

**Ecology Review Draft
Investigation Data Report
Cap Sante Marine Lease Area
Anacortes, Washington**

July 25, 2007

Prepared for

**Port of Anacortes
Anacortes, WA**

 **LANDAU
ASSOCIATES**
130 2nd Avenue South
Edmonds, WA 98020
(425) 778-0907

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION	1-1
1.1 BACKGROUND	1-1
1.1.1 PROPERTY DESCRIPTION	1-1
1.1.2 SITE HISTORY	1-1
1.2 PREVIOUS SITE ENVIRONMENTAL INVESTIGATIONS	1-2
1.3 CHEMICALS OF POTENTIAL CONCERN	1-3
1.4 FUTURE SITE LAND USE	1-4
2.0 REMEDIAL INVESTIGATION ACTIVITIES	2-1
2.1 SEDIMENT INVESTIGATION	2-1
2.1.1 Sampling Locations	2-1
2.1.2 Sample Collection Methodology	2-1
2.1.3 Field Grain Size Wet Sieving	2-2
2.1.4 Sediment Chemical Analyses	2-3
2.2 SOIL INVESTIGATION	2-3
2.2.1 Sampling Locations	2-3
2.2.2 Soil Sample Collection	2-4
2.2.3 Soil Sample Field Screening	2-5
2.2.4 Soil Sample Chemical Analyses	2-5
2.3 GROUNDWATER INVESTIGATION	2-5
2.3.1 Groundwater Monitoring Well Installation and Development	2-6
2.3.2 Groundwater Monitoring	2-7
2.3.2.1 Water Level Measurements	2-7
2.3.2.2 72-hour Tidal Study	2-7
2.3.2.3 Slug Tests	2-8
2.3.2.4 Monitoring Well Groundwater Sample Collection	2-8
2.3.2.5 Direct-Push Groundwater Sample Collection	2-8
2.3.2.6 Field Parameters	2-9
2.3.2.7 Groundwater Sample Analyses	2-9
3.0 SITE INVESTIGATION RESULTS	3-1
3.1 SEDIMENT INVESTIGATION	3-1
3.2 SOIL INVESTIGATION	3-1
3.2.1 Physical Characterization of Site Soils	3-1
3.2.2 Soil Sample Chemical Characterization	3-2
3.2.2.1 Preliminary Soil Cleanup Levels	3-2
3.2.2.2 Comparison of Soil Analytical Results to Preliminary Cleanup Levels	3-4
3.3 GROUNDWATER INVESTIGATION RESULTS	3-6

3.3.1	Hydrogeologic Characterization	3-7
3.3.2	Hydrogeologic Units	3-7
3.3.2.1	Groundwater Levels and Tidal Influence	3-7
3.3.2.2	Groundwater Flow Direction	3-8
3.3.2.3	Site Hydraulic Conductivity	3-8
3.3.3	Groundwater Chemical Characterization	3-9
3.3.3.1	Preliminary Groundwater Cleanup Levels	3-9
3.3.3.2	Comparison of Groundwater Analytical Results To Preliminary Cleanup Levels	3-10
4.0	SUMMARY	4-1
5.0	USE OF REPORT	5-2
6.0	REFERENCES	6-1

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>
1	Vicinity Map
2	Site Plan
3	Sediment Sampling Locations
4	2007 and Previous Soil Sampling Locations
5	Monitoring Well Locations
6	Cross Sections Locations
7	Cross Section A-A'
8	Cross Section B-B'
9	2007 Investigation Soil Sampling Locations with Preliminary Cleanup Level Exceedances in the Unsaturated Zone
10	2007 Soil Sampling Locations with TPH Preliminary Cleanup Level Exceedances in the Saturated Zone
11	Tidal Influence on Groundwater Elevations
12	Groundwater and Surface Water Elevations vs Time
13	Groundwater Elevation Contours at Low Tide – May 16, 2007
14	Groundwater Elevation Contours at Mid Tide – May 16, 2007
15	Groundwater Elevation Contours at High Tide – May 16, 2007
16	Groundwater Cleanup Level Exceedances

LIST OF TABLES

<u>Table</u>	<u>Title</u>
1	Summary of Sediment Sample Chemical Characterization Results
2	Preliminary Soil Cleanup Levels for Constituents of Potential Concern and Other Detected Constituents in Soil
3	Summary of Detected Constituents in Unsaturated Zone Soil and Comparison of Analytical Results to Preliminary Soil Cleanup Levels
4	Summary of Detected Constituents in Saturated Zone Soil and Comparison of Analytical Results to Preliminary Soil Cleanup Levels
5	Summary of Surveyed Elevations and Calculated Groundwater Elevations
6	Summary of Estimated Groundwater Hydraulic Conductivities for Shallow Saturated Soil
7	Preliminary Groundwater Cleanup Levels for Constituents of Concern and Other Detected Constituents
8	Summary of Detected Constituents in Groundwater and Comparison of Analytical Results to Preliminary Cleanup Levels

LIST OF APPENDICES

<u>Appendix</u>	<u>Title</u>
A	Soil Boring Logs and Well As-Builts
B	Tabulated Soil Analytical Results
C	Tabulated Groundwater Analytical Results

1.0 INTRODUCTION

This report presents field and laboratory data collected as part of the remedial investigation of the Cap Sante Marine (CSM) Lease Area (Site) located in Anacortes, Washington (Figure 1). The field data collection and analysis conducted at the Site includes a soil investigation, a groundwater investigation, and a sediment investigation as described in the Washington State Department of Ecology (Ecology)-approved Work Plan for the Site dated June 19, 2007 (Landau Associates 2007). These investigations were conducted as part of a Remedial Investigation/Feasibility Study (RI/FS) that is being conducted under an Agreed Order with Ecology. The investigations were conducted in general accordance with the RI/FS Work Plan.

1.1 BACKGROUND

This section describes the Site, including its known history, current uses, and existing property features, and summarizes previous environmental investigations.

1.1.1 PROPERTY DESCRIPTION

The Site is located within the Cap Sante Boat Haven in Anacortes, Washington. The Site is currently used as a boatyard, marina support area, and a marine fueling facility by Cap Sante Marine, Ltd., a tenant of the Port. The property is bounded by Fidalgo Bay, the Cap Sante Boat Haven marina (marina), and Cap Sante Waterway on the east, Q Avenue on the west, 11th Avenue on the north, and 13th Street to the south. The ground surface at the Site is asphalt in the roadway and a combination of asphalt, concrete slab, and gravel within the boatyard.

1.1.2 SITE HISTORY

Prior to 1947, the Site consisted of tide flats. In the late 1940s to early 1950s, the area was filled with dredged material from the adjacent federal waterway. The Port has owned the Site since 1956 and has leased it to various operators over time. The Site has been operated as a boatyard and marina support area, including a marine fueling facility, since approximately 1959. Cap Sante Marine, Ltd., the current tenant, has occupied the Site since the late 1970s and provides small vessel storage, launch, and minor maintenance services. Vessel fueling was provided from a float located offshore from the Site. Fuel was supplied to the float via a series of underground fuel lines from underground storage tanks (USTs) located within the Site (Figure 2). In the early 1980s, petroleum fuel was observed seeping into the marine waters at the marina at several locations near the fuel float. In 1983, under order from the U.S. Coast Guard, the

Port installed a petroleum recovery trench to control the seepage of fuel. The trench intercepted the fuel floating on the groundwater surface as it moved from the UST area toward the marina. According to the available documentation, approximately 1,250 gallons of fuel were recovered from the trench and the seepage stopped. It was determined that the seepage was the result of leakage from the USTs and supply lines that serviced the fuel float.

The USTs contained gasoline, diesel, and two-stroke oil pre-mix. The approximate total storage capacity of the original tanks was 22,000 gallons. In 1985, the Port replaced these USTs with two new 12,000-gallon tanks. Fueling service was stopped when the fuel float facility was demolished in 2006 as part of the boat haven redevelopment. To date, the USTs and supply lines installed in 1985 have not been removed.

1.2 PREVIOUS SITE ENVIRONMENTAL INVESTIGATIONS

In 1982, the USTs and supply lines were repaired; however, petroleum seepage continued to be observed at the Site. As a result, a Petroleum Seepage Study was conducted that included hydrogeologic explorations and analyses (Hart Crowser 1983).

In 1983, eight observation wells were installed and several test pits were excavated. The data obtained from the investigation indicated that petroleum present in the subsurface soil was migrating toward the shoreline on top of the water table. In 1984, a petroleum recovery system comprised of an interceptor trench system coupled with a recovery well was installed. The interceptor trench was excavated to a depth of approximately 8 to 10 ft at the approximate location shown on Figure 2, and was backfilled with coarse gravel. A petroleum recovery well was installed in direct hydraulic connection to the trench. Petroleum pumped from the well was directed into a storage tank. The recovery system operated for approximately 28 weeks, recovering approximately 1,250 gallons of petroleum. Groundwater wells were monitored for 6 months following the recovery system shutdown. Petroleum seepage into the marina was not observed following these remedial actions.

In 2004 and 2005, the Port conducted a series of environmental due diligence investigations into the extent of soil and groundwater contamination at the Site (Floyd|Snider 2005; Floyd Snider McCarthy 2004). As part of the 2004 investigation, soil and groundwater samples were collected from six locations near the former fuel recovery trench. A total of 13 soil and 6 groundwater samples were collected and analyzed for petroleum hydrocarbon contaminants. In 2005, soil and groundwater samples were collected from nine locations in the general vicinity of the USTs. A total of 7 soil samples and 5 groundwater samples were analyzed for petroleum hydrocarbon contaminants. The Port's investigations indicated soil

and groundwater contaminated with gasoline-range and diesel-range petroleum hydrocarbons, and benzene in a roughly fan-shaped area around the USTs, extending to the marina.

Sediments adjacent to the Site were tested in February 1999 and January 2000 in conjunction with maintenance dredging of the marina. Dredged materials were subjected to the chemical quality evaluations required by the Dredged Material Management Program and were found to be suitable for unconfined open-water disposal. The maintenance dredging was performed in two phases of work. Phase 1 was completed during the 2004/2005 dredging window and included dredging from the federal channel and from the entrance of the marina to the A- and B-Docks. Phase 2 included dredging the marina area between B-Dock and E-Dock, and was completed during the 2006/2007 dredging window. The dredged areas are shown on Figure 3.

1.3 CHEMICALS OF POTENTIAL CONCERN

As described in the Ecology-approved Work Plan, the chemicals of potential concern (COPCs) for soil and groundwater at the Site include those associated with the historical petroleum fuel tanks and supply lines associated with the fuel seepage in the early 1980s. COPCs include petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) associated with petroleum fuel, and lead. The specific COPCs are listed below:

- Gasoline-range petroleum hydrocarbons
- Diesel-range petroleum hydrocarbons
- Carcinogenic PAHs (cPAHs)
- Napthalene
- 1-Methylnaphthalene
- 2-Methylnaphthalene
- Benzene, toluene, ethylbenzene, xylenes (BTEX)
- Methyl tert-butyl ether (MTBE)
- Lead
- 1,2-Dibromoethane (EDB)
- 1,2-Dichlorethane (EDC)
- N-Hexane.

Previous investigations at the Site focused on identifying the nature and extent of these COPCs. The current investigation described in this report included analysis of the appropriate chemical parameters listed in Table 830-1 of the Model Toxics Control Act (MTCA; Chapter 173-340 WAC). Also, because heavy oil was detected in groundwater during the 2005 groundwater investigation, heavy oil was analyzed

for in some or all of the soil and groundwater samples. Chromium, copper, zinc, and polychlorinated biphenyls (PCBs) were also analyzed for in some samples collected in the vicinity of the waste oil tank.

1.4 FUTURE SITE LAND USE

Currently, the Port is redeveloping the Cap Sante Boat Haven including parts of the Site. Redevelopment activities include the following:

- Dredging of moorage areas to -12 ft mean lower low water
- Installation of new moorage floats for C-, D-, and E-Docks
- Demolition of the existing boat launch and fuel float facility and construction of a new fuel facility near the terminus of A-Dock
- Installation of a boat launch facility between the B-Dock and C-Dock
- Installation of a pedestrian esplanade along the shoreline.

2.0 REMEDIAL INVESTIGATION ACTIVITIES

This section presents a description of the activities associated with the sediment, soil, and groundwater investigations conducted as part of the RI field studies.

2.1 SEDIMENT INVESTIGATION

The sediment investigation consisted of collecting surface (0 to 10 cm) sediment samples from the marina in order to evaluate the potential impact from historical releases at the Site. The sediment investigation took place over 3 days, April 23rd through 25th, 2007. Samples were collected from throughout the marina to determine the range of total petroleum hydrocarbon (TPH) concentrations offshore of the Site and to determine sediment toxicity-based soil and groundwater cleanup criteria, if significant contaminant concentrations were detected. Sampling locations, sample collection, field screening, and laboratory analysis are described below. As discussed in Section 3.1, the results of the sediment sampling showed that there is no evidence that historical fuel releases from the Site have adversely affected sediment quality within the marina. Subsequently, based on the sediment analytical results, Ecology did not require sediment toxicity testing for the purposes of determining soil and groundwater cleanup criteria.

2.1.1 SAMPLING LOCATIONS

Sediment sampling consisted of collecting surface sediments (0 to 10 cm) samples from twelve locations (SED-01 through SED-12) as shown on Figure 3. Three of the locations (SED-01, SED-2, and SED-3) were collected directly from intertidal areas located along the shoreline where historical fuel seepage was previously observed entering marine waters within the marina. Sample locations were pre-determined and mapped using the Global Positioning System (GPS) and final sample locations were recorded in the field using a GPS mounted on the A-frame of the work vessel. In accordance with Sediment Management Standards (SMS) regulations, multiple reference samples were collected from Samish Bay (representing clean reference sediment, similar in physical characteristics to the test sediments) for use in bioassay testing and data interpretation.

2.1.2 SAMPLE COLLECTION METHODOLOGY

Samples at locations SED-4 through SED-12 were collected using a pneumatic power grab device deployed from a work vessel. The procedure for collecting grab sediment samples followed that described in the work plan (Landau Associates 2007). The vessel was either tied to an adjacent dock or

anchored during sample collection. Up to three sub-samples (labeled A, B, and C in the field logs) were collected per location in order to obtain the desired quantity of sediment for chemical and bioassay analysis (up to 20 L total). The power grab sampler had a maximum penetration of 12 inches; however, only the upper 10 cm of sediment was collected with decontaminated stainless-steel spoons for testing. The subsamples were placed in decontaminated 5-gallon plastic buckets. Samples from locations SED-1 through SED-3 were collected using a stainless-steel spoon at the time when these areas were not submerged [tide approximately -3 feet mean lower low water (MLLW)]. Reference samples were collected using a standard van Veen-style grab sampler. General locations were based on the Puget Sound Ambient Monitoring Program (PSAMP) data and on in-field sampling in conjunction with wet-sieving (described below in Section 2.1.3).

Random subsamples from each of the sample locations were collected for analysis of VOCs and/or gasoline-range petroleum hydrocarbons. Each remaining sample was then homogenized on the dock using a power mixer (standard paint mixer with stainless-steel paddles) and samples for chemical analysis were transferred to sample containers provided by Analytical Resources, Inc. (ARI). All sample containers were filled, sealed, affixed with a completed label, placed in a plastic Ziplock® bag, and stored in a cooler with ice. The remaining volume was transferred to 5-gallon PVC buckets, labeled, and packed in ice for FedEx delivery to Northwest Aquatic Laboratory.

For each sample, a description of sediment following the American Society for Testing and Material (ASTM) D 2488-84 was recorded in the field, including observations on sample lithology, sorting, color, structure, relative density or consistency, and relative moisture content. The maximum depth of grab penetration, sample time, and any other relevant observations were recorded. Water depth was recorded at each location relative to National Oceanic and Atmospheric Administration (NOAA) tidal datum for Guemes Channel.

2.1.3 FIELD GRAIN SIZE WET SIEVING

Field grain size wet sieving was used to ensure that the grain size of the marina sediments appropriately matched the reference sediment samples. This field process separates the sediment sample into size fractions greater than 62.5 micrometers (μm) (i.e., sand and gravel) and less than 62.5 μm (i.e., silt and clay) for classification of sand and silt/clay fractions. This process quickly identifies the grain size range appropriate for the reference sediment samples, allowing for the reference samples to be collected in the same field mobilization. Procedures for field grain size sieving are described in the Work Plan (Landau Associates 2007).

2.1.4 SEDIMENT CHEMICAL ANALYSES

Sediment samples SED-1 through SED-12 were analyzed for petroleum hydrocarbon fractions using volatile petroleum hydrocarbons (VPH), extractable petroleum hydrocarbons (EPH), and NWTPH-Dx methodologies. Sample preparation, cleanup, and analytical methods were in accordance with Ecology protocols (Ecology 1997) for the VPH, EPH, and NWTPH-Dx analyses and PSEP protocols (PSEP 1997a,b,c) for the total organic carbon (TOC) analysis. Grain size determination used the Plumb (1981) method, and, for sediments, PSEP guidelines (PSEP 1997d) as described in the Work Plan (Landau Associates 2007). Gasoline-range petroleum hydrocarbons were analyzed for in the three samples collected nearest the shoreline (SED-1 through SED-3) using Method NWTPH-Gx.

Two reference samples, which were collected for bioassay testing, were also analyzed for TOC; grain size; NH₄ (pore water); NWPTH-Dx; EPH; and VPH. At the direction of Ecology, no bioassay testing was conducted based on the consistently low TPH concentrations in the sediment samples that were analyzed (as described in Section 3.1).

2.2 SOIL INVESTIGATION

The soil investigation consisted of collecting soil samples from 14 soil borings and four monitoring well boreholes to evaluate soil type and evidence of potential impact, and selecting soil samples from each boring for chemical analyses. Sampling locations, sample collection, field screening, and chemical analysis are described below.

2.2.1 SAMPLING LOCATIONS

The soil investigation consisted of collecting soil samples from the fourteen borings (SB-01 through SB-14) shown on Figure 4. Three of the borings (SB-02, SB-03, and SB-12) were located upgradient of the former USTs to better delineate the extent of petroleum-impacted soil in the vicinity of the former USTs. Six of the borings (SB-01, SB-04, SB-05, SB-06, SB-08, and SB-11) were located near the CSM shoreline to characterize the extent of impacted soil near the recovery trench. Soil boring SB-07 was located downgradient of the former waste oil tank and soil boring SB-09 was located between previous boring locations CSM-04 and CSM-14. Soil boring SB-10 was located near an area where a petroleum sheen was observed during construction activities in the area of the sampling location. Two additional soil borings, SB-13 and SB-14, were not planned, but were conducted to further investigate the extent of potentially impacted soil near the location where sheen had been reportedly observed during previous construction activities.

Soil samples were also collected from the borehole where installation of a deep monitoring well (MW-3D) was planned, although no well was installed as discussed in Section 2.3.1. The location of borehole MW-3D is shown on Figure 4.

At each boring location, except borings SB-01 and SB-02, a sample of the surface soil was collected. The depth interval from which the surface sample was typically collected ranged from 0 to 2.0 ft. At locations where the ground surface was paved, the surface soil was collected from a depth interval immediately below the pavement.

In accordance with the work plan, at soil boring locations SB-02, SB-04, SB-08, SB-14, and MW-3D, where zones of potential contamination were observed (e.g., debris, presence of oil or sheen, odor, and/or discoloration), a sample was collected from those zones and submitted for laboratory analysis. At these locations, a sample was also collected from a depth below the zone of potential contamination, where little or no evidence of contamination was observed.

At each of the other soil boring locations (SB-01, SB-03, SB-05, SB-06, SB-07, SB-09, SB-10, SB-11, SB-12, and SB-13) where no evidence of contamination was observed, a sample was collected from the 1 to 2 ft depth and from the capillary fringe, in accordance with the Work Plan. At some locations, the 1 to 2 ft depth interval was modified to 1.5 to 2.5 ft and, at boring SB-12 and SB-13, the depth interval was modified to 2 to 3 ft and 1.5 to 3 ft, respectively. The depth intervals were modified, as necessary, based on the depth interval of the surface sample.

2.2.2 SOIL SAMPLE COLLECTION

At each soil boring, the upper 4 ft of soil was removed using an air vacuum or hand-dug with shovels. Below 4 ft, the boreholes were drilled using a truck-mounted Geoprobe® direct-push drilling rig. Soil samples from the upper 4 ft of soil were collected from the hole sidewalls using hand implements (e.g., stainless-steel spoon). Below 4 ft, continuous soil samples were obtained from the soil borings using a closed-piston sampling device with a core sampler. Soil samples for laboratory analysis were selected based on field screening (described below). A portion of the selected soil sample was collected in accordance with U.S. Environmental Protection Agency (EPA) Method 5035 for the analysis of gasoline-range petroleum hydrocarbons by Method NWTPH-Gx and for the analysis of VOCs. The remaining portion of the selected soil sample was placed into a decontaminated stainless-steel bowl and homogenized using a decontaminated stainless-steel spoon. Larger-sized material (gravel or wood fragments greater than 2 millimeters in diameter) was removed by hand-sorting. The sample was then transferred to the appropriate sample containers.

2.2.3 SOIL SAMPLE FIELD SCREENING

The soil type of each soil sample collected was evaluated by the Landau Associates field representative and recorded on a Log of Exploration form and the sample was field-screened for evidence of impact (contamination). Field-screening was conducted by visually inspecting the soil for staining and other evidence of environmental impact, and monitoring soil vapors for VOCs using a portable photoionization detector (PID). Field screening results were recorded on the Log of Exploration form. Logs for each soil boring and monitoring well borehole are provided in Appendix A.

2.2.4 SOIL SAMPLE CHEMICAL ANALYSES

Soil samples submitted for analysis were analyzed for the COPCs identified in Section 1.5, which consist of gasoline-range, diesel-range, and heavy oil-range petroleum hydrocarbons; cPAHs; naphthalenes (naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene); BTEX; MTBE; EDB; EDC; n-Hexane, and lead. Gasoline-range petroleum hydrocarbons were analyzed using Method NWTPH-Gx. Diesel-range and heavy oil-range petroleum hydrocarbons were analyzed using Method NWTPH-Dx. Naphthalenes and cPAHs were analyzed using EPA Method 8270 with selected ion monitoring (SIM). BTEX, MTBE, EDB, EDC, and n-hexane were analyzed using EPA Method 8260 and lead was analyzed using EPA Method 6010B. Soil samples submitted for laboratory analysis from soil boring SB-07, located near the former waste oil tank, were analyzed for the COPCs, as well as total chromium, hexavalent chromium, copper, zinc, and PCBs. Total chromium, copper, and zinc were analyzed using EPA Method 6010. Hexavalent chromium was analyzed using EPA Method 3500CRD and PCBs were analyzed using EPA Method 8082. An acid/silica gel cleanup was applied to all soil samples analyzed for diesel-range and heavy oil-range petroleum hydrocarbons. None of the soil samples were analyzed for TPH fractions using EPH and VPH methodologies (Ecology 1997) because, as discussed in the work plan, these methodologies would only be applied, as necessary, for development of TPH cleanup levels that are protective of sediment. As described in Section 3.2.2.1, development of TPH cleanup levels protective of sediment was not necessary.

2.3 GROUNDWATER INVESTIGATION

As described in the Work Plan, the groundwater investigation consisted of installation and development of four groundwater monitoring wells, collection of groundwater samples from each of the monitoring wells, collection of one groundwater sample from one of the soil borings during the soil investigation, chemical analysis of the groundwater samples, manually measuring groundwater levels in

each of the monitoring wells, completing a 72-hour tidal study using the monitoring well network, and completing slug tests at each of the monitoring wells. Each of these activities is described below.

At least one additional round of groundwater monitoring will be conducted using the existing monitoring wells. However, following this additional round of monitoring, it is expected that some or all of the wells will be abandoned as part of an interim action to remove petroleum-impacted soil at the Site. Subsequently, the need for any further groundwater monitoring will be evaluated and discussed with Ecology.

2.3.1 GROUNDWATER MONITORING WELL INSTALLATION AND DEVELOPMENT

Four shallow monitoring wells (MW-01, MW-02, MW-03, and MW-04) and one deep monitoring well (MW-03D) were planned to be installed for groundwater monitoring at the Site. Each of the four shallow monitoring wells were installed at or near the monitoring well locations proposed in the work plan. Shallow monitoring well MW-01 is located upgradient from the former USTs to determine the chemical quality of groundwater entering the area. Shallow monitoring well MW-02 is located approximately 30 ft northeast of the location proposed in the work plan to reduce possible conflict with use of the new boat lift; however, the location of the well remains upgradient of the historical petroleum seepage areas and south of the former USTs, as planned. Monitoring wells MW-03 and MW-04 are located downgradient of the former USTs and historical petroleum recovery trench. Monitoring well locations are shown on Figure 5. As approved by Ecology, the deep monitoring well was not installed due to the thickness of the silt confining unit at this location (over 20 ft of confining unit was encountered).

Drilling and construction of the monitoring wells were conducted in accordance with the work plan and the *Minimum Standards for Construction and Maintenance of Wells* (Chapter 173-160 WAC; Ecology 2006). Soil borings for each monitoring well were drilled using a truck-mounted hollow-stem auger rig. The boreholes extended to the top of the confining unit [about 10 ft below ground surface (BGS)]. The depth of the fill/confining unit interface at each location was determined based on field observation of the soil samples collected continuously to the full depth of each boring.

Each monitoring well was constructed of 2-inch diameter, flush-threaded Schedule 40 PVC casing with PVC machine-slotted screen (0.010-inch). The screen interval for each well extended 5 ft upward from the top (or near the top) of the native silt. The shallow monitoring wells were installed within the dredged fill material that extends about 10 ft BGS.

Following placement of the well screen and casing in the borehole, a filter pack was installed around each well screen. The filter pack extended from the bottom of the end cap to a minimum of 1 ft

above the screen. Filter pack material consisted of commercially prepared, presized, prewashed No. 10-20 silica sand.

A bentonite chip seal at least 1-ft thick was placed above the sand pack to about 1.5 ft BGS. The surface of each well was completed with a concrete seal and surface pad extending from the top of the bentonite seal to slightly above the ground surface. Locking steel flush-mount monuments were cemented in place from the surface to a depth of about 1.5 ft BGS. The well construction details are presented with the boring logs in Appendix A of this report.

Each monitoring well was developed after the bentonite chip seal had been allowed to hydrate in the well annulus for a minimum of 24 hours. Development was accomplished using a centrifugal pump and the procedures described in the work plan. Development continued until a minimum of 5 casing volumes were removed and turbidity of the discharged water was visibly low.

2.3.2 GROUNDWATER MONITORING

Groundwater monitoring was performed in May 2007 and included measurements of groundwater levels at each onsite monitoring well (MW-1 through MW-4) and collection of groundwater samples for laboratory analysis at each monitoring well and at soil boring SB-1.

2.3.2.1 Water Level Measurements

Groundwater levels for evaluating groundwater flow direction were measured at each well on May 3, 2007 during the groundwater monitoring event. Each groundwater level measurement was collected by measuring from a surveyed reference point (located on the northern edge of the top of the PVC well casing) to the top of the groundwater using a hand-held water level indicator. These measurements were recorded to the nearest 0.01 ft. A water level was also measured in the marina from a surveyed point at the edge of a stationary dock.

2.3.2.2 72-hour Tidal Study

A 72-hour tidal study was conducted May 15 through May 18, 2007. Water levels in all of the Site monitoring wells (MW-01 through MW-04) and in the marina were recorded using a combination of pressure transducers with internal dataloggers and an electronic water level indicator. The data collection included continuous (every 5 minutes) transducer-based water level measurements in all wells and in the marina. The dataloggers were programmed to automatically convert pressure changes to water levels. Results of the tidal study are presented in Section 3.3.1.

2.3.2.3 Slug Tests

The hydraulic conductivity of shallow saturated soil at the Site was estimated using slug tests. Slug tests were performed in all onsite monitoring wells (MW-01 through MW-04) to identify the range of hydraulic conductivities in the vicinity of the monitoring wells. The slug tests were performed following the 72-hour tidal study on May 18, 2007. The tests were performed at a low tidal stage to minimize the interference of tidal fluctuations on the aquifer and the determination of the hydraulic conductivities.

Slug tests were performed using a PVC slug rod, a down-hole pressure transducer, and a water level indicator in general accordance with ASTM D 4044-96 (1999). The slug test response data was analyzed using the Bouwer and Rice method (Bouwer and Rice 1976, Bouwer 1989). Results of the slug tests are presented in Section 3.3.2.3.

2.3.2.4 Monitoring Well Groundwater Sample Collection

Groundwater quality samples were collected at each monitoring well during the May 3, 2007 groundwater monitoring event using dedicated polyethylene tubing and a peristaltic pump. Prior to sample collection, each well was purged until field parameters (pH, conductivity, turbidity, dissolved oxygen, and temperature) stabilized. Groundwater samples were collected directly into clean laboratory-prepared containers, labeled, stored on ice in a cooler, and transported to the laboratory in accordance with proper chain-of-custody procedures. To prevent degassing during sampling for VOCs and gasoline-range petroleum hydrocarbons, a pumping rate below 100 mL/min was maintained. VOCs and gasoline-range petroleum hydrocarbon containers were filled completely so that no head space remained. Groundwater for dissolved metals analyses was collected last and was field filtered through a 0.45 micron, in-line disposable filter prior to placement in sample containers.

2.3.2.5 Direct-Push Groundwater Sample Collection

One groundwater sample and a blind field duplicate were collected from boring SB-01. The sample was collected using a groundwater sampler consisting of a 4-ft long, wire-wrapped, stainless-steel screen (0.010-inch slot size) with a retractable protective steel sheath. The groundwater sampler was advanced to the sample depth and the protective sheath was retracted to expose the stainless-steel screen to the formation. Low-flow purging was performed until the purge water was clear. Groundwater was sampled using disposable polyethylene tubing and a peristaltic pump.

2.3.2.6 Field Parameters

Field parameters, including pH, temperature, conductivity, dissolved oxygen, turbidity, and oxidation reduction potential (Redox) were measured at each well using a flow-through cell. Ferrous iron was also measured using a field test kit.

2.3.2.7 Groundwater Sample Analyses

Groundwater samples collected from the monitoring wells and soil boring SB-01 were analyzed for the COPCs identified in Section 1.5, which consist of gasoline-range, diesel-range, and heavy oil-range petroleum hydrocarbons, PAHs, BTEX, MTBE, EDB, EDC, n-hexane, and lead. Both total and dissolved lead were analyzed for in each groundwater sample. Each groundwater sample, including the groundwater sample collected from the direct-push location, was analyzed for total dissolved solids (TDS), salinity, and chloride to support demonstration that groundwater at the Site should not be classified as potable. Also, during the first groundwater monitoring event, each groundwater sample, including the direct-push groundwater sample, was analyzed for parameters that can be used to evaluate the feasibility of natural attenuation as a cleanup option. These parameters include nitrate, dissolved manganese, sulfate, and methane. Other parameters used to evaluate natural attenuation (ferrous iron and oxidation reduction potential) were measured in the field. For all analyses except dissolved metals, any suspended material in the sample was allowed to settle. For the dissolved metal analyses, the sample was filtered in the field to remove any suspended material. An acid/silica gel cleanup was applied to all groundwater samples analyzed for diesel-range and heavy oil-range petroleum hydrocarbons.

3.0 SITE INVESTIGATION RESULTS

This section presents the physical and chemical results of the sediment, soil, and groundwater RI.

3.1 SEDIMENT INVESTIGATION

Analytical results for the sediment samples are presented in Table 1. As shown in Table 1 concentrations of diesel-range and motor oil-range petroleum hydrocarbons using Method NWTPH-Dx were consistently low in all of the samples that were analyzed. Results for the samples collected nearest the shoreline (i.e., SED-1, SED-2, and SED-3) ranged from 36 mg/kg to 200 mg/kg for diesel-range and motor oil-range petroleum hydrocarbons. Gasoline-range petroleum hydrocarbons were analyzed for in the three samples collected nearest the shoreline using Method NWTPH-Gx. Gasoline-range petroleum hydrocarbons were not detected in any of the samples. Results for EPH and VPH confirmed the low results reported for petroleum hydrocarbons using the NTWPH-Dx and NWTPH-Gx methods. EPH results ranged from 3.2 mg/kg to 100 mg/kg and VPH was not detected. Results for the other nine sediment samples (SED-4 through SED-12) for diesel-range petroleum hydrocarbons ranged from non-detect to 110 mg/kg and results for motor oil-range petroleum hydrocarbons ranged from non-detect to 370 mg/kg.

The results of the sediment sampling showed that there is no evidence that historical fuel releases from the Site have adversely affected sediment quality within the marina. Subsequently, based on the sediment analytical results, Ecology did not require sediment toxicity testing for the purposes of determining soil and groundwater cleanup criteria Benson (2007).

3.2 SOIL INVESTIGATION

This section presents the physical and chemical results of the current soil investigation.

3.2.1 PHYSICAL CHARACTERIZATION OF SITE SOILS

The soil was physically characterized by collecting and logging continuous soil samples at 15 soil borings (SB-1 through SB-14 and MW-03D) and 4 monitoring well boreholes (MW-01, MW-02, MW-03, and MW-04). Logs for these soil borings are provided in Appendix A.

Based on previous investigations (Hart Crowser 1983), the subsurface geology at the Site consists of dredged fill material overlying native marine sediment and glacial deposits. The fill generally consists of grey gravelly sand with varying amounts of silt overlying a silty, fine to medium sand. The thickness

of the fill material ranged from 4.5 ft to about 12 ft. At most locations, however, the thickness of the material was about 8 ft. The native soil underlying the dredged fill material consists of a sandy silt. Most soil borings only extended to the top of the native silt layer; therefore, the thickness of the silt layer was not determined. However, at boring MW-3D, a step-down procedure was used during drilling to allow drilling through the top of the silt layer and into the underlying material. Continuous samples were collected during drilling. The top of the native silt layer was encountered at about 10 ft BGS at this location. The soil boring was completed at 31 ft BGS and the bottom of the native silt layer was not encountered. No monitoring well was installed within the deeper confined aquifer because the native silt layer at this location was at least 21 ft thick and migration of contaminants in groundwater through the silt confining unit was considered to be unlikely. Two cross-sections (A-A' and B-B') showing the subsurface lithology were developed. The cross-section locations are identified on Figure 6. The cross sections are shown on Figures 7 and 8.

3.2.2 SOIL SAMPLE CHEMICAL CHARACTERIZATION

Analytical results for the soil samples collected during the current soil investigation were compared to preliminary cleanup levels to characterize the nature and extent of soil contamination at the Site. Development of the preliminary cleanup levels and the results of the comparison are described below.

3.2.2.1 Preliminary Soil Cleanup Levels

Because access to the property by the general public is currently allowed and will continue to be allowed after redevelopment, preliminary soil cleanup levels were developed for the Site based on unrestricted land use, in accordance with WAC-173-340-740.

Except for TPH, MTCA Method B cleanup levels were used as preliminary soil cleanup levels. The project Work Plan required the preliminary cleanup levels for TPH to be based on protection of sediment quality in the marine areas adjacent to the site. Sediment quality sampling showed that there is no evidence of sediment quality impacts to the marine areas as the result of the historical fuel releases from the Site and, therefore, preliminary cleanup levels for TPH were based on cleanup levels provided in Table 740-1(MTCA Method A). Under MTCA Method B, soil cleanup levels must be as stringent as:

- Concentrations established under applicable state and federal laws
- Concentrations protective of terrestrial ecological receptors
- Concentrations protective of direct human contact with soil

- Concentrations protective of groundwater.

Consideration of the above criteria was made, as follows, during development of preliminary soil cleanup levels:

- Except for MTCA, there are no soil cleanup levels established under applicable state or federal laws for the detected constituents in soil at the Site.
- A terrestrial ecological evaluation is not required for the Site because it does not meet any of the criteria in WAC 173-340-7491(1). Copies of the forms documenting this decision for the Site were included in Appendix G of the work plan (Landau Associates 2007). As a result, the Site meets the exclusion for a terrestrial ecological evaluation. Therefore, human contact and leaching to groundwater are the only applicable pathways for Site soil.
- Except for TPH, standard MTCA Method B soil cleanup levels protective of direct human contact were developed for the COPCs and other detected constituents in the soil at the Site. These cleanup levels were developed in accordance with WAC 173-340-740(3) using Ecology's on-line CLARC database (Ecology 2001). Table 2 shows the preliminary soil cleanup levels for protection of human health. The preliminary cleanup level for benzo(a)pyrene was used for the sum of cPAHs using total equivalency factors (TEFs) in accordance with WAC 173-340-708(8)(e) and Ecology guidance (Ecology 2001). MTCA Method A cleanup levels will be used as TPH cleanup levels protective of direct human contact, as shown in Table 2.
- Because no nonaqueous phase liquid (NAPL) was observed during the May 2007 groundwater monitoring event, preliminary soil cleanup levels for the saturated and unsaturated soil zones that are protective of groundwater were determined for the COPCs (except TPH) and other detected constituents using the fixed parameter three-phase partitioning model in accordance with WAC 173-340-747(4). Based on the exposure pathways identified in Section 3.3.3.1 for Site groundwater, because groundwater is not a current or likely future source of drinking water and because it discharges to marine surface water, marine surface water preliminary cleanup levels protective of human health and aquatic organisms developed in accordance with WAC 173-340-730 were used in the calculation. Table 2 shows the preliminary soil cleanup levels for protection of groundwater as marine surface water.
- Soil TPH cleanup levels that are protective of groundwater and that prevent sediment toxicity and recontamination were not calculated. The low petroleum hydrocarbon results for the sediment samples, discussed in Section 3.1, indicate that there is no evidence of TPH impacts to sediments from the Site; therefore, as approved by Ecology (Benson 2007), no toxicity testing on the sediments was performed and MTCA Method A soil cleanup levels were used to evaluate petroleum hydrocarbon concentrations in Site soil.

For each COPC and other detected constituents in soil, a preliminary cleanup level was established for the unsaturated and the saturated zone, based on the lowest applicable soil criteria as described in the Work Plan. The selected criteria are the shaded values shown on Table 2. In accordance with WAC 173-340-740(5)(c), the preliminary soil cleanup levels may be adjusted to be no less than natural background. Background concentrations for metals, based on statewide 90th percentile values

(Ecology 1994), were compared to preliminary soil cleanup levels protective of human direct contact and groundwater. Preliminary cleanup levels for copper in the unsaturated and saturated zones and for zinc in the saturated zone were adjusted upward to the natural background level. Preliminary soil cleanup levels adjusted based on natural background are identified in Table 2.

3.2.2.2 Comparison of Soil Analytical Results to Preliminary Cleanup Levels

Chemical data for constituents detected in the soil samples collected in May 2007 were compared to the preliminary cleanup levels described in Section 3.2.2.1. Analytical results for the constituents detected in the unsaturated soil zone are summarized in Table 3. Analytical results for the constituents detected in the saturated soil zone are summarized in Table 4. Preliminary cleanup levels are also presented on Tables 3 and 4 for comparison to the concentrations of detected constituents. A summary of all analytical results for the current soil investigation is presented in Appendix B.

The results of the comparisons of detected constituents to preliminary cleanup levels are described below.

Unsaturated Zone

Based on the field measurements taken at the Site and discussions with Ecology, the unsaturated zone is generally characterized as extending from the ground surface to 6 ft BGS. A total of thirty-three soil samples collected from the unsaturated zone in borings SB-01 through SB-14 were submitted for chemical analysis. These samples collected from the unsaturated zone included those from within the capillary fringe, typically encountered at a depth interval of 5 to 6 ft BGS, except at SB-7, where the groundwater was much shallower. A comparison of the concentrations of detected constituents in these soil samples to preliminary cleanup levels for the unsaturated zone (discussed in Section 3.2.2.1) is presented in Table 3. The comparison shows that the soil samples collected at eight of the fourteen soil sampling locations do not exceed the preliminary soil cleanup levels. The six sampling locations where soil concentrations exceed the preliminary soil cleanup levels are SB-4, SB-6, SB-7, SB-11, SB-12, and SB-13. The exceedances at these locations are as follows:

- At SB-4, concentrations of diesel-range and gasoline-range petroleum hydrocarbons, and benzene, exceed the preliminary soil cleanup levels in the sample collected from 5 to 6 ft BGS.
- At SB-6, concentrations of gasoline-range petroleum hydrocarbons exceed the preliminary soil cleanup levels in the samples collected from the 0.5 to 1.5 ft and 1.5 to 2.5 ft depth intervals.

- At SB-7, copper was detected at a concentration that exceeds the preliminary soil cleanup level in the sample collected from the 0.5 to 1 ft depth interval.
- At SB-11, lead was detected at a concentration (4,410 mg/kg) that exceeds the preliminary soil cleanup level (250 mg/kg) in the sample collected at the 5 to 6 ft depth interval.
- At SB-12, gasoline-range petroleum hydrocarbons exceed the preliminary soil cleanup level in the sample collected at the 5 to 6 ft depth interval.
- At SB-13, the total concentration cPAHs (calculated using appropriate TEFs) exceed the preliminary cleanup level in the sample collected at the 5 to 6 ft depth interval.

Soil sample locations with preliminary cleanup level exceedances in the unsaturated zone are shown on Figure 9.

Saturated Zone

Thirteen soil samples collected from the Site saturated zone were submitted for chemical analysis. These samples were generally collected at depths of 6 ft BGS or greater, except at SB-7. At SB-7, the 5 to 6 ft depth interval was considered to be within the saturated zone because groundwater was much shallower at this location at the time of drilling. Locations where samples from the saturated zone were collected and analyzed are shown on Figure 10 and include soil borings SB-2, SB-3, SB-4, SB-7, SB-8, SB-9, SB-14, and MW-3D.

Comparison of the concentrations of detected constituents in the saturated zone soil samples to preliminary cleanup levels (discussed in Section 3.2.2.1) indicates the presence of gasoline-range petroleum hydrocarbons at all of the sampling locations except SB-7 and SB-9. In accordance with Table 740-1 of MTCA, the gasoline-range petroleum hydrocarbons concentrations were compared to a preliminary cleanup level of 30 mg/kg because benzene was detected in the samples. Concentrations of gasoline-range petroleum hydrocarbons exceeded the preliminary cleanup level of 30 mg/kg at each location except SB-7 and SB-9. Diesel-range and motor oil-range petroleum hydrocarbons were detected in several of the samples. All of the detected concentrations of motor oil-range petroleum hydrocarbons were less than the preliminary soil cleanup level. Concentrations of diesel-range petroleum hydrocarbons exceeded the preliminary soil cleanup level of 2,000 m/kg at location MW-3D. Locations where petroleum hydrocarbons were detected at concentrations exceeding the preliminary cleanup levels within the saturated zone are shown on Figure 10.

At two soil sampling locations, MW-3D and SB-8, where gasoline-range petroleum hydrocarbons were detected at concentrations exceeding the preliminary soil cleanup level, other gasoline-related constituents (benzene and ethylbenzene) were also detected at concentrations exceeding the preliminary

cleanup levels. Naphthalene was also detected at SB-8 at concentrations exceeding the preliminary cleanup level.

At several locations (MW-3D, SB-3, SB-8, SB-9, and SB-14) cPAHs were detected at concentrations exceeding the preliminary soil cleanup levels for the saturated zone. These preliminary cleanup levels are protective of groundwater as marine surface water. However, in accordance with WAC 173-340-747(9), it can be empirically demonstrated that the cPAH concentrations present in soil are protective of groundwater as marine surface water. This demonstration is based on meeting the requirements listed in WAC 173-340-747(9)(b). The empirical demonstration requirements are as follows:

- Measured groundwater concentrations must be less than or equal to the groundwater cleanup level
- Sufficient time must have elapsed for migration of the hazardous substance from soil to groundwater to have occurred
- Characteristics of the Site that would impact migration of contaminants to groundwater must be representative of future Site conditions.

The Site conditions meet these requirements because, as discussed in Section 3.3.3.2, cPAHs were not detected in the groundwater samples collected from the monitoring wells or soil boring SB-01 in May 2007. Secondly, the contamination in the soil at the Site is associated with releases from leaking USTs that occurred in the early 1980s, which is sufficient time for migration of the cPAHs from soil to groundwater to have occurred. Finally, physical conditions at the Site that would impact migration of soil contaminants to groundwater are not likely to change significantly. The Site is currently used as a boatyard and for retail. The ground surface at the Site is asphalt roadway and a combination of asphalt and concrete slab, and gravel within the boatyard. Redevelopment of the Site is planned, but Site uses under the redevelopment plan will remain commercial and the ground surface will remain mostly paved. A large volume of impacted soil will be removed from the Site as part of the interim remedial action and this contaminant source removal will significantly improve groundwater quality at the Site. In summary, the detected concentrations of cPAHs in the saturated zone soil that exceed the calculated preliminary cleanup criterion for the Site are considered to be protective of groundwater or adjacent marine water quality based on this empirical determination.

3.3 GROUNDWATER INVESTIGATION RESULTS

This section presents the hydrogeologic and groundwater sample chemical characterization results.

3.3.1 HYDROGEOLOGIC CHARACTERIZATION

Hydrogeologic conditions at the Site were evaluated using data collected during the current groundwater monitoring event, which included a tidal study and slug tests, and based on geologic data collected during the current investigation and previous investigations.

3.3.2 HYDROGEOLOGIC UNITS

Based on the geologic information collected to date at the Site, three hydrogeologic units have been identified: a shallow unconfined aquifer, a confining unit, and a deeper confined aquifer. The shallow unconfined aquifer occurs in the dredged fill material consisting of gravelly sand and fine to medium sand with varying amounts of silt. The confining unit (underlying the shallow aquifer) consists of the native marine silts. During the field investigation, no soil borings were encountered at the bottom of the confining unit; therefore, the thickness of the confining unit was not confirmed. Previous investigations (Hart Crowser 1983) indicate that the thickness of the confining unit may be approximately 3 to 4ft. However, at soil boring MW-03D drilled during the current investigation, the thickness of the confining unit was greater than 20 ft. Also, based on previous investigations (Hart Crowser 1983), a deeper confined aquifer consisting of silty, fine sand is present below the native marine silt.

3.3.2.1 Groundwater Levels and Tidal Influence

The depths to groundwater measured during the groundwater monitoring event on May 3, 2007 ranged from approximately 4 ft BGS at monitoring well MW-01 to approximately 6 ft BGS at monitoring well MW-02. The depth to groundwater measurements were collected within 2 hours of low tide (the surface water elevation was +1.47 ft MLLW). The depths to groundwater were converted to elevations, which are summarized in Table 5. No measurements were collected with a hand-held water level indicator during a high tide; however, groundwater levels were measured electronically on a semicontinuous basis for a 72-hour period in May at each well. Surface water elevations in the marina during this 72-hour period ranged from -1.1 to +10.7 ft MLLW, a fluctuation of about 11.8ft. The tidal influence on groundwater levels at the Site was evaluated using data collected during the 72-hour period. The measured groundwater level fluctuations (in feet) and the calculated tidal efficiency¹ (expressed in percent) at each monitoring well indicate that the groundwater levels at the shoreline wells (MW-02, MW-03, and MW-04) have some tidal influence but groundwater level elevations at the inland well, MW-

¹ Tidal efficiency (TE) was calculated using the following equation:

$$TE = \frac{(\text{groundwater elevation at high tide}) + (\text{groundwater elevation level at low tide})}{(\text{surface water elevation at high tide} - \text{surface water elevation at low tide})}$$

01, have little to no tidal influence. The maximum groundwater level observed at well MW-02 during one tidal cycle was 7.60 ft MLLW and the minimum groundwater level observed at the well during that tidal cycle was 6.78 ft MLLW, a fluctuation of about 0.82 ft and a tidal efficiency of 7.2%. At well MW-01, the observed groundwater level fluctuation during a tide cycle was about 0.09 ft or a tidal efficiency of 0.77%. Groundwater level fluctuations and tidal efficiency values calculated for each well monitored during the tidal cycles on May 16, 2007 are shown on Figure 11. A graph of groundwater elevations recorded at wells MW-01, MW-02, MW-03, and MW-04, and the surface water elevations in the marina during the 72-hour period are shown on Figure 12.

3.3.2.2 Groundwater Flow Direction

The effect of tidal fluctuations on groundwater flow direction was evaluated using the information obtained during the 72-hour tidal study. Groundwater elevations at low tide, mid tide, and high tide on May 16, 2007 at the wells monitored during the tidal study were contoured and presented on Figures 13 through 15. As shown on these figures, groundwater flow direction does not change significantly between low tide and high tide.

3.3.2.3 Site Hydraulic Conductivity

The hydraulic conductivity of the saturated soil around wells MW-01 through MW-04 was estimated by using *in situ* variable head tests (as described in Section 2.3.2.3). Slug tests were conducted in the field and the data was analyzed using a computer program.

Both falling and rising head tests were performed in each of the four wells, and water levels were recorded with a datalogger. The tests were conducted by placing a stainless-steel rod (slug) below the groundwater surface in the well and measuring the rate of water level decline to the original static water table condition (falling head test). The slug was then removed and the rate of water level rise was recorded (rising head test). The slug test data was analyzed using the Bouwer and Rice method and AQTESOLV (version 2.1.3). An effective porosity of 0.25 was assumed for the 10/20 Colorado sand pack, a casing radius of 0.086 ft, and a well borehole radius of 0.34 ft were used in the AQTESOLV program. Furthermore, the slug tests analyses are predicated on the simplifying assumptions that the aquifers are approximately infinite in spatial extent and homogeneous.

The hydraulic conductivity estimates for MW-2 through MW-4 are similar and about 4 to 6 times greater than MW-1. The geometric means for MW-2, MW-3, and MW-4 are 6.1×10^{-2} cm/s, 6.3×10^{-2} cm/s, and 7.3×10^{-2} cm/s, respectively. A range for hydraulic conductivity for silty sand is approximately between 10^{-5} - 10^{-1} cm/s (Freeze and Cherry 1979). Hydraulic conductivity for MW-1 was 1.4×10^{-2} . The

estimates for MW-1 through MW-4 fall within this range, although closer to the higher end. These values are considerably higher than the 1.4×10^{-4} cm/s conductivity values for the Site that were estimated by Hart Crowser during studies completed for design of the historic product recovery trench. Estimated hydraulic conductivities from the current study are summarized in Table 6.

3.3.3 GROUNDWATER CHEMICAL CHARACTERIZATION

Analytical results for the groundwater samples collected during the May 2007 groundwater monitoring event were compared to preliminary cleanup levels to chemically characterize the groundwater at the Site. Development of the preliminary cleanup levels and a summary of the chemical analytical results are presented below.

3.3.3.1 Preliminary Groundwater Cleanup Levels

Groundwater at or potentially affected by the Site is not currently used for drinking water and is not a reasonable future source of drinking water due the availability of a municipal water supply and, in accordance with WAC 173-340-720(2)(d), due to its proximity to marine surface water. Additionally, groundwater samples collected from each of the monitoring wells and soil boring SB-01 were analyzed for total dissolved solids (TDS). The results ranged from 1,460 mg/L at monitoring well MW-01 to 15,500 mg/L at monitoring well MW-04. In accordance with WAC 173-340-720(2)(b)(ii), groundwater containing TDS at concentrations greater than 10,000 mg/L are not a suitable drinking water source. TDS in the groundwater sample collected at boring SB-01 was 14,800 mg/L and at monitoring well MW-03 was only slightly below 10,000 mg/L at 9,030 mg/L. Based on the TDS results for groundwater samples collected at MW-03, MW-04, and SB-01, the groundwater at the Site is not a reasonable future source of drinking water.

As a result, the potential exposure pathways for Site groundwater include:

- Human ingestion of marine organisms contaminated by releases of affected Site groundwater to adjacent marine surface water
- Acute or chronic effects to aquatic organisms resulting from exposure to constituents in groundwater discharging to adjacent marine surface water.

Groundwater cleanup criteria that are developed based on the exposure pathways identified in this subsection must be adequately protective of aquatic organisms and of humans that ingest these marine organisms. Except for TPH, MTCA Method B marine surface water preliminary cleanup levels were developed in accordance with WAC 173-340-730(3) for the COPCs. As approved by Ecology (Benson 2007), preliminary TPH cleanup levels based on sediment toxicity testing were not developed because, as

discussed in Section 3.1, TPH concentrations in sediment were not high enough to warrant toxicity testing. Also, in accordance with WAC 173-340-730(3)(b)(iii)(C), because no cleanup levels protective of marine surface water have been established for TPH, TPH cleanup levels for groundwater are based on TPH cleanup levels provided in MTCA Table 720-1. Preliminary groundwater cleanup levels for the COPCs and other constituents detected in groundwater and the development of these cleanup levels, including the concentrations established under applicable state and federal laws, are presented in Table 7.

3.3.3.2 Comparison of Groundwater Analytical Results To Preliminary Cleanup Levels

The analytical results for the May 2007 groundwater samples indicate that very few constituents are present at detectable concentrations in the groundwater at most of the sampling locations at the Site. Only MTBE was detected at MW-01; only carbon disulfide was detected at MW-04; only benzene was detected at SB-01; and only a few PAHs (acenaphthene, fluorene, and phenanthrene) and lead were detected at MW-02. All of the detected concentrations were significantly below the preliminary cleanup levels (described in Section 3.3.3.1). At monitoring well MW-03, no cPAHs, diesel-range petroleum hydrocarbons, motor oil-range petroleum hydrocarbons, or lead were detected. Several PAHs were detected, but at concentrations significantly below the preliminary cleanup levels. Several VOCs were also detected at MW-03, but only benzene was detected at a concentration exceeding the preliminary cleanup level. Only well MW-03 had a detected concentration of gasoline-range petroleum hydrocarbons. The detected concentration, 2.8 mg/L, exceeds the preliminary cleanup level of 0.8 mg/L. Analytical results for the constituents detected in groundwater are summarized in Table 8. Preliminary cleanup levels are also presented in Table 8 for comparison to the concentrations of detected constituents. The location and concentration of the constituents that exceed preliminary cleanup levels in groundwater are shown on Figure 16. All analytical results for groundwater samples collected at the four monitoring wells and soil boring SB-01 in May 2007 are presented in Appendix C.

4.0 SUMMARY

The results of the RI field study of sediment, soil, and groundwater show that there is no evidence of petroleum hydrocarbon impacts to sediment, but that there are impacts to soil and groundwater resulting from the historical fuel releases at the Site. The impacts to soil and groundwater are primarily related to gasoline-range petroleum hydrocarbons. Gasoline-range petroleum hydrocarbons and gasoline-range petroleum hydrocarbons-related constituents (i.e., benzene, ethylbenzene, naphthalene) were detected in soil and groundwater at concentrations exceeding the preliminary cleanup levels. The preliminary soil cleanup level exceedances occurred primarily within the capillary fringe and saturated zone soil at locations adjacent to or near the former USTs. However, gasoline-range petroleum hydrocarbon-impacted soil was also found approximately 170 ft south of the USTs at soil boring SB-14 and approximately 170+ ft north of the former USTs at soil boring SB-6. These appear to be limited-area exceedances (“hot spots”) not related to the historical UST release. Gasoline-range petroleum hydrocarbon-impacted groundwater was found at monitoring well MW-03, which is located downgradient of the former USTs. Diesel-range petroleum hydrocarbons were also detected in soil at concentrations exceeding the preliminary cleanup levels, at two locations (SB-4 and MW-3D).

Other constituents detected at concentrations exceeding the preliminary cleanup levels in soil were lead, copper, and cPAHs. Each of these exceedances was a single occurrence and none of these constituents were detected in groundwater at concentrations exceeding the preliminary cleanup levels.

5.0 USE OF REPORT

This investigation data report has been prepared for the exclusive use of the Port of Anacortes for specific application to the Cap Sante Marine Lease Area. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau Associates. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau Associates, shall be at the user's sole risk. Landau Associates warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. We make no other warranty, either express or implied.

This document has been prepared under the supervision and direction of the following key staff.

LANDAU ASSOCIATES, INC.



Stacy J. Fischer, L.G.
Senior Project Geologist



Kristy J. Hendrickson, P.E.
Principal

SJP/KJH/tam

6.0 REFERENCES

- ASTM. 1999. *Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers, (Method D 4044-096), Standards on Determining Subsurface Hydraulic Properties and Ground Water Modeling*. Second Edition, pp. 19-21. American Society for Testing and Materials.
- Benson. 2007. Email to John Herzog; cc: Panjini Balaraju, Sandra Caldwell, and Michelle Wilcox, Ecology; Bob Elsner, Port of Anacortes; and Stacy Pischer, Landau Associates, re: *Preliminary TPH Results for Cap Sante Marine Sediments*. Ted Benson, Washington State Department of Ecology. May 7.
- Bouwer, H. 1989. *Slug Test – An Update*. Ground Water 27:15-20.
- Bouwer, H. and M.R. Rice. 1976. *A Slug Test Determining the Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells*. Water Resources Research. 12:423-428.
- Ecology. 2006. *Minimum Standards for Construction and Maintenance of Wells* (Chapter 173-160 WAC). Washington State Department of Ecology. Update November.
- Ecology. 2001. *Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation*. CLARC Verison 3.1. <http://www.ecy.wa.gov/biblio/94145.html>. Washington State Department of Ecology Toxics Cleanup Program. Publication No. 94-145, updated November 2001.
- Ecology. 1997. *Analytical Methods for Petroleum Hydrocarbons*. Publication No. ECY 97-602. June.
- Ecology. 1994. *Natural Background Soil Metals Concentrations in Washington State*. Toxics Cleanup Program, Department of Ecology. Publication #94-115. October.
- Floyd|Snider. 2005. *Limited Environmental Due Diligence Investigation Report, Former Shell Oil Tank Farm, Cap Sante Marine Lease Area*. Prepared for the Port of Anacortes. November 8.
- Floyd Snider McCarthy, Inc. (FSM). 2004. Letter Report, *Results of Limited Environmental Due Diligence Investigation, Cap Sante Boat Haven - Anacortes, Washington*. June 14.
- Freeze, R.A. and Cherry, J.A. 1979. Prentice-Hall, Inc. N.J., USA.
- Hart Crowser. 1983. *Petroleum Seepage Study, Port of Anacortes, Anacortes Washington*. Prepared for the Port of Anacortes. November 1.
- Landau Associates. 2007. *Ecology Review Draft Work Plan, Remedial Investigation/Feasibility Study and Interim Action, Cap Sante Marine Lease Area, Anacortes, Washington*. Prepared for the Port of Anacortes. March 2.
- Plumb, R.H., JR. 1981. *Procedure for Handling and Chemical Analysis of Sediment and Water Samples*. Technical Report EPA/CE-81-1. U.S. Environmental Protection Agency and U.S. Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.
- PSEP. 1997a. *Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound*. Prepared by U.S. Environmental Protection Agency, Region 10 for Puget Sound Estuary Program. April.

PSEP. 1997b. *Recommended Guidelines for Measuring Organic Compounds in Puget Sound Water Sediment and Tissue Samples*. Prepared by U.S. Environmental Protection Agency, Region 10 for Puget Sound Estuary Program. April.

PSEP. 1997c. *Recommended Guidelines for Measuring Metals in Puget Sound Marine Water, Sediment, and Tissue Samples*. Prepared by U.S. Environmental Protection Agency, Region 10 for Puget Sound Estuary Program. April.

PSEP. 1997d. *Recommended Quality Assurance and Quality Control Guidelines for the Collection of Environmental Data in Puget Sound*. Puget Sound Estuary Program. April.