TPH results correspond to samples collected in soil with a hydrocarbon-like odor. TPH-D and TPH-O were detected in all 15 surface soil samples, with *maximum* concentrations of 1,800 and 3,100 mg/kg, respectively. TPH-G was detected in 4 of 12 samples analyzed, with a *maximum* concentration of 840 mg/kg. BTEX was detected (at low concentrations) in less than half the samples analyzed. TPH-D, TPH-O, TPH-G, and BTEX concentrations were highest underneath the pipe run located in the southwest part of the lower yard (SS-103 and SS-104). TPH-O concentrations were similarly high in certain locations in the former soil stockpile area (SS-109 and SS-114). TPH results for the lower yard are shown on Drawing No. 5.

Upper Yard. Eleven upper yard surface soil samples for TPH and BTEX analysis were collected by focused sampling in the areas most likely to contain petroleum hydrocarbon impacts. Elevated TPH results correspond to samples collected in areas of odorous soil. TPH-D and TPH-O were detected in all 11 surface soil samples, with *maximum* concentrations of 10,000 (estimated) and 6,500 mg/kg, respectively. TPH-G and BTEX were detected (at low concentrations) in less than half of the samples analyzed. The maximum concentrations of TPH-G and BTEX were in samples collected underneath pipe valves (at SS-201 and SS-213). Maximum concentrations of TPH-D and TPH-O were in samples collected underneath pipe valves (at SS-201, SS-209, and SS-213) and in certain tank basins (at SS-204 and SS-205). TPH results for the upper yard are shown on Drawing No. 6.

6.4.1.2 PAHs

Lower Yard. PAHs were detected in all 15 samples, with most detections in the low µg/kg range. The highest concentrations of PAHs were found in samples with elevated TPH concentrations. Maximum carcinogenic PAH (cPAH) detections were found in one sample collected in the lower yard tank farm (SS-101) and one sample collected beneath the pipe run located in the southwest part of the lower yard (SS-103).[7] The *maximum* cPAH concentrations in these 2 samples were 0.55 and 0.14 mg/kg of benzo(a)pyrene. The *maximum* noncarcinogenic PAH (nPAH) detections were found in SS-101 and SS-103, with 0.60 mg/kg of benzo(g,h,i)perylene in SS-101 and 0.38 mg/kg of

[7] cPAHs include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

phenanthrene in SS-103. Chrysene was identified as an indicator hazardous substance (see Section 7.1.3), and the results for this cPAH are presented on Drawing No. 7.

Upper Yard. PAHs were detected in all 11 samples, with most detections in the low µg/kg range. The highest concentrations of PAHs were found in samples with elevated TPH concentrations. Maximum cPAH detections were found in one sample collected beneath valves in a pipe run located in the eastern part of the upper yard (SS-213). The *maximum* cPAH concentrations in this sample were 1.0 mg/kg of chrysene and 0.46 mg/kg of benzo(a)anthracene. The maximum nPAH detections were found in SS-201, located underneath the manifold at the base of the lower yard, and SS-213. The *maximum* nPAH concentrations in these samples were 2.70 mg/kg of fluoranthene and 0.96 mg/kg (estimated) of fluorene, respectively. Chrysene results are presented on Drawing No. 8.

6.4.1.3 Metals

Lower Yard. Lower yard surface soil samples for metals analysis were collected by focused sampling in the areas most likely to contain sand blast grit or paint chips, and in areas directed by Ecology (SS-109 through SS-114). Elevated metals results correspond to samples collected in areas of sand blast grit and paint chips. Antimony, arsenic, and copper were detected in all 10 samples, with *maximum* concentrations of 200 (estimated), 2,000, and 4,200 mg/kg, respectively. Cadmium was detected in about half of the 16 samples, with a *maximum* concentration of 15 mg/kg. Chromium, lead, and zinc were detected in all 16 samples, with *maximum* concentrations of 250, 2,100, and an estimate of 24,000 mg/kg, respectively. Mercury was detected in 8 of the 10 samples, with a *maximum* estimated concentration of 0.23 mg/kg. Sample SS-103 was selected for toxicity characteristic (TC) metals analysis, based on its highest concentration of total metals. Concentrations of leachable arsenic, cadmium, chromium, and lead were low, and leachable mercury was not detected, indicating that leaching of metals from surface soil is not likely.

Metals concentrations were highest underneath the pipe runs located in the southwest part of the lower yard (SS-103 through SS-106). Metals concentrations in samples collected underneath the pipe runs significantly exceed the on-site background concentrations (SS-107 and SS-108) and also exceed the Puget Sound background soil metals concentrations (Ecology, 1994).[8] Metals concentrations in a sample collected in the lower yard tank farm (SS-101), in samples collected in the former soil stockpile (SS-109 through SS-114), and in samples collected on the north berm of Detention Basin No. 1 are in the range of the on-site and Puget Sound background concentrations.

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[8] The Puget Sound background soil metals concentrations for arsenic, cadmium, chromium, copper, lead, mercury, and zinc are 7, 1, 48, 36, 24, 0.07, and 85 mg/kg, respectively. No Puget Sound background concentration exists for antimony.

Antimony and arsenic were identified as indicator hazardous substances (see Section 7.1.3), and the results for these two metals are presented on Drawing No. 4.

Upper Yard. Upper yard surface soil samples for metals analysis were also collected by focused sampling in areas of visible sand blast grit or paint chips, or in the areas most likely to contain sand blast grit or paint chips. Elevated metals results correspond to samples collected in areas of sand blast grit and paint chips. Antimony, arsenic, chromium, copper, lead, and zinc were detected in all 13 samples, with *maximum* concentrations of 130, 2,000 (estimated), 120, 4,100, 1,500, and an estimate of 12,000 mg/kg, respectively. Cadmium was detected in about one third of the 13 samples, with a *maximum* concentration of 8.9 mg/kg. Mercury was detected in 11 of the 13 samples, with a *maximum* estimated concentration of 0.76 mg/kg. Samples SS-203 and SS-205 were analyzed for TC metals. Concentrations of leachable arsenic, cadmium, chromium, and lead were low or non-detectable, indicating that leaching of metals from surface soil is not likely. This was confirmed by the lack of significant metals concentrations in subsurface soil.

Metals concentrations were highest underneath the manifold at the base of the upper yard (SS-201), in an area covered with sand blast grit at the base of the upper yard (SS-203), and in the basin with Tank 2603 (SS-205). Metals concentrations in these areas are much higher than the on-site background concentrations (SS-208). Arsenic, cadmium, chromium, copper, lead, mercury, and zinc concentrations in samples SS-201, SS-203, and SS-205 also exceed the Puget Sound background soil metals concentrations (Ecology, 1994). Soil samples were collected at a depth of 0.5 feet at the two upper yard locations with the highest surface soil metals concentrations (SS-203 and SS-205) to evaluate metals concentrations with depth. The metals concentrations of these two near-surface samples were in the range of the on-site and Puget Sound background concentrations, indicating that elevated metals concentrations in the upper yard are confined to surface soil with sand blast grit and paint chips.

Certain metals concentrations in two samples collected at the west end of the upper yard (SS-202 and SS-204) exceed the on-site and Puget Sound background concentrations. Metals concentrations in the remaining upper yard surface soil samples (SS-206, SS-207, and SS-209 through SS-213) are in the range of the on-site and Puget Sound background concentrations.

Antimony and arsenic results are presented on Drawing No. 4.

6.4.1.4 VOCs

Only one chemical was detected in the one surface soil sample analyzed for (non-BTEX) VOCs: SS-101 located in the lower yard tank farm. SS-101 was collected in an area most likely to contain non-BTEX VOCs. Methylene chloride was detected at an estimated concentration of 6.6 µg/kg. The chemical is a common laboratory solvent, is often a laboratory-introduced contaminant in VOC analyses, and was found in a blank.

The detection of methylene chloride in this analysis is therefore considered spurious. Since no other VOCs were detected (including 1,2-dibromoethane [EDB] and 1,2-dichloroethane [EDC]), non-BTEX VOCs are not considered chemicals of concern for surface soil. BTEX in surface soil is discussed above.

6.4.1.5 SVOCs

No (non-PAH) SVOCs were detected in the surface soil sample (SS-101) analyzed for SVOCs. This sample was collected in an area most likely to contain SVOCs. Since no SVOCs were detected, SVOCs are not considered chemicals of concern for surface soil. PAHs in surface soil are discussed above.

6.4.1.6 Glyphosate

Glyphosate results are provided in Table 6-14. Glyphosate (the active ingredient in the herbicide Roundup®) was not detected in three surface soil samples (SS-206, SS-207, and SS-210). It was also not detected in the catch basin sediment sample (CB-U31). Based on these results, glyphosate is not considered a chemical of concern for the site.

6.4.2 Unsaturated Subsurface Soil

Following is a discussion of the unsaturated (vadose zone) subsurface soil results by chemical class. A comparison of unsaturated soil results to Method C industrial screening levels (lower yard) and Method B residential screening levels (upper yard) is provided in Section 6.4.5.

6.4.2.1 TPH/BTEX

Lower Yard. TPH-D, TPH-O, and TPH-G were detected in most subsurface soil samples, with *maximum* concentrations of 120,000 (estimated), 27,000, and 12,000 mg/kg, respectively (Drawing No. 5). Total xylenes were detected in most of the samples analyzed, with a *maximum* detection of 590 mg/kg. Benzene, toluene, and ethylbenzene were detected in less than half of the samples analyzed, with *maximum* concentrations of 78, 350, and 160 mg/kg, respectively.

The highest concentrations of TPH-D and TPH-O were found in former operational areas (e.g., SB-104, SB-112, SB-130, and MW-110), on the south side of Detention Basin No. 1 (e.g., SB-114 and MW-117), in the central part of the lower yard (e.g., MW-133), and in the eastern part of the lower yard (e.g., SB-178). Based on field observations, it appears that the eastern part of the lower yard (between SB-165 and SB-178) is a lobe of fill; the extent of soil with elevated TPH concentrations is either bounded by borings with relatively low TPH concentrations (e.g., SB-182) or by the extent of the fill lobe itself. The highest concentrations of TPH-G and BTEX were found in former operational areas, in the central part of the lower yard (including SB-157 and SB-161), at the south end of the former soil stockpile area, and in the eastern part of the lower yard. Except in the former railcar unloading area, near the lower yard tanks, and on the south side of

Detention Basin No. 1, TPH-D, TPH-O, TPH-G, and BTEX were low in the top 1 to 3 feet of soil and increased with depth to the water table.

TPH-D, TPH-O, TPH-G, and BTEX were not detected or were detected only at low concentrations off site along the BNRR right of way, along the west and north sides of Detention Basin No. 1, and in most of the random lower yard soil borings (e.g., SB-154, SB-162, and SB-168). A further discussion of off-site results is provided in Section 6.4.4.

Upper Yard. TPH-D, TPH-O, and TPH-G were detected in less than one third of the samples, with *maximum* concentrations of 24,000, 5,300, and 550 mg/kg, respectively (Drawing No. 6). BTEX was detected, at low concentrations, in less than 10 percent of the samples.

The highest concentrations of TPH-D and TPH-O were found in the basins of Tanks 2606 (SB-209) and 2913 (SB-211) and in the area where the french drain drops down to the storm drain system (T-203). Elevated concentrations of TPH-D were also found on the north side of Tank 4120 (SB-219 and SB-220). The highest concentrations of TPH-G were found in the basin of Tank 2913 and on the north side of Tank 4120. Elevated concentrations of TPH-D, TPH-O, and TPH-G were only found in the upper 5 feet of soil. The dense, fine-grained soil prevented further downward migration. Samples collected outside of the tank basins had non-detectable or very low concentrations of TPH and BTEX.

6.4.2.2 PAHs

Lower Yard. The percentage of detected cPAHs ranged from 4 percent for benzo(b)fluoranthene to 65 percent for chrysene. Most detections were in the low µg/kg range. *Maximum* cPAH concentrations ranged from 0.350 mg/kg for indeno(1,2,3-cd)pyrene to 14 mg/kg for chrysene, most occurring in a sample from SB-172. The highest concentrations of cPAHs were found at isolated locations with elevated concentrations of TPH, including former operational areas (e.g., SB-103, and SB-109 [former railroad spur], and SB-126 [former asphalt plant]), on the south side of Detention Basin No. 1 (e.g., SB-114 and MW-117), in the central part of the lower yard (e.g., MW-133), at the south end of the former soil stockpile area (SB-150), and in the eastern part of the lower yard (e.g., SB-178). Based on field observations, it appears that the eastern part of the lower yard (between SB-165 and SB-178) is a lobe of fill; the extent of soil with elevated cPAH concentrations is either bounded by borings with relatively low cPAH concentrations (e.g., SB-182) or by the extent of the fill lobe itself. Subsurface cPAHs concentrations generally increased with depth to the water table, exceptions being near the lower yard tanks and on the south side of Detention Basin No. 1. Chrysene results are presented on Drawing No. 7.

The percentage of detected nPAHs ranged from 10 percent for acenaphthene to 78 percent for phenanthrene. Most detections were in the µg/kg range. The *maximum* nPAH concentrations ranged from 1.6 mg/kg for benzo(g,h,i)perylene to 160 mg/kg for fluoranthene. The highest concentrations of nPAHs were found at locations with elevated concentrations of TPH, as noted above. Subsurface nPAHs concentrations generally increased with depth to the water table, exceptions being near the lower yard tanks and on the south side of Detention Basin No. 1.

Upper Yard. Benzo(b)fluoranthene and dibenzo(a,h)anthracene were not detected in any subsurface soil sample. The percentage of detected cPAHs ranged from 3 percent for benzo(a)anthracene to 47 percent for chrysene. Except for chrysene, the *maximum* cPAH concentrations were in the low µg/kg range. The *maximum* chrysene concentration was 1.2 mg/kg in a shallow sample from the Tank 2606 basin (SB-209). Chrysene results are presented on Drawing No. 8.

Acenaphthene and acenaphthylene were not detected in any subsurface soil sample. The percentage of detected nPAHs ranged from 7 percent for naphthalene to 54 percent for phenanthrene. Most detections were in the µg/kg range. The *maximum* nPAH concentrations ranged from 0.16 mg/kg for anthracene to 7.1 mg/kg for fluoranthene. The highest concentrations of nPAHs were found at locations with elevated concentrations of TPH, as noted above.

6.4.2.3 Metals

Lower Yard. Cadmium was detected in less than 5 percent of the samples, at concentrations in the range of the on-site and Puget Sound background concentrations. Chromium, lead, and zinc were detected in all samples analyzed, with *maximum* concentrations of 63, 240, and 410 mg/kg, respectively. Most chromium, lead, and zinc results were in the range of the on-site and Puget Sound background concentrations. These results indicate that subsurface soil metals concentrations are low, even at locations with elevated TPH concentrations. Based on these results, metals are not considered chemicals of concern in subsurface soil.

Upper Yard. Cadmium was detected in less than 25 percent of the samples, at concentrations in the range of the on-site and Puget Sound background concentrations. Chromium, lead, and zinc were detected in all samples analyzed, with *maximum* concentrations of 85, 92, and 280 mg/kg, respectively. Most chromium, lead, and zinc results were in the range of the on-site and Puget Sound background concentrations. These results indicate that subsurface soil metals concentrations are low, even at locations with elevated TPH concentrations. Based on these results, metals are not considered chemicals of concern in subsurface soil.

6.4.2.4 VOCs

Lower Yard. Only 2 chemicals were detected in the 10 subsurface soil samples analyzed for (non-BTEX) VOCs, acetone and methylene chloride. Acetone and methylene chloride were detected in most samples at concentrations in the low µg/kg range. These chemicals are common laboratory solvents, are often laboratory-introduced contaminants in VOC analyses, and were typically found at uniform concentrations near the method detection limit. The detection of acetone and methylene chloride in these analyses are, therefore, considered spurious.

The subsurface soil samples for VOC analysis were collected in areas most likely to contain VOCs. Since no VOCs were detected in these samples (including EDB and EDC), VOCs are not considered chemicals of concern for lower yard subsurface soil.

Upper Yard. Only four chemicals were detected in the six subsurface soil samples analyzed for (non-BTEX) VOCs: acetone, methylene chloride, 2-butanone, and tetrachloroethene. Acetone and methylene chloride were detected in half of the samples at concentrations in the low µg/kg range. 2-butanone was detected in two samples and concentrations in the low µg/kg range. These chemicals are common laboratory solvents, are often laboratory-introduced contaminants in VOC analyses, and were typically found at uniform concentrations near the method detection limit. The detection of acetone, methylene chloride, and 2-butanone in these analyses are therefore considered spurious. Tetrachloroethene was detected in one sample at 0.6 µg/kg. Since the method detection limit was 0.5 µg/kg and tetrachloroethene was not detected in any other samples, the detection is considered spurious.

The subsurface samples were collected in areas most likely to contain VOCs. Since no VOCs were detected in these samples (including EDB and EDC), non-BTEX VOCs are not considered chemicals of concern for upper yard subsurface soil.

6.4.2.5 SVOCs

Lower Yard. Only four chemicals were detected in the five subsurface soil samples analyzed for (non-PAH) SVOCs. All detections were in the low µg/kg range. Phenol and dibenzofuran were each detected near the method detection limit in one sample. Di-n-butylphthalate was detected near the method detection limit in two samples, and bis(2-ethylhexyl)phthalate was detected near the method detection limit in all five samples. Bis(2-ethylhexyl)phthalate was also detected in a blank.

These samples were collected in areas most likely to contain SVOCs. Since only low concentrations of SVOCs were detected in these samples, SVOCs are not considered chemicals of concern for lower yard surface soil. PAHs in subsurface soil are discussed above.

Upper Yard. No (non-PAH) SVOCs were detected in the soil sample analyzed for SVOCs (SB-202). This sample was collected in an area most likely to contain SVOCs. Since no SVOCs were detected in this sample, non-PAH SVOCs are not considered chemicals of concern for upper yard subsurface soil. PAHs in subsurface soil are discussed above.

6.4.3 Saturated Subsurface Soil

Following is a discussion of the saturated subsurface soil results by chemical class. A statistical summary of the saturated soil samples is provided in Table 6-7. Analytical results for each sample are provided in Tables 6-15 through 6-17. Constituent concentrations in saturated subsurface soil samples were generally lower than corresponding unsaturated samples.

6.4.3.1 TPH/BTEX

TPH-D, TPH-O, and TPH-G were detected in less than half of the saturated subsurface soil samples, with *maximum* concentrations of 4,500 , 1,700, and 10,000 mg/kg, respectively (Drawing No. 5). Benzene, toluene, ethylbenzene, and total xylenes were detected in half or less of the samples analyzed, with *maximum* concentrations of 4.1, 6.9, 22, and 37 mg/kg, respectively.

6.4.3.2 PAHs

Benzo(b)fluoranthene and dibenzo(a,h)anthracene were not detected in any saturated subsurface soil sample. The percentage of detected cPAHs ranged from 5 percent for benzo(k)fluoranthene to 30 percent for chrysene. Most detections were in the low µg/kg range. *Maximum* cPAH concentrations ranged from 0.027 mg/kg for indeno(1,2,3-cd)pyrene to 0.53 mg/kg for chrysene. Chrysene results are presented on Drawing No. 7.

Acenaphthene was not detected in any saturated subsurface soil sample. The percentage of detected nPAHs ranged from 6 percent for benzo(g,h,i)perylene to 58 percent for phenanthrene. Most detections were in the µg/kg range. The *maximum* nPAH concentrations ranged from 0.017 mg/kg for pyrene to 6.2 mg/kg for fluoranthene and naphthalene.

6.4.3.3 Metals

Cadmium was detected in 19 percent of the saturated subsurface soil samples with a *maximum* concentration of 0.23 mg/kg. Chromium, lead, and zinc were detected in all samples analyzed, with *maximum* concentrations of 37, 29, and 45 mg/kg, respectively.

6.4.4 Off-site Soil

TPH-D, TPH-O, TPH-G, and BTEX constituents were detected in less than 20 percent of the 27 subsurface soil samples collected from the five RI monitoring well borings drilled off of the Terminal along the BNRR right of way (MW-105, MW-106, MW-107, MW-137, and MW-138). Detections were near the MDLs. Results of the off-site soil TPH samples are shown on Drawing No. 5.

cPAHs were detected in about two-thirds of the samples, with detections generally in the low µg/kg range. The *maximum* cPAH concentrations ranged from 0.011 mg/kg (estimated) for dibenzo(a,h)anthracene to 0.320 mg/kg for benzo(b)fluoranthene. Most of the maximum detections were in the shallowest sample from MW-105, which had the highest off-site TPH concentration (110 mg/kg TPH-O). Chrysene results are presented on Drawing No. 7.

nPAHs were detected in about 80 percent of the samples, with detections generally in the low µg/kg range. Naphthalene and acenaphthylene were not detected. The *maximum* detected nPAH concentrations ranged from 0.015 mg/kg (estimated) for fluorene to 0.340 mg/kg for benzo(g,h,i)perylene. Most of the maximum detections were in the shallowest sample from MW-105, which had the highest off-site TPH concentration (110 mg/kg TPH-O).

Chromium, lead, and zinc were detected in all off-site soil samples. Cadmium was detected in 85 percent of the samples. Metals concentrations were low, in the range of the on-site and Puget Sound background concentrations.

TPH, BTEX, PAH, and metals results for samples collected off of the Terminal property indicate that off-site soil chemical concentrations are low. These results are consistent with soil results in monitoring well borings MW-27, MW-28, MW-29 that were sampled before the RI.

6.4.5 Comparison of Soil Results to Screening Levels

Lower yard unsaturated soil results are compared to direct contact-based screening levels (Method C industrial cleanup levels) and groundwater-based screening levels in Table 6-1a. Upper yard vadose zone soil results are compared to direct contact-based screening levels (Method B residential cleanup levels) in Table 6-1b. In both the upper and lower yards, TPH screening levels were calculated using the Interim TPH Policy. Saturated soil samples were not compared to screening levels since chemical analysis of saturated soil samples measures both soil and groundwater constituents and since constituent concentrations in saturated subsurface soil samples were generally lower than corresponding unsaturated samples.

Lower Yard. None of the BTEX, PAH, antimony, cadmium, chromium, copper, mercury, or zinc results were above the direct contact-based screening levels. Less than 5 percent of the TPH (sum of TPH-G, TPH-D, and TPH-O) and lead results were above their associated direct contact-based screening levels. Fifty percent of the arsenic results were above the direct contact-based screening level.

Greater than 5 percent of the TPH results were above the groundwater-based screening levels.

Upper Yard. None of the BTEX, nPAH, cadmium, chromium, mercury, or zinc results were above the direct contact-based screening levels. Less than 5 percent of the cPAH, results were above the direct contact-based screening levels. Greater than 5 percent of the TPH, antimony, arsenic, copper, and lead results were above the direct contact-based screening levels.

Off Site. TPH-D, TPH-O, and TPH-G in samples collected off the Terminal boundary along the BNRR right of way were all below the associated screening levels.

6.4.6 Tar-like Substance

A tar-like substance occurs on the ground surface in specific areas of the lower yard. The substance occurs both on gravel and paved surfaces. During warm weather, the tar-like substance softens, and new accumulations are reported by Terminal personnel to be seen on the ground surface. To determine the horizontal extent of the tar-like substance, surface accumulations were mapped during the RI. Locations with multiple accumulations of the substance are shown on Drawing No. 4 and are concentrated in the former asphalt plant area and in the area southwest of the northern truck loading rack. Less than about 25 percent of the ground surface in these areas is covered with the substance. Each isolated accumulation of the substance typically covers an area less than 5 square feet and is less than 1 inch thick.

Three test pits were excavated in the lower yard to explore the nature and vertical extent of the tar-like substance. The test pits were located in areas with multiple accumulations of the substance. Two of the three pits encountered the tar-like substance in the subsurface. The substance was found up to depths of 1.5 feet bgs. In one pit (TP-101), the tar-like material was in a thin layer, and in the other (TP-102), it was found only as scattered chunks in a sandy matrix. Based on the test pits and boring logs, it appears that the tar-like material does not occur in a continuous subsurface layer, but in shallow, isolated lenses and pockets.

A sample of the substance from TP-101 (0.5 foot sample) contained concentrations of TPH-G, TPH-D, and TPH-O of 830 mg/kg, 15,000 mg/kg, and 22,000 mg/kg, respectively (Table 6-18). Three cPAHs were detected at concentrations ranging from 1.7 to 18 mg/kg, and seven nPAHs were detected at concentrations ranging from 8.3 to 71 mg/kg. Leachable (TC) concentrations of cadmium, chromium, and lead were 0.0019 mg/L, 0.0064 mg/L, and 0.22 mg/L, respectively. Leachable SVOCs were not detected. The gross heat of combustion was 6,259 Btu/pound in the sample.

In summary, it appears that the accumulations of the tar-like substance in the lower yard are located primarily in the former asphalt plant area and in the area southwest of the northern truck loading rack. The substance occurs in shallow, laterally and vertically discontinuous lenses.

6.4.7 Soil Gas Vapors

Tables 6-19, 6-20, and 6-21 present the combustible gas indicator (CGI) readings as a percentage of the lower explosive limit (LEL) of methane. Table 6-22 provides additional CGI readings and oxygen readings. The methane LEL is 5.3 percent by volume, and the methane upper explosive limit (UEL) is 14 percent by volume. The LEL represents the minimum concentration of vapor in air below which propagation of a flame will not occur in the presence of an ignition source. The UEL is the maximum concentration of a vapor in air above which propagation of a flame will not occur in the presence of an ignition source. From a safety standpoint, CGI readings between the LEL and UEL indicate the potential for combustion if an ignition source is present. Health and safety plans typically specify an action level (10 to 20 percent of the LEL) above which ventilation or ceasing work is required. As stated in Section 4.4.4 of the Work Plan, the need to install and monitor gas probes would be evaluated if CGI measurements in the buildings or in at least two borings, monitoring wells, or storm drains were above 20 percent of the methane LEL.

6.4.7.1 Borings

CGI readings ranged from 0 to 60 percent of the LEL at the top of 12 lower yard monitoring well borings (Table 6-19), with three readings above 20 percent of the LEL. Monitoring wells subsequently installed in two of these three borings contained free product, and the third monitoring well boring was located near a free product plume. The CGI measurements were 0 percent of the LEL at the top of all 24 lower yard soil borings, the upper yard monitoring well boring, and all 5 upper yard soil borings.

6.4.7.2 Test Pits and Trenches

CGI measurements were 0 percent of the LEL in the two lower yard test pits and the two upper yard test trenches (Table 6-19). The lower yard test pits were located in or near a free product plume.

6.4.7.3 Monitoring Wells

CGI readings at the top of the 61 lower yard monitoring wells ranged from less than 2 to over 1,000 percent of the LEL in January 1996 and from 0 to 415 percent of the LEL in June 1996 (Table 6-20). CGI readings at the top of four monitoring wells near the northern truck loading rack in October 1996 ranged from less than 38 to 660 percent of the LEL (Table 6-22). October 1996 oxygen readings varied from 2 to 12 percent (Table 6-22). Twenty-five of the January CGI measurements and twenty-eight of the June measurements were above 20 percent of the LEL. Most of these wells were located in or adjacent to free product plumes. Wells and soil borings closest to the three lower yard offices had CGI readings below 20 percent of the LEL. The first round CGI reading in MW-126 (115 percent of the LEL) may have been influenced by the adjacent septic system drain line.

It should be noted that CGI readings were taken by placing a well slip cap with a fitting on top of the well casing. Tubing was connected to the fitting, and gas was pumped from the well through the CGI until the CGI readout stabilized. No attempt was made to completely purge the well of accumulated vapor. At eight locations with readings above 50 percent of the LEL, a reading was also taken at the top of the well casing without the slip cap assembly. All eight of these readings were substantially lower (at or below 40 percent of the LEL), indicating that the well gas quickly vents. CGI readings taken during drilling in product plume areas (at the top of soil borings and monitoring well borings) also indicate that the subsurface gas quickly vents.

CGI measurements were 0 percent of the LEL at the top of the seven upper yard monitoring wells and the three upper yard piezometers.

6.4.7.4 Catch Basins and Buildings

CGI measurements were 0 percent of the LEL in all 43 lower yard catch basins and in all rooms in all buildings except the bathroom of the garage (Tables 6-21 and 6-22). Field personnel attributed the detectable CGI reading in the garage bathroom (0.02 percent of the LEL) to the room air freshener. Measurements taken a few days later in the same bathroom were 0 percent of the LEL. Oxygen readings in four lower yard catch basins were 21 percent (Table 6-22).

6.4.7.5 Conclusions

Based on the CGI readings measured during the RI, the following conclusions were reached:

- Wells and soil borings closest to the three lower yard offices had low CGI readings. These readings were below 20 percent of the LEL and indicate a low combustible gas risk.

- Measurable levels of combustible gases were not present in the catch basins or in the buildings.

- Combustible gas was present in the subsurface in and locally near product plume areas, based on measurements in monitoring well borings and at wellheads.

- Subsurface combustible gas vents quickly.

- A CGI should be used to monitor work when the monitoring wells are open and when excavation work is occurring in product plume areas. Appropriate ventilating and work procedures, as outlined in the site Health and Safety Plan, should be followed when combustible gas levels exceed action levels (10 to 20 percent of the methane LEL).

6.4.8 Basin Sediment/Soil

The analytical results for each basin sediment/soil sample are provide in Tables 6-8 through 6-10. Following is a discussion of the basin sediment/soil results by chemical class.

6.4.8.1 TPH/BTEX

Of the 16 sediment/soil samples analyzed from Detention Basin No. 1, TPH-D was detected in 11 samples, TPH-O in 10 samples, and TPH-G in 5 samples. *Maximum* concentrations of TPH-D, TPH-O, and TPH-G were 400,000, 190,000, and 190 (estimated) mg/kg, respectively. Benzene, toluene, ethylbenzene, and total xylenes were detected in less than one third of the samples, with *maximum* concentrations (estimated) of 0.24, 2.1, 0.57, and 4.6 mg/kg, respectively. Drawing No. 5 presents the Detention Basin No. 1 TPH results.

The highest concentrations of TPH and BTEX in Detention Basin No. 1 were found in the central portion of the basin (BSS-107A), in the southeast corner of the basin (BSS-111), and in and near the northern submerged portion of Detention Basin No. 1 (BSS-101 through BSS-104). Results of the two borings drilled to assess the vertical soil profile (BSS-105 and BSS-110) indicate that elevated concentrations of TPH are confined to the upper few feet of the basin.

TPH-D, TPH-O, and TPH-G concentrations were 1,800, 2,000, and 13 (estimated) mg/kg, respectively, in the Detention Basin No. 2 sample. BTEX constituents were not detected in Detention Basin No. 2. Drawing No. 5 presents the Detention Basin No. 2 TPH results. Observations at the time of sampling indicate that the maximum accumulation of sediment on top of the Detention Basin No. 2 liner was 1 foot (at the northwest end of the basin), with an approximate average thickness of 6 to 8 inches.

6.4.8.2 PAHs

cPAHs were generally detected in less than half of the Detention Basin No. 1 samples. Due to the elevated concentrations of TPH, cPAH MDLs were occasionally elevated. Detected cPAH concentrations varied widely. The *maximum* cPAH concentrations ranged from 0.250 mg/kg (estimated) for indeno(1,2,3-cd)pyrene to 14 mg/kg for chrysene. The highest concentrations of cPAHs were generally found at locations with elevated concentrations of TPH. Chrysene results are presented on Drawing No. 7.

Four of seven cPAHs were detected in the Detention Basin No. 2 sediment/soil sample. The chrysene concentration was the highest (0.210 mg/kg, estimated).

nPAHs were generally detected in less than half of the Detention Basin No. 1 samples, fluoranthene and phenanthrene being the exceptions. Due to the elevated concentrations of TPH, nPAH MDLs were occasionally elevated. Detected nPAH concentrations varied widely. The *maximum* nPAH concentrations ranged from 0.400 mg/kg (estimated) for acenaphthylene to 250 mg/kg for fluoranthene. The highest concentrations of nPAHs were generally found at locations with elevated concentrations of TPH.

About half of the nPAHs were detected in the Detention Basin No. 2 sediment/soil sample. The pyrene concentration was the highest, at an estimated 0.150 mg/kg.

6.4.8.3 Metals

Arsenic, chromium, copper, lead, and zinc were detected in all sediment/soil samples collected from Detention Basin No. 1. Cadmium was detected in most samples, mercury was detected in about half the samples, and antimony was only detected in one sample. Metals concentrations were low, in the range of the on-site and Puget Sound background concentrations.

All metals but antimony were detected in the Detention Basin No. 2 sediment/soil sample. Metals concentrations were also low in this basin, in the range of the on-site and Puget Sound background concentrations.

6.5 Groundwater

Table 6-23 provides a statistical summary of the site-wide aquifer groundwater results, including number of samples analyzed, detections, MDLs, mean, and median. Tables 6-24 through 6-35 provide the analytical results for each sample collected in the site-wide aquifer and in the upper yard perched zones. The following discussion includes the groundwater samples collected in the November 1995 and February, May, and August 1996 RI groundwater sampling events. A comparison of groundwater results to screening levels is provided in Section 6.5.7.

6.5.1 TPH/BTEX

Figures 6-1 through 6-9 present the TPH distributions in groundwater. TPH-D, TPH-O, and TPH-G were detected in about 65, 35, and 50 percent of the on-site groundwater samples that were collected in the site-wide aquifer. *Maximum* concentrations were 43, 25, and 8.5 mg/L, respectively. Benzene, toluene, ethylbenzene, and total xylenes were detected in about 47, 40, 47, and 50 percent of the on-site groundwater samples that were collected in the site-wide aquifer. Results were generally consistent through the four sampling events and do not indicate significant seasonal variations. The highest TPH and BTEX detections were found near the free product plumes near the former railroad spur (e.g., MW-124), at the former northern truck loading rack (e.g., MW-104), in the former asphalt plant area (e.g., MW-7), at the former southerly extension of Detention Basin No. 1 (e.g., MW-117), and on the northwest side of Detention Basin No. 1 (e.g., LM-2). Two other wells in the central part of the lower yard (MW-133) and in the eastern part of the lower yard (MW-136) also contained elevated concentrations of TPH-D and TPH-O in at least one sampling event. A well west of the former southern truck loading rack (MW-125) also contained elevated concentrations of TPH-G and BTEX, and a well between the two former truck loading racks (MW-123) contained elevated concentrations of benzene.

Based on field observations, MW-136 lies at the eastern edge of a lobe of fill, next to the southern edge of the marsh. The well is located approximately 15 feet from the organic-rich marsh. TPH-D and TPH-O detections in samples collected from MW-136 during the RI field investigation appear to reflect analytical interferences caused by natural organics in groundwater at this location. Groundwater at other locations adjacent to Willow Creek or the marsh are probably similarly affected.

TPH and BTEX were not detected or were detected at concentrations near the method detection limit in the site-wide aquifer on the north side of Detention Basin No. 1, beneath and immediately downgradient (north) of the upper yard, and in deeper lower yard monitoring wells (MW-120, MW-121, and MW-122). TPH and BTEX were also not detected or were detected at low concentrations off-site along the BNRR right of way as discussed in Section 6.5.7. TPH and BTEX were not detected or were detected at concentrations near the method detection limit in groundwater samples collected from the upper yard perched zones.

6.5.2 PAHs

cPAHs. The percentage of cPAHs detected in on-site groundwater samples from the site-wide aquifer ranged from 0 percent for benzo(b)fluoranthene to 30 percent for chrysene. Most detections were less than 0.1 µg/L. The *maximum* cPAH concentrations ranged from 0.018 µg/L for indeno(1,2,3-cd)pyrene to 13 µg/L for chrysene. Results were generally consistent through the four sampling events and do not indicate significant seasonal variations. The highest cPAH concentrations were found at locations with elevated concentrations of TPH, including the former railroad spur (MW-8), west of the former southern truck loading rack (MW-125), at the former northern truck loading rack (MW-119 and MW-123), in the former asphalt plant area (MW-7), at the former southerly extension of Detention Basin No. 1 (MW-117), in the central part of the lower yard (MW-133), and in the eastern part of the lower yard (MW-136). Since well MW-136 was installed with a small-diameter auger and the small-diameter well yields relatively high turbidity water, the cPAHs detected in MW-136 likely represent cPAHs sorbed to particulate matter in groundwater.

cPAHs were not detected or were detected at concentrations near the method detection limit in the site-wide aquifer on the north side of Detention Basin No. 1, beneath and immediately downgradient (north) of the upper yard, in deeper lower yard monitoring wells (MW-120, MW-121, and MW-122), and off-site along the BNRR right of way (MW-28, MW-105, MW-106, MW-107, MW-137, and MW-138). cPAHs were not detected or were detected at concentrations near the method detection limit in groundwater samples collected from the upper yard perched zones.

nPAHs. The percentage of nPAHs detected in on-site groundwater samples from the site-wide aquifer ranged from 15 percent for acenaphthene to 47 percent for fluorene. The *maximum* nPAH concentrations ranged from 1.1 µg/L for anthracene to 62 µg/L for naphthalene. Results were generally consistent through the four sampling events and do not indicate significant seasonal variations. The highest nPAH concentrations were found at locations with elevated concentrations of TPH, including the former railroad spur (MW-8), west of the former southern truck loading rack (MW-125), between the two former truck loading racks (MW-123), in the former asphalt plant area (e.g., MW-7), at the former southerly extension of Detention Basin No. 1 (MW-117), on the south side of Detention Basin No. 1 (MW-131), in the central part of the lower yard (MW-133), and in the eastern part of the lower yard (MW-136). Since well MW-136 was installed with a small-diameter auger and the small-diameter well yields relatively high turbidity water, the nPAHs detected in MW-136 likely represent nPAHs sorbed to particulate matter in groundwater.

nPAHs were not detected or were detected at concentrations near the method detection limit in the site-wide aquifer on the north and northwest sides of Detention Basin No. 1, beneath and immediately downgradient (north) of the upper yard, in deeper lower yard monitoring wells (MW-120, MW-121, and MW-122), and off-site along the BNRR right of way (MW-28, MW-105, MW-106, MW-107, MW-137, and MW-138). nPAHs were not detected or were detected at concentrations near the method detection limit in groundwater samples collected from the upper yard perched zones. Isolated detections of naphthalene were found in groundwater samples collected in one perched zone well and four site-wide aquifer wells beneath the upper yard.

6.5.3 Metals

The detected percentage of dissolved metals in on-site groundwater samples from the site-wide aquifer ranged from approximately 3 percent for mercury to approximately 85 percent for zinc. The *maximum* dissolved metals concentrations ranged from 0.00024 mg/L for mercury to 0.22 mg/L for zinc. The detected percentage of total metals in on-site groundwater samples from the site-wide aquifer ranged from approximately 4 percent for mercury to approximately 87 percent for copper. The *maximum* total metals concentrations ranged from 0.00024 mg/L for mercury to 0.41 mg/L for zinc. Results were generally consistent through the four sampling events and do not indicate significant seasonal variations. The highest dissolved and total metals concentrations were found in isolated locations around the Terminal, LM-2 (total and dissolved zinc), MW-136 (total lead, total and dissolved zinc), MW-8 (total and dissolved lead), and MW-7U (total chromium). The higher metals concentrations at MW-136 and MW-7U are likely due to the higher concentrations of particulates found in groundwater samples collected in these wells. TSS concentrations were consistently higher in these two wells than in most other wells on-site.

Metals were not detected or were detected at concentrations near the method detection limit in the site-wide aquifer elsewhere at the Terminal and in all off-site wells except MW-106 (see Section 6.5.8). Metals were not detected or were detected at concentrations near the method detection limit in groundwater samples collected from the upper yard perched zones.

6.5.4 VOCs

Only one chemical was detected in the groundwater samples analyzed for non-BTEX VOCs. Methylene chloride was detected at concentrations ranging from 0.8 (estimated) to 4 µg/L in five samples from five different monitoring wells in the May 1996 sampling event. The chemical is a common laboratory solvent, is often a laboratory-introduced contaminant in VOC analyses, and was found in blanks associated with all of the samples with methylene chloride detections. The detection of methylene chloride in this analysis is therefore considered spurious.

Groundwater samples from monitoring wells MW-104, MW-123, MW-127, MW-22, and MW-13U, were collected in areas most likely to contain non-BTEX VOCs. Since no non-BTEX VOCs were detected in these samples (including EDB and EDC), non-BTEX VOCs are not considered chemicals of concern for groundwater. BTEX in groundwater is discussed above.

6.5.5 General Chemistry

TDS ranged from 50 to 18,000 mg/L in on-site groundwater samples that were collected in the site-wide aquifer. Concentrations were generally below 1,000 mg/L in lower yard monitoring wells and below 350 mg/L in upper yard monitoring wells. Maximum concentrations were found in wells between Willow Creek and Detention Basin No. 1 (LM-2, LM-3, MW-108, and MW-109). These concentrations are similar to ditch sediment pore water measurements (EMCON, 1995b). Other wells with higher concentrations included certain wells adjacent to Willow Creek (MW-20, MW-101, MW-129, MW-135, MW-136, and MW-139), deeper wells (MW-120 and MW-122), and isolated wells at the Terminal (MW-123, MW-127, and MW-133). TSS, which reflects the amount of particulate matter in a sample, ranged from less than the MDL (10 mg/L) to 690 mg/L. Concentrations were generally below 100 mg/L. The consistently highest concentrations were in wells MW-125, MW-133, MW-136, and MW-7U.

TDS and TSS concentrations in the site-wide aquifer were generally lower in off-site wells than in on-site wells. TDS concentrations in MW-137 and MW-138, which are adjacent to Willow Creek, were comparable with the higher on-site TDS concentrations in wells adjacent to the creek. TDS and TSS concentrations in the upper yard perched zones were lower than typical values in the site-wide aquifer.

Three off-site and two on-site samples were analyzed for various remedial parameters. Hardness (as $CaCO_3$) ranged from 67 to 170 mg/L, ammonia (as nitrogen) ranged from 0.96 to 6.8 mg/L, nitrate/nitrite (as nitrogen) ranged from less than the MDL (0.05 mg/L) to 1.9 mg/L, dissolved iron ranged from an estimated concentrations of 0.058 mg/L to 14 mg/L, and orthophosphate (as phosphorus) ranged from less than the MDL (0.05 mg/L) to 0.3 mg/L.

6.5.6 Groundwater Field Parameters

Specific conductance ranged from 89 to 21,900 µS/cm in on-site groundwater samples from the site-wide aquifer. Concentrations were generally below 1,500 µS/cm in lower yard monitoring wells and below 500 µS/cm in upper yard monitoring wells. As with TDS, maximum measurements were found in wells between Willow Creek and Detention Basin No. 1 (LM-2, LM-3, MW-108, and MW-109). Other wells with higher measurements included certain wells adjacent to Willow Creek (MW-20, MW-101, MW-135, MW-136, and MW-139), deeper wells (MW-120 and MW-122), and isolated wells at the Terminal (MW-123, MW-127, MW-131, and MW-133). The specific conductance measurements in MW-137 and MW-138 were comparable to the higher on-site measurements in wells adjacent to Willow Creek. The specific conductance measurements of samples collected in the upper yard perched zones were low.

Turbidity, which reflects the amount of particulate matter in a sample, ranged from less than 1 NTU to 510 NTU. Measurements were generally below 25 NTU. The highest measurements were generally in the first sampling event in newly installed wells. The consistently highest measurements over multiple sampling rounds were in MW-108, MW-126, MW-136, MW-7U, MW-201, and MW-202. Measurements in wells screened in upper yard perched zones were higher than in wells screened in the site-wide aquifer, likely due to well construction techniques and the lack of well redevelopment.

Measurements of pH ranged from 4.5 to 7.8 in on-site groundwater samples from the site-wide aquifer and from 6.0 to 6.8 in upper yard perched zone samples. Dissolved oxygen measurements ranged from 0.1 to 5.8 mg/L in on-site groundwater samples from the site-wide aquifer, from 0.5 to 7.4 mg/L in off-site samples, and from 0.6 to 4.6 mg/L in upper yard perched zone samples.

Temperature measurements ranged from 8 to 20 C in on-site groundwater samples from the site-wide aquifer. The lowest temperatures were in samples collected in the February sampling event, and the highest temperatures were in samples collected in the August sampling event.

6.5.7 Comparison of Groundwater Results to Screening Levels

Groundwater results for the site-wide aquifer beneath the upper yard were compared to Method B screening levels (based on its potential use as drinking water). In the absence of a Method B screening level for TPH, a 1 mg/L Method A-based screening level was used for comparative purposes (for TPH in the gasoline, diesel and oil ranges). None of the toluene, ethylbenzene, total xylenes, or PAH results were above the screening levels. In addition, dissolved arsenic and chromium, and total and dissolved antimony, cadmium, copper, lead, mercury, and zinc results were all below the screening levels (Table 6-4). Only 2 of 24 results were above the TPH and benzene screening levels. Only 1 of 6 total arsenic and 1 of 24 total chromium results were above the screening levels.

As previously discussed, screening levels for the site-wide aquifer were based on protection of surface water. To evaluate potential impacts of groundwater beneath the site on surface water, groundwater data were compared to Method B surface water cleanup levels. Table 6-2 lists screening levels identified per Method B (WAC-173-340-730(3)): water quality standards for state surface waters (chapter 173-201A WAC) and water quality criteria based on the protection of aquatic organisms published pursuant to section 304 of the Clean Water Act. Method B also provides for the protection of human health; associated section 304 criteria and MTCA Method B formula values (Ecology, 1996) therefore also were included in the table. Both freshwater and marine criteria were included. In cases where the most stringent screening level was below a chemical’s practical quantitation limit (PQL), the PQL was used as the screening level.

Table 6-3 compares groundwater sampling results to the most stringent screening level/water quality value from Table 6-2. Maximum concentrations of hazardous substances detected in groundwater for each of the four quarters of on-site, site-wide aquifer results were used in the comparison.

Concentrations of benzene above the screening level (0.043 mg/L) were found within the boundaries of the site, primarily near free product plumes. Results from the one surface/storm water sampling event, and groundwater TPH/benzene concentrations in wells downgradient of areas of elevated TPH/benzene (e.g., MW-139 and MW-106), indicate that TPH and benzene concentrations decline quickly with distance from the free product plumes. Chrysene, which was above the screening level of 0.00006 mg/L at three perimeter wells (LM-3, MW-135 [one round only], and MW-8), likely decreases in concentration quickly away from these wells due to its tendency to sorb to organic particulates. Concentrations of lead and chromium above the screening levels (0.008 and 0.024 mg/L, respectively) were found in wells in the interior or upgradient side of the site. Low concentrations were found in wells near Willow Creek. Dissolved lead and chromium concentrations were considerably lower than total lead and chromium concentrations indicating that lead and chromium are not being transported in groundwater. Non-qualified concentrations of total zinc above the screening level of

0.081 mg/L were found in three perimeter wells (LM-2, in two of four sampling events; LM-3, one sampling event; and MW-136, in two of four sampling events). Non-qualified concentrations of dissolved zinc were found only in LM-2, in one of four sampling events. Concentrations of total zinc were detected above the screening level in one off-site well (MW-106); non-qualified, dissolved zinc concentrations were above the screening level in two of four sampling events.

6.5.8 Off-site Groundwater

TPH-D and TPH-O were detected in about 25 percent of the groundwater samples collected in monitoring wells located off of the Terminal property along the BNRR right of way (MW-28, MW-105, MW-106, MW-107, MW-137, and MW-138). All TPH-D and TPH-O detections were in the southern portion of the right of way (MW-105 and MW-106). TPH-G and BTEX constituents were not detected. TPH-D detections ranged from 0.51 to 1.7 mg/L, and TPH-O detections ranged from 0.89 to 1.3 mg/L.

cPAHs were detected in about 25 percent of the samples, with detections at or near the MDLs. The *maximum* concentrations of the only three cPAHs detected were 0.029 µg/L (estimated) for benzo(a)pyrene, 0.013 µg/L (estimated) for chrysene, and 0.029 µg/L (estimated) for indeno(1,2,3-cd)pyrene.

nPAHs were detected in about 65 percent of the samples, with detections at or near the MDLs. Naphthalene, acenaphthylene, acenaphthene, anthracene, and fluoranthene were not detected. The *maximum* detected nPAH concentrations ranged from 0.013 µg/L (estimated) for phenanthrene to 0.089 µg/L (estimated) for benzo(g,h,i)perylene.

Dissolved cadmium and mercury were not detected in any sample. Total cadmium was detected in only one sample near the MDL. Chromium and lead were detected in about 80 percent of the samples, with detections at or near the MDLs. Antimony and arsenic were detected in about two-thirds of the samples, with detections at or near the MDLs. Copper was detected in all of the samples; the maximum concentrations of total and dissolved copper were 0.011 (estimated) and 0.0089 mg/L, respectively. Zinc was detected in all samples. Most detections were near the MDL, but detections in MW-106 were higher than those found in on-site wells. Total and dissolved zinc concentrations up to 1.2 and 1.1 mg/L were found in groundwater collected from MW-106. The source of zinc in off-site groundwater is not known.

The specific conductance measurements of samples collected in the southern off-site wells (MW-105, MW-106, MW-107, and MW-28) were generally lower in off-site wells than in on-site wells screened in the site-wide aquifer. The specific conductance measurements of MW-137 and MW-138 were comparable to other wells adjacent to Willow Creek. Turbidity measurements in off-site wells were comparable to measurements in on-site wells. Measurements of pH ranged from 5.2 to 6.6 in off-site groundwater samples. The temperature measurements in off-site monitoring wells were comparable to on-site wells in the lower yard.

TPH, BTEX, PAH, and metals results for the off-site groundwater samples generally indicate that off-site groundwater chemical concentrations are low, except for zinc detections in MW-106, which are elevated. These results are consistent with off-site groundwater TPH and BTEX results in MW-27, MW-28, and MW-29 that were sampled before the RI.

The off-site wells located adjacent to the southwest boundary of the site (MW-28, MW-105, MW-106, MW-107, and MW-137) lie about 50 feet downgradient of on-site product plumes or wells with elevated concentrations of TPH or BTEX (MW-8, MW-20, MW-123, MW-124, MW-125, and MW-128). The relatively high specific gravity and high viscosity of the product in these plumes (see Section 6.6.2) indicate that the product is of relatively high molecular weight and low water solubility, limiting product movement and impact on groundwater (see Section 6.6.3). Groundwater flow in this area is nearly horizontal and to the northwest at about 110 feet per year (based on data from MW-119), fast enough that an increase in constituent concentrations in off-site wells would have been detected by now if TPH and BTEX were migrating off-site in groundwater. These results indicate that it is likely that natural attenuation processes are responsible for the minimal TPH and BTEX detections in the off-site wells (USEPA, 1994). Natural attenuation processes include a variety of physical, chemical, or biological processes that can act to reduce the mass, toxicity, mobility, volume, or concentration of constituents in groundwater. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants (USEPA, 1997).

6.6 Product

6.6.1 Lateral Extent of Product Plumes

During a Phase 1 site assessment conducted in 1986, five product plumes were identified in the lower yard (GeoEngineers, 1986). For purposes of the RI, these are called the Railroad Spur plume, the Truck Loading Rack plume, the Asphalt Plant plume, the RW-2 plume, and the Office plume. In February 1995, a sixth product plume (D.B. No. 1 plume) was identified due to the discovery of monitoring wells MW-W and MW-E. Figure 6-10 shows the locations and estimated lateral extents of the product plumes on June 2, 1995, prior to conducting the RI. Approximately 9,500 gallons of product have been recovered from these plumes during the last 13 years.

To define the lateral extent of the floating (free) product plumes, EMCON measured depths to groundwater and free product, if present, in all of the lower yard wells (including the RI wells) on a monthly basis from December 1995 through November 1996. The average length of time between the main product pumping events (all wells) and the groundwater/product level measurement events was 6.3 days. The average length of time between the partial product pumping events (5 wells) and the groundwater/product level measurement events was 2.5 days. The groundwater monitoring data collected during the RI are presented in Table F-1 of Appendix F. As part of the interim product recovery activities at the site, EMCON measured depths to groundwater and free product, if present, in all of the lower yard wells on at least a quarterly basis during 1995, 1996, and 1997 (EMCON, 1996b, 1997, and 1998). To evaluate if the product in a well represents a localized product area, product near the edge of a floating plume, or product within a floating plume, EMCON established the following criteria to determine product within a floating plume: 1) product was consistently present in the well and the apparent product thickness accumulated to over 0.10 feet within a year, and/or 2) the well yielded more than ¼ gallon (32 ounces) of product during a year of passive pumping (interim product recovery activities).

In December 1995, free product was detected in 18 of the 64 monitored wells in the lower yard; however, 4 of these wells (LM-1, MW-E, MW-6, and MW-129) did not meet the criteria to be included within a floating product plume. By November 1996, free product was detected in 28 of the wells; however, 9 of these wells (LM-1, LM-3, MW-E, MW-6, MW-20, MW-102, MW-114, MW-124, and MW-128) did not meet the criteria to be included within a floating product plume. Figures 6-11 and 6-12 show the locations and estimated lateral extents of the floating product plumes on December 7, 1995, and November 4, 1996, respectively. The extents of most of the product plumes in November 1996 were approximately the same as in December 1995. The asphalt plant plume, both RW-2 plumes, and the truck loading rack plume were larger due to product entering RI wells for the first time. During 1996, a second D.B. No. 1 plume was identified when over 0.10 feet of product accumulated in RI well MW-129.

In December 1997, product was detected in only 17 wells, and 5 of those wells (MW-6, MW-114, MW-126, MW-128, and MW-133) did not meet the criteria to be included within a floating product plume (EMCON, 1998). Figure 6-13 shows the locations and estimated lateral extents of the floating product plumes on December 31, 1997. The lateral extents of product plumes in December 1997 were approximately the same size or slightly smaller than in November 1996, due to slow product migration rates, a better understanding of the product conditions beneath the site, and the effectiveness of the interim product recovery activities. The estimated lateral extent of the northern RW-2 plume was significantly smaller after April 1997 due to a better understanding of the product conditions in the area. In April 1997, recovery well RW-2 was replaced to find out if the original well was screened too low to allow product from the arms of the recovery trench to enter the well. The lack of product in the replacement well indicated that RW-2 was located beyond the southern extent of the northern RW-2 plume, there was no recoverable product in the vicinity of the arms of the recovery trench, and the estimated extent of the northern RW-2 plume prior to April 1997 was too large.

In addition to monitoring groundwater conditions to determine the extent of the plumes, EMCON also visually inspected all of the soil samples from the RI soil borings for the presence of product and collected soil samples from the borings for laboratory analysis. Product was observed in samples from borings MW-117, MW-119, MW-123, MW-125, MW-128, MW-130, MW-133, SB-102, SB-103, SB-126, SB-136, SB-144, SB-161, SB-168, and SB-178. The product typically occurred in thin zones, and exhibited a high viscosity. It did not appear that the product in the samples would be part of a floating product plume. Seven of the borings that contained visible product in soil samples were completed as monitoring wells (MW-117, MW-119, MW-123, MW-125, MW-128, MW-130, and MW-133). As of November 4, 1996 (up to 13 months after drilling), product had only been detected in two of the seven wells (MW-128 [only a film] and MW-130), which supports the observation that the product was typically trapped in soil rather than part of a floating product plume. By December 1997, free product had been detected in four of the seven wells (MW-123, MW-128, MW-130, and MW-133), and the apparent product thicknesses in all of the wells, except MW-130, did not accumulate over time to greater than 0.10 feet (EMCON, 1998).

Based on the groundwater monitoring data, the borings that contained visible product in soil samples (except MW-130 and SB-103) were not considered to be located within any of the floating product plumes. MW-130 was considered to be located within a product plume because it contained apparent product thicknesses greater than 0.10 feet, and SB-103 was considered to be located within a product plume because it was located approximately 35 feet from a well (MW-11) that contained recoverable free product (Figure 6-11).

Select soil samples from the RI borings were submitted for laboratory analysis. The samples were analyzed for TPH-G, TPH-D, TPH-O, and for other parameters unrelated to the determination of the extent of the product plumes. To further evaluate which soil borings may be located within product plumes, it was assumed that TPH-G, TPH-D, and/or TPH-O concentrations greater than or equal to 10,000 mg/kg in soil reflected free product at that location. Based on the depths to groundwater beneath the lower yard, only the analytical results for samples collected at depths of 3 to 9 feet bgs were used to evaluate the locations of product associated with a floating plume. At least one soil sample from borings MW-114, MW-115, MW-117, MW-121, MW-133, SB-106, SB-121, SB-126, SB-157, SB-173, SB-178, and SB-181 contained a TPH-G, TPH-D, and/or TPH-O concentration that equaled or exceeded 10,000 mg/kg. The soil sample analytical results for TPH-G, TPH-D, and TPH-O are presented in Table 6-8.

Five of the borings that contained TPH concentrations equal to or greater than 10,000 mg/kg were completed as monitoring wells (MW-114, MW-115, MW-117, MW-121, and MW-133). MW-121 was completed as a deep well. Based on the monthly depth to groundwater and free product measurements from December 1995 through November 1996, free product was only detected in wells MW-114 and MW-115. Free product was initially detected in MW-115 and MW-114 during February and

August 1996, respectively. Free product was not detected in well MW-133 until August 1997, and product had not been detected in well MW-117 by December 1997 (EMCON, 1998). The apparent product thicknesses in MW-114 and MW-133 did not meet the criteria to be included in a floating product plume. Based on the length of time for the product to enter the wells and the low product thicknesses in MW-114 and MW-133, the TPH concentrations exceeding 10,000 mg/kg do not necessarily represent locations within a floating plume, but more likely indicate locations where product is trapped in soil. The soil sample observations support this conclusion. The borings that contained TPH concentrations that equaled or exceeded 10,000 mg/kg (except MW-115, MW-121, and SB-106) were not included within floating product plumes. MW-115 yielded approximately 17 gallons of product during the 1996 and 1997 interim product recovery activities (EMCON 1997 and EMCON, 1998), boring MW-121 (deep well) was located between two shallow wells that contained recoverable free product (MW-102 and MW-132), and SB-106 was located adjacent to a recovery trench that contained recoverable product (RW-1).

6.6.2 Chemical and Physical Product Characteristics

To determine the chemical and physical characteristics of the product in each product plume (except the Office plume), EMCON collected product samples from selected wells for chemical and physical analysis. The samples were collected from wells MW-5, MW-13, MW-113, MW-118, and MW-130 for laboratory analysis. The samples were analyzed for hydrocarbon identification as gasoline, diesel, and/or oil. All of the samples contained gasoline, diesel, and oil. The sample from MW-5 (Asphalt Plant plume) consisted mostly of diesel, and the rest of the samples consisted mostly of gasoline. The sample from MW-5 also contained the highest percentage of oil in the samples. The hydrocarbon identification results are presented in Table 6-36. The lower concentrations of oil in the product samples may reflect the lesser mobility of the higher-oil-percentage product within each plume. Since the three types of product within each plume are not likely to be thoroughly mixed and have the same chemical composition throughout the plume, the portions of the product plumes containing higher oil concentrations (less mobile fractions) would be less likely to migrate into the wells.

The product samples were also analyzed for BTEX, PAHs, total lead, specific gravity, and viscosity. Benzene results varied from less than 1 to 3,900 mg/kg, toluene concentrations ranged from 6.4 to 2,500 mg/kg, ethylbenzene concentrations varied from 24 to 18,000 mg/kg, and total xylenes concentrations ranged from 34 to 86,000 mg/kg. Seven of the 16 PAHs (acenaphthene, benzo(b)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene) were not detected in any of the product samples[9]. PAH concentrations were in the low mg/kg

[9] The method detection limits were elevated due to interferences from other constituents in the product sample.

range for anthracene, benzo(a)anthracene, benzo(a)pyrene (one sample only), benzo(g,h,i)perylene, and benzo(k)fluoranthene. Four PAHs (acenaphthylene, fluorene, naphthalene, and phenanthrene) were detected above 100 mg/kg in most samples. The highest BTEX and PAH concentrations were in product samples from wells MW-113, MW-118, and MW-130. Lead concentrations in the product samples ranged from 0.32 to 170 mg/kg. The highest lead concentrations were in samples from MW-113 and MW-118.

The specific gravity results ranged from 0.8338 to 0.9561. The highest specific gravities were in the samples from MW-5 and MW-13 (the Asphalt Plant plume and the Railroad Spur plume, respectively). The viscosity values ranged from 1.38 to 7.67 centistokes at temperatures of 40° C (104° F). The highest viscosity values were from MW-5 and MW-13. The samples from MW-113, MW-118, and MW-130 (RW-2 plume, Truck Loading Rack plume, and D.B. No. 1 plume, respectively) contained viscosity values that are comparable to diesel #1 product viscosities (1.3 to 2.4 centistokes at 40° C). The viscosities of the samples from MW-5 and MW-13 (5.05 and 7.67 centistokes at 40° Celsius) are slightly greater than diesel #2 product viscosities (personal communication with Steve Hibbs of Spectra; February 1996). The specific gravity and viscosity results are presented in Table 6-36.

6.6.3 Assessment of Product Migration

To evaluate product plume migration, GeoEngineers (during 1986), UNOCAL site personnel (from 1987 through 1997), and EMCON (1992 through 1997) measured depths to groundwater and free product, if present, in lower yard monitoring wells. From September 1994 through December 1997, EMCON measured depths to groundwater and free product, if present, in all lower yard monitoring wells on at least a quarterly basis. Due to the distance between monitoring points and the slow product migration rates, estimating the lateral extents of the plumes and the migration distances of the plumes was difficult. However, general migration distances were estimated based on groundwater flow directions (established during the 1995 monitoring well assessment and from RI data), the estimated locations of the product plumes in the past, and the distances to potential product receptors (i.e., wells and surface water). The approximate extents of the floating free product plumes on December 31, 1997 are shown on Figure 6-13. The general groundwater flow directions beneath the lower yard are shown on Figures 6-11, 6-12, and 6-13. As seen on these figures, in the vicinity of the Truck Loading Rack, Asphalt Plant, and RW-2 plumes, groundwater flows away from Willow Creek toward Puget Sound or toward Detention Basin No. 1. These flow directions limit the movement of product toward Willow Creek.

Based on the presence of product near MW-11 (and likely MW-10) in 1986 (GeoEngineers, 1986) and the lack of product in downgradient well MW-28 in 1997, the migration rate of the Railroad Spur plume is estimated at less than 35 to 55 feet in at least

11 years (less than 3.2 to 5 feet per year). Based on the presence of product near MW-5 in 1986 and the lack of product in downgradient well MW-101 in 1997, the migration rate of the Asphalt Plant plume is estimated at less than 35 to 55 feet in at least 11 years (less than 3.2 to 5 feet per year). Based on the presence of product in MW-2 in 1989 (GeoEngineers, 1987) and the lack of product in downgradient well MW-117, the migration rate of the RW-2 plume is estimated at less than 20 to 35 feet in at least eight years (less than 2.5 to 4.4 feet per year). Due to the operation of the RW-1 recovery system, the migration rate of the Truck Loading Rack plume could not be evaluated. Since the pre-RI wells within the D.B. No. 1 plume were not discovered until 1995 and product was present in well MW-W at the time of discovery, a migration rate of the D.B. No. 1 plume could not be estimated.

Of the RI wells installed from September through November 1995, product was initially detected in MW-110, MW-113, MW-118, MW-129, and MW-130 by December 1995, and in MW-124, MW-115, MW-132, MW-128, and MW-114 by January, February, March, April, and August 1996, respectively. Product was not initially detected in wells MW-133, MW-126, and MW-123 until August, October, and November 1997, respectively. Only the wells that initially contained product by February 1996, except MW-124, have yielded over ¼ gallon of product during the interim product recovery activities or have accumulated apparent product thicknesses of greater than 0.10 feet (EMCON, 1997a and EMCON, 1998a). Based on the apparent product thicknesses and the recovered volumes of product, it appears that all of the RI wells that contained product by March 1996 were installed within floating product plumes, and that the product took up to six months to enter the wells.

6.6.4 Actual Versus Apparent Product Thicknesses

In November 1992, product baildown tests were conducted at wells MW-2, MW-5, MW-10, MW-12, and MW-21 to estimate the actual (corrected) free product thickness floating on the water table beneath the site. The results of the tests suggested that the corrected product thicknesses were approximately 3 percent of the apparent (measured) product thicknesses in the wells. These results were low compared to typical corrected product thickness percentages of 5 to 30 percent based on baildown test results (Gruszczenski, 1987). The low baildown test results were due to slow product recovery rates into each well.

Based on a review of the literature addressing the determination of actual product thickness, there appears to be no equation that can accurately determine actual product thicknesses under conditions of slow product migration rates and significant water table fluctuations due to tidal effects. Ballestero, Fiedler, and Kinner (1994) used a physical model to compare six different equations that predict the actual free product thickness in a formation to the apparent free product thickness in a monitoring well. An equation developed by Ballestero, Fiedler, and Kinner was the most accurate of the six equations at predicting the actual free product thickness in a formation. The Ballestero, Fiedler, and Kinner equation was used to conservatively estimate the actual product thickness beneath the site. The equation is:

$$t_g = t\,(1-S_g) - h_a$$

where t_g is the actual free product thickness, t is the apparent free product thickness, S_g is the specific gravity of the product, and h_a is the distance between the groundwater table and the free product in the formation. In the formation, free petroleum product does not typically float on top of the water table, but on top of the capillary fringe. The term h_a represents the distance between the base of the product layer and the water table, or the capillary fringe thickness.

The equation shows that the lower the h_a value, the greater the actual product thickness. In order to be very conservative, an h_a of 0 was used. Based on the laboratory-determined product specific gravities of 0.8338 to 0.9561, the calculated actual product thicknesses were 4 to 17 percent of the apparent product thicknesses. For the product plume that was not analyzed for specific gravity (Office plume), an average specific gravity of 0.88 was used to calculate the actual product thicknesses. The calculated actual product thicknesses in the wells from December 1995 through June 1996 are presented on Table F-1, Appendix F.

6.6.5 Estimated Volume of Free Product

The estimated total product volume beneath the lower yard (as of December 2000) is approximately 3,100 gallons. The volume calculations are presented in Appendix M. The main variables used to estimate the product volume beneath the lower yard were the lateral extent of the plumes (based on December 1997 data), the actual product thicknesses, the soil porosity, and the oil saturation percentage. The actual product thicknesses were calculated from the apparent product thicknesses as described above. Average actual product thicknesses from January 1997 through December 2000 were used to calculate the product volumes. To be conservative, actual product thicknesses of less than 0.01 feet were assigned a value of 0.01 feet in the product volume calculations. Any apparent product thickness that was measured within five days after a product pumping event was not used to determine the average actual product thickness.

Based on the results of the interim product recovery operations, product thicknesses in the higher yield wells were typically fully recovered within 2 to 4 days after pumping. The product movement into the passive recovery wells within the plumes is significantly faster than product migration at the edge of the plumes because after several pumping events, the product is traveling into the wells through “chains” of pore spaces containing only product. For all multiple fluid systems, the movement of each fluid (e.g., air, water, product) is limited by the presence of the other fluids (Marle, 1981). The presence of one fluid proportionally reduces the hydraulic conductivity of the soil relative to the other fluid. Therefore, for product to move efficiently through soil, it must first displace the water or air that initially filled the pores.

The soil porosity (38 percent) was based on the average value from six soil samples collected at depths of 7 to 10 feet bgs. The soil porosity results are presented in Table 5-1. A conservative estimate of 60 percent oil saturation was used in the product volume calculations. A paper by Huntley, Wallace, and Hawk (1994) states that the pore spaces in the zone immediately above the oil/water interface are mostly filled by water.

6.7 Surface Water

Results of the surface water sample analyses are provided on Tables 6-37 through 6-43. Samples were collected during an April storm event, when storm water was discharging from the site. The sample furthest up Willow Creek (and unaffected by tidal influence) was collected at high tide, and the remaining surface water samples were collected on an outgoing tide. Field observations by sampling personnel were that the surface water samples were typically yellow to brown, cloudy, with no noticeable odor or sheen. Laboratory results indicated that where detected, the highest chemical concentrations in Willow Creek and tidal basin samples were typically found at the upstream sampling station near the fish hatchery. As storm water contaminants are often associated with particulate, these higher concentrations are probably due to the higher total suspended solids found at the upstream station. Few organic chemicals were detected in the samples. Regarding the results of surface water samples collected from station SW-3 (located downstream of Outfalls 001 and 002), only the concentrations of copper, lead, and zinc were slightly higher (+1-2 µg/L) at this station than at SW-2 (located upstream of Outfalls 001 and 002). No other increase was apparent.

TPH-D and zinc were the primary chemicals found in samples of surface water impounded in Detention Basins No. 1 and 2. Few organic chemicals were detected in these samples.

Results are more specifically described in the subsections below. A comparison of the results to water quality-based screening levels is discussed in Section 6.7.7.

6.7.1 TPH, BTEX, and Oil and Grease

There were no detections of TPH-D, TPH-O, TPH-G, BTEX (by EPA Method 8020), or oil and grease, in any of the samples collected from Willow Creek (SW-1, 2 and 3) and the tidal basin (SW-4) during the April sampling event. When analyzed by Method 8240 for VOCs, toluene, ethylbenzene, and xylene chemicals were detected in samples from stations SW-3 and SW-4 at concentrations up to an estimated 1 µg/L.

Samples of the impounded water collected from Detention Basin No. 1 (SW-5) and Detention Basin No. 2 (SW-6) showed no detections of TPH-O, TPH-G, or oil and grease. Although Detention Basin No. 1 generally has a sheen on the water surface, TPH-D was found in this basin at concentrations <1 mg/L. Benzene (by Method 8240), toluene, and xylenes were detected in both basins, at concentrations of approximately 0.6 (estimated value), 3, and 10 µg/L, respectively. Concentrations in basin No. 2 were slightly higher than in No. 1.

6.7.2 PAHs

Except for one estimated detection of pyrene (0.011 µg/L) in one of three samples from SW-3, PAHs were only detected at the upgradient station near the hatchery (SW-1); detections ranged from an estimated 0.017 µg/L for anthracene to 1.1 µg/L for fluoranthene. PAHs detected at the upgradient station are likely attributed to street runoff, as street runoff commonly contains these chemicals (58 FR 61146).

Basin water samples contained two PAHs, pyrene and chrysene. Respective concentrations ranged from an estimated 0.019 to 0.031 µg/L, and an estimated 0.009 to 0.023 µg/L.

6.7.3 Metals

Arsenic, chromium, copper, lead, and zinc were detected in almost all surface water samples, though the detections were estimated values due to the low concentrations and the chromium results were qualified due to chromium detections in an associated blank. While detected concentrations were low, the highest total metal values were detected at the upgradient station (SW-1). Antimony, cadmium, and mercury were not detected in any sample.

Surface water samples collected from the detention basins contained metals at concentrations within the range of those detected in Willow Creek and the tidal basin. Except for zinc, concentrations were below those detected in samples collected from the upgradient station. Metals concentrations in basin No. 1 were slightly higher than in No. 2, and may be associated with the higher TSS concentrations.

6.7.4 VOCs

Non-BTEX VOCs were not detected in any of the samples, with the exception of estimated detections of methylene chloride. This compound was also found in an associated blank.

In the detention basins, estimated and anomalous detections of chloromethane (1 µg/L) and chloroform (0.2 µg/L) were reported in one of the three samples from Detention

Basin No. 2. No other (Non-BTEX) VOCs were detected in the samples from either basin.

6.7.5 Total Suspended Solids

Total suspended solids (TSS) ranged from 140 mg/L at upgradient station SW-1 to less than 10 mg/L at stations SW-2 and SW-3. The average concentration of the three samples collected in Detention Basin No. 1 and No. 2 was 20 and 44 mg/L, respectively.

6.7.6 Surface Water Field Parameters

Specific conductance ranged from 99 to 4,520 µS/cm in the storm water samples. Measurements during the storm event were between 99 and 159 µS/cm in Willow Creek and 4,520 µS/cm in Detention Basin No. 1. Measurements of pH ranged from 5.7 to 7.8, and temperature measurements ranged from 11.5 to 13 C.

6.7.7 Comparison of Surface Water Results to Screening Levels

As noted in Section 6.3, Method B screening levels for surface water were used to evaluate results of surface water sampling at the site. A discussion of the comparison is provided in Section 6.8.6.

6.8 Storm Water

Results of the storm water analyses are provided on Tables 6-37 through 6-42. Samples were collected during the April storm event in conjunction with the surface water (Willow Creek, tidal basin) sampling. Observations of the sampling personnel were that storm water samples were typically yellow, slightly turbid, with no noticeable odor or sheen. Laboratory results showed TPH-D in all samples, at concentrations <1 mg/L. Oil and grease and TPH-O were not found. Detected petroleum-related chemicals were typically higher in runoff from the lower yard.

Results are more specifically described in the subsections below. A comparison of these results to screening levels is also provided below and was performed as part of the environmental baseline exposure evaluation discussed in Section 7.

6.8.1 TPH, BTEX, and Oil and Grease

TPH-D was detected in storm water samples collected during the April event at all three stations: lower yard station STW-L32, upper yard station STW-U44, and STW-API, which represented combined runoff from the lower and upper yards. Concentrations ranged from 0.28 mg/L for the upper yard to 0.95 mg/L for the lower yard. TPH-O was not detected in any sample. Estimated TPH-G concentrations of 0.61 and 0.63 mg/L were detected in the grab and composite samples from the lower yard station. BTEX chemicals were detected in samples from the lower and upper stations, with maximum estimated benzene concentrations of 2 µg/L for the lower yard and 0.5 µg/L for the upper yard. The maximum toluene concentration of 44 µg/L was found at the lower yard station, as were the maximum ethylbenzene and xylene concentrations (4 and 150 µg/L, respectively). Oil and grease was not detected in the storm water samples.

6.8.2 PAHs

PAHs were detected in the lower yard storm water composite sample and not in the upper yard composite sample. Lower yard storm water PAHs ranged from an estimated 0.01 µg/L phenanthrene to 0.099 µg/L chrysene. PAH concentrations in the lower yard storm water were an order of magnitude less than the concentrations detected at the upgradient station near the hatchery.

6.8.3 Metals

Antimony, arsenic, chromium, copper, lead, and zinc were detected in the samples collected from both the lower and upper yard stations. All but antimony were also detected at the combined (API) storm water station. Mercury was not found in any sample and cadmium was reported at the detection limit for two samples. The lower yard composite sample (STW-L32-C-1) contained the highest concentrations of arsenic, chromium, copper, lead and zinc, at 0.007, 0.015, 0.027, 0.031, and 0.41 mg/L, respectively.

6.8.4 VOCs

Excepting BTEX (see Section 6.7.1, above), no VOCs were detected in any storm water sample.

6.8.5 TSS

TSS concentrations in the storm water runoff from the lower yard, upper yard, and from the combined (API) station were 110, 69, and 44 mg/L, respectively.

6.8.6 Comparison of Surface Water and Storm Water Results to Screening Levels

As noted in Section 6.3, Method B screening levels for surface water were used to evaluate results of surface and storm water sampling at the site. For purposes of the RI, water in Willow Creek the tidal basin, and impounded in Detention Basins No. 1 and 2, was identified as "surface water," and runoff flowing from the upper and lower yards during the monitored storm event was identified as "storm water."

Table 6-2 lists screening levels identified per Method B (WAC 173-340-730(3)). Table 6-5 compares surface and storm water sampling results to the most stringent screening level/water quality value from Table 6-2. Oil and grease and BTEX concentrations were well below water quality values. PAHs were detected at concentrations above the most stringent value of 0.00006 mg/L only at the upstream sampling station (SW-1) and are probably associated with urban storm water runoff. Concentrations of copper and lead also exceeded the most stringent screening level at this upstream location. Zinc was the metal detected at the highest concentrations both upstream and along the ditch conveying Willow Creek. Zinc exceeded the 0.081 mg/L cleanup level in combined upper and lower yard runoff (0.094 mg/L); concentrations in Willow Creek and the tidal basin downstream of the Terminal outfalls (estimated at 0.0237 and 0.0200 mg/L) did not exceed the screening level.

6.9 Catch Basin Sediments

Sediment samples were collected from seven catch basins to characterize this material for disposal purposes and to evaluate the variance in sediment buildup and contamination (Table 6-44). Catch basin sediment results were in the range of lower yard soil results for all analyzed constituents (TPH-G, TPH-D, TPH-O, BTEX, PAHs, and metals). The catch basin sediment results (including Toxicity Characteristic metals) were below Dangerous Waste Thresholds (WAC 173-303-090).

6.10 Upland Sediments

The results of the upland sediment bioassay testing and the analysis of conventional parameters (grain size and TOC) are presented in Tables 6-45 through 6-49 and are discussed below. Drawing No. 2 shows the upland sediment sampling locations. Assessment of the bioassay testing results was conducted following the procedures specified in WAC 173-204-320(3) and as described in the work plan.

To evaluate the test results, first the reference and control sediments results were compared to performance standards for the biological tests. Performance standards for the biological tests were as follows:

- Amphipod bioassays - control sample mortalities less than 10 percent and reference sediment mortalities less than 25 percent. Each of the amphipod control sediment samples showed an average mortality of 2 percent, and the Nisqually River and Carr Inlet reference samples and the sample collected near the upstream edge of the site in Willow Creek (station US-15) showed mortalities of four, three, and four percent, respectively.

- Bivalve larvae bioassays - less than 30 percent combined mortality and abnormality in control samples. The mean normal development of larvae in the three control sediments was 96, 98, and 97 percent. The mean survivorship of normal larvae was 62 percent, 69 percent, and 92 percent in the control samples, giving a mean combined mortality and abnormality of 38 percent, 31 percent, and 8 percent. Only the results for one control sample (at 8 percent) passed the performance standard.

- Juvenile polychaete bioassay - less than 10 percent mortality in control sediments and a reference sediment mean biomass at least 80 percent of the mean biomass found in control sediment. The two control samples showed mortalities of 4 percent, and the mean biomass in the reference sediment samples from the Nisqually River, Carr Inlet, and the upstream location were all greater than the mean biomass of both control sediment samples.

Performance standards (and evaluation criteria) for bivalve larvae and juvenile polychaete bioassays were revised in December 1995, after the upland sediment bioassays were conducted. The revised bivalve larvae performance standard for the seawater control sample (combined abnormality and mortality of less than 30 percent) was used in this evaluation. In the Sediment Management Standards (SMS) *Draft Technical Information Memorandum Quality Assurance Guidelines for the Sediment Larval Bioassay* (March, 1996), a revised performance standard of less than 35 percent effective mortality (seawater normalized) was established for reference sediment. The reference sediment for the bivalve larvae passed this revised performance standard. The revised SMS control sediment performance standards for juvenile polychaete bioassays are a control sample mortality of less than 10 percent, a mean individual growth rate of greater than or equal to 0.72 mg/individual/day per dry weight basis for control samples, and a mean individual growth rate at least 80 percent of the control sample growth rate for the reference sediment. The control samples of the Terminal study showed mean growth rates of 0.43 mg/individual/day and 0.50 mg/individual/day, which were less than the revised performance standards. The low growth rates appeared to be a result of the relative lack of food (TOC) in the control sample sediment.

6.10.1 Bioassays

Amphipod Bioassay. The mortality and reburial results for the amphipod 10-day bioassay using the test organism *eohaustarius estuaris* are presented in Table 6-45. Mortality of *E. estuaris* ranged from 0 to 60 percent for individual replicate analyses of the test sediments. Average mortality for the test sediments ranged from 4 percent at station US-02 to 46 percent at station US-05. The average mortality for the control, reference (NISQ, CARR), and upstream sample (US-15) ranged from 2 to 4 percent. Amphipod reburial rates for the surviving test organisms varied from 96 to 100 percent.

Bivalve Larvae Bioassay. Bivalve larvae development and survival were evaluated using the test organism *mytilus edulis.* Development and survival data for *M. edulis* testing are presented in Table 6-46. Normal development of larvae ranged from 81 percent to 99 percent for individual replicate analyses of test sediments. The average percent normal development of test sediments ranged from 90 percent at station US-03 to 98 percent at stations US-01 and US-14. The normal development of larvae ranged from 44 to 100 percent for the upstream, reference area, and control sediment replicate analyses. Average percent normal development for control and reference sediments ranged from 76 percent for the Nisqually River reference sediment (NISQ) to 99 percent for sediment from the upstream station (US-15).

The percent survival of bivalve larvae in the individual replicate analyses of test sediments ranged from 14 to 96 percent. The average survival of larvae in test sediments ranged from 57 percent at station US-08 to 83 percent at station US-11. Replicate analyses of upstream, reference, and control sediment showed bivalve larvae survival ranging from 27 to 100 percent. The average survival ranged from 45 percent for the upstream sample (US-15) and Nisqually River reference sample (NISQ) up to 95 percent in one of the control samples.

Individual replicate analyses of test sediment showed a range of 11 percent to 90 percent normal survivors. The average percent normal survivors for test sediments ranged from 54 percent at station US-08 to 78 percent at station US-11. The control, reference, and upstream samples showed percent normal survivors in individual replicates ranging from 12 percent to 97 percent. The average percent normal survivors for the control, reference, and upstream samples ranged from 36 percent for the Nisqually River reference sediment up to 92 percent in one of the control samples.

Juvenile Polychaete Bioassay. The growth and survival of *neanthes arenaceodentata* was measured for the juvenile polychaete bioassay. The number of surviving individuals, percent survival, measured final biomass, mean final biomass, and the average individual growth rate for each replicate are presented in Table 6-47. The number of survivors ranged from 3 to 6 for the test sediments. The average percent survival of *N. arenaceodentata* at sampling stations ranged from 64 to 100 percent for the test sediments. Both control samples showed survival rates of 96 percent, and the reference samples and upstream sample showed 100 percent survival.

The final biomass in individual replicates of test sediments varied from 9.91 mg (dry-weight) for three individuals in replicate two at station US-09 to 71.65 mg for five individuals in replicate two at station US-01.[10] The mean final biomass for five replicate analyses ranged from 17.47 mg at station US-09 to 53.27 mg at station US-01. The mean final biomass per individual, calculated by dividing the mean final biomass by the total number of surviving individuals, ranged from 1.09 mg/individual at station US-09 to 2.42 mg/individual at station US-01. The reference, control, and upstream sediments showed measured final biomass ranging from 12.06 mg for five individuals in a control sample replicate up to 55.46 mg for five individuals in a replicate analysis of the Nisqually River reference sediment. Average final biomass ranged from 26.44 mg for a control sample up to 43.73 mg for the Nisqually River reference sediment. Average biomass per individual ranged from 1.10 mg for one of the control samples up to 1.75 mg for the Nisqually River reference sediment. The average individual growth rates for test sediment ranged from 0.273 mg/individual/day at station US-09 to 0.609 mg/individual/day at station US-01.

6.10.2 Grain Size, TOC, and Ammonia

Grain size and TOC results are summarized on Table 6-48. TOC concentrations ranged from a low of 0.779 percent for the test sediment from station US-01 up to an average of 9.698 percent for the field duplicate samples from station US-13. The coarsest test sediments were collected from station US-01, which showed greater than 96 percent gravel and sand. Test sediment from stations US-08 and US-14 showed over 80 percent fine grained (silt and clay fraction) material.

Sulfide (as dissolved sulfide ion) and ammonia (as NH_3) were analyzed in each of the test sediment replicate analyses prior to bioassay testing and after testing was completed. All of the sulfide measurements were non-detect at a detection limit of 0.001 mg/L. Results of ammonia analyses are presented in Table 6-49. The Carr Inlet reference sediment produced the highest ammonia levels in the initial bioassay water for all three bioassay tests (0.37 mg/L to 4.56 mg/L). As might be expected, samples US-13 and US-14 with relatively high TOC concentrations (9.4 percent and 7.0 percent) exhibited relatively high ammonia levels (3.05 mg/L and 3.16 mg/L, respectively) in the initial phase of the amphipod test. However, the Carr Inlet sediments, with very low TOC (0.55 percent), produced an even higher level of ammonia in the amphipod test (4.56 mg/L). Most of the ammonia concentrations measured at the end of the bioassays were non-detect at a 0.17 mg/L detection limit. The highest concentration of ammonia measured at the end of the bioassay testing was 1.27 mg/L in the amphipod bioassay with US-09 sediments.

[10] The initial worm size was 1.0 to 1.4 mg/individual.

6.10.3 Summary

The bioassay testing identified upland sediments that produced effects on amphipod survival, bivalve larvae survival and development, and juvenile polychaete growth. Each of the tests identified different sediments as producing the greatest effect, and none of the sediment samples produced significant effects in all three tests. The results from the analysis of conventional parameters did not show a correlation with the observed effects in the bioassays. An evaluation of testing results against the State Sediment Management Standards of chapter 173-204 WAC is presented in Section 7.2.3.

6.11 Waste Identification

Residuals generated during the RI field activities were soil cuttings, water used for driller decontamination purposes, and groundwater extracted during well development and purging. Approximately 35 cubic yards of soil cuttings were generated and stockpiled in the lower yard. Approximately 3,800 gallons of water were generated and placed in 55-gallon drums. The water was sampled following Work Plan procedures and results indicated that, where detected, contaminant concentrations were substantially below site NPDES discharge limitations for all but TSS, and the water did not meet the definition of a dangerous waste per chapter 173-303 WAC. Quality of the water was as clean or cleaner than groundwater beneath the lower yard in the vicinity between MW-26, MW-27, and MW-133 and Ecology approved discharge of the water to this graveled area. Water was discharged in June and July 1996. The stockpiled soil will be characterized pursuant to Work Plan procedures prior to final disposition.

6.12 Discussion of Results

Remedial investigation field explorations and laboratory analyses indicate that the primary environmental and/or human health impacts at the Terminal include free product on the water table, related petroleum hydrocarbon chemicals in subsurface soil and groundwater, and paint/sand blast grit-related metals in the surface soil. Free product has been found in six lower yard plumes at the Terminal: the Railroad Spur Plume, the Truck Loading Rack Plume, the Asphalt Plant Plume, the Office Plume, the RW-2 Plume, and the Detention Basin No. 1 Plume. These plumes are the result of releases during former Terminal operations including possible tank and piping leaks, transfer spillage, tank overtopping, process area releases, and spills into Detention Basin No. 1. Approximately 9,500 gallons of product have been recovered from these plumes to date, and it is estimated that approximately 3,300 gallons of product remain in these plumes. Recovered product results indicate that the free product consists of gasoline-range, diesel-range, and oil-range hydrocarbons. Field observations indicate that much of the free product may be heavier-end hydrocarbons. Based on product thickness measurements over the last 13 years, product migration rates are low and are estimated at less than 5 feet per year.

Petroleum hydrocarbons dissolved in groundwater were primarily found near free product plumes and in areas with free-phase product trapped in the vadose zone near the water table. The highest concentrations of TPH-D, TPH-O, TPH-G, BTEX, and PAHs were found near former operational areas, at the former southerly extension of Detention Basin No. 1, and inside the Detention Basin No. 1 berm on the northwest side. These chemicals were not found in significant concentrations on the north side of Detention Basin No. 1, beneath and immediately downgradient of the upper yard, in deeper lower yard monitoring wells, or off site along the BNRR right of way. Except for zinc, metals concentrations in groundwater were generally low, with the highest concentrations found in isolated locations around the Terminal. Zinc was the most frequently detected metal in groundwater, with the highest concentrations found in wells along the perimeter of the site. Non-BTEX VOCs were not found in groundwater at the Terminal.

Petroleum hydrocarbons in soil were primarily found near free product plumes and in areas with free-phase product trapped in the vadose zone. The highest concentrations of TPH-D, TPH-O, TPH-G, BTEX, and PAHs were found in former operational areas, on the south side of Detention Basin No. 1, in the central and far eastern parts of the lower yard, and in two upper yard tank basins. High concentrations of petroleum hydrocarbons were also found in the material in Detention Basin No. 1. These chemicals were not found in significant concentrations along the west and north sides of Detention Basin No. 1, in most of the random lower yard soil borings, in random upper yard soil borings, or off site along the BNRR right of way. Non-BTEX VOCs and non-PAH SVOCs were not found in significant concentrations in Terminal soil. Glyphosate was not found in soil. Additionally, metals were not found in significant concentrations in subsurface soil at the Terminal.

Elevated metals concentrations were only found in surface soil in areas of sand blast grit and paint chips which occur under pipe runs and manifolds, in isolated grit piles, and in certain tank basins. Leachable metals concentrations were low, indicating that leaching of metals from surface soil is not likely.

Petroleum-related chemicals were detected in on-site storm water, primarily from the lower yard. Results may in part be due to groundwater seepage into the drainage system. Storm water metals concentrations were generally low, with zinc detected at the highest concentrations. Non-BTEX VOCs, and oil and grease were not found in storm water. Similarly, these constituents were also not detected in surface water in Willow Creek and the tidal basin, nor were TPH-G, TPH-D, or TPH-O. The highest metals concentrations, and elevated PAH concentrations, were found in surface water upgradient of the site and were likely associated with street runoff.

Toxic effects were exhibited by sediment from the creek at six locations along the northwest boundary, as well as by sediment upgradient of the site; no sediment exhibited toxic effects to all three test species. No discernible pattern was identified that would point to a single sediment toxicity source. The majority of the stations showed no toxic effect on any of the species tested, including sediment from the downstream tidal basin and sediment from Willow Creek adjacent to the marsh.

7 BASELINE EXPOSURE EVALUATION

7.1 Human Health Evaluation

7.1.1 Overview

A baseline exposure evaluation was conducted to evaluate potential impacts to human health and the environment posed by selected hazardous substances detected at the Terminal. Following MTCA procedures, indicator hazardous substances (IHSs) were identified and reasonable maximum exposure (RME) scenarios were developed. Where not specified in MTCA regulations, assumptions and methodologies used in the evaluation were consistent with EPA methodologies (EPA, 1989). The soil, groundwater, surface water and storm water data were statistically reduced to generate exposure point concentrations for the baseline exposure evaluation; at Ecology's request, maximum detected concentrations were subsequently used in the assessment.

7.1.2 Reasonable Maximum Exposure Assessment

The extent of exposure was evaluated by identifying actual and potential human exposure routes and exposed receptors based on current and potential future uses of the site, groundwater beneath the site, and surface water adjacent to the site. Land use is currently industrial and the current human receptors are site workers. Future land use is potentially a mix of residential, commercial, and industrial, and human receptors may be site workers, residents, and occasional visitors.

MTCA defines the reasonable maximum exposure (RME) scenario as "the highest exposure that is reasonably expected to occur at the site under current and potential future site use" (WAC 173-340-709[3][b]). The RME scenario for soil at the Terminal is therefore residential, based on the upper yard's potential future use for residential purposes. Soil cleanup levels for the residential scenario are based on a child incidentally ingesting soil.

MTCA defines the RME for most groundwater as exposure to hazardous substances in drinking the water and in other domestic uses. As provided in MTCA, at sites where affected groundwater flows into nearby surface water, the RME scenario for groundwater may be established based on potential surface water exposures. For the Terminal, surface water exposure may occur as associated with Willow Creek or Puget Sound.

Per chapter 173-201A WAC Water Quality Standards for Surface Waters of the state of Washington, Puget Sound in the vicinity of the Terminal and Willow Creek are classified as Marine water Class AA and Freshwater Class AA, respectively. Water quality for Class AA is considered to support characteristic uses such as water supply, stock watering, fish and shellfish rearing, spawning, and harvesting, fish migration, wildlife habitat, recreation, commerce, and navigation. Water supply and stock watering were not considered relevant for Puget Sound, and were not considered relevant for Willow Creek based on marine water influence in the creek along the Terminal boundary. Therefore, the RME for site surface water was considered as that described by MTCA Method B for surface water: exposure by aquatic organisms and human exposure through ingestion of aquatic organisms. For the reasons provided above, this may also be considered the RME for groundwater beneath the site.

As discussed in Section 6.3, Ecology has determined that the highest beneficial use of the site-wide aquifer beneath the upper yard is as a drinking water resource. Based on this determination, the RME for groundwater in the site-wide aquifer beneath the upper yard is exposure to hazardous substances by drinking this water or through other domestic use.

7.1.3 Identification of Indicator Hazardous Substances

Soil. Following evaluation of the RI data, IHSs in soil were selected by considering frequency of detection and characteristics of mobility and by comparing the maximum detected concentrations with MTCA Method B soil cleanup levels, natural background concentrations, and site background concentrations. The method for selecting IHSs was in accordance with WAC 173-340-708(2) and with the Work Plan, except that maximum detected concentrations were subsequently used at Ecology's request rather than the upper 95 percent confidence limits on the mean concentrations. As discussed in the Work Plan, thoroughness of testing was not an issue, because the sampling approach was designed for the purpose of identifying IHSs. Degradation by-products were not considered, because there are limited ways to account for the by-products of petroleum.

MTCA Screening Levels. The first step in the screening process was to compare the maximum concentrations for each detected chemical to the Method B soil cleanup level. Method B was used in this screening step as it is the standard approach for all sites and reflects more conservative (nonindustrial) exposure assumptions. If the ratio of the maximum concentration to the Method B cleanup level was greater than 1, the chemical was retained as a preliminary IHS. If the ratio was 1 or less, the chemical was eliminated as an IHS. If no Method B value was available due to lack of toxicity data, the chemical was eliminated as an IHS because MTCA regulations to not provide a methodology to calculate cleanup levels without toxicity data.

The maximum concentrations were obtained from Tables 6-1a and 6-1b. Method B formula cleanup levels were used (Ecology, 1996). Antimony was assumed to be either trioxide or tetroxide (they have the same toxicity value and, hence, the same cleanup level). Chromium was assumed to be hexavalent. The Method A residential cleanup level was used for lead, because a Method B formula cleanup level is not available for this compound. The site-specific Method B screening level calculated for TPH in the upper yard (see Section 6.3) was used in this step of the IHS selection process.

The following chemicals were retained as preliminary IHSs during the first screening step for both the upper and lower yards, unless noted otherwise:

- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Chrysene
- Indeno(1,2,3-cd)pyrene
- TPH-D
- TPH-O
- TPH-G
- Benzene (lower yard only)
- Antimony
- Arsenic
- Copper
- Lead

Three non-carcinogenic PAHs (acenaphthylene, benzo(g,h,i)perylene, and phenanthrene) were eliminated in this step of the process due to lack of toxicity data.

Frequency of Detection. The second step in the screening process was to consider the frequency of detection. A detection frequency of 5 percent was selected as the screening criterion, consistent with EPA convention under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Since all of the chemicals retained as preliminary IHSs during the first step had frequencies of detection greater than 5 percent, no chemicals were eliminated during this step of the screening process.

Background. For antimony, arsenic, copper, and lead, the final step in the screening process was to compare the maximum concentrations to natural background concentrations in the Puget Sound region (Ecology, 1994) and site background concentrations measured at the site. No natural background concentration was available for antimony. For this screening process, site background concentrations were considered to be the mean of the three background samples (SS-107, SS-108, and

SS-208) taken at the site. The maximum concentrations for each of the metals exceeded their respective natural and site background concentrations, so no metals were eliminated as IHSs during this step of the screening process.

Mobility and Persistence. For the organic hazardous substances, the final step in the screening process was to consider water solubility and the log of the octanol-water partition coefficient (K_{ow}) as indicators of environmental mobility and persistence. Solubility and log K_{ow} values were obtained from EPA's Superfund Public Health Evaluation Manual (EPA, 1986). Mobility data for TPH constituents were obtained from the Interim TPH Policy. Metals generally have low solubility; the parameter K_{ow} is not defined for inorganic chemicals. Instead, the mobility of metals was evaluated using the adsorption coefficient (K_d), which is defined as the ratio of the concentration adsorbed on soil surfaces to the concentration in water.

Organics. Since the carcinogenic PAHs tend to have similar water solubilities and similar log K_{ow}s, they are likely to move similarly in the environment. Chrysene was chosen from the preliminary IHS set to represent the carcinogenic PAHs at the site, because it was detected the most frequently and at the highest concentrations in both the lower and the upper yards.

Inorganics. The affinity of a metal for soil increases as the K_d increases. Therefore, metals with high K_d values will tend to sorb to soils and leach to a lesser extent than metals with lower K_d values. Under typically encountered soil pH (6 to 8), the K_d values for arsenic average between 1.2 and 1.9, depending on the valence state of the metal (Dragun, 1988). The K_d values for antimony vary widely, from 2 to over 45 (EPA, 1996). The Kd values for lead and copper average 4.6 and 3.1, respectively (Dragun, 1988). This indicates that lead and copper have more affinity for soil than does arsenic; as a result, the mobility of lead and copper is expected to be less than that of arsenic. Based on this lower mobility, arsenic was selected as an IHS for the metals, and lead and copper were eliminated. Based on the range of Kd values, antimony was retained as a metals IHS.

Additional Metals Evaluation. Based on IHS selection discussions with Ecology, an additional assessment was performed to support the selection of arsenic and antimony as metals IHSs and the elimination of copper and lead as metals IHSs. Copper concentrations in only 4 of 25 lower yard soil samples and 1 of 15 upper yard samples were greater than the Method B screening criteria. All five of the samples which exceeded the screening level were located in mapped paint chip/sandblast grit areas. For lead, only 4 of 192 lower yard soil samples and 3 of 65 upper yard soil samples contained concentrations greater than the Method A screening level. All seven samples were located in mapped paint chip/sandblast grit areas. Remedial decisions based on arsenic and antimony and the mapped paint chip/sandblast grit areas will not result in these small areas of the site with high metals concentrations being overlooked. A data point by data point comparison showed that if arsenic and antimony were used as IHSs in remediating the paint chip/sandblast grit areas, copper and lead would also be removed.

Summary of Soil IHSs. Using the procedures described above, the following chemicals were selected as IHSs in soil for both the lower and the upper yard, unless noted otherwise:

- Chrysene
- TPH-D
- TPH-O
- TPH-G
- Benzene (lower yard only)
- Antimony
- Arsenic

Groundwater IHSs. To identify IHSs for groundwater beneath the upper yard (drinking water RME), a process comparable to that performed for soil was followed. As the following chemicals were above Method B screening levels (from Table 6-4), they were retained as preliminary IHSs during the first screening step:

- TPH (the sum of TPH-G, TPH-D, and TPH-O)
- Benzene
- Chromium
- Arsenic

As with soil IHS screening, the second step in the process was to consider the frequency of detection. Chromium was eliminated in this step for the following reasons. Over the RI monitoring period, 24 samples were collected from wells which monitor the site-wide aquifer beneath the upper yard. Total chromium was detected in 18 of 24 samples (75 percent); however, only 3 of the 24 sample results (12 percent) were non-qualified (detected above the PQL and not flagged with a data qualifier) data points. Dissolved chromium was detected in 3 of 24 samples (12 percent); however, all of the detections were qualified. Although the percentage of total chromium results detected above the PQL was greater than the 5 percent frequency screening level, dissolved chromium concentrations are more representative of groundwater chromium concentrations because of the relatively high TSS concentrations in the three, deep, upper yard wells (MW-201, MW-202, and MW-7U).

Only arsenic in the total form was retained during the first screening step; dissolved arsenic was eliminated. Total arsenic was detected in three of six samples collected from the site-wide aquifer beneath the upper yard during the RI monitoring period (50 percent); however, only one of six detections were non-qualified (17 percent). The one non-qualified detection (0.0082 mg/L) was above the background concentration identified for Washington in 1991 (0.005 mg/L; WAC 173-340-720(2)), but this concentration is likely too low and Ecology is re-evaluating the arsenic background concentration for western Washington (Ecology, 1998e). Based on the form of arsenic (total versus dissolved), the limited number of data points (six), and the background re-evaluation, total arsenic was tentatively retained as a groundwater IHS (drinking water RME).

Groundwater IHSs selected for the site-wide aquifer beneath the upper yard (drinking water RME) are:

- TPH (the sum of TPH-G, TPH-D, and TPH-O)
- Benzene
- Arsenic (tentative)

The selection of groundwater IHSs assuming a surface water protection RME is discussed in Section 7.2.

Surface Water and Storm Water IHSs. IHSs for these media were selected based on potential environmental effects and are described in the environmental evaluation, Section 7.2.

7.2 Environmental Evaluation

To characterize potential risks to the environment posed by the site, a qualitative environmental evaluation was performed for pathways and receptors identified in the conceptual site model by (1) comparing groundwater, surface water, and storm water sampling results to existing state and federal ambient water quality criteria and sediment sampling results to state Sediment Management Standards; and (2) identifying potential aquatic and terrestrial biota receptors through a survey. Results are described below. A full copy of the Wildlife and Habitat Study report, prepared by Adolfson Associates, Inc. (AAI), is provided in Appendix I; findings are summarized and excerpted below.

To assess residual risk to the environment that may be posed by the site following remediation to meet human health-based requirements, an ecological evaluation will be performed in conjunction with the feasibility study. This assessment will serve to predict whether cleanup decisions made to protect human health will also protect aquatic and terrestrial wildlife.

7.2.1 Environmental Evaluation of Groundwater

As discussed in Section 6.3, screening levels for the site-wide aquifer were based on protection of surface water. To evaluate potential impacts of groundwater beneath the site on surface water, groundwater data were compared to Method B surface water cleanup levels. Table 6-2 lists screening levels identified per Method B (WAC-173-340-730(3)): water quality standards for state surface waters (chapter 173-201A WAC) and water quality criteria based on the protection of aquatic organisms published pursuant to section 304 of the Clean Water Act. Method B also provides for the protection of human health; associated section 304 criteria and MTCA Method B formula values (Ecology, 1996) therefore also were included in the table. Both freshwater and marine criteria were included. In cases where the most stringent screening level was below a chemical's practical quantitation limit (PQL), the PQL was used as the screening level.

Groundwater sampling results were compared to the most stringent screening level/water quality standard (Table 6-3). Maximum concentrations of hazardous substances detected in groundwater for each of the four quarters of on-site, site-wide aquifer results were used in the comparison.

To identify IHSs for groundwater, an evaluation comparable to that performed for soil was performed. As the following chemicals were above the screening levels, they were retained as preliminary IHSs during the first screening step:

- TPH
- Benzene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Chrysene
- Arsenic
- Copper
- Lead
- Zinc

As with soil IHS screening, the second step in the screening process was to consider the frequency of detection. Benzo(a)anthracene was detected in 5 percent of the samples and was eliminated as an IHS.

Maximum detected concentrations for the remaining preliminary IHSs were then compared with background concentrations in MW-7U. As stated in WAC 173-340-708(11)(b), background samples shall be collected from "areas that have the same basic characteristics as the medium of concern at the site, have not been influenced by releases from the site, and in the case of natural background concentrations, have not been influenced by releases from other localized human activities." Monitoring well MW-7U meets these conditions; it is in the deep (site-side) aquifer on the upgradient edge of the upper yard. The maximum concentrations of all preliminary IHSs are above the MW-7U results.

As a final step in the screening process, the frequency of detection and concentrations of the two PAHs (benzo(a)pyrene and chrysene) were compared. Since the two constituents have similar water solubilities and similar log K_{ow}s, they are likely to move similarly in the environment. Chrysene was chosen to represent the cPAHs at the site, because it was detected the most frequently and at the highest concentrations in the site-wide aquifer. The frequency of detection, and concentration and solubility of the metals (arsenic, copper, lead and zinc) were also compared. While data points for arsenic and copper are limited, no metals were screened out at this step of the evaluation.

After the four screening steps, the selected groundwater IHSs (surface water protection RME) were those listed below. Arsenic and copper were retained as tentative IHSs, pending evaluation of additional data.

- TPH
- Benzene
- Chrysene
- Lead
- Zinc
- Arsenic (tentative)
- Copper (tentative)

7.2.2 Environmental Evaluation of Surface Water and Storm Water Runoff

As discussed in Section 6.3, Method B screening levels for surface water were used to evaluate results of surface and storm water sampling at the site. This comparison was performed to evaluate potential environmental risks posed by the site in its existing condition. For purposes of the RI, water in Willow Creek and the tidal basin, and impounded in Detention Basins No. 1 and 2, were identified as "surface water" and runoff flowing from the upper and lower yards during the monitored storm event was identified as "storm water." Sampling results were compared to the most stringent screening level/water quality standard (Table 6-5).

Based on the observed sampling results, the concentrations of contaminants found at the upstream station, and a comparison to the most stringent screening levels, zinc was identified as an IHS for surface/storm water. While TPH/oil and grease were detected at concentrations well below the water quality standard, they were retained as a surface water IHS due to groundwater concentrations.

7.2.3 Environmental Evaluation of Upland Sediments

Assessment of the biological testing results was conducted following the procedures specified in WAC 173-204-320(3) and described in the work plan, and *Draft PSDDA*

Clarification Paper, Draft SMS Technical Information Memorandum, March 7, 1996 Statistical Evaluation of Bioassay Results. Biological testing results were also compared to minimum cleanup level biological criteria in WAC 173-204-520(3). Adverse biological effects from sediment samples collected for the RI were determined as follows:

- Amphipod mean mortality in the test sediment is higher (statistically significant, t test, $p \leq 0.05$) than the mean mortality of the reference sediment, and the mean mortality in the test sediment exceeds 25 percent on an absolute basis.

- Mean survivorship of normal bivalve larvae in test sediment is less than (statistically significant, t test, $p \leq 0.05$) the reference sediment mean survivorship of normal larvae, and the mean survivorship of normal larvae in the test sediment is less than 85 percent of mean normal survivorship in the reference sediment.

- The mean individual growth rate of juvenile polychaetes in test sediment is less than 70 percent of the mean individual growth rate of juvenile polychaetes in reference sediments and the test sediment mean individual growth rate of juvenile polychaetes is statistically different than (t test, $p \leq 0.05$) the reference sediment mean individual growth rate of juvenile polychaetes.

Amphipod Bioassay. The percent mortality for test sediments and results from the evaluation of test sediments using reference sediments collected from the Nisqually River are presented in Table 7-1. Test sediments from stations US-03, US-05, US-09, US-12, and US-13 showed amphipod mortalities that were higher than the reference sediment (t test, $p \leq 0.05$). Statistical calculations are presented in Appendix L. On an absolute basis, only test sediment from station US-05 showed amphipod mean mortality greater than 25 percent. Based on the criteria, only the sediment sample from station US-05, located along the northwest side of the Terminal boundary, failed the sediment quality standards (SQS) for amphipod bioassay biological effects criteria (WAC 173-204-320(3)).

A comparison of the amphipod bioassay results for station US-05 with the cleanup screening level (CSL) criteria of WAC 173-204-520(3) indicates that the test sediment showed a statistically higher mean mortality and the mean mortality (46 percent) was greater than the reference sediment mean mortality plus 30 percent. As such, the sediment sample from station US-05 also failed the CSL criteria. No correlation was noted between grain size, TOC, or ammonia concentration and measured mortality in the amphipod bioassays.

Bivalve Larvae Bioassay. The sediment sample collected near the upstream edge of the site (US-15) and Nisqually River reference sediment sample (NISQ) both showed a combined mortality and abnormality greater than the sediments collected along Willow

Creek at the Terminal boundary (and greater than 50 percent). The only sediment sample that produced a reduction in normal development below 90 percent was the reference sample NISQ. Because of the combined mortalities and abnormalities greater than 50 percent in the Nisqually River reference sample, the reference sample from Carr Inlet was selected for the statistical evaluation. This sample passed the performance standards as specified in the work plan (though fell below the revised reference area standards). Based on acceptable performance in control sample 3 and in the Carr Inlet reference sample at the time the test was performed, a statistical evaluation of results was performed using the Carr Inlet sediment.

The sediment bivalve larvae bioassay test results and their comparison to Carr Inlet reference sample results are presented in Table 7-2. Statistical calculations are presented in Appendix L. Only the test sediment from station US-08 and upstream station US-15 showed a statistically lower survivorship of normal bivalve larvae and a mean normal survivorship less than 85 percent of the Carr Inlet sample. Stations US-03, US-05, and US-09 also showed a mean survivorship of normal larvae that was less than 85 percent of the reference sample, but the mean survivorship was not significantly lower than for the reference sample. Based on the criteria evaluation, only sediment from stations US-08 and US-15 failed the SQS for bivalve larvae biological effects criteria (WAC 173-204-320(3)). The bivalve larvae bioassay results for these stations were also compared with the CSL criteria (significantly lower mean normal survivorship, mean normal survivorship less than 70 percent of the reference sediment mean normal survivorship). Sediment from station US-08 passed the CSL criteria and sediment from upstream station US-15 failed the CSL criteria for bivalve larvae bioassays.

No correlation between mean survivorship of normal larvae and TOC, grain size, or ammonia concentrations were noted for the Terminal sediments. Sediments from all Terminal stations showed normal development of bivalve larvae greater than 90 percent. One of the replicate counts of initial larvae density was not recorded, resulting in an estimate of initial larvae density based on four rather than five measurements. Since two measurements were approximately 445 and the other two were approximately 350, a fifth measurement might have resulted in different estimates of survival

Juvenile Polychaete Bioassay. Results of the statistical comparison of mean individual growth rates of juvenile polychaetes from Terminal sediment samples to mean individual growth rates for the Nisqually River reference sample are presented in Table 7-3. Statistical calculations are presented in Appendix L. Sediment samples from stations US-09 and US-13 showed a mean individual growth rate that was statistically different than the mean individual growth rate for the Nisqually River sample. The mean individual growth rates for sediment from stations US-09 and US-13 were less than 70 percent of the mean individual growth rate for the reference sample. Based on the criteria evaluation, sediment from stations US-09 and US-13 failed the SQS for juvenile polychaete biological effects criteria (WAC 173-204-320(3)). Although sediment from US-01 showed a mean individual growth rate that was statistically different (as defined in

WAC 173-204-320(3)) from the reference sediment, the growth rate for US-01 was significantly greater than the reference sediment and was not further evaluated.

The juvenile polychaete bioassay results for stations US-09 and US-13 were also compared to the CSL (mean individual growth rate statistically lower than reference sediment mean individual growth rate and mean individual growth rate less than 50 percent of reference sediment mean individual growth rate). None of the test sediment failed the CSL criteria.

Summary. Sediment samples from 8 of 15 stations passed all criteria for bioassay testing. Sediment samples from six stations and the upstream station (US-15) failed one or more of the individual bioassay testing criteria. Of these seven stations that failed one or more criteria, five failed two testing criteria within one bioassay evaluation, resulting in failure of an SMS criterion. Sediment from two of these stations (US-03 and US-12) failed only one of two SMS evaluations and therefore passed the SMS criterion. Sediment from US-05 failed the SQS criteria for the amphipod bioassay, while sediment from US-08 and US-15 failed the SQS for the bivalve larvae bioassay. Sediment from US-09 and US-13 failed the SQS criteria for the juvenile polychaete bioassay. Station US-05 and US-15 also failed the CSL criteria for the amphipod and bivalve larvae bioassay, respectively. Each of the bioassay tests indicated that one or more stations exhibited toxic effects, but none of the stations failed more than one of the three bioassays. A highly toxic sample would be expected to exhibit some impact on each of the three test species. The Terminal results might suggest that the components in the samples that produced the responses in the three species are not the same. No direct correlation between toxicity and sediment characteristics such as TOC or grain size was noted.

Sediment stations that failed bioassay testing did not form a discernible pattern that would point to a single sediment toxicity source. Observations of the sediment upstream of the Terminal at US-15 during field sampling indicated a clean sand matrix; however, this sediment failed the bivalve larvae bioassay. Sediment collected adjacent to Detention Basin No. 1 (US-14, US-13, US-12, US-11, US-10, US-09, and US-08) and downstream of US-15 all showed greater than 50 percent fine grained (silt and clay) material, indicating these locations are depositional areas that would potentially serve as receptor sites for migrating contaminants. Although sediment from US-13, US-09, and US-08 each failed one of the three bioassays, sediments downgradient from these locations (i.e., US-12, US-07) passed all three bioassays, indicating that any potential sediment toxicity is localized. Sediments collected at US-10, US-11, and US-12, adjacent to the marsh, did not fail any of the SQS criteria, indicating that these sediments do not appear to be serving as a receptor for off-site migration of contaminants from Detention Basin No. 1 or the Terminal.

Sediment collected from Willow Creek along the west boundary of the Terminal (US-01 through US-09) failed bioassay testing at three locations: two adjacent to Detention

Basin No. 1 (US-08 and US-09) and one immediately downstream from Outfall 001 (US-05). The sediment downstream from US-05 (US-04) did not fail any of the bioassay testing, indicating a low potential for outfall contaminants to cause toxic effects on downstream receptors. The sediment collected from the tidal basin (US-01 and US-02) did not fail any of the bioassay testing, indicating that the potential for toxic effects further downstream of the Terminal is low.

7.2.4 Wildlife and Habitat

Vegetation. Four different vegetation communities are found at the Terminal: emergent wetland, forested/shrub wetland, mixed deciduous and conifer forest ("upland forest"), and disturbed upland area (Figure 7-1). Disturbed upland and upland forest are the primary and secondary on-site habitat communities. All of the Terminal has been logged within the past 100 years, although several large grand fir trees (36- to 48-inch-diameter at breast height) exist in the vicinity of the Deer Creek Fish Hatchery. The adjacent marsh, which is fed by Willow and Shellabarger Creeks, is approximately 23 acres. In 1989, the tide gate that serves as the outlet to the marsh was permanently opened, restoring a saltwater influence to the marsh. It now supports both brackish and freshwater species. A list of the trees, shrubs, and herbs observed in each of the four vegetation communities is provided in Appendix I.

Emergent wetlands are found in portions of the Terminal (primarily in Detention Basin No. 1 and in Willow Creek along the northwest property boundary) and the marsh. Emergent wetlands in Willow Creek and the marsh are tidally influenced and vegetative makeup has changed from freshwater wetland species to brackish- and saline-tolerant species since the permanent opening of the tide gate in 1989. Vegetation in Detention Basin No. 1 (approximately 2.75 acres) is dominated by common cattail, spreading bentgrass, purple loosestrife, and American threesquare. Willow Creek and the tidal basin are saltwater influenced and vegetation is dominated by seashore saltgrass and Baltic rush, with oracle and seaside plantain as associated species. Dominant vegetation in the western, brackish portion of the marsh includes seashore salt grass, American threesquare, and Baltic rush, with seaside plantain and oracle as common associates. Cattail and purple loosestrife dominate the eastern, freshwater portion of the marsh; associated species include water parsley, field horsetail, and yellow flag.

The quality of the emergent wetland habitat available in Detention Basin No. 1 is considered low due to low plant diversity and small size. Emergent wetland quality in the marsh is considered high due to the high number of plant species, its relatively large size (>20 acres), the presence of both brackish and freshwater marsh, and the proximity of shrub and forest habitat.

Forested/shrub wetland vegetation dominates the southwest corner of the marsh and extends onto the Terminal along the creek. The forest canopy is dominated by red alder, big leaf maple and Scouler's willow. Himalayan blackberry, beaked hazelnut, salmonberry, red current and red elderberry predominate in the shrub layer. Herbaceous species include reed canary grass, American brooklime, and horsetail, and hydrophytic species include skunk cabbage, fringecup and creeping buttercup.

The quality of the forested/shrub habitat along the creek and extending east of the Terminal is considered moderate to high due to moderate size (approximately 10 acres), large number of plant species present, its association with a permanent stream, the presence of snags and downed trees, and potential use of these habitat features by sensitive species (bald eagle). Approximately 3.5 of the 10 acres are estimated to be on the Terminal property.

Upland forest on the Terminal consists of a mixed deciduous/coniferous forest. Dominant species include big leaf maple, grand fir, western red cedar, Douglas fir, and red alder. Red elderberry, ocean spray, Himalayan blackberry, stinging nettle and horsetail are dominant understory vegetation. A 150- to 400-foot-wide band of upland forest exists on the west-facing Terminal bluff, where the dominant canopy vegetation consists of red alder, big leaf maple and bitter cherry. Associated species include English ivy and salmonberry. Snags and downed trees are present. No conifers were observed in this area.

The overall quality of the upland forest habitat is considered low to moderate due to low to moderate plant diversity, small area of contiguous forest (<8 acres on the Terminal property), and proximity of disturbed or paved areas which limit access by smaller species of nonavian wildlife. The upland forest located north of the UNOCAL access road and adjacent to the marsh is considered high habitat value due to proximity to a large area of undeveloped habitat and the presence of surface water.

Disturbed upland habitat, i.e., highly altered topography that is dominated by non-native species, exists in the upper and lower yards of the Terminal, along the roadway, on the berm between Detention Basin No. 1 and the marsh, and along the BN railroad. Much of the upper and lower yards are sparsely vegetated. In the area north of the access road, adjacent to the creek, disturbed meadow vegetation is dominated by bentgrass species, birdsfoot-trefoil, pink and white clover, and bull thistle. The detention basin berm is dominated by Himalayan blackberry, Scot's broom, non-native pine, and birch.

The habitat value of the disturbed areas of the Terminal is low, due to sparse vegetative cover, low species diversity, and human activity, which limit wildlife use.

A review of the Washington State Department of Natural Resources (WDNR) Natural Heritage Information System indicated that there were no records of significant natural features, rare plants, high quality native wetlands, or high quality native plant communities on the Terminal or in the adjacent marsh (WDNR, 1996; Appendix I).

Threatened and Endangered Species. Bald eagles are listed as a state and federal threatened species. According to a database search of the Washington Department of Fish and Wildlife, bald eagle territory is located primarily south of the Terminal and extends into the south end of the site. No bald eagle nests are known to exist closer than one mile of the Terminal; the nearest known nest is located approximately one mile south of the south Terminal property line in the town of Woodway (WDFW, 1996; Appendix I). Bald eagles were observed perched in deciduous trees on the bluff south of the Terminal during 1995 field surveys (AAI, 1996; Appendix I). The marsh and the riparian corridor along the creek contain a high number of large grand fir and Douglas fir trees and snags that could be used for perches.

No endangered species and no other threatened species were identified as associated with the Terminal or marsh.

Fish. Fisheries habitat associated with the Terminal is Willow Creek. Willow Creek originates in a residential area in the vicinity of SR 104 and 6th Avenue. The creek flows west beneath SR 104, northwest under Pine Street, and into the marsh. The creek is also fed by runoff from the residential area to the south of the Terminal. A dredged channel exists in the marsh, entering the drainage ditch along the northwest Terminal boundary. The ditch channels water into the tidal basin and then into a 48-inch-diameter culvert, located under the Edmonds marina, and discharging into Puget Sound. The culvert is approximately 1,300 feet long (CH2M Hill and AAI, 1995; Appendix I).

The creek supports coho and chum salmon, sea-run and resident cutthroat trout, sculpin and three-spined stickleback. The Deer Creek Fish Hatchery, which recommenced operations in 1995, raises coho salmon primarily for release in other creeks. A small number of fish (5,000 to 6,000) are reportedly released to Willow Creek. Fifty-five to sixty salmon were observed returning to the hatchery in 1994 and 75 to 80 fish in 1995 (W. Thompson, 1996: Appendix I). Spawning activity has been recorded in the hatchery vicinity, where fair to good habitat is present in an approximately 250-foot reach of the creek adjacent to the hatchery. Adult fish have been recorded as moving upstream of the hatchery.

Other Wildlife. Habitat value for wildlife use depends on the complexity of the vegetative community, plant species, and proximity of other habitat types used by wildlife species. A list of wildlife species that are known to use the habitat types identified at the Terminal and the marsh is provided in Appendix I; lists include vertebrate species identified directly or indirectly (i.e., vocalizations, tracks, scat) and other species expected to be found due to their occurrence in similar habitats. Thirty-two species of birds were observed at the Terminal and the marsh during the April 1996 survey; eighty species are expected to utilize the habitat types. Thirty mammal species, nine amphibian species, and three reptile species are expected to use the habitat types found at the Terminal and marsh.

Specific to the *emergent wetland habitat* at the Terminal, species observed in Detention Basin No. 1 included red-winged blackbird, Canada goose, and mallard. Raccoon, river otter, coyote, beaver, muskrat, and amphibian and reptile species such as Pacific chorus frog and northwestern garter snake, are expected to use this habitat. Species observed in the *forested/shrub wetland* included 12 species of passerine birds and downy woodpecker. This habitat type is particularly productive for wildlife and raccoon, river otter, coyote, beaver and mountain beaver are expected to use this habitat.

The *upland forest* areas provide potential nesting and foraging habitat for a variety of bird and mammal species. Thirteen bird species were recorded during the April 1996 survey, including American crow, American robin, Bewick's wren, black-capped chickadee, bushtit, downy woodpecker, and European starling. Up to 11 great blue herons were observed using snags and living trees for daytime roosting north of the Terminal access road in January 1995; however, no great blue heron nests are present. The herons forage primarily in the emergent habitat in the marsh, Detention Basin No. 1, Willow Creek, and the tidal basin. Douglas squirrel, raccoon, river otter, coyote, beaver and mountain beaver are mammal species expected to be found in the upland forest areas, as well as amphibian and reptile species such as rubber boa, northern alligator lizard, ensatina, and Pacific tree frog.

The *disturbed upland* areas are used by numerous urban-adapted, native and introduced, bird and mammal species. Species observed during the April 1996 survey included American crow, bushtit, California quail, Canada goose, European starling, house finch, pine siskin, rock dove, and killdeer. Black rat, eastern gray squirrel, raccoon, opossum, house mouse, and deer mouse are expected to use these areas; northern alligator lizard and northwest and common garter snakes may use the disturbed area to the north of the access road.

7.3 Summary

Soil IHSs were selected based on MTCA screening levels, frequency of detection, background concentrations, and chemical mobility. Selected lower and upper yard soil IHSs were TPH-D, TPH-O, TPH-G, benzene (lower yard only), chrysene, antimony, and arsenic. Using similar selection criteria, groundwater, surface water, and storm water IHSs were chosen. Groundwater IHSs for the site-wide aquifer beneath the upper yard (drinking water RME) were TPH, benzene, and arsenic (tentative). Groundwater IHSs for the site-wide aquifer (surface water protection RME) were TPH, benzene, chrysene, lead, zinc, and, tentatively, arsenic and copper. Zinc was identified as a surface/storm water IHS, and TPH/oil and grease were retained as surface water IHSs.

Based on the potential for future residential site use of the upper yard, the RME scenario for soil at the Terminal is residential. Based on the flow of groundwater to nearby surface water, the RME scenario for the site-wide aquifer is based on potential exposure to surface water. Groundwater is not currently used for drinking water and is not likely to be used for drinking water in the future (since it is shallow and adjacent to a large, marine water body). Based on the chapter 173-201A WAC classification of surface water bodies near the Terminal and the current and potential use of surface water near the Terminal, the RME for site surface water is considered to be exposure of aquatic organisms and human exposure by ingestion of aquatic organisms. Based on Ecology's determination of highest beneficial use of the site-wide aquifer as it exists beneath the upper yard, the RME scenario for this portion of the aquifer is exposure through drinking water.

Upland sediment from 8 of 15 locations along the Terminal boundary passed all criteria for bioassay testing. At six locations, as well as the upstream location, toxic effects were exhibited in bioassay testing. No sediment exhibited toxic effects to all three test species, and no discernible pattern was identified that would point to a single sediment toxicity source. Sediment from the downstream tidal basin and sediment from creek locations adjacent to the marsh showed no toxic effect on any of the species tested.

Four different vegetation communities are found at the Terminal, with disturbed upland and upland forest being the primary and secondary communities. The habitat value of the disturbed upland area of the Terminal is low, due to sparse vegetative cover, low species diversity, and human activity. The overall quality of the upland forest habitat is considered low to moderate due to low to moderate plant diversity, small area of contiguous forest, and proximity of disturbed or paved areas which limit access by smaller species of nonavian wildlife. Bald eagle territory is located to the south of the Terminal and extends into the south end of the site. No other threatened species and no endangered species were identified as associated with the site or marsh. The Willow Creek fisheries habitat supports salmon, cutthroat trout, sculpin, and three-spined stickleback. Thirty-two species of birds were observed at the Terminal and marsh during the April survey; eighty species are expected to utilize the habitats. Thirty mammal species, nine amphibian species, and three reptile species are expected to use the habitat types found at the Terminal and marsh.

8 CONCEPTUAL SITE MODEL AND CONTAMINANT MIGRATION

8.1 Conceptual Site Model

The conceptual site model (CSM), which was first developed based on historic site operations and data from previous site investigations, was re-evaluated in light of the RI results. The updated model, shown in Figure 8-1, summarizes potential contaminant sources, release mechanisms, routes of exposure, and receptors. Primary model components and updates are discussed below.

8.1.1 Contaminant Sources

Potential contaminant sources are as indicated on the CSM. The site is closed, and therefore sources of contamination from Terminal operations are no longer present. Based on the results of the RI, it appears that the former USTs and Detention Basin No. 1 are less significant sources than the aboveground tanks, former asphalt plant, interconnecting piping, the former truck loading racks, and the former railroad spur. RI results confirm that both soil and groundwater are significant secondary sources of contamination. The pre-RI CSM included Detention Basin No. 2 as a potential secondary source through storm water runoff. Based on the RI results, this basin does not appear to be a secondary contaminant source to storm water and the updated CSM reflects these findings.

8.1.2 Migration Routes

Field observations and laboratory results indicate that chemicals have migrated into and through the soil, reaching groundwater. Chemical movement to soil and groundwater represents a primary migration pathway. Groundwater flow, and therefore chemical transport, is primarily toward Detention Basin No. 1 in the north-central part of the lower yard, toward Willow Creek in the eastern part of the lower yard, and toward Puget Sound in the southwest part of the lower yard. Since water levels in Detention Basin No. 1 are artificially lowered by pumping, the detention basin serves as a groundwater sink, with groundwater being pulled toward the basin as it is pumped. Because creek water levels are higher than both on-site groundwater levels adjacent to the creek and water levels in Detention Basin No. 1, the creek around and downstream of the detention basin serves as a source, with groundwater flowing toward the site from the creek. This condition substantially controls the migration of contaminants in this area of the site.

Storm water runoff conveys chemicals onto the site from upstream locations. Storm water runoff from the Terminal also conveys chemicals to off site surface water, though RI results indicate that this is not a significant pathway in part due to on-site detention and treatment via the site's storm water system and API separator. Infiltration and percolation of precipitation to groundwater is not a significant pathway for the transport of surface metals based on the low leachability of surface metals and the low metals concentrations in subsurface soil and groundwater. Entrainment and transport of chemicals in air can occur through volatilization or dust emissions. Due to the extent to which the site is covered by structures, pavement, coating, gravel, and vegetation, and due to the nature and extent of site contaminants, which are primarily subsurface and nonvolatile, this is not a significant migration route for the Terminal.

8.1.3 Receptors

Potential receptors include area residents, site workers, future site residents (upper yard only), and terrestrial and aquatic biota.

8.2 Chemicals of Concern

Primary chemicals of concern for the Terminal are petroleum hydrocarbons (diesel, oil, and gasoline range), benzene, and carcinogenic PAHs. These constituents are elevated in both soil and groundwater. TPH, benzene, and chrysene (representing carcinogenic PAHs) were selected as soil IHSs; TPH and benzene were selected as IHSs for the site-wide aquifer beneath the upper yard (drinking water RME); and TPH, benzene, and chrysene were selected as IHSs for the site-wide aquifer (surface water RME). Heavy metals are of concern in the surface soil under pipe runs and manifolds, in isolated grit piles, and in certain tank basins; selected heavy metal IHSs for soil are antimony and arsenic. Heavy metal IHSs in groundwater are arsenic (tentatively) for the site-wide aquifer beneath the upper yard (drinking water RME) and zinc, lead, and tentatively arsenic and copper for the site-wide aquifer (surface water RME). Surface/storm water chemicals of concern were limited to zinc, though TPH and oil and grease were added as IHSs due to their occurrence in groundwater.

8.3 Chemical Migration

Site hydrogeology, the termination of site operations, chemical and product characteristics, and product recovery operations all contribute to limit chemical migration from the site, as further summarized below.

Site Hydrogeology

Beneficial site hydrogeological characteristics include:

- Low permeability soil beneath the upper yard. Extensive deposits of silt, with hydraulic conductivities two to five orders of magnitude less than hydraulic conductivities in the site-wide aquifer, serve as barriers to the downward movement of water and contaminants beneath the upper yard.

- Groundwater flow away from Willow Creek along the northern and western boundaries of the site. Since creek water levels along this boundary are higher than on-site groundwater levels adjacent to the creek, groundwater flow is toward the site at this location. This condition substantially controls the migration of contaminants in this area of the site. The lack of petroleum detections in groundwater at off-site well MW-138 further substantiates this condition.

- Natural attenuation processes. These in-situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

  The off-site wells located along the southwest boundary of the site lie about 50 feet downgradient of on-site product plumes or wells with elevated concentrations of TPH or BTEX constituents. Groundwater quality in the off-site wells is significantly cleaner. The relatively high specific gravity and high viscosity of the on-site product plume indicates that the product is of relatively high molecular weight and low water solubility, limiting product movement. Groundwater flow directions, flow rates, and chemistry in this area indicate that it is likely that natural attenuation processes are responsible for the minimal detections of dissolved TPH and BTEX constituents in the off-site wells downgradient of the southwestern site boundary. At the eastern property boundary, natural attenuation processes are also expected to reduce groundwater contaminant concentrations as groundwater moves to the creek in this area of the site.

Site Operations

Collection of storm water runoff at the Terminal reduces the amount of water that percolates through the vadose zone to groundwater. Additionally, the pumping of water from Detention Basin No. 1 through the API separator draws adjacent groundwater toward the basin rather than the creek. Product recovery operations in recovery well RW-1, and the interconnecting trenches, limit the amount of product available to migrate.

Chemical and Product Characteristics

A high percentage of the free product at the Terminal is in the diesel and oil range. The age of the product and the high product viscosities cause the product to act like a heavy oil, resulting in lower migration rates. The age of the product, and the resulting product degradation, also slows product migration. Metals in surface soil have low leachability, resulting in low migration rates, and subsurface metals concentrations are low.

Free product occurs under the lower yard, a number of petroleum-hydrocarbon-related chemicals and paint/sand blast grit-related metals have been identified as site IHSs, and groundwater and storm water have been identified as migration pathways. However, chemical concentrations in groundwater at the perimeter of the site and in surface water in the creek are relatively low. Additionally, upland sediment bioassay tests showed no toxic effects at the majority of the stations. These results indicate that chemical migration off site appears to be limited.

LIMITATIONS

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

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, nor the use of segregated portions of this report.

The purpose of a geologic/hydrogeologic study is to reasonably characterize existing site conditions based on the geology/hydrogeology of the area. In performing such a study, it is understood that a balance must be struck between a reasonable inquiry into the site conditions and an exhaustive analysis of each conceivable environmental characteristic. The following paragraphs discuss the assumptions and parameters under which such an opinion is rendered. No investigation is thorough enough to describe all geologic/hydrogeologic conditions of interest at a given site. If conditions have not been identified during the study, such a finding should not therefore be construed as a guarantee of the absence of such conditions at the site, but rather as the result of the services performed within the scope, limitations, and cost of the work performed.

We are unable to report on or accurately predict events that may change the site conditions after the described services are performed, whether occurring naturally or caused by external forces. We assume no responsibility for conditions we were not authorized to evaluate, or conditions not generally recognized as predictable when services were performed.

Geologic/hydrogeologic conditions may exist at the site that cannot be identified solely by visual observation. Where subsurface exploratory work was performed, our professional opinions are based in part on interpretation of data from discrete sampling locations that may not represent actual conditions at unsampled locations.

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ACRONYMS AND ABBREVIATIONS

AST	aboveground storage tank
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CGI	combustible gas indicator
cm/sec	centimeters per second
cPAH	carcinogenic polycyclic aromatic hydrocarbon
DQO	data quality objective
Ecology	Washington State Department of Ecology
EDB	1,2-dibromoethane
EDC	1,2-dichloroethane
FS	feasibility study
gpm	gallons per minute
GC/MS	gas chromatograph/mass spectrophotometer
HASP	health and safety plan
HCID	hydrocarbon identification
IHS	indicator hazardous substance
LEL	lower explosive limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MLLW	mean lower low water (datum)
MRLs	method reporting limits
MTCA	Model Toxics Control Act
MW	monitoring well
NAPL	nonaqueous phase liquid
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum of 1929
nPAH	non-carcinogenic polycyclic aromatic hydrocarbon
PAH	polycyclic aromatic hydrocarbon
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
SAP	sampling and analysis plan
SVOCs	semi-volatile organic compounds
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure

TDS	total dissolved solids
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-G	total petroleum hydrocarbons as gasoline
TPH-D	total petroleum hydrocarbons as diesel
TPH-O	total petroleum hydrocarbons as oil
TSS	total suspended solids
UEL	upper explosive limit
UST	underground storage tank
VOCs	volatile organic compounds
WAC	Washington Administrative Code

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