REMEDIAL INVESTIGATION REPORT

Remedial Investigation/Feasibility Study
Astoria Area-Wide Petroleum Site
Astoria, Oregon

June 17, 2008

Prepared by:

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This report has been prepared by *EnviroLogic Resources, Inc.*, of Portland, Oregon.

EnviroLogic Resources, Inc. Project No. 10077.009

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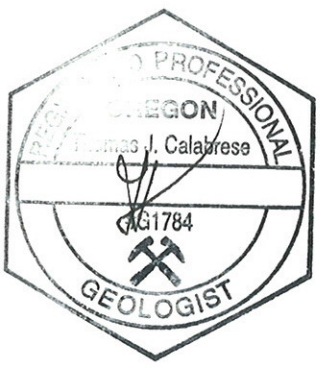

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1.0 INTRODUCTION

The Oregon Department of Environmental Quality (DEQ) issued a unilateral order on December 14, 2001, requiring the investigation and potential cleanup of properties at and near the Port of Astoria in Astoria, Oregon. The Order (DEQ Unilateral Order No. ECSR-NWR-01-11) was issued to several of the current and former facility operators, property owners, and leaseholders that have engaged in industrial and commercial activities. A copy of the Order is presented in Appendix A. Chevron Products Company (Chevron), Delphia Oil Company (Delphia), McCall Oil and Chemical Company (McCall), Ed Niemi Oil Company (Niemi Oil), Flying Dutchman and Harris Enterprises (Harris/Van West), Port of Astoria (the Port), Qwest Communications International (Qwest), and Shell Oil Products Company (Shell) are collectively potentially responsible parties (PRPs) identified in the Order and have agreed to comply with its requirements. Qwest subsequently withdrew from participation in site investigations in 2004. ExxonMobil Corporation agreed to participate in investigations conducted by the PRP group in November 2003. The following is a list of the consultants representing each PRP:

PRP	CONSULTANT
Chevron	ARCADIS U.S., Inc.
Delphia Oil	Maul, Foster & Alongi, Inc.
ExxonMobil	Lovely Consulting, Inc.
Harris/Van West	Kleinfelder, Inc.
McCall Oil	Anchor Environmental, LLC
Niemi Oil	AMEC E & E, Inc.
Port of Astoria	None
Qwest	Tetra Tech EM, Inc.
Shell Oil	Hart Crowser, Inc.

The area within which investigations are focused is termed the Astoria Area-Wide Petroleum Site (Astoria Area-Wide). The Regional Study Area (RSA) includes the Astoria Area-Wide site and the surrounding areas. The location of the RSA is shown on Figure 1-1 and the boundaries of the RSA and Astoria Area-Wide site are shown on Figure 1-2.

This Remedial Investigation (RI) Report presents a summary of the remedial investigations and remedial actions performed by the Astoria Area-Wide PRP Group at and near the Port of Astoria since 2002. One or more Feasibility Study (FS) Reports will be prepared on the basis of the risks identified in the human health and ecological risk assessments.

1.1 OBJECTIVES

The primary objectives of the RI are to provide sufficient data to characterize the nature and extent of petroleum-related contamination at the Astoria Area-Wide site and to determine appropriate exposure scenarios for risk assessments so that remedial action alternatives that are protective of human health and the environment can be identified and evaluated. General objectives of the work to be performed under the Order include:

- Identify the hazardous substances released to the environment;
- Determine the nature, extent, and distribution of hazardous substances in affected media on and offsite;
- Determine the direction and rate of migration of hazardous substances;
- Identify migration pathways and receptors;
- Determine the risks to human health and the environment;
- Identify hot spots of contamination;
- Generate or use data of sufficient quality for site characterization, risk assessment and the selection of remedial alternatives.; and
- Develop the information necessary to evaluate remedial action alternatives and select a remedial action.

Site specific objectives to be addressed under the work performed pursuant to the Order include the following:

- Develop and implement interim remedial action measures (IRAMs) to limit discharge of contamination to the Columbia River during the RI/FS Phase 1 Work Plan and Implementation process;
- Develop and implement an IRAM to mitigate volatile organic compound (VOC) vapor intrusion into buildings at levels exceeding DEQ risk-based concentrations;

- Document and evaluate the current storm water system. Locate and evaluate all oil water separators, discharge points, dry wells, sumps, and other applicable features. Evaluate surface water quality data;
- Locate underground utilities and evaluate their potential to act as potential conduits for contaminant migration;
- Determine how tidal and seasonal influences are likely to effect interim or final remedial options for the facility;
- Complete a beneficial land and water use survey; and
- Characterize affected media consistent with DEQ Risk-Based Decision Making for Petroleum-Contaminated Sites.

In addition, the Order set forth tasks for specific PRPs that were to be completed during the RI. These tasks, as described in the Order are presented below.

Tasks specific to the Port are:

- Collect surface and subsurface sediment samples from within Slips 1 and 2. Analyze the samples for petroleum-related contaminants and other hazardous substances associated with the Port's maritime activities. Work with McCall Oil to design an IRAM to stop discharge of petroleum impacted ground water to the Columbia River.
- Collect soil and ground-water data sufficient to evaluate air quality in buildings potentially impacted by the contaminant plume. Evaluate findings in relation to the Port's Central Waterfront Development Plans.
- Investigate other potential sources of contaminants on Port property that have not been previously investigated. Potential sources include the old Portway Machine Works (Columbia Iron and Steel Works) that occupied the area between the Shell Oil facility and the Niemi Bulk Oil facility from pre-1930s to the 1970s, and Astoria Oil Services, Inc. The area-specific investigation needs to address other potential hazardous substances related to these facilities such as polychlorinated biphenyls (PCBs), metals, or semi-volatile organic compounds (SVOCs).
- Provide a comprehensive figure of the storm water and sewer systems. Show how adjacent properties tie into the systems. Include the reporting of four quarters of storm water outfall data as a Phase 1 task.

Tasks specific to McCall are:

- Inspect, repair, and redevelop the existing monitoring well network. Install additional wells as necessary to develop and evaluate IRAM system designs for the pipeline diesel release.
- With input from the Port, design an IRAM to mitigate on-going releases of free product and petroleum impacted ground water to the Columbia River.
- Perform a source area investigation of McCall's bulk plant and sludge disposal area (conducted by Chevron).

Tasks specific to Harris/Van West:

- Describe the on-site cleanup of contamination that resulted from the major gasoline release discovered in 1990.
- Determine the extent and magnitude of on site residual soil and ground-water contamination around the perimeter and below the base of the previous excavation, if any.
- Characterize the extent of ground-water contamination off-site in coordination with Niemi Oil and Qwest.

Tasks specific to Niemi Oil Cardlock Facility:

- Conduct on-site source area monitoring. Describe current storm water management and install surface water controls, if necessary.

Tasks specific to Niemi Oil Former Bulk Fuel Facility:

- Develop a plan for removal of abandoned fuel line and tanks.

Tasks specific to Chevron (formerly Youngs Bay Texaco):

- Describe the release and cleanup of gasoline from an above ground vault. Collect additional soil and ground-water samples as needed to complete an updated risk-based evaluation. Determine if the vault gas release has impacted soil and ground-water quality on the Qwest site and along utility trenches.

Tasks specific to Shell Oil Company:

- Develop a plan for removal of abandoned fuel pipelines, if present. Evaluate potential contamination associated with past operation of the fuel lines.

Tasks specific to Delphia Oil Company:

- Summarize the 1973 gasoline release documented by the fire department. Describe how many gallons of gasoline were spilled and corrective actions taken to address the release.
- Describe the history of pavement at the site. Include approximate dates that various portions of the site were paved.
- Describe the on-site system of catch basins. Include approximate installation dates and the historic and current operation and maintenance of the catch basin system.

Tasks specific to Val's Texaco:

- Design a soil and ground-water sampling program to determine if there is residual soil or ground-water contamination at the site.

The PRP-specific objectives were met during the RI process, development of the RI/FS and IRAM Development Work Plan, Phase 1, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon dated July 15, 2002 (RI/FS Work Plan) (*EnviroLogic Resources*, 2002), and through investigations conducted by the PRP group.

1.2 REGULATORY FRAMEWORK

The Order issued by the DEQ requires that a RI/FS be performed at the Astoria Area-Wide site in accordance with Oregon Revised Statutes (ORS) 465.200 et seq., and rules promulgated as a result of the statute. The scope of investigation and analysis for the RI is contained in the hazardous substances remedial action portion of the rules. However, portions of the underground storage tank (UST) rules were applied to aspects of the RI where they were deemed applicable or relevant and appropriate. Specifically, Oregon Administrative Rule (OAR) 340-122-0244 (Risk-Based Concentrations) and Risk Based Decision Making (RBDM) Guidance developed by DEQ (Oregon DEQ, 2003) was used to evaluate risk associated with the release of petroleum hydrocarbons to the environment.

The environmental investigations conducted in the past at the properties that comprise the Astoria Area-Wide site have been performed under several regulatory programs. Matters relating to USTs have been investigated and, in some cases, remedied under rules promulgated in OAR 340-122-0205 through 340-122-0360, and their predecessors. Aboveground storage tanks (ASTs) and releases from pipelines have been investigated under OAR 340-122-0010 through 340-122-0140, and their predecessors. In addition, permits for discharge of storm water have been issued pursuant to ORS 468B.050.

1.3 REPORT ORGANIZATION

The RI Report is organized into the following sections:

Section 1.0 Introduction. This section presents the RI objectives and regulatory framework; background and development histories for the Astoria Area-Wide Site and the

individual facilities; a summary of previous and current investigations conducted at each facility; and a listing of the work plans and technical memoranda submitted to DEQ as part of the RI.

Section 2.0 Study Area Investigation. This section summarizes the investigations performed during the RI. These investigations include source characterization, soil investigations, ground-water investigations, surface-water and sediment investigations, storm-water investigations, beneficial land and water use survey, and IRAMs.

Section 3.0 Physical Characteristics of the Study Area. This section presents the physical, topographic, and regional hydrogeologic setting of the Astoria Area-Wide site. The information enhances the understanding of site characteristics in the context of the regional setting.

Section 4.0 Local Hydrogeology. This section describes the Astoria Area-Wide site hydrostratigraphy. This includes a description of the vadose zone, saturated zone, and ground-water quality parameters.

Section 5.0 Potential Migration Pathways and Potential Sources. This section presents facility-specific potential sources and potential pathways for the migration of hazardous substances in environmental media. This section also introduces the concept of areas of concern. The concept of areas of concern allows for a concise and clear discussion of analytical data in Section 6.0. The areas of concern were defined on the basis of the presence of potential or confirmed sources, soil analytical data, and ground-water analytical data that show the extent of migration of petroleum hydrocarbons.

Section 6.0 Nature and Extent. This section describes the nature and extent of hazardous substances in soil, ground water, storm water, sediment, and air/soil gas by area of concern. This section also presents the nature and extent of free product; and introduces constituents of interest (COI).

Section 7.0 IRAMS Undertaken as Part of the RI. This section presents IRAMS that have been undertaken at the facilities in the Astoria Area-Wide site. A discussion of the effectiveness of the IRAMS is also presented.

Section 8.0 Fate and Transport. This section presents the factors and processes that affect the fate and transport of COI.

Section 9.0 Beneficial Land and Water Use. This section summarizes the beneficial land and water use analysis that has been completed for the Astoria Area-Wide site. A discussion of zoning, property use, recent land development, and water rights is included.

Section 10.0 Conceptual Site Exposure Model. This section presents the conceptual site model (CSM) for the Astoria Area-Wide site and discusses their development.

Section 11.0 Human Health Risk Assessment. This section summarizes the human health risk assessment and identifies any data gaps related to the human health risk assessment. A hot spot evaluation is also discussed in this section.

Section 12.0 Ecological Risk Assessment. This section summarizes the ecological risk assessment and identifies any data gaps related to ecological risk assessment.

Section 13.0 Conclusions. This section summarizes the results and conclusions reached during the RI.

Section 14.0 References. A comprehensive list of references used in the development of the RI is provided in this section.

1.4 SITE BACKGROUND

The Astoria Area-Wide site comprises facilities or former facilities (collectively, facilities) located at and near the Port in Astoria, Oregon (Figure 1-2). The RSA includes the Astoria Area-Wide site and the surrounding areas. The RSA is located in Section 7, Township 8 North, Range 9 West, and Section 12, Township 8 North, Range 10 West, Willamette Base and Meridian. As defined by the Order, the Astoria Area-Wide site includes property bounded by the Burlington Northern Railroad tracks to the southeast, Portway to the northeast, the Columbia River to the northwest, and Hamburg Street (including the former Chevron/McCall bulk plant); and the property bounded by the Burlington Northern Railroad tracks to the northwest, Hamburg Street to the southwest, Marine Drive to the southeast, and Portway to the northeast (Figure 1-2). This is also considered the locality of the facility for this remedial investigation.

A topographic high to the southeast forms a prominent hill overlooking the RSA. West Marine Drive (US Highways 26, 30, and 101) is located on a topographic bench approximately 15 feet above the level of the Port facilities. The Columbia River flows to the west on the north side of the RSA. Youngs Bay is west and south of the RSA.

The Astoria Area-Wide site has been used for petroleum storage and distribution since the 1920s. ASTs, USTs, and pipelines are present on several of the facilities subject to this investigation. Historically, at least four bulk petroleum storage facilities and five vehicle fueling or service stations have occupied the area between West Marine Drive and the Columbia River in the RSA. Pipelines from at least three of the bulk fuel storage facilities extend onto piers at the Port. The Astoria Area-Wide site is currently zoned for industrial and commercial uses and is expected to remain so. Figure 1-2 shows the RSA and the locations of each of the facilities subject to the Order.

1.5 SITE HISTORY

Aerial photographs, Sanborn Fire Insurance maps, and other historical photographs and maps were reviewed to develop an understanding of the site history. Aerial photographs from years 1939 to 2001 and Sanborn Fire Insurance maps for the years 1948, 1959, 1965, 1967, and 1969 were acquired and reviewed by *EnviroLogic Resources*. Historical photographs available at the Port were also reviewed. Maul, Foster & Alongi, Inc. reviewed Sanborn maps for 1908, 1921, 1924, 1934, 1940 and 1954 at the Astoria Public Library. A complete description of the aerial photographs, Sanborn Maps, and historical facilities is included in the RI/FS Work Plan. (*EnviroLogic Resources, Inc.* 2001). Aerial photographs from 1939, 1966, and 1989 are included as Figures 1-3, 1-4, and 1-5. Electronic copies of all the aerial photographs reviewed are included on the enclosed compact disk. In Section 1.5.1 the history for the general Astoria Area-Wide site is presented. In Sections 1.5.2 to 1.5.11 the development history for each PRP facility is presented.

1.5.1 General Astoria Area-Wide Site History

The lower elevations of the RSA were initially part of the Columbia River, as shown by a photograph taken in 1915 and indicated by a 1908 Sanborn map. During the early 1900s the shoreline appears to have been on the north side of present day Marine Drive. No known development was present in the western portion of the RSA. In the eastern portion of the RSA a 1908 Sanborn map indicates a "bunk house" and boardwalk were present in the approximate vicinity of the former Val's Texaco site. The boardwalk extended toward a wharf that extended out into the Columbia River. At that time tidal flats were located east of the Val's Texaco property.

In time, the area comprising the currently developed area was constructed with fill, primarily from dredge spoils (sands and silts) and rip rap, and the piers were constructed. All three piers were constructed by 1922 and later improvements included buildings and warehouses. Railroads were constructed on Industry Street, in the area southeast of the piers, and railroad spurs and crane tracks extended onto the piers. Although significant building development

and redevelopment occurred after 1922, additional fill placement appeared to be limited to extending land along the southwest side of Pier 3. Part of this historical development and redevelopment included a large water tower at the base of Pier 2, bulk petroleum facilities, service stations, marine fueling docks in Slip 2, bulk petroleum receiving stations on Pier 2 and associated petroleum distribution lines.

In general development in the RSA remained fairly consistent from the 1940s through the late 1980s. Starting in the 1990s, a redevelopment trend started with historical facilities closing, building demolition, and other redevelopment occurring on selected properties.

Recently the land use on Pier 3 changed from general storage to primarily boat storage, and detention ponds for dredge spoils were constructed on the west and north sides of Pier 3. Road improvements in 2004 and 2005 included the realignment of Hamburg Street and repaving of Industry Street. In the summer and fall of 2005, construction began for new buildings at the former Chevron/McCall bulk plant. Englund Marine opened at this location beginning in 2006. In the vicinity of the former water tower, a new building housing Bornstein Seafoods was completed in 2006. This development included construction of a dock at the base of Slip 1. The Youngs Bay Texaco facility was observed during an October 2006 site visit, to no longer be dispensing gasoline, and the apartment building located between the former Youngs Bay Texaco and the former Harris/Van West site had been demolished. In addition, redevelopment of the former ExxonMobil/Niemi Oil bulk plant was underway.

An April 2008 site visit revealed that the Youngs Bay Texaco facility had been converted to a restaurant and fish market with the car wash still operating. The former apartment building property was vacant and the Bergeson facility had been completely redeveloped. The old office and warehouse had been removed and now located on the property was a 3-story office building, shop, and garage all still occupied by Bergeson. Business Park development at the former ExxonMobil/Niemi Oil bulk plant and adjoining Port property was partially complete with a least some of the buildings occupied. As part of the redevelopment activities Portway

street in the vicinity of the Port office buildings had been renamed to Gateway Avenue. Recent land development is noted on Figure 1-6.

1.5.2 Port of Astoria

The main Port of Astoria properties located within the Astoria Area-Wide site include the piers, the land at the base of the piers, and the properties between the former ExxonMobil/Niemi Oil bulk plant and the former Shell bulk plant. Astoria Oil Services is a historical facility of interest that was located on Pier 3. Each area is discussed below.

Piers: Piers 1 and 2 were constructed by 1915 and Pier 3 was constructed by 1922. The 1927 Port of Astoria utility map indicates Pier 1 was occupied by a flour mill, Pier 2, by officers' quarters, barracks, a shop building, two-Standard Oil Company receiving stations, and a General Petroleum receiving station. Pier 3 was occupied by a large warehouse. The utility map also shows several small office type buildings located at the base of Slip 1, a Shell Oil Co. marine filling station and a General Petroleum marine filling station in Slip 2. A large water tower was located at the base of Pier 2 and storage sheds were located at the base of Pier 3. Petroleum distribution lines are shown along Portway and on Pier 2 for the receiving stations and upland of Slip 2 for the marine filling stations.

On the 1948 Sanborn map the Slip 2 marine filling stations are still shown. Two small buildings at the base of Slip 2 were described as a paint shop and wash rack, and two small buildings south of these stored a fueling/maintenance cart. By 1959, the marine filling stations were gone from the small dock in Slip 2. Shown on this map was the addition of a small office building next to the two small buildings at the base of Slip 2. North of the Port office building, between the Port office and the water tower, was a small building used as a welding and machine shop. The 1959 Sanborn map shows a building north of the former Chevron/McCall bulk plant was a Contractor's Warehouse. There was a small building north of this at the base of Pier 3 used for welding.

In the late 1960s, several small buildings at the Port were removed and portions of Slip 2 were reconfigured with fill added at the south end of the slip. Development continued on Piers 1 and 2 as new buildings were added. A portion of the dock on the southwest side of Pier 2 was burned in a fire that occurred in approximately 1985. The 1989 aerial photograph shows much of the north part of the Astoria Area-Wide site being used for wood/log storage. The building on Pier 3 was torn down by 2001 and the foundation was mostly removed several years later. In April 2002, the historic water tower overlooking the Astoria Area-Wide site was demolished.

Astoria Oil Services: Astoria Oil Services operated at the north end of Pier 3 from approximately 1983 to 1993 (JCR Consulting, 1986). The operation of this facility is not evident from review of the aerial photographs or Sanborn maps. Initially, documentation from DEQ (Appendix A) indicated Astoria Oil Services was located next to the west corner of the former ExxonMobil/Niemi Oil bulk plant. However, the building on that property housed a boiler locally referred to as the "Bergeson's Boiler." This area has been redeveloped and is now occupied by Hamburg Street.

Port Maintenance Shop UST: By 1945, the Port office and shop buildings were constructed. The shoreline along Slip 2 was not far from the Port buildings and there was a dock connecting Piers 2 and 3. The 1959 Sanborn map indicates the United States Navy leased the Port office building. North of the Port office building, between the Port office and the water tower, was a small building used as a welding and machine shop. A third Port building (shop) is present in the 2001 aerial photograph on the west side of the older shop building.

Former Furniture Manufacturing and Steel Works Facilities: The 1927 Port of Astoria utility map shows Fellman Furniture Manufacturing located to the east of the former ExxonMobil/Niemi Oil bulk plant and Columbia Iron & Steel Works located west of the former Shell bulk plant. The 1948 Sanborn map shows the furniture warehouse building was run by the Uptegrove Lumber Company. The building was a veneer plant by this time, which included veneer dryers, a saw mill, a peeler, and fuel storage. The 1948 map shows a building was constructed labeled "boiler house", just east of the former ExxonMobil/Niemi Oil bulk

plant. By 1953 the two former steel works buildings were joined by an addition. Additions to the furniture and steel works buildings occurred between 1958 and 1963. All these buildings appear to be under one roof by 1963. Port Plywood Company occupied the former furniture manufacturing building by 1965. Operations included wood storage, veneer manufacturing and storage, a machine shop, and fuel storage.

Between 1973 and 1974, the furniture manufacturing building was removed. The property was left vacant with a few storage containers as shown on the 1974 aerial photo. The former steel works building was removed by 1983. In the 1989 aerial photograph the properties are used for log storage. Aerial photographs from the 1990s indicate the properties were used for open storage. Redevelopment of this area by Riverland Company LLC Business Park started in 2007 and with building occupancy in 2008. The Riverland Company LLC Business Park includes the area formerly occupied by the former ExxonMobil/Niemi Oil bulk plant.

1.5.3 Former Chevron/McCall Bulk Plant

The former Chevron/McCall bulk plant had been a heavy oil, marine terminal since the late 1920s. The Port of Astoria 1927 utility map shows three ASTs and a pump house on this site. These are also visible in the 1939 aerial photograph. By 1944, a fourth AST is visible in the aerial photograph. These four ASTs are shown on the 1948 Sanborn Fire Insurance Map. In aerial photographs from 1944 to the 1990s the facility appeared relatively unchanged. Initial photographs show tidal flats at the limits of the western property boundary and by the 1990s additional fill has been placed so land is adjacent to the western boundary. In 2006 two large commercial buildings were developed on the former bulk plant property.

1.5.4 Former ExxonMobil/Niemi Oil Bulk Plant

One or more of Mobil's predecessors, including General Petroleum Corp. and/or Pilot Oil (PNG Environmental, 1998), built the bulk plant at 490 Industry Street in 1925. A 1927 utility map shows the bulk plant included two fuel ASTs (420,000-gallon and 26,000-gallon), acid and alkali ASTs, ancillary equipment (pump house, piping), a warehouse, a garage, a steam

boiler, and a cesspool. Between 1948 and 1953 a new office, warehouse, garage building (same dimensions as recently demolished structure), additional ASTs, and new loading rack were added to the former ExxonMobil/Niemi Oil bulk plant. By 1957, a total of seven ASTs were in place at the former ExxonMobil/Niemi Oil bulk plant, ranging in size between 2,000 to 420,000 gallons. There appear to be seven ASTs visible in the 1974 aerial photograph. Two ASTs were removed from the former ExxonMobil/Niemi Oil bulk plant in 1974. In 1976, Mobil terminated its lease with the Port and sold the improvements to Niemi Oil. There appear to be only three ASTs visible in aerial photographs from 1978 to 1998. By 2001 all the ASTs had been removed. Redevelopment of the site started to occur in 2007 with the construction of the Riverland Company LLC Business Park.

1.5.5 Youngs Bay Texaco

The Sanborn Fire Insurance maps do not cover the area occupied by the Youngs Bay Texaco facility. However, in the 1939 aerial photograph the site appears to be mostly vegetated with some structures. Hamburg Street has not been developed but the apartment building on the adjoining property to the northeast is present. By 1944 Hamburg Street has been developed, but the Youngs Bay Texaco site remains primarily vegetated. By 1948 most of the vegetation has been cleared from the property (but no visible development) and there is more development on the adjoining parcels. Aerial photographs from the 1950s and 1960s show more development on and around the site; one structure is present on the site, a warehouse is present on the Qwest property, and buildings are present on the property to the northwest (currently International Longshoremen's Workers Union [ILWU] building). In the 1970 aerial photograph a service station appears on the site. The Chevron service station appears to have operated from the late 1960s until the early 1990s. Aerial photographs from 1970 to 1990 show the layout of the former Chevron service station. A 1994 aerial photograph shows vacant land and a 1995 photograph shows buildings with the layout of the current Youngs Bay Texaco service station. At the time of an October 2006 site visit, the Youngs Bay Texaco facility was observed to no longer be dispensing gasoline. At the time of an April 2008 site visit the car wash was operating and the service station building had been converted to a restaurant and seafood market.

1.5.6 Qwest Vehicle Service Center

The 1939 historical aerial photograph reveals several small buildings on the property occupied by Qwest and the adjoining parcel to the west (ILWU). Although Hamburg Street is not visible, the former Mobil/Niemi Oil bulk plant and Industry Street are. Railroad cars are visible along the north side of Industry Street as is Port of Astoria development on the north side of Industry Street. By 1953 a warehouse is present on the Qwest site. This warehouse is similar to the current warehouse but does not extend as far to the east. In the 1966 and 1970 aerial photographs the former dispenser is visible just north of the north corner of the warehouse. In the 1973 aerial photograph the warehouse has the configuration of the current warehouse and the dispenser is no longer visible in the photograph. By 1989 the building currently occupied by ILWU is located on the adjoining property to the west.

1.5.7 Former Harris/Van West Service Station

In the 1939 aerial photograph the Harris/Van West site appears to be occupied by a large commercial type structure and residential structures. The adjoining parcels along Marine Drive are vegetated or occupied by residential type structures. By 1958 the property appears to be occupied by a junk yard, which also includes the adjoining properties (the Niemi Oil Cardlock site also appears to be occupied by the junk yard). The Harris/Van West service station first appears in the 1966 aerial photograph and is reported to have operated until 1991. In the 1994 aerial photograph the property appears vacant. The retaining wall between the Niemi Oil Cardlock site and the former Harris/Van West service station is visible in the 1995 aerial photo. By 1998 the property had been redeveloped with the current structure which is a drive-thru "quick lube" facility for cars.

1.5.8 Niemi Oil Cardlock

The 1927 Port of Astoria utility map indicates the east portion of the Niemi Oil Cardlock site is occupied by an Associated Oil Company facility which included one AST, two-fueling

racks, a pump house, and a garage. The 1939 aerial photograph indicates that the area of the current Niemi Oil Cardlock facilities is actually vacant. Structures are visible on the adjoining property to the east in the 1939, 1944 and 1948 aerial photographs but the AST, if present, cannot be distinguished. The 1948 Sanborn map does not cover this area. A possible fuel loading rack or AST is visible in the 1958 aerial photograph but by 1963 this structure is gone and the property is occupied by a junkyard. By 1970 the junkyard is gone. In the 1974 aerial photograph the Burns-Johanson facility is visible at the location of the current Niemi Oil Cardlock facility.

1.5.9 Former Shell Bulk Plant

The 1927 Port of Astoria utility map shows a Shell bulk plant at the current location of the Oregon State Police, Astoria Patrol Office. At that time the facility included two ASTs, a warehouse, pump house, garage, office building, and other ancillary facilities. In 1939 the former Shell bulk plant had five ASTs surrounded by berms and a few buildings. Between 1948 and 1953, two more tanks were added to the former Shell bulk plant facility for a total of seven ASTs. A couple of the buildings were removed to accommodate the new tanks. Between the former Shell bulk plant and Portway were the Bergeson buildings that are still present today. The former Shell bulk plant closed in 1972. By 1974, all above ground tanks and other above ground on-site bulk petroleum handling facilities were decommissioned. Only the warehouse/office building appeared to remain. The building currently occupied by the Oregon State Police was constructed in the late 1980s in the same location as the original Shell warehouse. The warehouse in the south corner of the Shell site first appears in the 1989 aerial photograph.

1.5.10 Former Delphia Bulk Plant

The 1908 Sanborn Fire Insurance Map labeled the north portion of this property as the Columbia River. By 1921 the property appears to have been filled and a small structure was present. The Port of Astoria 1927 utility map indicates the property was vacant. In the 1939 aerial photograph, two ASTs in the south corner of the property, an original warehouse along

Industry Street, and some smaller buildings are visible. A third AST was added between 1957 and 1958 and a fourth AST by 1973. All the visible ASTs are located in the south corner of the property. By 1953, a machine shop was constructed on the northeast side of the former Delphia bulk plant site. The machine shop operated until the early 1980s. In the early 1980s, the Delphia bulk plant office and warehouse operations were moved from the original oil warehouse into the machine shop building. An oil tank farm was installed in the early 1990s directly southwest of this office/warehouse building.

In 1993, the original oil products warehouse along Industry Street was removed and the area was graveled. Wilson Oil, Inc. purchased the Delphia Oil operations (including the buildings and tanks) effective August 1, 2002. Between 2002 and 2006 the four ASTs in the southern corner of the property were removed.

1.5.11 Former Val's Texaco

The 1908 Sanborn Map indicates that the Val's Texaco site was occupied by a boarding house at that time. The 1927 utility map indicates a building was located on the site. The 1939 aerial photograph and Sanborn Fire Insurance maps from between 1921 and 1954 reveal that residences and a grocery store were located at the site. In general the surrounding properties were mostly vegetated. In the 1966 photograph a service station is visible on the former Val's Texaco site. The service station layout appears consistent up to the most recent photograph (from 2001). In the 1995 and 2001 photographs what appears to be a concrete pad in the northeast corner of the site, is likely to be the vault for the ASTs that was installed in approximately 1995. In May 2006 a diesel UST northeast of the service station building and ancillary equipment were removed from the former Val's Texaco site; this included the service islands. The ASTs in the vault are empty, but remain on-site.

1.6 INVESTIGATIVE SUMMARY

Investigations to define the hydrogeology and extent of contamination at the Astoria Area-Wide site have been performed at the site since the 1990s. Some investigations relating to

environmental issues were conducted in the 1980s. The investigations performed prior to development of the PRP group are summarized by facility in Section 1.6.1. A listing of the current work plans and technical memorandums generated by the PRP group is listed in Section 1.6.2.

1.6.1 Previous Investigations

Several investigations and remedial actions were previously conducted at facilities at the Astoria Area-Wide site. These previous site investigations have included UST decommissioning; characterization of soil and ground water at UST, AST, and pipeline release sites; ground-water monitoring; and soil and ground-water treatment activities. The locations of historical soil borings are shown on Figure 1-7. The locations of the petroleum transfer lines are shown in Figure 1-8.

In addition to the following summaries a detailed summary of activities conducted in association with two free product releases is presented in Table 1-1. A 1990 free product release from Harris/Van West was located near the common property boundary with Harris/Van West, Neimi Oil Cardlock, and Qwest. The second free product release occurred in 1997 from Youngs Bay Texaco near the common property boundary with Qwest. The activities associated with these releases are briefly summarized below, but because these releases involved multiple sites, PRPs, investigations, and off-site investigations, the activities are summarized separately in Table 1-1. Figure 1-9 presents the associated explorations.

Youngs Bay Texaco: A Chevron service station operated in the southern area of the Astoria Area-Wide site (Youngs Bay Texaco on Figure 1-10) from the late 1960s until 1990. The station was decommissioned in 1990 and five USTs, product dispensers, product and vent lines, hoists, and the building were removed. In 1990 and 1991, subsurface investigations identified soil and ground-water impacts in the area of the pump islands. DEQ was notified and the site was assigned DEQ Leaking Underground Storage Tank (LUST) File 04-91-0250. In 1992, the USTs were removed. Over the next four years a program of investigation, UST decommissioning, soil treatment, and ground-water monitoring was conducted. The

approximate limits of the remedial excavation are shown on Figure 1-10. Ground water was monitored until 1994. In 1994, DEQ issued No Further Action (NFA) status for the Chevron service station and the monitoring wells were abandoned.

By 1995, the Youngs Bay Texaco had been constructed on the property. The station does not have USTs. ASTs were installed in a below ground vault at the rear of the property. The base of the below ground vault is at the ground level of the adjacent Qwest vehicle service center. In May 1997, an overfill of an AST at Youngs Bay Texaco caused a release of gasoline to the adjacent Qwest property. Due to the alignment of the vent pipes and some confusion with the inventory records, the overspill was not identified until June. In June 1997, the fire department located the overspill in the vault during an investigation of gasoline vapors in the adjacent Qwest building (DEQ Release #97-1497). Over the month, approximately 164 gallons had seeped out of the containment vault into the soil along the sanitary sewer line between the Youngs Bay Texaco and Qwest properties. The remaining gasoline was removed from the vault and the sewer was vented to remove vapors.

Air sparging and soil vapor extraction systems were installed and operated until August 1997. At that time the system was shut down and the compressor was connected to a vent line in the trench to remove soil vapors. In late 1997, in the proximity of this release, Qwest explorations identified minor gasoline range petroleum hydrocarbons in soil and elevated BTEX (benzene, toluene, ethylbenzene, xylenes) concentrations in ground water (beneath the Qwest building immediately down gradient of the release). A detailed chronological listing of activities associated with this release is presented in Table 1-1 and exploration locations in the vicinity of this release are included in Figure 1-9.

Qwest Vehicle Service Center: Qwest decommissioned one UST in place, removed a fuel dispenser, conducted two soil investigations, and completed one remedial excavation at their vehicle service center during 1997. The site investigation conducted prior to the decommissioning identified minor petroleum contamination in soil, with the exception of elevated gasoline range hydrocarbons in the vicinity of the fuel dispenser. Elevated BTEX was detected in two ground-water samples (both samples down gradient of 1997 Texaco

release). Further investigation conducted after the UST decommissioning and fuel dispenser removal/remedial excavation, detected significantly elevated gasoline range hydrocarbons at the northeast and southeast property corners. A detailed chronological listing of activities conducted at Qwest in relative proximity to the 1990 Harris/Van West release and the 1997 Youngs Bay Texaco release is included in Table 1-1. Exploration locations in close proximity to the releases are included in Figure 1-9 The location of the current buildings, former UST, former dispenser, and associated remedial excavation are shown on Figure 1-10. Based on a review of reports concerning the resulting cleanup associated with the tank decommissioning, a NFA letter was issued to Qwest by DEQ in 1998.

Former Chevron/McCall Bulk Plant: The former Chevron/McCall bulk plant had been a heavy oil marine terminal since the late 1920s. From at least the 1940s until the 1960s, tank bottom wastes were placed in open pits in the field behind the bulk plant. The layout of current site buildings, the former facilities and location of the residual tank bottom wastes are shown on Figure 1-11. During the 1980s, environmental issues at the former Chevron/McCall bulk plant focused on tank bottom wastes. In 1984, 52,000 gallons of these wastes were removed. In 1985, most of the remaining tank bottom wastes were removed and the residual waste was consolidated into one pit. In 1987, US Environmental Protection Agency (EPA) conducted a Preliminary Assessment of the bulk plant. Based on the removal of the waste, the non-drinking water-use of the aquifer, and the containment of surface runoff at the site, USEPA recommended No Further Action under Superfund. In 1996, a subsurface investigation identified the Bunker C waste and elevated total petroleum hydrocarbons (TPH) and metals concentrations in shallow soil in limited areas near the tanks as the areas of concern. During the demolition of the tanks and site structures in April 2002, petroleum contaminated soil (PCS) was identified in the area of the former pump building and a previously unknown UST was located.

The contaminated soil from the tank bottom wastes and the tanks was excavated from the former Chevron/McCall bulk plant and disposed of at the Hillsboro Landfill in 2002. During the excavation of the contaminated soils, additional vertical and lateral characterization by visual inspection and shallow test pits was performed. The excavated soils were temporarily

stockpiled and loaded into the trucks for transport to the landfill. Confirmatory closure samples were collected to verify that the contaminated soil had been removed. Excavations did not extend below the water table, however water was encountered in a few instances. There appeared to be a sheen on the water in some excavations. In total, 6,800 tons of soil were removed. The area was then backfilled with imported gravels, soils, and fill material; much of it crushed concrete that formed the walls and foundation of the building formerly occupying Pier 3. A new building, Englund Marine's retail store and service shop, was recently built on top of the previously excavated area.

In May 1993, a diesel pipeline leading from the former Chevron/McCall bulk plant to the piers failed a tightness test and subsurface investigations ensued. Free phase petroleum hydrocarbons were detected migrating to the Columbia River at Slip 2 and a recovery system was installed. The recovery system was designed to recover free product and treat ground water. The system had minimal success, as free product recovery and ground-water treatment were impacted by biological growths in the treatment system. The system operated for only a short time in 1995 before it was shut down.

Former Val's Texaco: The layout of the current site building and former facilities at the former Val's Texaco site are shown on Figure 1-12. At the former Val's Texaco site on the Delphia property along West Marine Drive, 25 gallons of gasoline were spilled near the pump island in 1991. The spill was caused by an attempted theft and occurred after the station had closed for the night. Sorbent material was used to contain the spill. There was no indication that the spill reached a storm or sanitary sewer drain. Five gasoline USTs and one used oil UST were removed from the former Val's Texaco site in October of 1996. The former product lines for these USTs were removed from the pump island dispensers, cut off near the USTs, and capped when new ASTs were installed in 1993 (prior to the UST decommissioning) (PNE, 1994b). Eleven confirmation soil samples were obtained from the UST excavation pit and analyzed for total petroleum hydrocarbon identification (as TPH). Petroleum hydrocarbons were not detected at or above the laboratory reporting limit in any of the samples. Ground water was not encountered in the tank pit.

Other environmental activities conducted at Val's Texaco include removal of the diesel UST, product dispensers, and product piping in August 2006. These activities were not conducted by the PRP group and are discussed further in Section 7.1.10.

Former Delphia Oil Bulk Plant: No previous investigations have been conducted on the former Delphia bulk plant portion of the Delphia property. The layout of the current site buildings and historical facilities at the former Delphia bulk plant are shown on Figure 1-12. Other environmental activities conducted at the former Delphia Oil bulk plant include removal of four ASTs between 2002 and 2006 from the west tank farm. These activities are discussed further in Section 7.1.10.

Former Harris/Van West Service Station: Historically, Harris/Van West operated a service station from the mid-1960s to 1991. The layout of the current site building and historical facilities are shown on Figure 1-13. In 1990, inventory control records indicated losses of product were occurring associated with the gasoline UST/piping system. As a result, the gasoline product lines between the fuel dispensers and USTs were replaced. In October 1990, impacted soil was observed in association with the failed gasoline line. The release was reported to DEQ (File No. 09-90-392).

In December 1990, a tenant in the nearby apartments (now former apartments) reported petroleum-like vapors emanating from her shower drain. Riedel Environmental Services (RES) provided initial response at the request of the City of Astoria (Rittenhouse-Zeman, 1990). Subsequent investigations determined that gasoline was migrating through the soil from the Harris/Van West site into a combined sanitary sewer/storm water line. Impacted soil and free product was also identified in a localized area around the combined sewer line. Gasoline apparently entered the sewer line through holes created by concrete from stakes driven for constructing the retaining wall that ran parallel and directly above the sewer line. Explorations revealed the sewer line appeared to be bedded on and backfilled with native material and preferential pathway migration along backfill was not identified as a concern. Free product samples from the sewer line and from a test pit adjacent to the sewer line (in the

vicinity of where the sewer line first appeared to be impacted) were identified as gasoline by the DEQ laboratory (Rittenhouse-Zeman, 1990).

Follow-up site characterization activities in December 1990 by Rittenhouse-Zeman & Associates, Inc. (RZA) included: installing an initial product recovery well (RW-1/identified as culvert well on Figure 1-13), installing a second recovery well (RW-2, identified as RW-1(F) on Figure 1-13), uncovering and inspecting all product lines, advancing soil borings, installing monitoring wells, and collecting soil and ground-water samples. The initial free product and ground-water recovery system was installed in December 1990 on the Niemi Oil Cardlock site (RW-1/culvert well). A more permanent total free product recovery and ground-water treatment system was installed using RW-1(F) (on Harris/Van West site) in 1991. A ground-water monitoring program was also initiated in 1991. A corrective action plan (CAP) was submitted to the DEQ in October 1992 recommending excavation and off-site soil aeration of petroleum-contaminated soil followed by quarterly monitoring. Formal decommissioning of the USTs and treatment of excavated soil were conducted in 1993. The approximate limits of the UST excavation and the remedial excavation are shown on Figure 1-13 (Pacific Northern Environmental, 1996). The initial free product recovery system (installed in Culvert Well (N) on Figure 1-13 which during initial reports was called RW-1) recovered approximately 50-60 gallons of free product and treated approximately 8,000-gallons of ground water. The subsequent free product recovery/ground-water treatment system was installed in RW-2 (labeled as RW-1(F) on Figure 1-13). RW-2/RW-1(F) was removed during the remedial excavation activities and a final recovery well identified as "Sump/Pipe" was installed during backfilling of the remedial excavation. The ground-water treatment system in Sump/Pipe operated until March 1994 when the operation was permanently discontinued due to the assessment that impacted ground water from off-site sources was being pulled into the recovery well. Ground-water quality was monitored beneath the Harris/Van West site for approximately five years.

The gasoline release at the former Harris/Van West service station, located adjacent to and immediately upgradient of the Niemi Oil Cardlock facility, appeared to have migrated beneath a portion of the Niemi Oil Cardlock facility. Specifically, petroleum impacted soil and free

product (identified as gasoline) were identified in the southwest corner of the Niemi Oil Cardlock during the initial response activities. A more detailed summary of the historical investigations/events conducted in relation to the Harris/Van West 1990 release are presented in Table 1-1.

Port of Astoria: The Port has leased properties to various tenants through the years. The types of operations conducted at some of these properties suggest that there is the potential for releases to have occurred. The layout of historical facilities on Port properties is shown on Figure 1-14.

Astoria Oil Services: Astoria Oil Services operated at the north end of Pier 3 at the Port. A previous soil investigation conducted at Astoria Oil Services indicated that one area sampled contained soils impacted with VOCs. The impacted soil from this former waste management area was excavated and disposed of in 1986.

Port Maintenance Shop UST: A 1,000-gallon UST was decommissioned in 1993 on the north side of the Port maintenance shop. The tank had been previously used for diesel and gasoline. The Port encountered PCS and perched water overlying clayey layers in the tank excavation at the time of decommissioning. The release was cleaned up by overexcavation of the tank excavation. PCS was removed until clean sidewalls and bottom soils were exposed in the excavation. The remaining soils had levels of petroleum hydrocarbons below the DEQ Level II matrix cleanup levels (Neil Shaw, 1993a). Impacted soil was treated on Pier 3 using bioremediation and land-farming techniques. Subsequently, the remedied soil was reported to have been used as fill upland of Slip 1.

Former Furniture Manufacturing and Steel Works Facilities: No previous environmental investigations have been conducted at these facilities.

Niemi Oil Cardlock: No environmental investigations were conducted at the site prior to 1990. Environmental investigations performed at the Niemi Oil Cardlock site in 1990 and 1991 that were discussed above under the former Harris/Van West service station site, are

presented in detail in Table 1-1, and are briefly summarized here. As discussed above, free product that was released into the subsurface soils and ground water entered the combined sewer line located between the properties. A product recovery well (culvert well/RW-1) was installed at the Niemi Oil Cardlock site in 1990 (the recovery well currently remains at the site). Quantitative analysis of free product sampled from inside this recovery well indicated the presence of gasoline and diesel range hydrocarbons. Fuel fingerprint analysis of two free product/ground-water samples indicated the hydrocarbons were characteristic of gasoline (RZA, 1991). Soil and ground-water samples from explorations around the Niemi Oil Cardlock site showed detections of gasoline and diesel-range hydrocarbons. Exploration locations are shown on Figure 1-7. The layout of current features and historical facilities at the Niemi Oil Cardlock site are shown on Figure 1-13.

In 1996 DEQ conducted an investigation at the Astoria Area-Wide site that included one boring on this site. In 1997 and 1998 Niemi Oil completed subsurface investigations beneath portions of the Niemi Oil Cardlock site (PNG Environmental, 1997). Quantitative analysis including fuel fingerprint of samples from inside this recovery well concluded the hydrocarbons were characteristic of gasoline (PNG, 1998). Soil and ground-water samples from temporary borings around the Niemi Oil Cardlock site showed detections of gasoline and diesel-range hydrocarbons. The primary hydrocarbon constituent was identified as gasoline with the gasoline range hydrocarbons carrying over into the diesel hydrocarbon range (PNG, 1998). Hydrocarbons characteristic of diesel were also identified but primarily in the northeast portion of the Niemi Oil Cardlock site (PNG, 1998).

Former ExxonMobil/Niemi Oil Bulk Plant: DEQ conducted some soil sampling at the former ExxonMobil/Niemi Oil bulk plant property in 1996 and elevated levels of gasoline and diesel-range hydrocarbons were found. DEQ identified a need for further investigation but none had been performed prior to the beginning of the Astoria Area-Wide RI/FS work. The layout of historical facilities at the former ExxonMobil/Niemi Oil bulk plant is shown on Figure 1-14.

Former Shell Bulk Plant: By 1974, all above ground tanks and other above ground on-site bulk petroleum handling facilities were decommissioned and removed from the Portway site. No environmental investigations prior to this RI were conducted at the former Shell bulk plant facility. The layout of the current structures and former Shell bulk plant facilities are shown on Figure 1-14.

1.6.2 Current Investigation

The Astoria Area-Wide PRP Group conducted additional remedial investigations in response to the Order issued by DEQ. The scope of the investigations was determined by the RI/FS Work Plan (*EnviroLogic Resources*, 2002b), which served as both a Phase 1 Work Plan and as a general guide for subsequent investigations. The RI/FS Work Plan was amended by several task-specific work plans that detailed the methods and procedures to be used to conduct that task. The following task-specific work plans were prepared and approved by DEQ to amend the RI/FS Work Plan and direct the scope of additional investigations:

- Interim Remedial Action Measures Work Plan, Former McCall Oil Bulk Facility, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated July 26, 2002.
- Storm Water Monitoring Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated March 26, 2003.
- Phase 1 Ground-Water Assessment, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated July 2, 2003.
- RI/FS Work Plan Addendum, Phase 2 Soil Characterization, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated July 28, 2003.
- Vapor Inhalation Pathway Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated December 12, 2003.
- Historical Shell/Niemi Oil/Mobil Petroleum Pipelines Investigation and Decommissioning Work Plan, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated December 18, 2003. (cover letter to DEQ dated January 12, 2004)
- Hydrocarbon Seep IRAM Specifications, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated December 22, 2003.
- RI/FS Work Plan Addendum, Slip 2 Hydrocarbon Seep Interim Action Removal Measures Work Plan, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated August 5, 2004. (commonly known as Upland Data Collection Work Plan)

- IRAM As-Built Drawings, Hydrocarbon Seep IRAM at Slip 2, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated December 17, 2004.
- IRAM Work Plan, Port of Astoria Property Redevelopment, Former Mobil/Niemi Oil Bulk Plant, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated December 23, 2004.
- IRAM Work Plan Addendum, Port of Astoria Property Redevelopment, Former Mobil/Niemi Oil Bulk Plant, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated February 9, 2005.
- Work Plan for Sub-Slab Site-Specific Assessment of Subsurface Vapor Intrusion to Indoor Air, Port of Astoria Office Building, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated June 9, 2005.
- Work Plan for Additional Upland Data Collection, Slip 2 Hydrocarbon Seep Interim Removal Action Measures, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated June 30, 2005.
- RI/FS Work Plan Addendum, Ecological Risk Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated September 22, 2005.
- RI/FS Work Plan Addendum, Human Health Risk Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, October 10, 2005.

These work plans were submitted to DEQ for comment prior to initiation of the work. The data collected as part of the implementation of the task-specific work plans were presented in technical memoranda upon completion of the work. In addition, the methods and procedures used to collect the data are described in task-specific technical memoranda. These memoranda documented the methods and procedures used to collect the data and provided the DEQ with the raw data used for interpreting site conditions at the Astoria Area-Wide site. Technical memoranda submitted to the DEQ have included:

- Technical Memorandum, Phase 1 Source/Soil Characterization, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated January 30, 2003.
- Technical Memorandum, Beneficial Land and Water Use Surveys, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated February 21, 2003.
- Technical Memorandum, Remedial Investigation/Interim Removal Action Measures, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated August 5, 2003. (relating to sediments)

- Technical Memorandum, Geophysical Investigation, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated November 25, 2003.
- Technical Memorandum, Storm Water Sampling – Third Quarter 2003, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated January 28, 2004.
- Technical Memorandum, Quarterly Ground-Water Monitoring, Fourth Quarter 2003 – 1st Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated March 15, 2004.
- Technical Memorandum, Storm Water Sampling – Fourth Quarter 2003, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated March 17, 2004.
- Technical Memorandum, Quarterly Ground-Water Monitoring, First Quarter 2004 – 2nd Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Site, Astoria, Oregon, dated April 23, 2004.
- Technical Memorandum, Phase 1 Monitoring Well Installation, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated April 30, 2004.
- Technical Memorandum, Storm Water Sampling – First Quarter 2004, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated May 20, 2004.
- Forensic Analysis of Samples of Separate-Phase Hydrocarbon from the Astoria Area-Wide Petroleum Site, Astoria, Oregon (2003 and 2004 Samples), dated June 17, 2004.
- RI/FS Technical Memorandum, Historical Shell/Niemi Oil/Mobil Petroleum Pipeline Investigation and Decommissioning Report, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated July 30, 2004.
- Technical Memorandum, Quarterly Ground-Water Monitoring, Second Quarter 2004 – 3rd Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Site, Astoria, Oregon, dated August 12, 2004.
- RI/FS Technical Memorandum, Level 1 Ecological Risk Assessment, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated August 12, 2004.
- Technical Memorandum, Phase 2 Soil Characterization, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated November 1, 2004.
- Technical Memorandum, Quarterly Ground-Water Monitoring, Third Quarter 2004 – 4th Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated November 23, 2004.

- Technical Memorandum, Storm Water Sampling – Fourth Quarter 2004, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated December 20, 2004.
- Technical Memorandum, Vapor Intrusion Pathway Assessment, Port of Astoria Office Building, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated April 29, 2005.
- Technical Memorandum, Slip 2 Hydrocarbon Seep Interim Removal Action Measures, Upland Data Collection, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated June 14, 2005.

Critical to the successful completion of the additional remedial investigations was the construction of a database management system to store and retrieve environmental data associated with the Astoria Area-Wide site. The database contains data for soil, ground water, storm water, sediment, and soil gas samples collected at the Astoria Area-Wide site since the RI began.

2.0 STUDY AREA INVESTIGATION

This section summarizes the task-specific investigations performed as part of the RI. These include source characterization, soil investigations, ground-water investigations, surface-water and sediment investigations, storm-water investigations, beneficial land and water use survey, and IRAMs.

2.1 SOURCE CHARACTERIZATION/INVESTIGATION

The potential source areas at the Astoria Area-Wide site and the petroleum hydrocarbon constituents in the soil, ground water, sediment, storm water, and air/soil gas have been investigated as described below. The specific potential sources of petroleum hydrocarbons in the environment at the Astoria Area-Wide site were identified based on historical records and known uses, site reconnaissance, and historical site investigations (Section 1.6). Data were collected in order to identify chemicals of potential concern (COPC) and characterize the nature and extent of COPC from releases that may have occurred during former site operations. Review of laboratory data indicated petroleum products (gasoline, diesel and/or heavy oil) and their constituents are the primary COPC.

2.2 SOIL INVESTIGATIONS

A soil-boring program was developed to characterize potential source areas and identify suitable locations for the placement of monitoring wells in the shallow water-bearing zone at the Astoria Area-Wide site. Soil samples were collected from borings to evaluate the presence of hazardous substances associated with spills and past practices. Soil samples were collected for laboratory analysis from the unsaturated zone and/or from the zone of water-table fluctuation. The samples were field-screened with a photo-ionization detector (PID), examined for lithology, as well as for visual evidence of petroleum hydrocarbon impacts. The locations of soil borings completed during RI activities are shown on Figure 2-1. The soil investigations are summarized below and discussed in more detail in Sections 2.2.1, 2.2.2, and 2.2.3. Soil analytical results are discussed in detail in Section 6.0.

Phase 1 soil investigation activities conducted in 2002 consisted of completing and sampling 139 soil borings and excavating two test pits. The two test pits were excavated at the former Shell bulk plant in an attempt to locate the petroleum distribution pipelines. No petroleum distribution lines were identified in either test pit. A total of 50 borings were drilled as part of the Phase 2 soil and ground-water investigation during August and September 2003, and March 2004. Based on a review of all the boring logs most of the Astoria Area-Wide site is underlain by grey and light brown sand fill. Lenses of silt and clay are present in the fill as well as gravel, wood, and other organic material. Native river deposits (alluvium) and the Astoria Formation underlie the fill material at depths of about 10 and 50 feet, respectively. A description of the Astoria Formation is included in Section 3.5. Results from the soil investigations are reported in the Phase 1 and Phase 2 Soil technical memoranda (*EnviroLogic Resources*, 2003a and *EnviroLogic Resources*, 2004i).

Additional soil characterization was completed in 2004 and 2005 as part of the upland characterization and a pipeline investigation. The upland characterization consisted of 35 CPT/ROST® (cone penetration test/rapid oscillation screening tool) explorations and 12 soil boring explorations. The pipeline investigation consisted of five soil boring and four test pit explorations. Results from the CPT/ROST® explorations are reported in the Slip 2 Hydrocarbon Seep Interim Removal Action Measures Technical Memorandum (*EnviroLogic Resources*, 2005g). The results from the upland characterization have been incorporated into this report, with analytical data presented in Section 6.0. The results of the pipeline investigation are presented in the Historical Shell/Niemi Oil/Mobil Petroleum Pipeline Investigation and Decommissioning Report (HartCrowser, 2004).

2.2.1 Phase 1 and 2 Soil Investigations

Soil samples were collected from the Phase 1 and 2 soil borings. The majority of the samples were analyzed for hydrocarbon identification and follow-up quantification as appropriate for VOCs and SVOCs. Selected samples were analyzed for an expanded list of constituents. No samples were analyzed from TP-900 and TP-901. Results of Phase 1 activities were used to

develop the Phase 2 work plan. Phase 2 soil samples were generally analyzed for the same petroleum constituents. Soil boring logs are included in Appendix B.

Results of Phase 1 and 2 activities generally identified PCS in locations associated with former facilities and light non-aqueous phase liquid (LNAPL). This generally includes the former Val's Texaco, former Delphia bulk plant, Niemi Oil Cardlock, former Shell bulk plant, and the area of the LNAPL plume near the former ExxonMobil/Niemi Oil bulk plant, the McCall pipelines and Port properties extending to Slip 2. Gasoline and diesel range petroleum hydrocarbons were the primary constituents identified.

2.2.2 Pipeline Characterization

Soil characterization along the ExxonMobil/Niemi Oil/Shell pipelines was conducted in March and April 2004. Characterization consisted of five push-probe soil borings and four test pits. Selected soil samples were submitted for analysis of petroleum hydrocarbons, and select samples were submitted for analysis of VOCs and SVOCs. In general, the laboratory analysis detected minimal concentrations of petroleum hydrocarbons. Test pit locations (EX-1 to EX-4) are shown on Figure 2-2 and push probe soil boring locations (SB-915(S) to SB-919(S)) are shown on Figure 2-1.

2.2.3 Upland Characterization

CPT/ROST® explorations were conducted in September 2004 to further delineate the extent of PCS upland of the hydrocarbon seep. CPT/ROST® exploration techniques are in-situ, and therefore, do not generate soil samples. However, continuous logs of lithology and petroleum contamination are generated based on cone penetration resistance and laser signal response, respectively. Generally, the petroleum contamination identified was consistent with previous explorations. The Fugro GeoSciences, Inc., report, that includes the CPT and ROST® logs, is presented in Appendix C.

Additional upland characterization was conducted in September 2005 to further delineate the extent of PCS and LNAPL in the vicinity of Pier 2 and at the former ExxonMobil/Niemi Oil bulk plant. Twelve additional soil borings were completed in the vicinity of Pier 2 and one additional soil boring at the former ExxonMobil/Niemi Oil bulk plant. Select samples were submitted for analysis of petroleum hydrocarbons. Generally these two additional phases of exploration allowed for better delineation of the extent of PCS and LNAPL in the vicinity of the LNAPL plume. The locations of the CPT/ROST® explorations are shown on Figure 2-3.

2.3 GROUND-WATER INVESTIGATIONS

A total of 94 ground-water samples collected from 86 unique temporary wells were submitted for analysis during the Phase 1 ground-water investigation. The results of the Phase 1 activities were used in developing a ground-water monitoring program at the Astoria Area-Wide site. Thirty-six monitoring wells were installed and sampled for four consecutive quarters between October 2003 and July 2004 as part of the ground-water monitoring program. The monitoring well locations are shown on Figure 2-1. The ground-water investigation and monitoring activities are summarized below. Ground-water analytical results and LNAPL characterization are discussed in detail in Section 6.0. The monitoring well logs are included in Appendix B.

2.3.1 Phase 1 Ground-Water Investigation

Initial one-time reconnaissance ground-water samples were collected from temporary wells installed in the Phase 1 soil borings. The majority of the ground-water samples collected from beneath the Astoria Area-Wide site were analyzed for BTEX, SVOCs, and lead. Select Phase 1 ground-water samples were analyzed for an expanded list of VOCs, metals, hydrocarbon identification, PCBs, and formaldehyde, depending on the nature of the source being investigated. Results from the Phase 1 ground-water activities are presented in the RI/FS Work Plan Addendum, Phase 1 Ground-Water Assessment (*EnviroLogic Resources*, 2003f).

A review of the Phase 1 ground-water data suggested that three primary areas of impacted ground water are present beneath the site: the eastern, central, and western plumes. The eastern plume is located beneath the former Val's Texaco, former Delphia bulk plant, and the former Shell bulk plant facilities. The ground water in the eastern plume is impacted by dissolved gasoline, diesel, and oil constituents. During these activities LNAPL was not identified in the eastern plume, but LNAPL was identified during subsequent work.

The central plume is located beneath the northwestern property corner of the former Harris/Van West service station, the Niemi Oil Cardlock facility and easternmost portion of the Qwest vehicle service center, beneath Industry Street and the Port property southeast of Portway. Dissolved phase gasoline and diesel constituents are identified in this plume.

The western plume is located beneath the former ExxonMobil/Niemi Oil bulk plant, Portway, the McCall petroleum distribution lines and the Port office building near the historical McCall pipeline release, and beneath the southeastern (landward) portion of Slip 2. LNAPL and dissolved phase gasoline and diesel constituents are identified in this plume. The hydrocarbon seep into Slip 2 is part of the LNAPL portion of the western plume.

The purpose of the reconnaissance ground-water sampling was to determine the optimal location of monitoring wells for quarterly ground-water monitoring. Results from quarterly ground-water sampling and subsequent characterization are more accurate indicators of ground-water quality and LNAPL presence. Therefore the understanding of these impacted areas was refined and subsequently referred to as an area of concern. Areas of concern are discussed further in Section 5.0 and the extent of impacted ground water and LNAPL are discussed in Section 6.0.

2.3.2 Quarterly Ground-Water Monitoring

A ground-water monitoring network and program was developed based on data collected from the Phase 1 RI field activities and historical information documented in the RI/FS Work Plan (*EnviroLogic Resources*, 2002b). The objectives of the monitoring program were to collect

sufficient data to characterize the native ground water and the extent of ground-water contamination present at the Astoria Area-Wide site, identify potential sources, and to provide an understanding of the ground-water flow directions and gradients beneath the study area.

Thirty-six monitoring wells were installed at the Astoria Area-Wide site in 2003. Ten wells already existed from previous investigations upland of the hydrocarbon seep in Slip 2. The results of the monitoring-well installation fieldwork are provided in the Technical Memorandum, Phase 1 Monitoring-Well Installation (*EnviroLogic Resources*, 2004c). The reasoning behind the monitoring-well locations is discussed in the Phase 1 Ground-Water Assessment (*EnviroLogic Resources*, 2003e). Ground water was generally encountered between 7 to 11 feet below ground surface (bgs) at the Astoria Area-Wide site, except along West Marine Drive, where due to the rise in ground elevation the depth to ground water ranged from 14 to 23 feet bgs. The apparent ground-water flow direction at the Astoria Area-Wide site is generally to the northwest and toward Pier 2. The depth to product, product thickness, and depth to water were measured monthly for a period of one year (2003 to 2004).

The characterization of the ground-water conditions beneath the Astoria Area-Wide site included four quarterly monitoring events starting in the fourth quarter 2003 (1st round) and finishing in the third quarter 2004 (4th round). The ground-water quality sampling of wells in the monitoring-well network was conducted by the same field geologist to minimize introduction of potential variables that could affect comparability of the data among the wells. All of the wells were sampled during each sampling event unless they contained measurable LNAPL. The apparent thickness of LNAPL was recorded when encountered. This information is presented in detail in Section 6.0.

2.3.3 Characterization of the Aquifer System

Hahn & Associates originally conducted an aquifer test in the upland area in 1995. Due to the limited information available from this test, tidal elevation data were collected between September and December 2004 to obtain additional information to characterize the hydraulic

properties of the shallow aquifer. An evaluation of the results of these activities is discussed in Section 4.0 of this report.

2.4 SEDIMENT AND SURFACE WATER INVESTIGATIONS

Sediment sampling was performed in 2003 at the head of Slip 2 in the area of the hydrocarbon seep. Two sediment samples were collected in 2003 from the southeast corner of Slip 2 – one inside the containment boom area and one outside of the containment boom area. The Technical Memorandum, Sediment Sampling (*EnviroLogic Resources*, 2003d) describes the results of the sediment sampling including the methods and procedures, analytical results, and a preliminary analysis of petrogenic and pyrogenic PAHs in the sediment samples.

In 2006, five surface water samples and seven additional surface sediment samples were obtained for use/support in the Level III Baseline Ecological Risk Assessment. The preliminary results and findings are presented in the Preliminary Results for Sediment, Water Column Sampling, and Bioassay, Ecological Risk Assessment (Kennedy/Jenks Consultants, 2006), and in the Ecological Risk Assessment (Appendix I).

2.5 STORM WATER MONITORING

An investigation of the storm water system and storm water discharge was performed at the Astoria Area-Wide site. The storm water catchments and their outfalls were surveyed and documented, and the surface water pathways were evaluated. The piping system is shown on Figure 2-4. Information obtained during Phase 1 work identified two representative outfalls for monitoring, Outfall #2 in Catchment Area 2 and Outfall #6 in Catchment Area 4. A description of the storm water drainage catchments and the quarterly storm water-sampling program are documented in the Work Plan, Storm Water Monitoring (*EnviroLogic Resources*, 2003c).

The results of storm water sampling performed at the Astoria Area-Wide site are provided in the four technical memoranda documenting the quarterly storm water monitoring events

(*EnviroLogic Resources*, 2004a, 2004b, 2004d and 2004g). Storm water samples were collected from the Outfall #2 sampling location and Outfall #6. As shown on Figure 2-4, the sampling location for Outfall #2 was the first catch basin upstream of the outfall. The actual outfall could not be sampled due to the inability to locate the exact discharge point. A dye test performed in January 2003 indicated the approximate location of the discharge area within the riprap on the bank of Slip 2. After rerouting of this storm sewer, samples were collected from the relocated Outfall #2. The methods and procedures and a summary of the storm water analytical results are provided in each of the storm water technical memoranda and included in Section 6.0.

2.6 BENEFICIAL LAND AND WATER USE SURVEY

The current and reasonably likely future beneficial land and water uses within the RSA were identified as part of the evaluation of potential pathways for human or ecological receptors to be exposed to petroleum compounds encountered at the site. The beneficial use determinations are included in the Technical Memorandum, Beneficial Land and Water Use Surveys (*EnviroLogic Resources*, 2003b).

A summary of the beneficial land and water uses, including updated information is included in Section 9.0. Land use within the RSA is primarily commercial industrial. A water-rights search performed as part of the Beneficial Land and Water Use surveys showed that no water rights exist within or near the locality of the facility. Results of the ground water well survey did not identify any ground-water supply wells within the RSA or surrounding area. Ground water is not likely to become a water-supply source in the foreseeable future because all water for facilities in the area is supplied by the City of Astoria and because on site water quality parameters indicate ground water is generally of poor quality for potable use (see Section 4.0).

Surface waters bordering the Astoria Area-Wide site include the Columbia River on the east and northwest and Youngs Bay to the west and southwest. Beneficial surface water uses include commercial navigation, commercial and recreational fishing, aquatic life/habitat,

recreation, and aesthetic quality. Surface water in the vicinity of the Astoria Area-Wide site is zoned aquatic development (City of Astoria, 2002).

2.7 IRAMs

Several interim remedial action measures have been completed during the RI at the Astoria Area-Wide site. The IRAMs completed include bunker C and related contaminated soil removal from the former Chevron/McCall bulk plant, rerouting of the storm water piping system near Slip 2, decommissioning of USTs at the former ExxonMobil/Niemi Oil bulk plant, investigation and decommissioning of the Shell/Niemi Oil/ExxonMobil petroleum pipelines, LNAPL recovery, Slip 2 boom replacement, soil removal upland of Slip 1, installation of an upgraded HVAC system at the Port of Astoria main office building, and former ExxonMobil/Niemi Oil bulk plant IRAMs for redevelopment activities. IRAMs are discussed in further detail in Section 7.0.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The physical characteristics and environmental processes of the area surrounding the Astoria Area-Wide site are important in the understanding of the stratigraphy and hydraulic factors prevailing at and beneath the site. The regional environmental setting and human alteration of the setting have impacted the soils, sediments, and hydraulics of ground-water flow at the Astoria Area-Wide site.

The RSA is within the western margin of the Oregon Coast Range, near the mouth of the Columbia River. The Coast Range is a north-south trending range with a maximum elevation of about 5,000 feet above mean sea level (msl), extending from the latitude of Coos Bay northward into Washington State. Generally, mountain passes through the range reach about 1,000-feet elevation. The Coast Range in Oregon is bounded on the east by the Willamette Valley and on the west by the Pacific Ocean.

The City of Astoria is situated on a peninsula (Astoria Peninsula) that protrudes westward into the mouth of the Columbia River and estuaries of Youngs Bay. The Astoria Area-Wide site is located on the northwest side of this peninsula. North of the peninsula is the Columbia River. South and west of the peninsula is Youngs Bay. Across Youngs Bay and to the west are fine-grained bay sediments and young, active dunal sands (Sweet, 1977; Schlicker and others, 1972; and Niem and Niem, 1985). Much of these low-lying areas are at, or just above sea level. Because of the low elevation, many areas associated with bay sediments are marshy or just above the water table.

Within a one-mile radius of the Astoria Area-Wide site is industrial, commercial, recreational, and residential development. The industrial development is generally related to marine activities. The commercial development includes hotels, restaurants, gas stations, and other retail businesses. Recreational development includes a boat mooring basin, greenways, walkways, and parks. Residential development includes apartments and houses. The beneficial land and water use survey is described in detail in a 2003 technical memorandum (*EnviroLogic Resources*, 2003b) and summarized in Section 9.0.

3.1 SITE TOPOGRAPHIC FEATURES

In the vicinity of the Astoria Area-Wide site there is a distinct slope to the northwest that dominates the topography (Figure 1-1). The west flank of this ridge descends steeply toward the southeast side of West Marine Drive. The topography of the ridge flank that descends to West Marine Drive has been altered by residential and commercial development. In particular, the natural slope has been cut away for building pads and roadways, and filling has taken place to make West Marine Drive. West Marine Drive is essentially the southeast boundary of the Astoria Area-Wide site. Site-specific topographic features are primarily a result of human activities that can be divided into two topographic areas: the area immediately northwest of West Marine Drive (at an elevation of approximately 30 feet msl); and the rest of the site representing the results of fill placement and pier construction to create land (at a general elevation of approximately 15 feet msl). There is a steep slope between these two areas and retaining walls are present along the northwest side of some of the properties along West Marine Drive.

Dredge materials generated from the Columbia River have been used as the fill material in the Astoria area. Often times, large rocks or riprap were placed along the seaward limit of the dredge sand fill to protect it from erosion. The dredged materials typically are fairly uniform fine to medium sand that have been transported by the Columbia River from the surrounding mountains as well as from upland areas. The dredge fill material was placed on top of alluvial sediments or the Astoria Formation. Dredging also alters the underwater topography. The Columbia River Channel, Port of Astoria slips, and the West Mooring Basin that occupy the westernmost part of the RSA are dredged routinely.

3.2 METEOROLOGY

The climate of the Astoria area is mild and cool. January is typically the coldest month, with an average high temperature of 48°F and average low temperature of 37° F. The hottest month is typically August, with an average high temperature of 69° F and an average low temperature

of 53° F. The extreme high temperature was 100° F in 1961. The average high and low temperatures by month are shown on Figure 3-1 (National Oceanographic and Atmospheric Administration, 2005).

Precipitation occurs through-out the year. Winter precipitation averages 10-inches per month and decreases to a 1.15-inch average during July, the driest month. The wettest month can be November, December, or January. Snowfall is rare in Astoria. At higher elevations in the Coast Range snowfall accumulation is common during the winter months. The average yearly rainfall between 1971 and 2000 is 65 inches. The average monthly rainfall from 1971 to 2000 is shown on Figure 3-1.

Wind speeds average 8- to 10-miles per hour each month of the year. Winter wind directions are typically easterly, but become northwesterly during the summer months. In the spring and fall, wind directions predominantly are southwesterly or southeasterly (Weather Underground, 2002).

3.3 NATURAL RESOURCES and BENEFICIAL USES

The natural resources of the area include surface water, ground water, air, sediment, aquatic life, and soils for development uses. All of these resources are potentially affected by the release of the petroleum hydrocarbon constituents at the Astoria Area-Wide site. Although the extent of the area affected for each natural resource is different.

Ground water within the Astoria Area-Wide site and surrounding areas is currently not used for drinking, other domestic uses, or industrial purposes. A well survey was conducted and no ground-water supply wells were located within the RSA. The survey was conducted using Oregon Water Resources Department (WRD) on-line search tools. The WRD search included all Township 8 North, Range 10 West, Section 12 and 13 and Township 8 North, Range 9 West, Section 7. Users in the area rely exclusively on the municipal water system to meet drinking water and other water needs. The beneficial land and water use survey is described

in detail in a 2003 technical memorandum (*EnviroLogic Resources*, 2003b) and summarized in Section 9.0.

Surface waters bordering the RSA include the Columbia River on the northwest and Youngs Bay to the west. Beneficial surface water uses include commercial navigation, commercial and recreational fishing, aquatic life/habitat, recreation, and aesthetic quality. The river and sediment pore water serve as or contribute to habitat for aquatic life, including mammals, birds, fish, macroinvertebrates, and benthic organisms. Surface water on the site includes Slips 1 and 2, which are used primarily for navigable waters/commercial marine use.

3.4 REGIONAL GEOLOGY

The Coast Range is composed primarily of Tertiary volcanic and sedimentary rocks. The basement rocks are the Siletz River Volcanics, which are oceanic basalts that originated as seamounts on the ocean floor. Approximately 55 million years ago (mya), the accreted Siletz terrane began subsiding, while areas to the east were uplifted. The uplift resulted in the erosion and incursion of large volumes of sediment into the subsiding coastal area. The northern Coast Range subsided about 33 mya, with development of a marine environment with brackish embayments and development of the classic continental shelf and slope profiles. The subsidence of the northern Coast Range led to the burial of the Siletz Volcanics by the Yamhill Formation, representing continental shelf muds and silts (Wells and Others, 1983). These formations were in turn overlain by the Tillamook Volcanics (subaerial basalt flows) and the 5,000-feet thick Nestucca Formation, representing deep-water deposition of muds and silts. The Cowlitz Formation was deposited in shallow brackish waters at approximately the same time. Overlying the Cowlitz Formation is the Keasey Formation (Niem and Van Atta, 1973), composed of fine volcanic ash deposited in a deep-water setting (Niem and Niem, 1985; Orr and Orr, 1999).

Approximately 33 mya, shallow-water conditions developed in the northern Coast Range, with shifting deltas and brackish backwater bays. The Astoria Formation, which is the predominant rock unit of the Astoria Peninsula, is composed of fossiliferous sandstones and siltstones. The

fossil assemblage is suggestive of a shallow to very shallow marine environment (Niem and Niem, 1985; Orr and Orr, 1999; Wells and Others, 1983; Niem and Van Atta, 1973).

About 15 mya to the present is characterized by general uplift and retreat of the marine shoreline from the area now characterized as the northern Coast Range. During this time period, flows of the Columbia River Basalt Group flowed through the Columbia River valleys and along the channel of the Columbia River, until they reached the ocean margins. The basalt flows are typically found at higher elevations, including as the capping unit on the Astoria Peninsula. Also present near the top of the Astoria Peninsula is the Troutdale Formation (Niem and Niem, 1985; Niem and Van Atta, 1973). Alluvial/Bay muds and tidal flats are present along portions of the Columbia River mouth. Active dunes and shore sands are present along the Columbia River spit and surrounding shoreline areas (Sweet, 1977; Reckendorf and others, 2001).

3.5 REGIONAL HYDROGEOLOGY

The Columbia River is the predominant river of the Pacific Northwest, draining very large areas consisting of the Columbia Plateau, Deschutes Basin, Willamette Valley, Owyhee Region, Snake River Basin, and highlands surrounding those basins. Between 1997 and 2002, Columbia River mean daily streamflows measured near Quincy, Oregon, varied between 117,000 and 400,000 cubic feet per second (United States Geological Survey, 2002). Other smaller rivers and creeks flow out of the Northern Coast Range directly to the ocean or to the Columbia River and its estuary.

In the lower reach of the Columbia River and within the estuaries at the mouths of the smaller rivers and creeks, water levels rise and fall in response to tidal forces. The stream gage at Quincy in the Columbia River shows that between early January 2002 and mid-February 2002, Columbia River gage levels varied from 0 to 8.1 feet (Oregon Climate Service). The tidal influence in the Columbia River extends upstream approximately 130 river miles to Bonneville Dam in the center of the Cascade Range. The tidal influence coupled with dam releases results in daily changes in the gradient of the river and sediment transport processes.

Ground-water use is generally limited in the Coast Range to domestic wells because of low permeability of bedrock units (Frank, 1970). Ground water in some of the bedrock units bears relatively high concentrations of sodium and chloride due to connate water present in the marine deposits. Ground-water use is also generally limited in the mud flats, marine beach deposits, and sand dune areas, because of water quality issues and possible seawater intrusion into wells.

On a regional level the ground water is recharged from rain fall and snow melt in the Coast Range and Cascade Range. Ground water discharges to the numerous streams that are a part of the Columbia River watershed. No specific regional horizontal or vertical ground-water gradient information was identified during the RI process.

4.0 LOCAL HYDROGEOLOGY

The hydrogeology of the Astoria Area-Wide site has been investigated by collecting data throughout the remedial investigation process. During field exploration activities, lithologic logs for monitoring wells (MW) and borings (SB) were maintained. In addition, depth-to-ground water and ground-water quality parameters were monitored and recorded during the quarterly ground-water monitoring events. The results of these activities identified three hydrostratigraphic units of interest beneath the site. These units, comprising the shallow water-bearing zone, are the dredge sand fill, native alluvial deposits, and to a limited degree, the Astoria Formation.

The conceptual hydrogeologic site model for the Astoria Area-Wide site includes rain and storm water infiltrating into the shallow water-bearing zone. Rain and storm water are also directed to catch basins that discharge to nearby surface water bodies (Figure 2-4). After water has infiltrated into subsurface soils it flows as ground water. The direction of ground-water flow at the site is to the north and northwest, toward the nearby Columbia River. Ground water then discharges to surface water. The discharge of ground water and the near-shore interaction between ground water and surface water is strongly influenced by the tides.

As discussed in Section 2.2 the site is underlain by dredge fill deposits, native alluvial deposits, and the Astoria Formation. The data suggest the dredge fill, native alluvial deposits, and Astoria Formation are hydraulically connected. The ground water within these deposits discharges either to an adjacent unit (e.g., ground water in native alluvial deposits along West Marine Drive discharges to dredge fill) or to surface water adjoining the site (Youngs Bay and the Columbia River).

Figure 4-1 illustrates the site hydrogeology and average depth to water. The shallow water-bearing zone (the zone of interest) was generally identified in the upper 5 to 15 feet of the site, except in the southeast portion of the site along West Marine Drive. In the southeast portion of the site near the former Val's Texaco the shallow water-bearing zone was encountered at approximately 20 to 25 bgs. However, ground water was not encountered in a soil boring that

extended to 25 feet bgs in the southeast corner of the site at Youngs Bay Texaco; no monitoring wells are currently located in this portion of the Astoria Area-Wide site.

A visual understanding of the site hydrostratigraphy from a historical perspective can be obtained by looking at the 1915, 1920, and 1939 historical photographs shown on Figures 4-2 and 4-3. The 1915 photograph shows what is interpreted to be Pier 1 and Pier 2. The road access to the piers is over water. The wood pile walls in the foreground and the fact that water is present on the shore side of the pile wall all imply land in the port area was constructed by placing fill. The raised road access is believed to be in the approximate location of present day Portway. The 1920 photograph shows that the entire site west of West Marine Drive was at one time beneath water and all the present day land northwest of West Marine Drive was constructed using fill. The 1939 aerial photograph gives some perspective on the areal extent of the fill placed at the site and shows many of the historical facilities that are of interest. These three photos emphasize the geologic interpretation of fill overlaying alluvium overlaying bedrock. The 1939 aerial photograph also gives some insight as to the ground-water flow direction interpretation, which is discussed in Section 4.4.

In the following sections each portion of the hydrogeologic conceptual site model is discussed in further detail. Components of the hydrogeologic site model are shown on Figure 4-1. Appendix B presents the lithologic logs for soil borings and monitoring wells advanced during the course of site investigations.

4.1 VADOSE ZONE

The vadose zone beneath the Astoria Area-Wide site is generally comprised of a dredge sand fill, gravel base rock, and fill debris. Generally, the gravel base rock was only present at the surface or beneath asphalt pavement. The dredge sand fill is characterized by grey and light brown fine to medium sand with silt and clay lenses. The nature of the sand is fairly consistent across the site although the amount of silt and clay is variable within the dredge sand fill. In certain areas, the thin silt lenses were more extensive and contiguous than others. In other areas of the Astoria Area-Wide site, these silt and clay lenses were not encountered.

Fill debris was encountered in the near shore area. Upland of the seep several explorations encountered refusal, it appears there is more rip rap or large debris present in this area. A cross section through the seep and Slip 2 is presented on Figure 4-4 and a cross-section through the eastern portion of the site is shown on Figure 4-5. The location of the cross-sections are shown on Figure 4-6.

In the southeast corner of the site near West Marine Drive (former Val's Texaco) the vadose zone is comprised of the dredge sand fill overlain by fill consisting of silt and sandy silt with gravel (Figure 4-5). The silt fill appears to be derived from the Astoria Formation. The thickness of silt fill increases and the thickness of dredge sand fill decreases to the southwest so at Youngs Bay Texaco, silt fill is directly underlain by bedrock of the Astoria Formation. At Youngs Bay Texaco the vadose zone extended to the total depth explored. This includes the silt fill and Astoria Formation as encountered in borings SB-101(C) and SB-103(C). Asphalt was noted in the silt fill at depths up to 10 feet bgs. The depth to the bottom of the fill in the area of Youngs Bay Texaco is approximately 16 feet bgs.

The thickness of the vadose zone beneath the Astoria Area-Wide site varies from 2 feet to at least 25 feet depending on the season and location. Boring logs indicate the thickness of the vadose zone varies along West Marine Drive from 14 feet to at least 25 feet, from 9 to 13 feet beneath Pier 2 and the vadose zone varies from 3 to 15 feet for the remainder of the site. Figure 4-7 presents hydrographs for MW-13(A), adjacent to West Marine Drive, MW-11(A) located on Pier 2, and MW-30(A), MW-46(A), and MW-34(A), located in the central portion of the site. Monitoring data indicates that seasonal fluctuations of ground-water levels are generally on the order of two to five feet.

4.2 SHALLOW WATER-BEARING ZONE

The shallow water-bearing zone is primarily in the dredge sand fill. The dredge sand fill is comprised of fine sands with lenses of silt and clay as well as gravel, wood, and other organics, as discussed above. CPT/ROST® data indicate that the presence of the silt and clay

lenses have an important role on LNAPL distribution in the shallow aquifer zone. The LNAPL distribution is discussed further in Section 6.0.

The fine-grained lenses occur in a range of depths beginning at one to four feet bgs and appear to continue down to where the native alluvial deposits were encountered. Fine-grained lenses were not logged in every exploration. The lenses were generally ½ to 3 feet in thickness, although in several locations fine grained soil of various composition was identified up to 10 feet thick. The lenses do not appear to extend across the site and are interpreted to be more local in nature. In adjacent borings and CPT logs some local correlation appears appropriate.

The water table fluctuates within the dredge sand fill. The dredge sand fill also contains the known occurrence of petroleum hydrocarbons in soil and ground-water. The vertical extent of the Locality of the Facility is defined within the fill and generally occurs from the ground surface to what is interpreted to be the historical seasonal low water table. The seasonal low water table appears to occur at an elevation of approximately 2 feet or a depth of 12 feet bgs in the main portion of the site and at a depth of 22 feet bgs along West Marine Drive.

The native alluvial deposits consist of dark greenish-gray silty sandy clay with cobbles. The top of the alluvial deposits were encountered beneath the southeastern portion of the site, along West Marine Drive, from 20 feet bgs (SB-102(C) and SB-104(C)) to 25 feet bgs (SB-329(D)). The alluvial deposits were encountered beneath the Qwest vehicle service center site at approximately 9 to 10 feet bgs (SB-802(Q) and SB-835(Q)). The alluvial deposits appear as a homogeneous horizontal layer that varies in thickness from 10 to 16 feet in the southwestern and southeastern areas of the Astoria Area-Wide site to 35 feet in the most northern areas of the site. Very hard, mostly dry gray clay was encountered beneath the native alluvial deposits at approximately 13 to 16.5 feet in soil borings in the vicinity of the Niemi Oil Cardlock, Qwest vehicle service center, and former Harris/Van West service station (SB-017(A), SB-834(Q), SB-632(N), and SB-004(A)). Mudstone and yellowish-red and yellowish-brown silts were encountered between 14 and 18 feet bgs in soil borings located at the former Harris/Van West service station (SB-404(F)) and the Youngs Bay Texaco (SB-101(C) and SB-103(C)) sites, respectively. The very hard clay, mudstone, and yellowish

silts are all interpreted to be the Astoria Formation. Based on the information collected to date for the Astoria Area-Wide site, the native alluvial deposits and the Astoria Formation have not been affected by petroleum hydrocarbons and are not included in the Locality of Facility.

The Astoria Formation constitutes the lower boundary of hydrogeologic media of interest for the Astoria Area-Wide site. Monitoring wells completed or partially completed in the Astoria Formation do not produce significant amounts of water - they typically purged dry during ground-water sampling and are slow to recover. Soil boring SB-004(A) near West Marine Drive encountered the Astoria Formation at approximately 16 feet bgs, was drilled to a depth of 25 feet bgs, and was not completed as a monitoring well because no water was encountered during drilling. The Astoria Formation also was encountered in geotechnical borings B-1, B-2 and B-3 advanced in the southern portions of Pier 2 at depths of 50 feet, 50 feet, and 57 feet bgs, respectively (Terra Dolce Consultants, 2005).

4.3 GROUND-WATER QUALITY PARAMETERS

During quarterly ground-water monitoring events, select ground-water quality parameters were measured and recorded in the field. Field parameters included temperature, pH, specific conductance, oxygen reduction potential (ORP), and dissolved oxygen. No obvious difference was noted in specific conductance between the shoreline and inland. In addition to the ground-water quality parameters measured in the field, additional ground-water quality parameters were evaluated by laboratory analyses for anions and cations. These included total alkalinity, calcium, chloride, iron, magnesium, manganese, nitrogen, nitrate-nitrite, potassium, sodium, and sulfate. Field parameters and laboratory parameters are discussed below.

The temperature of the ground water generally ranged between 10° and 17° Celsius (C). Three temperature readings below 10°C (8.8°C, 9.2°C, and 9.6°C) were recorded during the January 2004 event. It is unclear if those temperatures are representative of field conditions. Ground- water pH ranged between 6.16 and 7.46. There were no anomalous pH readings.

Specific conductance provides an indication of ion concentration. As ion concentrations increase, conductance of the solution increases. Typically saltwater would have a higher specific conductance than fresh water. Specific conductance was measured in micro Siemens per centimeter (µS/cm) and ranged from 41 to 881 µS/cm. Specific conductance varied across the site and between monitoring events. The lowest specific conductance was consistently measured during the January 2004 event and the higher specific conductance values were recorded during the April and June 2004 events.

Dissolved oxygen is a measurement of the concentrations of the microscopic oxygen bubbles present between water molecules. Background dissolved oxygen concentrations in ground water generally range between 5 and 10 milligrams per liter (mg/L). Free oxygen is a common oxidizer and a high dissolved oxygen concentration is generally associated with higher ORP values. Typically, a petroleum hydrocarbon release will impact dissolved oxygen concentrations in ground water. Biological degradation of the petroleum hydrocarbon compounds occurs until the system becomes oxygen limited, resulting in low dissolved oxygen concentrations. The dissolved oxygen concentrations in the monitoring wells ranged from 0.08 to 7.2 mg/L. Some correlation between high DO concentrations and analytical results was noted. Generally the larger DO readings were recorded for monitoring wells where water quality is not impacted or has only been slightly impacted by petroleum hydrocarbons. However, not all monitoring wells considered not impacted or slightly impacted had high DO readings. Dissolved oxygen readings from the August 2004 event are presented on Figure 4-8.

ORP is a measurement of the oxidizing strength of a solution, the higher the ORP value the stronger the oxidizing strength. Generally water from a well is a very weak oxidizer with an ORP value around 200 millivolts (mV). A common oxidizer in ground water is free oxygen, so a high dissolved oxygen concentration is generally associated with a higher ORP value. ORP values ranged from –56mV to 235 mV.

When petroleum hydrocarbons or other chemicals are introduced to ground water, the water composition changes. The ground-water chemical analytical data were reviewed and six monitoring wells were identified as potentially representative of natural background water quality. The six wells are MW-19(A), MW-22(A), MW-32(A), MW-35(A), MW-38(A), and MW-43(A). The specific conductance of ground water from these wells during various sampling events ranged from 85 to 461 µS/cm; the ORP ranged from 52 to 235 mV, and dissolved oxygen concentrations ranged from 0.10 mg/L to 5.32 mg/L (0.2% to 49.7% of solubility). Ground-water field parameters for all wells are summarized in Table 4-1. Review of Table 4-1 indicates the water chemistry based on field parameters varies widely throughout the site.

Ground-water quality parameters determined by laboratory analyses of certain anions and cations included total alkalinity, calcium, chloride, iron, magnesium, manganese, nitrogen, nitrate-nitrite, potassium, sodium, and sulfate. Iron is one analyte of interest because iron enriched ground water is generally associated with petroleum hydrocarbons. Iron enrichment occurs because biological degradation of the petroleum hydrocarbon compounds occurs until the system becomes oxygen limited or anaerobic. Anaerobic processes begin to predominate which results in iron becoming enriched in the dissolved phase. Dissolved iron concentrations are shown on Figure 4-9. A review of the data reveals that high iron concentrations were generally detected in wells that were significantly impacted by petroleum hydrocarbons. There are exceptions to this trend and iron analytical data could not be used to consistently predict the presence of ground water significantly impacted by petroleum hydrocarbons or LNAPL.

To evaluate background water quality, the anions and cations results from the six monitoring wells (MW-19(A), MW-22(A), MW-32(A), MW-35(A), MW-38(A), and MW-43(A)) identified as representative of natural background water quality were converted from milligrams per liter (mg/L) into milli-equivalents (mEq). This conversion takes into account the ionic charge of each chemical and allows for a direct comparison between chemicals. In an analysis expressed in mEq, unit concentrations of all ions are chemically equivalent. Table 4-2 presents the cation and anion analyses in mg/L and mEq for the six wells.

While there are water-compositional similarities (mostly in wells close to each other), there are differences in the aquifer system depending on location. The monitoring well most different from the other wells in terms of general chemistry appears to be MW-32(A), which is closest to the shoreline and most likely has the largest influence from a mixture of brackish water and fresh water. Accordingly, ground water in MW-32(A) appears to generally contain a higher percentage of cations and anions found in seawater. The remaining five wells investigated show that the water composition varies beneath the Astoria Area-Wide site as reflected by the various percentages of anions/cations.

Quarterly ground-water quality parameters and the general chemistry evaluation do not indicate that salt water intrusion is significant at the site. As noted above, MW-32(A) potentially shows some indication of being impacted by saline water. Surface water adjoining the Astoria Area-Wide site is significantly impacted by saline water depending on tidal stage. Intrusion of salt water into the Lower Columbia River estuary is documented upstream to river mile 23 (Harrington Point) (LCFRB 2004) and surface water salinity concentrations of 30 parts per thousand (ppt) have been documented upstream to river mile 25 (Hydrodynamic Process & Ecosystem Group, undated).

4.4 HYDRAULIC GRADIENT

The potentiometric surface contours for October 2003 and January, April, and July 2004, are presented on Figures 4-10 through Figure 4-13. The direction of ground-water flow beneath the site appears to be to the north/northwest throughout the year for the majority of the site. In the vicinity of the former Chevron/McCall bulk plant the potentiometric surface is not as well defined due to the low density of monitoring wells. However, based on the three data points in that area and the location of surface water, the direction of ground-water flow is most likely to the northwest. Generally the direction of the hydraulic gradient in the shallow water-bearing zone has remained constantly north/northwest throughout the year. The Pier 2 surface water elevation presented on Figures 4-11 through 4-13 is corrected for tidal stage. The measured depth to surface water was corrected to mean water level based on the National

Oceanic Atmospheric Administration (NOAA) tidal data at Tongue Point (NOAA, 2008). Mean water is the average water level between high water and low water.

Ground water is recharging surface water in the Columbia River throughout the year (using mean water river stage) based on the quarterly monitoring data. Although this may be the predominate case there are times when surface water is recharging ground water in the near shore area. For example at the time of the January 11, 2004, event the uncorrected surface water elevation was higher than the near shore ground-water elevation. The extent of recharge is unknown and locally along the shoreline this recharge/discharge relationship depends on the tide cycle. The tidal influence on ground water is discussed further in Section 4.6.

The seasonal high water level occurred during March 2004, during the period monitored. Water levels in March 2004 were on the order of 2 feet higher than the dry season water levels on the lower, flat portion of the site and 5 to 7 feet higher in the upper portion of the site along West Marine Drive. The lowest water levels were generally recorded in August, September, or October. Steeper hydraulic gradients were identified during the wet season and flatter hydraulic gradients were identified during the dry season.

The horizontal hydraulic gradient in the shallow water-bearing zone ranges from 0.003 to 0.007 feet per foot (ft/ft) for most of the site. Along West Marine Drive the hydraulic gradient ranges from 0.025 to 0.05 ft/ft. No site-specific vertical gradients are available.

Hydraulic gradient also appears to influence the characteristics of the seep/river interface. This is supported by visual observations of the seep which varied depending on tidal stage. The tidal stage appears to be the dominant factor influencing the hydraulic gradient in this near shore environment. The detailed cross section included as Figure 4-14 shows this relationship. One detail is for low tide and the other is for high tide. Included on each detail is a scenario for how ground water, surface water, and LNAPL are interacting. The basis for these scenarios is visual observations as no quantitative information is available. Visual observations are discussed further in Section 6.0.

4.5 AQUIFER PARAMETERS

Ground water is generally encountered between 7 and 11 feet bgs at the Astoria Area-Wide site, except along West Marine Drive. The three properties along West Marine Drive have a surface elevation approximately 15 feet above the remainder of the site and the depth to ground water is generally 22 feet bgs in this area.

The aquifer test conducted upland of Slip 2 by Hahn & Associates in February 1995 included a step drawdown test, pumping test, and a recovery test. Transmissivity and storage coefficient values derived from the test are 3,000 gallons per day per square foot (gpd/ft^2) or 401 square feet per day (ft^2/day) and 0.3, respectively.

EnviroLogic Resources collected tidal and monitoring data from September through December 2004. A surface water monument was installed in the head of Pier 2 near the seep to record surface water levels in the river. Ground-water levels were measured in wells MW-9(M), MW-11(M), MW-34(A), and MW-35(A). The Pier 2 surface water monument was established prior to the commencement of the tidal evaluation fieldwork. A transducer was installed in the Pier 2 monument and was continuously recording data during the evaluation period. The Pier 2 transducer provided actual surface water elevation readings to determine the tidal maxima and minima at the shoreline. In order to help define the inland extent of the tidal influence, additional transducers were temporarily installed in monitoring wells. Graphs displaying the change in ground-water levels with respect to time along with the supporting shallow water level data are presented in Appendix E and on Figures 4-15 and 4-16. The details of the monitoring process are provided in the Technical Memorandum, Slip 2 Hydrocarbon Seep Interim Removal Action Measures, Upland Data Collection (*EnviroLogic Resources*, 2005b).

Further evaluation of the aquifer parameters by *EnviroLogic Resources* using a tidal peak lag time method (Ferris, J.G., 1963) revealed that each method of analysis resulted in similar transmissivities in the shallow water-bearing zone near the Port office building. However,

different storage coefficients were identified for the shallow aquifer system using the tidal peak damping method, as further explained below. The pumping test allows measurement of aquifer parameters in the vicinity of the pumping well. The tidal peak damping method evaluates aquifer parameters from the shoreline to the observation wells.

The published range of storage coefficients (S), equivalent to specific yield for an unconfined aquifer is 0.01 to 0.30. The published range for S in a confined aquifer is 0.00005 to 0.005. A storage coefficient of 0.3 would be considered at the high end of the range for a very uniform coarse sand (large amount of pore space between sand grains). The shallow water-bearing zone at the Astoria Area-Wide site is a fine to medium sand with some inherent fine-grained silt and clay layers. This is supported by the Astoria Area-Wide site dredge sand fill lithologies observed during drilling operations. Although local portions of the shallow water-bearing zone may have an S value of 0.3, it is unlikely that an S value of 0.3 is representative of the shallow water-bearing zone in the area near shore with the presence of the interconnected fine-grained lenses.

The influence from the tide on the shallow water-bearing zone was apparent in most of the monitoring wells monitored with transducers. The continuous monitoring of the water levels provided relations between the tide cycle and water level as the tidal front advanced inland beneath the site. These relations are expressed in terms of lag time from when a tidal peak (high or low) was recorded at Pier 2 and in a monitoring well.

Compared to the water levels recorded at Pier 2, the response in the monitoring wells is small. Figure 4-15 presents a comparison plot between the Pier 2 monument, MW-9(M), and MW-34(A); and Figure 4-16 presents Pier 2, MW-11(M), and MW-35(A). From these figures, time lags were calculated between river levels in the Pier 2 monument and water levels in the monitoring wells. The area included in the tidal analysis was in the vicinity of the Port office building extending back to Industry Street. The maximum effect of the tides was estimated to be approximately 0.3 to 0.4 feet nearest to the shore. The graphs also show water level fluctuations due to other factors (rain events).

As shown on Figures 4-15 and 4-16, the time lag between the water in Slip 2 (at Pier 2 Monument) and the upland monitoring wells is relatively short. The lag time from the tidal peak measured at Pier 2 to MW-11(M), which is 80 feet away from the shoreline is 0.05 days. The time lag from the shoreline to MW-35(A), which is 420 feet away is 0.23 days. Several tide periods were evaluated then averaged when calculating the time lag. Two other wells analyzed during this tidal analysis are MW-9(M) and MW-34(A). The lag times for these two wells are 0.12 days and 0.11 days respectively. MW-9(M) is 120 feet from shoreline and MW-34(A) is 270 feet from shoreline.

The measured lag times were used in calculating transmissivity. A variable assumed in calculating the transmissivity is storage coefficient. In the analysis, the storage coefficients were varied from 0.01 to 0.10, which seem to represent a reasonable range for the materials in the shallow water-bearing zone. By using storage coefficients of 0.01, 0.05 and 0.10 in the analysis, site-specific transmissivities were calculated in the range of 450 to 14,000 feet squared per day (ft^2/day) given a shallow aquifer thickness of 45 feet. The shallow aquifer thickness is based on the depth to the contact with the Astoria Formation as shown on the site hydrogeologic cross section (Figure 4-1). Table 4-3 presents transmissivity values for the site.

These transmissivity values represent the nature of the bulk sediments between the shoreline and the observation well of interest. The result is directly related to the assumed storage coefficient used in the analysis. For example, observation wells closer to the shoreline (MW-9(M), MW-11(M)) generally exhibit a lower transmissivity than those further from the shoreline (MW-34(A), MW-35(A)) when the same storage coefficient is assumed (0.03). This is reasonable considering that finer-grained sediments predominate closer to the shoreline and coarser-grained materials are more typical inland. The finer-grained near shore sediments have a more significant effect on the calculated transmissivity when they compose the bulk of the material between the shoreline and the observation well, as in the results for MW-9(M). Where finer-grained sediments are a smaller percentage of the bulk material between the shoreline and the observation well, a higher transmissivity is observed, as in the results for MW-35(A).

In addition, the storage coefficient is likely variable in the shallow water-bearing zone. Finer-grained sediments do not readily gravity drain as do coarser-grained sediments and they may be locally semi-confined. As such, transmissivities in near shore areas should be evaluated using a lower storage coefficient than further from the shoreline.

Ground-water velocities cannot be readily calculated for areas influenced by tides. Hydraulic gradients in these areas are not static and are influenced by tides, seasonal river levels, and rain events. Effective porosity is also variable over the area influenced by tides, as this parameter is similar to the storage coefficient in an unconfined aquifer. The calculation of LNAPL flux and rate of contaminated ground-water flux into Slip 2 will be addressed during the feasibility study portion of the project.

While the distribution of transmissivity calculated from the tidal damping study generally compares to the lithology observed in monitoring wells and borings, the data are not sufficient to evaluate and design specific remedial alternatives. The storage coefficient was not determined by the study. Further aquifer testing will be necessary in order to evaluate location-specific remedial systems.

4.6 TIDAL INFLUENCE

The Astoria Area-Wide site experiences a mixed diurnal tidal cycle (two high tides and two low tides of unequal magnitude a day) as is typical of the west coast of North America. On Figures 4-15 and 4-16 the peaks (both positive and negative) represent the tidal peaks. The high high-tide, low high-tide, and high low-tide are apparent. The low low-tide was often below the level of the transducer in the Pier 2 surface water monument so the low low-peak is recorded as flat line.

The tidal cycle is clearly imposed upon fluctuating river levels and ground-water levels. There appears to be a 2 (Figure 4-16) to 7 day (Figure 4-15) lag between the surface water base level and the ground-water base level. No obvious correlation was noted between rain

data or river level data to explain the fluctuations in surface and/or ground-water levels. The relationship is likely to be complex based on the size of the Columbia River watershed and the presence of dams on the river that moderate the stage changing effects of precipitation events.

In near shore monitoring wells the tidal range recorded in Slip 2 during December 2004 was on the order of 10 feet. At the same time the tidal influence on ground-water levels was on the order of 0.2 to 0.4 feet and diminished to hundredths of a foot in monitoring wells along Portway. Figure 4-15 shows the tidal hydrographs for monitoring-wells MW-9(M) and MW-34(A), and Figure 4-16 shows the tidal hydrographs for wells MW-11(M) and MW-35(A), in relation to tidal measurements from the Pier 2 monitoring station during a two-week interval in December 2004.

5.0 POTENTIAL SOURCES AND POTENTIAL MIGRATION PATHWAYS

The site development history presented in Section 1.5 identified the installation and demolition of features that are considered related to potential sources of releases of COPC. In the RI/FS Work Plan a table presenting a listing of potential sources (RI/FS Work Plan, Table 2) was developed that was based primarily on the site development history. Phase 1 explorations were then conducted to evaluate these identified potential sources. Subsequent remedial investigations were conducted to define subsurface conditions, delineate the nature and extent, and to identify specific potential sources. In addition, several development activities have been conducted at the Astoria Area-Wide site; during these development activities additional underground features (petroleum distribution lines) were encountered that are potential sources of releases of COPC to environmental media. The additional information regarding potential sources gathered since the RI/FS Work Plan was developed and is now incorporated into an updated listing as shown in Table 5-1.

5.1 POTENTIAL SOURCES

The following sections discuss the potential sources by facility and present figures showing the locations of the potential sources. A chronology of environmental activities at each facility is presented in Table 5-2. The east/west trending combined sewer line located between the Youngs Bay Texaco facility and the Qwest vehicle service center has been identified as a partial preferential pathway. This combined sewer pipeline extends from westward of the Qwest facility and flows to the northeast to Portway. Prior to 1990 this combined sewer alignment was straight to Portway street. In 1990 petroleum hydrocarbons released from the Harris/VanWest site were observed inside the pipe and the pipe was partially abandoned and partially rerouted. The reroute resulted in a portion of the combined sewer being located beneath Industry Street. In 1997 vapors associated with an AST overfill at Youngs Bay Texaco followed this preferential pathway. This pipeline is discussed in further detail in the following sections.

5.1.1 Youngs Bay Texaco

Research identified that a service station (two different configurations) has occupied the property since the 1960s. Typically, the former and current petroleum facilities would be considered the primary potential sources. The former and current layouts of the facilities are shown on Figure 5-1. Potential sources at the Youngs Bay Texaco identified in the RI/FS Work Plan included the former USTs and dispensers and a 1997 AST overfill. A summary of the potential sources is included in Table 5-1. The combined sewer line located between the Youngs Bay Texaco facility and the Qwest vehicle service center to the northwest has been identified as a potential pathway allowing preferential migration. Petroleum hydrocarbon vapors associated with the 1997 AST overfill followed this preferential pathway.

The following paragraphs discuss in detail the history of the combined sewer line mentioned above (located between Youngs Bay Texaco and Qwest) because this sewer line is a likely preferential pathway for vapors associated with the 1997 release and a feature of interest for several sites.

Prior to 1990, the general layout of this combined sewer system was an east/west trending line at the base of the slope below the former Val's Texaco, Harris/Van West, and Youngs Bay Texaco. This emptied into a sewer line beneath Portway that flowed toward the Red Lion. Qwest and Youngs Bay Texaco are near the upgradient terminus of this sewer line with the direction of flow in the pipe to the east, toward Portway. Several north/south trending laterals from catch basins in Industry Street empty into this sewer line. One such lateral was located along the property line between Qwest and the Niemi Oil Cardlock. In 1990, as a result of the 1990 Harris/Van West release, this lateral and the portion of the main line between Harris/Van West and Niemi Oil Cardlock was abandoned and not replaced (Rittenhouse-Zeman & Associates, 1990b). The upgradient portion of the sewer line between Youngs Bay Texaco and Qwest was left undisturbed and it was reconnected to the sewer system by extending the line to connect into the Industry Street sewer line. The new sewer line was located adjoining the abandoned lateral (Figure 5-4).

The underground sewer system in the vicinity of Youngs Bay Texaco, Qwest, Harris/Van West, Niemi Oil Cardlock, former Val's Texaco, and the former Delphia bulk plant could act as potential preferential pathways. This is evidenced by environmental responses conducted in 1990 and 1997. In 1990, Reidel Environmental Services (RES) observed and sampled LNAPL from a sewer manhole located in the east/west sewer line near the southeastern portion of the Niemi Oil Cardlock. In addition to RES providing emergency response for the LNAPL, a response was initiated for petroleum vapors in the former apartment building that was located between the Youngs Bay Texaco and the former Harris/Van West properties. In 1997, Astoria Public Works and Astoria Fire Department responded to a gasoline vapor complaint coming from the drains at Qwest (Oregon State Fire Marshall Hazardous Material Emergency Incident Report, June 5, 1997). Historically, the fact that RES observed and sampled LNAPL from a manhole in the combined sewer line confirms that at least historically the combined sewer line in near proximity to that manhole acted as a preferential pathway for that release.

RI and historical activities indicate that either the abandoned sewer line itself (not the backfill) acts as a preferential pathway, the new sewer line/backfill acts as a preferential pathway, or the sewer lines are coincidently located to appear that they are acting as a preferential pathway. Older sections of the sewer line appear to have been directly buried in native sand. During explorations along the east/west trending sewer line between Harris/Van West and the Niemi Oil Cardlock, coarse grained backfill material was not encountered. The north/south trending sewer line between Qwest and the Niemi Oil Cardlock is newer and may have been constructed using gravel bedding as backfill. However, this has not been verified. The east/west trending sewer line located beneath Industry Street appears to have been constructed using gravel bedding.

Petroleum hydrocarbon constituents were detected in soil and ground water (during investigations conducted at the Niemi Oil Cardlock and former Harris/Van West service station) near the combined sewer line east of the Youngs Bay Texaco site. However, although the extent of petroleum hydrocarbons near the combined sewer may be adequately defined it is

unclear if gasoline contaminants detected along the preferential pathway represented by the sewer line are the result of one or multiple sources in which one source could be facilities at Youngs Bay Texaco.

The environmental history of the Youngs Bay Texaco property is presented in detail in the RI/FS Work Plan and summarized in Table 5-2. RI characterization efforts confirmed the completeness of the historical remedial actions conducted at Youngs Bay Texaco. No additional potential sources or preferential pathways were identified during the RI/FS process. Data from the Qwest site indicates migration of COPC along the combined sewer line has not significantly impacted the portion of the Qwest site adjoining the Youngs Bay Texaco property. The Qwest vehicle service center facility is discussed further in Section 5.6.

5.1.2 Former Delphia Bulk Plant and Former Val's Texaco

Research identified that the western part of the former Delphia bulk plant has been used as a bulk petroleum facility since at least the 1930s and that a service station operated at the former Val's Texaco property from the 1960s until recently. Currently, the service station building at the former Val's Texaco is vacant and oil is stored at the bulk plant warehouse.

Typically, the former and current petroleum facilities would be considered the primary potential sources at these properties. The former and current layouts of the facilities are shown on Figure 5-2. Potential sources identified in the RI/FS Work Plan included the former Delphia bulk plant facilities, former Val's Texaco gasoline, diesel and used oil USTs, former product piping, former dispensers, and two historical spills. No additional potential sources were identified through the RI. Potential sources identified are summarized in Table 5-1.

At the former Delphia bulk plant and former Val's Texaco several on-site and off-site utilities may be potential preferential pathways. The larger utilities include a water line and a combined storm sewer in Industry Street and the combined sewer located between the former Delphia Bulk Plant and the former Val's Texaco (downgradient portion of the combined sewer discussed in Section 5.1 before it empties into a sewer line beneath Portway). In addition to

the complaints of vapors from the former apartment, Qwest building, and in the vicinity of the Red Lion, DEQ documented complaints of vapors in 2002 from the manhole cover in the parking lot behind the Portway Tavern. This manhole is part of the same combined sewer system indicating that this combined sewer system acts as a preferential pathway. The specific origin of the vapors in the Portway Tavern manhole was not identified during the RI process. The vapor complaint does not necessarily indicate a preferential pathway in association with the former Delphia bulk plant or former Val's Texaco.

The environmental history of the former Delphia bulk plant and the former Val's Texaco is presented in detail in the RI/FS Work Plan and summarized in Table 5-2. No remedial actions had been completed at the Delphia bulk plant facility prior to initiating the RI. Five gasoline USTs and one used oil UST were removed at the former Val's Texaco in 1996. Petroleum hydrocarbons were not detected above reporting limits in the confirmation samples from the UST excavation pit. This limited previous remedial activity did not identify preferential pathways or potential source areas. No additional potential sources or preferential pathways were identified during the RI/FS process. However, LNAPL was identified at the former Delphia bulk plant.

LNAPL was observed in monitoring well MW-15(A) at the Delphia bulk plant facility. The LNAPL consists of gasoline, diesel, and oil-range organics. The source of LNAPL has not been identified, although potential sources are described in Table 5-1.

5.1.3 Former Chevron/McCall Bulk Plant

Research identified that a bulk facility has occupied the site since the late 1920s. Typically, the former and current petroleum facilities would be considered the primary potential sources. The former and current layouts of the facilities are shown on Figure 5-3. Potential sources identified in the RI/FS Work Plan for the former Chevron/McCall bulk plant included the tank bottom wastes, releases from ASTs, releases from pumps and piping systems, and a heating oil UST. This facility also had petroleum distribution pipelines that extended from the former Chevron/McCall bulk plant along Portway, and to the end of Pier 2. Specific potential sources

are summarized in Table 5-1. The petroleum pipelines were identified as a source in 1993 and further pipeline characterization was included as part of the RI activities. In a 1996 subsurface investigation, Bunker C hydrocarbons, TPH, and metals were identified in association with the former facility. In 2002, activities conducted by Chevron in association with the PRP group removed these impacted soils.

An additional potential source identified is historical boiler cleaning activities. The additional potential source was identified by the presence of chromium VI in monitoring wells located on the former Chevron/McCall bulk plant facility. Boiler cleaning may have occurred on or adjacent to the former Chevron/McCall bulk plant facility and could be related to maintenance of the on-site boiler and discharge to the septic system, or maintenance for boilers in trains stopping along the siding adjacent to the facility. Figure 5-3 shows the layout of the former facilities at the bulk plant and Figure 5-4 shows the location of the petroleum distribution lines.

Potential preferential pathways included the underground piping and the petroleum distribution pipelines (these have all been removed from the former Chevron/McCall bulk plant and only remain on other portions of the Astoria Area-Wide site). Other underground utilities that are in close proximity to the petroleum distribution pipelines may also have acted as preferential pathways. The petroleum distribution lines have not been confirmed as a preferential migration pathway.

A summary of the known environmental history associated with the former Chevron/McCall bulk plant is presented in Table 5-2. The principal remediation conducted at the former Chevron/McCall bulk plant prior to the RI was tank bottom waste removal conducted in 1984. Remedial activities conducted beginning in 2002 in association with the Astoria Area-Wide PRP group included explorations, ground-water assessment and monitoring, and a remedial excavation. No additional characterization is planned in association with the former bulk plant site.

5.1.4 Former Chevron/McCall Petroleum Distribution

In 1993, one of the diesel pipelines leading from the former Chevron/McCall bulk plant out to Pier 2 failed a tightness test. Subsequent investigations confirmed the distribution pipeline was a source and diesel range petroleum hydrocarbons were released. The LNAPL associated with the release was identified between the pipeline and Slip 2 and remedial activities were conducted between 1993 and 1995. Although the source of the release was stopped, remedial activities were not successful. LNAPL continues to be present on the ground-water surface. A summary of the known environmental history associated with the petroleum distribution pipelines is presented in Table 5-2.

Although the pipeline was a confirmed source, the pipeline or associated backfill did not appear to act as a preferential pathway. A Port storm drain located in the LNAPL area upland of Pier 2 was identified as a potential pathway and was the focus of an IRAM conducted in 2004.

5.1.5 Niemi Oil Cardlock

Research identified that bulk petroleum facilities have occupied portions of the site intermittently since 1927. A junkyard once occupied portions of the property in the 1970s. Typically, the former and current petroleum facilities would be considered the primary potential sources. Potential sources at the former Associated Oil Co. facility (eastern half of the Niemi Oil Cardlock site) include a former AST, pump house, fueling racks, and garage. At the Niemi Oil Cardlock, potential source areas include USTs, ASTs, an overhead loading rack, fuel dispensers, and underground piping. Potential sources are summarized in Table 5-1 and the layout of current and historical facilities at the Niemi Oil Cardlock is shown on Figure 5-5.

Potential preferential pathways for the Niemi Oil Cardlock site include utilities underground adjoining the property. The north/south trending sewer lines (abandoned lateral and extended sewer line) between the Niemi Oil Cardlock and the Qwest vehicle service center, the sewer

main line in Industry Street, and the east/west trending sewer line that runs between Niemi Oil Cardlock and the former Harris/Van West service station are the most likely preferential migration pathways as discussed in Section 5.1.

During the initial response to the release at the former Harris/Van West site, RES excavated several test pits in the vicinity of the east/west sewer line and the north/south lateral from Industry Street. RES determined that gasoline was migrating through the soil from the Harris/Van West site into the sewer line (*EnviroLogic Resources,* 2002b). Samples of LNAPL were collected from the sewer line and a test pit. LNAPL was identified as being undegraded gasoline (See Table 1-1).

The environmental history of the Niemi Oil Cardlock facility is presented in detail in the RI/FS Work Plan and summarized in Table 5-2. Remedial investigation activities completed at the Niemi Oil Cardlock identified potential sources of releases of gasoline and diesel range petroleum hydrocarbons. Specific facilities or source areas of releases at the Niemi Oil Cardlock have not been identified. No additional potential sources or preferential pathways were identified and LNAPL was not observed in this area during the RI/FS process.

5.1.6 Former ExxonMobil/Niemi Oil Bulk Plant

Research identified that a bulk petroleum facility has occupied the property since 1925. Currently the property is vacant but is in the process of being redeveloped. All of the known former bulk plant facilities have been removed. Typically, the former and current petroleum facilities would be considered the primary potential sources. The former facilities and potential source areas include the ASTs, pump house, USTs, fueling racks, garage/warehouse, other ancillary facilities, and petroleum distribution lines to Slip 2 and Pier 2. Potential sources are summarized in Table 5-1. No new potential sources were identified. The layout of the former facilities is shown on Figure 5-6 and petroleum distribution lines are shown on Figure 5-4.

Potential preferential pathways for releases from the former ExxonMobil/Niemi Oil bulk plant include underground utilities along Portway. No specific preferential pathways have been identified for potential sources located at the former ExxonMobil/Niemi Oil bulk plant property.

The environmental history of the former ExxonMobil/Niemi Oil bulk plant is presented in detail in the RI/FS Work Plan and summarized in Table 5-2. No remedial actions had been completed at the former ExxonMobil/Niemi Oil bulk plant facility prior to initiating the remedial investigation. Characterization during the remedial investigation did not identify a specific feature or features as the source(s). A relatively thin layer of LNAPL, which has a source associated with the former ExxonMobil/Niemi Oil bulk plant has been identified in monitoring wells MW-37(A), MW-44(A), and MW-40(A). The product forensics analysis identified that the LNAPL in MW-37(A) is clearly different from the LNAPL in MW-40(A) and MW-44(A). The source of the LNAPL in MW-37(A) has not been identified. LNAPL associated with the former ExxonMobil/Niemi Oil bulk plant extends off the facility, under Portway, before it co-mingles with LNAPL associated with the 1993 Chevron/McCall pipeline release. Additional details regarding the nature and extent of LNAPL in this area is provided in Section 6.0. The former ExxonMobil/Niemi Oil petroleum distribution pipelines were characterized to a limited extent in order to determine if these are a potential LNAPL source (HartCrowser, 2004a). In the areas investigated, no specific source was identified.

5.1.7 Former Facilities at the Port of Astoria

Research identified that a wide range of facilities have occupied the Port of Astoria properties through the years. Primarily the facilities have been marine, timber, or fishery related. Potential sources identified in the RI/FS Work Plan at the Port of Astoria facilities include the former furniture manufacturing facility, veneer plant, sawmill, boiler, former steel works, a diesel UST, and Astoria Oil Services. The potential sources are summarized in Table 5-1. No new potential sources were identified during remedial investigation activities.

No historical environmental activities have been conducted at the former furniture manufacturing site or former steel works. Former historical activities at Astoria Oil Services are described in Table 5-2. Historical remedial activities at the Port facilities include removal of the 1,000-gallon diesel UST located at the northeast corner of the maintenance shop. Historical environmental activities did identify petroleum hydrocarbons in the UST excavation, which were subsequently excavated (Neil Shaw Consulting Geologist, 1993a). Petroleum hydrocarbons identified at some locations in the vicinity of the former furniture manufacturing facility and the former steel works appear to be related to off-site sources. An unknown source of heavy oil was identified in the location of Astoria Oil Services. This heavy oil was identified in association with organic material in the fill on Pier 3. During site development activities related to Bornstein Seafood upland of Slip 1 in August 2005, heavy oil/Bunker C was encountered in a catch basin that had been buried with soil. It is unclear whether this material was waste from a nearby bulk plant/pipeline or deposited at this location for some other reason. The layout of current and former Port of Astoria facilities is shown on Figure 5-7.

Numerous underground utilities are located on the Port properties, under the roadways, and beneath the piers. One specific preferential pathway that has been identified on Port property is the downstream extension, near the Red Lion, of the combined storm sewer line that runs between Youngs Bay Texaco and the Qwest vehicle service center and along Industry Street. This combined sewer line is the only underground utility on the Port properties that specifically has had vapor complaints associated with it.

The storm line between the Port office building and Port maintenance shop was rerouted because it was suspected to be a preferential pathway exacerbating the hydrocarbon seep into Slip 2. The storm sewer reroute is documented in the IRAM as-built drawings (RSV Engineering, 2004). A former sanitary sewer line extending from the Slip 2 docks under the Port office building is considered a suspected preferential pathway for migration of LNAPL to Slip 2.

Petroleum hydrocarbons from an unknown source were identified in soil at the Astoria Oil Services facility on Pier 3. Ground water discharges to the Columbia River within a few tens of feet of this area. The Port built a disposal area for dredge materials at the former location of Astoria Oil Services (*EnviroLogic Resources,* 2005j). DEQ provided its conditional approval of this activity (DEQ, 2005). No further remedial actions are planned for this area.

5.1.8 Qwest Vehicle Service Center

Research identified that the Qwest site has been occupied by structures since the 1930s and by warehouse type structures since the 1950s. As summarized in Table 5-1, potential sources identified at the Qwest vehicle service center facility include a former 10,000-gallon UST and associated piping and fuel dispenser. No additional potential sources were identified during the RI process.

The environmental history of the Qwest Vehicle Service Center is summarized in Table 5-2. As identified in the environmental history summary the UST and fuel dispenser were decommissioned in 1997. As part of decommissioning activities for the fuel dispenser a remedial excavation was conducted. Remedial investigation activities confirmed the UST, piping, or dispenser are no longer sources of releases of COPC. The limits of the former remedial excavation and locations of the former UST and dispenser are shown on Figure 5-8. Potential preferential pathways at the Qwest vehicle service center facility include underground sewer piping in Industry Street and the sewer lines along the south and eastern property boundary as discussed in Section 5.1.

5.1.9 Former Shell Bulk Plant

Research identified that a bulk petroleum facility occupied this site from the late 1920s to the 1970s. After 1970 one or more warehouse type structures occupied the site. Potential sources identified during the RI/FS Work Plan at the former Shell bulk plant included the former petroleum storage ASTs and ancillary equipment, and petroleum distribution lines. A listing of these potential sources is included in Table 5-1.

A summary of the environmental history is included in Table 5-2. Although all of the above ground facilities were removed in 1974, no historical environmental activities have been conducted at the former Shell bulk plant facility. The layout of the former Shell bulk plant facilities is shown on Figure 5-9 and the petroleum distribution lines are shown on Figure 5-4.

RI activities did not identify specific sources. However, petroleum hydrocarbons were identified that indicate sources are present at the former Shell bulk plant. Some constituents from the former Delphia bulk plant/Val's Texaco facilities may extend onto the former Shell bulk plant site. The petroleum distribution lines were not identified as potential sources where investigated during the pipeline investigation and decommissioning activities. However, underground piping and the petroleum distribution pipelines may be considered potential preferential pathways for migration of petroleum hydrocarbons. No preferential pathways were confirmed.

5.1.10 Former Harris/Van West Service Station

Research identified that a retail fueling facility occupied the site since 1973. An auto wrecking facility and junkyard occupied the site in the late 1940s and into the 1960s. Typically, the former and current petroleum facilities would be considered the primary potential sources. Information about the site previous to Harris/Van West is unknown. Potential sources identified and presented in the RI/FS Work Plan included fuel USTs and a waste oil UST. Two gasoline USTs and the waste oil UST were previously identified as confirmed sources. In response to a gasoline release identified in 1990 a historical remedial action was completed at the site for the confirmed sources. At the completion of the historical remedial action the potential sources on the Harris/Van West site were removed. During remedial activities the migration of petroleum hydrocarbons to the north was observed. Residual COPC that may have migrated off-site in association with the 1990 release were not resolved. The layout of the former facility and the limits of the historical remedial excavation are shown in Figure 5-10.

As discussed in Section 5.1, remedial investigation and historical activities indicate that the combined sewer system located to the north of the former Harris/Van West site is a likely preferential pathway. For the 1990 Harris/Van West release, the fact that RES observed and sampled LNAPL from a manhole in the combined sewer line confirms that at least historically the combined sewer line in near proximity to that manhole acted as a confirmed preferential pathway (Rittenhouse-Zeman & Associates, 1990b).

Remedial investigation activities did not identify new potential sources on the former Harris/Van West service station site. The property is currently operated as Quick-Lube, which services vehicles. However, at the completion of the 1990 historical remedial activities, residual COPC in ground water down gradient of the Harris/Van West site were still known to exist. The source of COPC in ground water down gradient of the Harris/Van West site and beneath Niemi Oil Cardlock appears to be historical releases at both facilities.

There is no identified current source or potential known residual source at the former Harris/Van West service station site for the gasoline- and diesel-range hydrocarbons present in the ground water in this area. Although, a report prepared by PNG (1998) attributes some diesel impacts to the weathered gasoline release at the Harris/Van West site. An analysis of chromatograms from a recovery well water sample indicates that the primary contaminant in the sample is gasoline and the elevated diesel concentrations resemble weathered gasoline (PNG, 1998). In addition, diesel and diesel/bunker oil impacts to soil, at 15 feet bgs, are present on the Harris/Van West property near the former pump island (SEACOR, 1996).

5.2 AREAS OF CONCERN

Although specific potential sources could not always be identified, impacted areas were identified. Generally a potential source area could be associated with an impacted area. These impacted areas are identified as areas of concern (AOC) and have been defined on the basis of the presence of potential or confirmed sources, soil analytical data that describe conditions near releases, and ground-water analytical data that show the extent of migration of petroleum hydrocarbons.

Based on ground-water analytical data from the temporary well point data, three AOC where ground water is impacted by petroleum hydrocarbons were initially identified (*EnviroLogic Resources*, 2003e). Two additional areas of concern were identified for the RI report. An AOC was identified in the vicinity of Astoria Oil Services because of petroleum hydrocarbons in soil and an AOC is identified at the former Chevron/McCall bulk plant because of the presence of COPC in soil and ground water in this area. While the nature and extent of COPC within each AOC are generally well delineated, not all sources, potential sources, or preferential pathways within each AOC have necessarily been completely characterized. Figure 5-11 shows the AOC in relation to the PRP sites.

AOC 1 is located in the central portion of the Astoria Area-Wide site from West Marine Drive and extends northwest. The Youngs Bay Texaco, former Harris/Van West service station, Qwest vehicle service center, and Niemi Oil Cardlock facilities are located in AOC 1. AOC 2 is located in the eastern portion of the Astoria Area-Wide site from near the intersection of West Marine Drive and Portway extending northwest. The former Val's Texaco, former Delphia bulk plant, and former Shell bulk plant sites are located in AOC 2. AOC 3 is located in the western portion of the Astoria Area-Wide site. AOC 3 is essentially the former Chevron/McCall bulk plant. AOC 4 is located in the central portion of the site on Port property and includes the hydrocarbon seep to the Columbia River in Slip 2. Facilities located in AOC 4 include the former ExxonMobil/Niemi Oil bulk plant, several petroleum distribution pipelines, a former UST at the Port, and portions of the former steelworks and furniture manufacturing facilities. AOC 5 is located on Pier 3 and includes the former Astoria Oil Services facility. These AOC, and the nature and extent of COPC in each environmental medium are presented in Section 6.0 for each AOC.

6.0 NATURE AND EXTENT

The site development history was used to define potential sources of constituents of interest (COI) and potential preferential migration pathways. RI investigations were then conducted to evaluate the identified potential sources and explore preferential pathways. Previously unidentified potential sources were identified. In some areas where a known source was present, the specific source of a release of petroleum hydrocarbon could not be identified. An analysis of the laboratory analytical data generated during RI activities was conducted and specific AOC were identified to help organize presentation of the data. Five AOC were defined on the basis of the presence of potential or confirmed sources, soil analytical data that describe the conditions near releases, and ground-water analytical data that show the extent of migration of petroleum hydrocarbons. The five AOC are shown in Figure 5-11. Figure 6-1 shows the extent of LNAPL, dissolved BTEX plume, and ground-water flow in July 2004 for the main portion of the site. The nature and extent of selected COI in each AOC are discussed below for each environmental medium.

Analytical data developed during the RI were validated in accordance with USEPA guidance (USEPA, 1994). Where appropriate, flags qualifying the quality of analytical results were appended to the data. These flags are retained with each data point in the data set and are presented on figures and in tables. A guide defining the meaning of these flags is presented in Table 6-1. COI in soil and ground water are presented in Tables 6-2 and 6-3.

Analytical data for those COI that had data with sufficient frequency of detection, frequency of elevated detection, and frequency of analysis to provide an adequate overview of constituent distribution are presented in this section. Based on this criteria the ten key COI are the three petroleum hydrocarbon ranges (gasoline, diesel, and heavy oil), benzene, toluene, ethylbenzene, xylenes, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and naphthalene. Generally, SVOC compounds were not detected at as high of frequency as the VOC compounds and were not detected at concentrations exceeding generic risk based concentrations (RBCs). Naphthalene is the only SVOC compound to meet the frequency of detection and concentration criteria. Laboratory analytical data for all constituents analyzed

during the RI are presented in Appendix D, Table D-1 to D-38. The nature and extent of each COI in each environmental medium impacted by petroleum hydrocarbons within each AOC is presented in the following sections. The location of the four larger AOCs is shown on Figure 6-1 and the location of all the AOCs is shown on Figure 5-11.

6.1 AOC 1

AOC 1 is located in the central portion of the Astoria Area-Wide site near West Marine Drive. Figure 6-1 shows the location of AOC 1 along with the July 2004 potentiometric surface and the identified BTEX plume. No LNAPL was identified in AOC1 during the RI process although it has historically been identified. Petroleum hydrocarbons identified in this AOC include gasoline and diesel range hydrocarbons. Sources of petroleum hydrocarbons within AOC 1 appear to include former facilities located at the former Harris/Van West service station, Qwest, as well as former and/or current facilities located at the Niemi Oil Cardlock and Youngs Bay Texaco. The nature and extent of petroleum hydrocarbon compounds in AOC 1 appears to be defined and limited.

6.1.1 Soil

Petroleum hydrocarbons occur in soil associated with potential sources in AOC 1. The nature and extent of COI in soil is presented for depths three feet and less and greater than three feet. For sample locations with multiple analytical results the highest concentration in each interval is considered when describing the distribution of COI. These intervals were selected because concentrations in the upper three feet of soil may best represent the locations of potential sources and are evaluated separately in the human health risk assessment (Section 11.0). COI occurring at depths greater than three feet help describe the extent of petroleum hydrocarbons in the vadose zone. Soil analytical data are presented in Appendix D.

TPH: Chemical analysis for hydrocarbon identification detected primarily gasoline and diesel-range hydrocarbons in AOC 1. Minor concentrations of heavy oil-range hydrocarbons were also detected. Analytical results for TPH in soil are presented in Appendix D, Table

D-1. These data are shown on Figures 6-2 to 6-7. In the upper three feet of soil, only diesel-range hydrocarbons were detected at concentrations elevated greater than one order of magnitude above the analytical reporting limit. Specifically, sample SB-408(F) had an elevated concentration of diesel-range hydrocarbons. This was also the maximum concentration of diesel-range hydrocarbons detected (1,470 milligrams per kilogram (mg/kg)) in the upper three feet of soil in AOC 1 (Figure 6-4). Sample SB-408(F) is located near the property line between Niemi Oil Cardlock and Harris/Van West, upgradient of identified facilities at the Niemi Oil Cardlock. A specific source of the diesel-range hydrocarbons at this location was not identified. There has been no known release of diesel from the Harris/Van West site. Diesel-range hydrocarbons were detected at a concentration of 150 mg/kg from a deeper sample (7.5 feet bgs) in SB-408(F).

Samples analyzed from depths greater than three feet in AOC 1 revealed elevated concentrations of gasoline and diesel-range hydrocarbons. Minor concentrations of heavy – oil-range hydrocarbons were also detected (Figures 6-3, 6-5, and 6-7). The elevated concentrations of gasoline-range hydrocarbons were primarily detected at or adjoining Niemi Oil Cardlock. The maximum concentration of gasoline-range hydrocarbons detected was 7,620 mg/kg from SB-822(Q) (Figure 6-3) located immediately east of the abandoned north-south storm sewer line. However, the next highest gasoline concentrations were detected at 3,750 mg/kg from borings SB-601(N) and SB-603(N) and at 3,000 mg/kg from boring SB-605(N) located just west of the Niemi Oil Cardlock overhead loading rack. The source of gasoline-range hydrocarbons at depth in the vicinity of SB-822(Q) is not well defined. The source is not likely to be a nearby surface source, as elevated gasoline-range hydrocarbons were not detected in samples collected from less than three feet at this location (Figure 6-2). As mentioned in Section 5.1 one potential source, in addition to the on-site facilities, for the gasoline-range hydrocarbons along this north-south storm sewer line is historical gasoline releases. As part of remedial activities conducted in association with the 1990 gasoline release LNAPL was detected in recovery well RW-1 located about 25 feet east of the north-south storm sewer line (Figure 1-8).

Concentrations of diesel-range hydrocarbons were detected on the Niemi Oil Cardlock. The maximum concentration detected at depths greater than three feet was 2,780 mg/kg in SB-604(N). The source of these diesel range hydrocarbons is likely to be the former diesel USTs in this location (Figure 5-5).

RBDM VOCs: The VOC analytical results are presented in Appendix D, Tables D-2 and D-3. Figures 6-8 through 6-19 show the concentration distribution of selected VOCs in AOC 1. In general, benzene, toluene, ethylbenzene, xylenes (collectively BTEX), 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene were the primary VOCs detected at elevated concentrations in soil. In soil samples collected from three feet or shallower, the maximum detected concentrations of these seven compounds were found in soil boring SB-605(N). Soil boring SB-605(N) is located just west of the overhead loading rack at the Niemi Oil Cardlock. The concentrations detected are: benzene (0.157 mg/kg), ethylbenzene (4.3 mg/kg), toluene (0.0785 mg/kg), xylenes (14.3 mg/kg), 1,2,4-trimethylbenzene (20.3 mg/kg), and 1,3,5-trimethylbenzene (4.02 mg/kg) (Figures 6-8, 6-10, 6-12, 6-14, 6-16, and 6-18, respectively).

In soil samples collected from greater than three feet, elevated concentrations of BTEX were detected from soil borings located on the Niemi Oil Cardlock and a nearby soil boring in Industry Street (Figures 6-9, 6-11, 6-13, 6-15). The maximum concentration of each BTEX compound was in a soil sample from SB-602(N). Soil boring SB-602(N) is located on the Niemi Oil Cardlock site northwest of the overhead loading rack. The maximum concentrations detected are benzene (7.84 mg/kg), ethylbenzene (204 mg/kg), toluene (169 mg/kg), and xylenes (1,160 mg/kg). Two compounds, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene, have a similar distribution pattern to BTEX except they were also detected in SB-405(F), located south of the Qwest storage yard. The maximum concentrations of 1,2,4-trimethylbenzene and 1,3,5-trimethylebenzene were also detected in a soil sample from soil boring SB-602(N).

RBDM SVOCs: The SVOC analytical results are presented in Appendix D, Tables D-4 and D-5. Naphthalene is the only SVOC compound with its concentration distribution presented

graphically (Figures 6-20 and 6-21). In soil samples collected from three feet or less, the maximum detected concentration of naphthalene in AOC 1 was in soil boring SB-605(N) at 5.22 mg/kg. In soil samples analyzed from greater than three feet below ground surface the maximum naphthalene concentration was detected in SB-602(N) at a concentration of 141 mg/kg.

6.1.2 Ground Water

Fourteen monitoring wells are located in or near AOC 1 (Figure 6-22, Table D-10 to D-18). Ground-water analytical results for all parameters are presented in Appendix D. Figures 6-23 to 6-32 present the distribution of key COI in ground water during the third quarter 2004 (fourth event). Petroleum hydrocarbons detected were generally in the gasoline and diesel range. Petroleum hydrocarbon constituents detected were compounds common to both diesel and gasoline or constituents associated with a gasoline source. Figure 6-23 shows the distribution of gasoline-range hydrocarbons in ground water in AOC 1. The highest gasoline concentrations are found in MW-29(A) located in Industry Street. The distribution of diesel-range hydrocarbons is shown on Figure 6-24. The highest concentrations of diesel are found in MW-26(A) located in the southwest corner of the Niemi Oil Cardlock upgradient of its fuel storage and distribution facilities. Monitoring-wells MW-26(A) and MW-29(A) are located within close proximity of the north-south sewer line located between Qwest and Niemi Oil Cardlock.

BTEX were detected associated with the gasoline range hydrocarbons. Figure 6-25 shows the distribution of total BTEX in ground water in AOC 1. Figures 6-26 through 6-29 show the distribution of the individual constituents. Benzene occurs at a slightly different distribution (Figure 6-26) than total BTEX and the other gasoline COI in AOC 1. The highest benzene concentration was in monitoring-well MW-31(A), which is further down gradient than the center of mass for the other gasoline COI (Figures 6-27 through 6-31). Naphthalene occurs in a similar distribution to gasoline and diesel, as shown on Figure 6-32. The highest concentration occurs in monitoring-well MW-29(A).

The change in concentration of key COI from October 2003 to August 2004 in monitoring-wells MW-29(A) and MW-30(A) is shown on Figures 6-33 and 6-34, respectively. The water level changes during this time are also shown on these figures. The concentrations of key COI remained relatively consistent over the measurement period with few exceptions. Concentrations of diesel range hydrocarbons in MW-29(A) appear to display the largest range of concentrations, changing from 4,120 micrograms per liter (µg/L) in October 2003 to not detected (detection limit 250 µg/L) in January 2004. These concentrations returned to concentrations similar in magnitude to October 2003 concentrations in subsequent sampling events. In monitoring-well MW-30(A), diesel and 1,2,4-trimethylbenzene display larger variations than the other key COI. There appears to be little direct correlation between changes in water level and changes in concentration in these wells.

The extent of COI in ground water in AOC 1 has been defined. Monitoring wells where COI were not detected or were detected at very low concentrations surround the plume. Potential sources of these COI appear to be related to the 1990 Harris/Van West gasoline release, facilities located or formerly located at Niemi Oil Cardlock, the sewer lines between these facilities, Qwest vehicle service center, and Youngs Bay Texaco.

6.1.3 LNAPL

In 1990 in explorations associated with the Harris/Van West release, LNAPL was identified in recovery well RW-1 and test pit T-6 (Rittenhouse-Zeman 1990b) (Figure 1-9). Recovery-well RW-1 was installed by Harris/Van West during the remedial activities associated with the 1990 gasoline release from the Harris/Van West site and used for recovery of LNAPL. RW-1 was located in the southern corner of the Niemi Oil Cardlock property, upgradient of the Niemi Oil Cardlock source area, and downgradient of the Harris/Van West release. T-6 was adjacent to RW-1. Remedial activities ceased in 1991 when the LNAPL was reportedly removed. LNAPL characterization identified undegraded gasoline in one sample obtained from T-6, and a gasoline/diesel mixture in RW-1. The presence of diesel in this RW-1

LNAPL sample was attributed to carry over of weathered gasoline from the release at the Harris/Van West site (PNG, 1998). During the RI activities LNAPL was not identified in AOC 1. However, concentrations of gasoline-range hydrocarbons in MW-29(A) ranged up to 62,000 µg/L.

6.1.4 Storm Water

Storm water is directed to catch basins in AOC 1 and discharges to the combined sanitary and storm sewer system located in West Marine Drive and Industry Street. Storm water that discharges to the combined sewer system travels through pipes to the City of Astoria wastewater treatment system. During heavy rain events, this system may overflow through an outfall located in the West Mooring Basin (Figure 2-4). Sampling of this outfall was not included in the storm water monitoring program.

6.1.5 Sediment

Sediment in the West Mooring Basin may be affected by combined sewer overflow discharges during heavy rain events. Sediment in the West Mooring Basin is routinely dredged by the Port and was not characterized during the RI.

6.1.6 Air

Air was not identified as a media of concern in AOC 1.

6.2 AOC 2

AOC 2 is located at the eastern end of the Astoria Area-Wide site. Figure 6-1 shows the location of AOC 2 along with the July 2004 potentiometric surface, the identified BTEX plume, and LNAPL.. Petroleum hydrocarbons identified include gasoline, diesel, and heavy oil range hydrocarbons. The source of the petroleum hydrocarbons appears to be historical

facilities associated with the former Shell bulk plant, former Val's Texaco service station, and the former Delphia bulk plant.

6.2.1 Soil

As discussed in Section 6.1.1, the evaluation of the distribution of COI in soil was conducted in two depth intervals; less than or equal to three feet and greater than three feet. Analytical data for soil are presented in Appendix D, Tables D-1 to D-9.

TPH: Chemical analysis for hydrocarbon identification detected gasoline, diesel, and heavy oil-range hydrocarbons in soil in AOC 2. These data are shown on Figures 6-35 to 6-40. In the upper three feet of soil, gasoline-range hydrocarbons were detected at the former Val's Texaco, the former Delphia bulk plant, and the former Shell bulk plant (Figure 6-35). The maximum concentration of gasoline range hydrocarbons detected was 392 mg/kg from SB-321(D). Although SB-321(D) is located in the area where LNAPL has been observed, analytical results from the upper three-feet of soil show it has not been impacted by the LNAPL presence. Diesel-range hydrocarbons in the upper three feet of soil were detected at the former Shell bulk plant and the former Delphia bulk plant (Figure 6-37). The maximum concentration of diesel-range hydrocarbons detected was 2,440 mg/kg in SB-913(S). Heavy oil-range hydrocarbons were detected at the former Val's Texaco, the former Delphia bulk plant and the former Shell bulk plant (Figure 6-39). The maximum concentration of heavy oil-range hydrocarbons detected in the upper three feet was 6,390 mg/kg in soil boring SB-913(S) at the former Shell bulk plant.

Samples analyzed from depths greater than three feet revealed elevated concentrations of gasoline, diesel, and heavy oil-range hydrocarbons. Gasoline-range hydrocarbons were detected in soil at the former Val's Texaco, the former Delphia bulk plant, and the former Shell bulk plant, as shown on Figure 6-36. Gasoline-range hydrocarbons were detected most frequently at the former Val's Texaco and the former Delphia bulk plant. Because the former Val's Texaco is located at a higher elevation than the former Delphia bulk plant, significantly more vadose zone is present at the former Val's Texaco. Gasoline-range hydrocarbons were

generally detected at higher concentrations at the former Val's Texaco facility than at the former Delphia bulk plant. In addition, the highest concentration of gasoline in soil at the former Delphia bulk plant occurs in soil boring SB-321(D) at the southern boundary of the former Delphia bulk plant, at the base of the terrace below the former Val's Texaco (Figure 6-36). This is the location of LNAPL identified in associated monitoring well MW-15(A). Gasoline at the former Shell bulk plant occurs in soil on the southern portion of the facility (Figure 6-36). The maximum concentration of gasoline range hydrocarbons detected from greater than 3 feet in AOC 2 was 2,160 J mg/kg from the Shell bulk plant in SB-900(S). This is greater than the concentration detected in SB-321(D), although LNAPL has not been observed in the area of SB-900(S).

Diesel-range hydrocarbons were detected at all three facilities in soil greater than 3 feet bgs in AOC 2 (Figure 6-38). The highest concentration of diesel detected in soil at Val's Texaco was 9,640 mg/kg (Figure 6-38). The only diesel range hydrocarbons detected and quantified at the former Delphia bulk plant occurred in boring SB-321(D) (where LNAPL is identified) at the southern portion of the property boundary and at the base of the terrace below the former Val's Texaco. The highest diesel-range hydrocarbon detections occur in soil generally in the western portion of the former Shell bulk plant. Concentrations of diesel range up to 23,000 mg/kg in SB-904(S) at the former Shell bulk plant.

Residual range hydrocarbons consisting of heavy oil occur at the former Delphia bulk plant, former Val's Texaco, and former Shell bulk plant as shown on Figure 6-40. The highest quantified detection was at the former Delphia bulk plant in SB-321(D) (where LNAPL is identified) at 19,200 mg/kg. Residual range hydrocarbons were detected in other locations but this was the only detection quantified. Residual range hydrocarbons were quantified in several borings at the former Shell bulk plant with the highest concentration in SB-908(S) at 12,300 mg/kg.

RBDM VOCs: The VOC analytical results for soil are presented in Appendix D, Tables D-2 and D-3. Figures 6-41 through 6-52 show the concentration distribution of selected VOCs by sample depth intervals. Only 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were

detected at elevated concentrations in samples analyzed from three feet and shallower. From depths greater than three feet benzene, toluene, xylenes, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene were all detected at elevated concentrations.

In soil samples collected from three feet or shallower, the maximum detected concentrations of 1,2,4-trimethylbenzene (34.9 mg/kg) and 1,3,5-trimethylbenzene (17 mg/kg) were both detected in a soil sample from SB-306(D) located at the former Delphia bulk plant site just east of the former ASTs in the west tank farm (Figures 6-49 and 6-51, respectively).

The distribution of VOCs is broader in the samples collected from the deeper depths. Elevated benzene was detected in soil borings at the former Val's Texaco and the former Delphia bulk plant with the maximum detected concentration of 1.52 mg/kg in SB-316(D). Soil boring SB-316(D) is located northeast of the service island at the former Val's Texaco (Figure 6-42). Benzene was not detected at the former Shell bulk plant. The maximum concentration of toluene (12.7 mg/kg), xylenes (304 mg/kg), 1,2,4-trimethylbenzene (174 mg/kg), and 1,3,5-trimethylbenzene (55.1 mg/kg) were all detected in SB-316(D). These VOCs display a similar distribution to the gasoline-range hydrocarbons, as would be expected for compounds contained in gasoline; however, on the former Delphia bulk plant property elevated concentrations of 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene are more widespread than elevated concentrations of benzene, toluene, and xylenes. Potential gasoline sources of VOCs have been identified at the former Val's Texaco, the former Delphia bulk plant, and the former Shell bulk plant. The specific sources of the release of gasoline to environmental media were not identified. However, the dispenser island and piping at the former Val's Texaco appear to be one likely source. The dispenser island and related piping at the former Val's Texaco were removed in May 2006. Other potential sources exist at both the former Delphia bulk plant and former Shell bulk plant.

RBDM SVOCs: The SVOC analytical results are presented in Appendix D, Tables D-4 and D-5. Naphthalene is the only SVOC compound with its concentration distribution presented on Figures 6-53 and 6-54. In soil samples collected from three feet or shallower, the maximum detected concentration of naphthalene was in soil boring SB-306(D) at 1.35 mg/kg.

Soil boring SB-306(D) is located east of the former ASTs in the west tank farm. This sample also contained the maximum concentration of 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene in soil in AOC 2 at three feet or shallower. In soil samples analyzed from greater than three feet below ground surface the maximum naphthalene concentration was detected in SB-904(S) at 15.1 mg/kg located on the former Shell bulk plant site. The distribution of naphthalene in soil deeper than three feet in AOC 2 reflects the distribution of gasoline-range hydrocarbons as well as diesel-range hydrocarbons. Naphthalene is a component of gasoline in addition to being present in diesel.

6.2.2 Ground Water

Eleven monitoring wells are located in AOC 2. The potentiometric surface measured in the monitoring wells is shown on Figure 6-55. Ground-water analytical results are presented in Appendix D, Tables D-10 to D-18 and the August 2004 analytical data is presented on Figures 6-56 to 6-65. Petroleum hydrocarbons detected were generally in the gasoline range and diesel range. Both ranges of petroleum hydrocarbons are found in ground water at each of the three facilities in AOC 2.

Ground-water samples from monitoring-wells MW-13(A) and MW-20(A) generally contained the highest concentrations of COI in AOC 2 (Figure 6-58). In addition, LNAPL was identified on the water table in monitoring-well MW-15(A). The concentrations detected in ground-water samples indicate there are likely sources of COI on all three properties.

The change in concentration of key COI from October 2003 to August 2004 in monitoring well MW-21(A) is shown on Figure 6-66. MW-21(A) is located near the downgradient edge of AOC 2. There was little significant change in the order of magnitude of concentrations. The concentrations in MW-21(A) indicate that this ground-water plume is in a steady state condition (i.e. is not expanding). The concentrations of COI in ground water from monitoring wells near the center of the plume in AOC 2 (e.g. MW-18(A)) have shown fluctuating concentrations which may be attributed to well installation (e.g. higher concentrations during the first sampling event) and/or seasonal fluctuations.

6.2.3 LNAPL

LNAPL was identified in AOC 2 in monitoring well MW-15(A) near the southern boundary of the former Delphia bulk plant as shown on Figure 6-55. The LNAPL was first detected in January 2004 at 0.03 foot thick. Monthly measurements of LNAPL in MW-15(A) showed the thickness increases to a maximum of 1.94 feet in March 2004 and then steadily decreases to 0.35 feet thick in March 2005. A sample of the LNAPL was submitted to Shell Global Solutions of Houston, Texas, for hydrocarbon identification. The LNAPL was identified as containing 40 percent hydrocarbons that are less than C12 (gasoline-range) and 60 percent hydrocarbons that are greater than C12 (diesel and heavier-range). The product in MW-15(A) was identified as rich in alkylates and containing a significant contribution of a heavier component.

In 2005 Specialty Analytical of Tualatin, Oregon, reviewed existing data and chromatograms for the LNAPL in MW-15(A). Specialty concluded that the chromatogram from the MW-15(A) LNAPL sample is indicative of a recent source of gasoline-range organics contamination, as it shows little indication of heavily weathered or degraded gasoline-range organics. The LNAPL also contained significant amounts of diesel-range organics and oil-range organics. Organic lead was also present in the LNAPL in MW-15(A).

The LNAPL at the former Delphia bulk plant is analytically different from LNAPL identified in other areas of the Astoria Area-Wide site. The results of the forensics analysis completed on LNAPL samples indicate that the LNAPL is likely a mixture of subsurface contaminants from multiple sources (containing different compositions of identical base ingredients) that may have occurred during the approximately 70-year operational history of the sites. The distribution of LNAPL in AOC 2 is defined by its occurrence in MW-15(A) and the lack of LNAPL in any other monitoring wells in AOC 2.

Cross section B-B' (Figure 4-5) is located in the vicinity of MW-15(A). The extent of the LNAPL smear zone is not well defined and additional CPT-ROST® characterization was not

completed in this area. The LNAPL smear zone included on cross section B-B' is estimated from ground water and LNAPL measurements. The LNAPL type shown on B-B' is correlated from Shell Global Solutions evaluation rather than directly from ROST® data.

6.2.4 Storm Water

Storm water is directed to catch basins in AOC 2 and discharges to the combined sanitary and storm sewer system. Storm water that discharges to the combined sewer system travels through pipes to the City of Astoria wastewater treatment system. During heavy rain events, this system may overflow through an outfall located in the West Mooring Basin. Sampling of this outfall was not included in the storm water monitoring program.

6.2.5 Sediment

Sediment in the West Mooring Basin may be affected by combined sewer overflow discharges during heavy rain events. Sediment in the West Mooring Basin is routinely dredged by the Port and was not characterized during the RI.

6.2.6 Air

Neither air nor soil gas samples were not collected in AOC 2. Potential impacts to air were evaluated using data regarding the nature, extent, and magnitude of volatile petroleum hydrocarbons in soil and ground water.. If future redevelopment occurs in the LNAPL area an evaluation of air as a media of concern may be appropriate based on conditions at that time.

6.3 AOC 3

AOC 3 is located at the western end of the Astoria Area-Wide site. Figure 6-1 shows the location of AOC 3. Petroleum hydrocarbons identified in AOC 3 include diesel and heavy oil-range hydrocarbons. Low concentrations of gasoline-range hydrocarbons were detected in AOC 3 as well. An extensive remedial excavation was performed in AOC 3 in 2002 and is

further discussed in Section 7.0. Approximately 6,800 tons of soil were removed from the former Chevron/McCall bulk plant facility. The source of the petroleum hydrocarbons appears to be former facilities that have been removed from the former Chevron/McCall bulk plant and shallow pits that contained tank bottom wastes generated during cleaning of the ASTs onsite.

6.3.1 Soil

As discussed in Section 6.1.1, the evaluation of the distribution of COI in soil was conducted in two depth intervals; less than three feet and greater than three feet. Analytical data for soil are presented in Appendix D, Tables D-1 to D-9.

TPH: Chemical analysis for hydrocarbon identification detected primarily diesel and heavy oil-range hydrocarbons. Gasoline-range hydrocarbons were detected in a few samples. The upper three feet of soil, which had maximum concentrations of gasoline-range hydrocarbons (5.03 mg/kg), diesel-range hydrocarbons (6,030 mg/kg), and heavy oil-range hydrocarbons (7,700 mg/kg), was all subsequently removed during the remedial excavation.

After the remedial excavation was completed samples analyzed from depths greater than three feet did not reveal elevated concentrations of diesel or heavy oil-range hydrocarbons. The maximum diesel concentration was 196 mg/kg in SB-255(C), the maximum heavy oil-range concentration was 159 mg/kg in SB-201(C), and the maximum gasoline range concentration was 10 mg/kg in SB-255(C). Sample SB-255(C) is located in the northwest corner of AOC 3 and sample SB-201(C) is located in the center of AOC 3. The concentrations of gasoline, diesel, and heavy oil-range hydrocarbons are shown on Figures 6-67 through 6-72.

RBDM VOCs and SVOCs: After the remedial excavation only minor concentrations of VOCs and SVOCs were detected in the soil in AOC 3, except for in the location of soil boring SB-255(C). The VOC analytical results are presented in Appendix D, Tables D-2 and D-3. SVOC analytical results are presented in Tables D-4 and D-5. Figures 6-73 through 6-76 show the concentration distribution of selected VOCs and the SVOC naphthalene. After the

completion of the remedial excavation only one soil sample (SB-255(C)) from a depth of greater than 3 feet had a detected concentration of naphthalene (10.2 mg/kg). In this sample (SB-255(C) at a depth of seven feet), numerous SVOC compounds were detected, including benzo(a)pyrene at a concentration of 5.84 mg/kg. This is the maximum concentration benzo(a)pyrene that was detected in soil at the Astoria Area-Wide site.

6.3.2 Ground Water

Three monitoring wells are located in AOC 3. The ground-water elevations and potentiometric surface are shown on Figure 6-77. Ground-water analytical results are presented in Appendix D, Tables D-10 to D-18 and on Figures 6-78 to 6-80. Only a few COI were detected in ground water in AOC 3. Generally the only petroleum hydrocarbon constituents detected were low concentrations of several SVOCs in monitoring well MW-48(A). Total BTEX, diesel-range hydrocarbons, and naphthalene concentrations are presented on Figures 6-78 to 6-80. Chromium VI was detected in monitoring wells MW-46(A) and MW-47(A). Monitoring of chromium VI concentrations was conducted by Chevron and reported to DEQ separately. The extent of impacted ground water at the former Chevron/McCall bulk plant is delineated except for low levels of SVOCs in MW-48(A).

6.3.3 LNAPL

No LNAPL was identified in monitoring wells in AOC 3. During the remedial excavation, a petroleum sheen was observed in some excavations that reached the water table. Petroleum affected media were removed to the extent practical during the remediation activities.

6.3.4 Storm Water

Historically, storm water infiltrated in AOC 3. A few catch basins may have existed that drained to the Port storm sewer system. Since development of the Englund Marine facility, the area has been paved and new catch basins collect runoff prior to discharging through a new storm sewer system at the Port.

6.3.5 Sediment

The potential for sediment to be affected by operations in this AOC appears limited and no areas containing submerged sediments were identified for characterization.

6.3.6 Air

Air or soil gas was not identified as a media of concern in this AOC.

6.4 AOC 4

AOC 4 is located in the central portion of the Astoria Area-Wide site (Figure 6-1). Petroleum hydrocarbons identified in AOC 4 are primarily diesel and gasoline-range hydrocarbons with some localized heavy-oil range hydrocarbons. AOC 4 includes the hydrocarbon seep in Slip 2 and the LNAPL present upland from the seep. Numerous pipelines, ASTs, USTs, and petroleum loading facilities have been documented in AOC 4. Of these, several are likely to have been sources in addition to the documented diesel release from the McCall pipeline. The sources of the petroleum hydrocarbons in AOC 4 appear to be former facilities now removed at the former ExxonMobil/Niemi Oil bulk plant, the documented diesel release from the McCall petroleum distribution pipeline, an UST formerly operated by the Port, and other pipelines from/to nearby facilities. The potentiometric surface in July 2004 and the extent of the LNAPL are shown on Figure 6-1. Select analytical are presented on Figure 6-116.

6.4.1 Soil

Petroleum hydrocarbons occur in soil associated with potential sources in AOC 4. As discussed in Section 6.1.1, the evaluation of the distribution of COI in soil was conducted in two depth intervals; less than three feet and greater than three feet. Analytical data for soil are presented in Appendix D, Tables D-1 to D-9.

TPH: Chemical analysis for hydrocarbon identification detected gasoline, diesel, and heavy oil-range hydrocarbons. In the upper three feet of soil, gasoline-range hydrocarbons were detected in the central portion of AOC 4 north of Portway (Figure 6-81). The maximum gasoline-range hydrocarbon concentration detected was 31.4 mg/kg in SB-627(N). SB-627(N) is located within the LNAPL area however soil from the upper three-feet is not considered to be impacted by the LNAPL presence. Although some diesel and heavy oil-range hydrocarbons were detected in the upper three feet of soil, concentrations were generally low. The maximum diesel concentration was 239 mg/kg in soil boring SB-618(N) and the maximum heavy oil-range concentration was 239 mg/kg in soil boring SB-627(N).

Soil samples analyzed from depths greater than three feet revealed elevated concentrations of gasoline and diesel-range hydrocarbons as shown on Figures 6-82 and 6-84. Minor concentrations of heavy oil-range hydrocarbons were also detected (Figure 6-86). The elevated concentrations of gasoline and diesel-range hydrocarbons were primarily detected within or adjoining the area where LNAPL has been identified. Within or near the LNAPL area the maximum concentration of gasoline-range hydrocarbons detected was 5,960 mg/kg in a soil sample collected from SB-019(A) and the maximum diesel-range hydrocarbons were detected at a concentration of 51,400 mg/kg in a sample collected in SB-510(M). Outside the LNAPL area the maximum concentration of gasoline-range hydrocarbons was 4000 mg/kg in a soil sample collected from SB-616(N) and the maximum concentration of diesel range hydrocarbons was 10,800 mg/kg in a soil sample collected from SB-619(N) (other higher concentrations were detected near the exterior boundary of the LNAPL area). At the former ExxonMobil/Niemi Oil bulk plant characterization of soil beneath a former below grade circular concrete structure detected gasoline-range hydrocarbons at a concentration of 1,120 mg/kg and diesel-range hydrocarbons at a concentration of 6,920 mg/kg (sample SS-1, Figures 6-82 and 6-84).

RBDM VOCs: The VOC analytical results for soil are presented in Appendix D, Tables D-2 and D-3. Figures 6-87 through 6-98 show the concentration distribution of selected VOCs in soil in AOC 4 by sample depth. In general, no VOCs were detected at elevated concentrations

in samples analyzed from three feet and shallower. From depths greater than three feet, BTEX, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene were all detected at elevated concentrations. Elevated concentrations were generally detected in the area of the identified LNAPL. The maximum concentrations of benzene (17.2 mg/kg), toluene (42.6 mg/kg), ethylbenzene (148 mg/kg), and xylenes (931 mg/kg) were all detected in a soil sample from SB-612(N). Soil boring SB-612(N) is located on the former ExxonMobil/Niemi Oil bulk plant in the area of the former tank farm that is near or within the LNAPL area. The maximum concentrations of 1,2,4-trimethylbenzene (480 mg/kg) and 1,3,5-trimethylbenzene (128 mg/kg) were also detected in SB-612(N). Essentially all of the significantly elevated VOC compounds were detected near or within the LNAPL area.

The distribution of trimethylbenzenes in soil in AOC 4 may provide the best representation of the overall distribution of VOCs (Figures 6-95 and 6-98). Detection limits for benzene were affected by dilution performed by the laboratory to allow quantification of COI that occurred at concentrations outside the calibration range of the analytical instrument. Trimethylbenzenes in AOC 4 occur most frequently in soil at the former ExxonMobil/Niemi Oil bulk plant. These COI also occur in soil near an UST located north of the Port maintenance shop removed in 1993, and in soil on Pier 2. Little data for trimethylbenzenes in soil were collected between the location of the McCall pipeline and Slip 2, however benzene was detected in most of these borings (Figure 6-88). It is unclear whether benzene occurs as a result of a gasoline release or from its presence in diesel released from the McCall pipeline, or both.

***RBDM SVOCs*:** The SVOC analytical results for soil are presented in Appendix D, Tables D-4 and D-5. Naphthalene is the only SVOC compound with its concentration distribution presented (Figures 6-99 and 6-100). In soil samples collected from three feet or shallower the maximum detected concentration of naphthalene was low (0.226 mg/kg). However, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene were all detected at elevated concentrations in a two-foot sample from soil boring SB-008(A). Soil boring SB-008(A) is located along the west boundary of AOC 1 upland of Slip 2. The maximum concentrations of these three SVOC compounds in AOC 4 were detected in this two-foot sample.

In soil samples analyzed from greater than three feet below ground surface the maximum naphthalene concentration was detected in SB-626(N) at 96.2 mg/kg (Figure 6-100). Soil boring SB-626(N) is located between Portway and the northern boundary of the former ExxonMobil/Niemi Oil bulk plant within the LNAPL area. Again, it is unclear whether the source of naphthalene was a gasoline or diesel release or both.

6.4.2 Ground Water

Twenty-six monitoring wells and two recovery wells are located in AOC 4. The potentiometric surface and ground-water elevations are shown on Figure 6-101. LNAPL has been identified in 13 wells (Figure 6-101). Ground-water analytical results are presented in Appendix D, Tables D-10 to D-18 and on Figures 6-102 to 6-110. Generally gasoline and diesel-range petroleum hydrocarbon constituents were detected in the monitoring wells.

The extent of gasoline-range hydrocarbons in ground water in AOC 4 is shown on Figure 6-102. Gasoline occurs nearly coincident with the area of identified LNAPL and the extent is well defined. Diesel-range hydrocarbons display a similar distribution. Of the VOCs identified as key COI, only benzene and 1,2,4-trimethylbenzene occur in ground water in AOC 4 at significant concentrations (Figures 6-104 and 6-108). Benzene occurred at a concentration of 15.5 µg/L and 1,2,4-trimethylbenzene at 16.3 µg/L in MW-2(M) in August 2004. Monitoring well MW-2(M) is located along the west side of the LNAPL area upland of Slip 2. These distributions are also similar to the distribution of gasoline-range hydrocarbons. The concentration of naphthalene in MW-2(M) in August 2004 was 179 µg/L (Figure 6-110).

Concentrations of key COI in MW-2(M) through time are presented on Figure 6-111. In AOC 4, there appears to be a weak inverse correlation between water level and concentration. Concentrations of these COI were lowest in January 2004 when water levels were highest. However, the maximum concentration measured does not directly correlate with the lowest water levels measured during quarterly monitoring events. The quarterly ground-water

monitoring program appears to have defined the range of concentrations that could be expected to occur in AOC 4.

The nature and extent of impacted ground water in AOC 4 has been adequately defined. This includes discharge of impacted ground water to surface water in Slip 2. The qualitative nature of this discharge was discussed in Section 4.0. No ground-water analytical results are available for the near shore area in the vicinity of the seep. LNAPL characterization in the near shore area in the vicinity of the seep is discussed in Section 6.4.3.

6.4.3 LNAPL

LNAPL has been identified in thirteen wells (including two recovery wells) in AOC 4. Samples of LNAPL from selected wells were submitted to Shell Global Solutions for hydrocarbon identification (Shell Global Solutions, 2004). LNAPL in monitoring-wells MW-37(A) and MW-40(A) are predominantly gasoline with approximately 30 percent diesel. Monitoring wells MW-42(A) and MW-44(A) contain slightly more diesel than gasoline. Monitoring wells MW-3(M), MW-4(M), MW-8(M), MW-9(M), and MW-41(A) contain mostly diesel with 8 to 25 percent gasoline. Although LNAPL from MW-37(A) and MW-40(A) were both predominantly gasoline, the nature of the LNAPL in MW-37(A) was markedly different than that observed in the other wells in AOC 4. (Shell Global Solutions, 2004)

Depending on the season, the number of monitoring wells containing a measurable thickness of LNAPL ranges from four to thirteen. Figure 6-112 shows the thickness of LNAPL measured in each well since September 2002. In general, LNAPL accumulates at its greatest thicknesses in wells in the early spring. Measurements made in the late summer and early fall usually indicate less LNAPL accumulation in these wells. As the water level retreats from its spring time highs, some LNAPL is left trapped in interstices within the vadose zone and becomes immobile. The zone over which water levels fluctuate is a LNAPL smear zone. The measurement of increased thicknesses of LNAPL is recorded when water levels rise indicating the rising ground water remobilizes LNAPL. Figure 6-112 shows the overall trend of

decreased LNAPL thickness with time. At the time of the last LNAPL monitoring event in December 2006 LNAPL was detected in only two (MW-50(A) and MW-44(A)) of the monitoring wells monitored.

An extensive characterization program utilizing a rapid oscillation screening tool (ROST) was implemented in AOC 4 in September 2004. Figure 6-113 shows the locations where ROST explorations were advanced using a cone penetrometer rig (CPT). At each ROST location, the nature of the residual LNAPL was defined on the basis of wavelength and fluorescence. Residual LNAPL that occurs below the former ExxonMobil/Niemi Oil bulk plant responded to the ROST similarly to a primarily gasoline-range hydrocarbon mixture. Further north, closer to Slip 2, residual LNAPL becomes a primarily diesel-range hydrocarbon mixture. Heavy oil hydrocarbons were detected outside the area of identified LNAPL. The nature of the petroleum hydrocarbons becomes more degraded in the zone where tidal influences on water levels are greatest.

Cross sections showing the vertical extent of residual LNAPL are presented on Figures 6-114 and 6-115. The smear zone is coincident with the range of seasonal water level fluctuation as measured in nearby monitoring wells. The gradation from primarily gasoline to primarily diesel to primarily degraded diesel is clearly shown as well.

The ROST defined the nature and most of the extent of residual LNAPL in AOC 4. During September 2005, additional soil borings and monitoring wells were installed on Pier 2 and at the former ExxonMobil/Niemi Oil bulk plant to define the northern boundary of the LNAPL. MW-50(A) was located to confirm information collected during the ROST effort. MW-49(A) and MW-51(A) were installed to define the boundary of the LNAPL. The locations of these wells are shown on Figure 6-102 (and others). No specific data were collected during the RI to determine the rate of LNAPL discharge to surface water or sediment in Slip 2.

6.4.4 Storm Water

Storm water in AOC 4 infiltrates into the subsurface in unpaved areas or flows over impervious surfaces to catch basins and enters the storm drain system at the Port. Storm water samples were collected quarterly from two outfalls for a one-year period. No water quality issues were identified as a result of storm water sampling.

6.4.5 Sediment

Sediment samples for the RI were collected in June 2003 and January 2006 from locations in Slip 2 in AOC 4. The sample locations are shown on Figure 6-116. The analytical results are presented in Appendix D, Tables D-25 to D-31. The petroleum related analytical results are summarized below with further detail provided in the Ecological Risk Assessment (Appendix I).

Two sediment samples were collected in June 2003 (SD-700(P) and SD-701(P)) from the southeast corner of Slip 2 and analyzed for petroleum hydrocarbons, SVOCs and VOCs. In January 2006 five sediment samples were collected from the southeast corner of Slip 2 - three inside the boom area (SD-100, SD-101, SD-102) and two outside the boom area (SD-103, SD-104). These sediment samples were analyzed for the full list of Washington State Sediment Management Standards (SMS) and six conventional parameters. Reference samples were also collected; these samples are discussed in the ecological risk assessment (Section 12.0).

Petroleum hydrocarbon analyses (samples SD-700(P) and SD-701(P) only) detected only diesel-range and heavy oil-range hydrocarbons. Sample SD-700(P) was collected closest to the bank, inside of the boom area, and contained a much higher concentration of the hydrocarbons (diesel-range hydrocarbons at 8,090 mg/kg and heavy oil-range organics at 800 mg/kg) than sample SD-701(P) that was collected just outside the containment boom (diesel range-hydrocarbons at 150 mg/kg and heavy oil-range organics at 143 mg/kg).

The analyte list for VOC analyses between the 2003 and 2006 sampling events were different. No VOCs were detected in either sample collected in 2003. No chlorinated benzenes, one phthalate esther (Di-n-odtyl phthalate) and one ionizable organic compound (4-mrthylphenol) were detected in the 2006 samples. The detected compounds were in samples SD-100, SD-101, and/or SD-102, all located within the absorbent boom area..

PAH analysis was conducted with a more complete compound list to allow for a comparison of pyrogenic PAHs and petrogenic PAHs. Pyrogenic PAHs are derived from combustion (i.e., has been burned) and petrogenic PAHs are generally from a noncombusted petroleum product. Typically, the primary potential source of pyrogenic PAHs is engine exhaust. Pyrogenic PAH contamination is also commonly associated with manufactured gas plants. In the case of Slip 2, the presence of pyrogenic PAHs may be associated with the fire in 1985 that destroyed a portion of Pier 2 immediately east of the absorbent boom and sampling locations. The primary potential source of petrogenic PAHs would be a petroleum release.

The alkylated PAH data were evaluated to consider whether the PAH signatures were representative of pyrogenic or petrogenic sources. Both Battelle (Andrew Smith, Research Chemist; Battelle, personal communication, September 2003) and Shell Oil (Ileana Rhodes; Shell Global Solutions, personal communication, September 2003) provided similar conclusions with regards to the potential sources of PAHs in the two 2003 sediment samples collected in Slip 2. Sample SD-700(P) (collected from within the boom area) has a larger relative contribution of petrogenic PAHs with abundance of alkylated PAHs than the heavier molecular weight PAHs (HPAH), which are of pyrogenic origin. Sample SD-701(P) (collected outside the boom area) contains less petrogenic PAHs or light PAHs (LPAH) in relation to contribution of HPAHs.

In the 2006 samples, elevated LPAHs (petrogenic origin) were detected primarily in samples SD-101, SD-102, and SD-103 (all located in the vicinity of burned pier). The total LPAH concentration was lowest in SD-100 (inside the absorbent boom furthest away from Pier 2) where they were not detected above the reporting limit and highest in SD-102 (located inside the absorbent boom closest to Pier 2) where the laboratory reported total LPAH at 1,540JD

µg/kg. The total HPAH concentration was lowest in SD-104 (located outside boom near middle of Slip 2) at 120J µg/kg and highest in SD102 (located inside boom closest to Pier 2) at 11,316JD µg/kg. Total LPAH and HPAH concentrations between the 2003 and 2006 samples are not directly comparable but in general the conclusion is the same; the concentration of LPAHs and HPAHs is higher in samples collected from inside the absorbent boom. Within the boom area the concentration of LPAH is lowest in the sample collected furthest from Pier 2 with higher concentrations increasing toward the eastern corner of the slip near Pier 2. The highest HPAH concentrations were detected in the vicinity of the burned dock, both inside and outside the boom area.

6.4.6 Surface Water

Five surface water samples (SW-100, SW-101, SW-102, SW-104, SW-105) were collected as part of the January 2006 sediment sampling effort. The objective of the surface water sampling and evaluation program was to evaluate whether petroleum constituents in the seep or sheen observed in Slip 2 may pose an ecological risk to pelagic (water column) aquatic receptors. Samples were collected from the mid-water column both inside the boom area and outside the boom area in Slip 2. Surface water samples were analyzed for petroleum constituents. In general, only low concentrations of BTEX, LPAHs, and HPAHs were detected in the samples. Numerous analytes were detected in SW-101 and SW-102 and only a few analytes were detected in SW-100, SW-104, and SW-105. The maximum LPAH concentration (naphthalene at 0.21 µg/L), HPAH concentration (pyrene at 0.025 µg/L), and VOC benzene (0.89 µg/L) were all detected in SW-102. Surface water analytical results are presented in Tables D-32 and D-33.

6.4.7 Soil Vapor

Soil gas sampling has been conducted in the vicinity of the Port office building in AOC 4. Soil vapor probes (SVP) screened at a depth of approximately five feet below ground surface, are located in four locations around the exterior perimeter of the Port office building. Seven sub-slab probes (SSP) are located in seven locations in the interior of the Port office building

to collect soil gas samples from just below the foundation slab. The exterior soil vapor locations are identified as SVP-01 through SVP-04. The interior soil vapor sample locations are identified as SSP-01 through SSP-07. Soil vapor sample analytical results are presented in Appendix D, Tables D-34 to D-37. The soil vapor sample locations are shown on Figure 6-117. A technical memorandum describing the results of the sub slab soil gas-sampling program is presented in Appendix H.

The samples were analyzed for gasoline-range petroleum hydrocarbons, benzene, toluene, ethylbenzene, o-xylene, p/m-xylene, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene. Standard analytical methods are not available to analyze the soil vapor samples for diesel-range petroleum hydrocarbons. The soil gas samples were also analyzed for fixed gases including methane, oxygen, and carbon dioxide.

Soil vapor samples were collected from the SVPs in two sampling events in October and December 2004. The compounds 1,3,5-trimethylbenzene and 1,2,4-trimethylbenzene were not detected in the SVP samples. During these two sampling events the gasoline-range hydrocarbons were detected from 338 ppm_v (parts per million by volume) in SVP-04 to 7,570 ppm_v in SVP-01. Benzene concentrations ranged from not detected in SVP-04 to 121,000 micrograms per cubic meter (ug/m^3) in SVP-01. The maximum toluene (24,900 ug/m^3), ethylbenzene (7,380 ug/m^3), o-xylene (912 ug/m^3), and m/p-xylene (22,600 ug/m^3) concentrations were also detected in samples collected from SVP-01. Methane concentrations in the SVP samples ranged from 6.0 percent (SVP-02) to 28.6 percent (SVP-04). Depleted oxygen concentrations and elevated carbon dioxide concentrations were measured in the SVP samples; indicating aerobic biodegradation of petroleum hydrocarbons is occurring.

SSP soil vapor samples were obtained in July 2005 and September 2006 to evaluate conditions beneath the slab of the Port office building. The maximum vapor concentrations were generally detected in the southwestern portion of the building (SSP-01 and SSP-06). The maximum concentrations for benzene (7,400 ug/m^3) and 1,2,4-trimethylbenzene (1800 ug/m^3) were detected in SSP-06 and the maximum concentrations for toluene (3200 ug/m^3), o-xylene (1200 ug/m^3), m/p-xylene (3300 ug/m^3), and TPH-G (1900 ppm_v) were detected in SSP-01.

The maximum concentrations for 1,3,5-trimethylbenzene (26 ug/m^3) and ethylbenzene (4.4 ug/m^3) were detected in SSP-05 and SSP-07, respectively. Methane was detected above the method reporting limit in SSP-01 (0.32 to 1.7 percent) and SSP-06 (1.4 percent). Methane concentrations in the other SSP locations (SSP-02, -03, -04, -05, and -07) were below the sample reporting limit. Depleted oxygen concentrations and elevated carbon dioxide concentrations were measured in the SSP samples; indicating aerobic biodegradation of petroleum hydrocarbons is occurring.

At the request of DEQ, areas identified as potential collection/accumulation areas for subsurface methane gas around the inside and outside of the Port office building were screened for methane. Nineteen locations around and within the building were identified and screened using a landfill gas detector for methane concentration and percent of lower explosive limit (LEL) (Figure 6-117). Three of these monitoring locations contained methane at elevated concentrations and one location detected methane at five percent of the LEL. Methane screening results are presented in Table D-38.

6.5 AOC 5

AOC 5 is located at the end of Pier 3. Figure 5-11 shows the location of AOC 5. Petroleum hydrocarbons identified in AOC 5 include diesel and heavy oil-range hydrocarbons. The source of the petroleum hydrocarbons is not clear but they are in the location of the former Astoria Oil Services facilities.

6.5.1 Soil

As discussed in Section 6.1.1, the evaluation of the distribution of COI in soil was conducted in two depth intervals; less than three feet and greater than three feet. Analytical data for soil are presented in Appendix D, Tables D-1 to D-9.

Hydrocarbon Identification: Chemical analysis for hydrocarbon identification detected diesel and heavy oil-range hydrocarbons. The upper three feet of soil contain the maximum

concentration of diesel-range hydrocarbons (35.3 mg/kg) in SB-709(P) and heavy oil-range hydrocarbons (2,450 mg/kg) in soil boring SB-710(P). These borings are located at the end of Pier 3.

Samples analyzed from depths greater than three feet did not reveal elevated concentrations of diesel but heavy oil-range hydrocarbons were detected at a concentration of 1,630 mg/kg in SB-712(P). The concentrations of diesel and heavy oil-range hydrocarbons are shown on Figures 6-118 through 6-121.

This area of Pier 3 is littered with wood debris from past log storage and shipment. The quantification of petroleum hydrocarbons can be compromised in soil with high organic matter content.

RBDM VOCs and SVOCs: Essentially only minor concentrations of VOCs and SVOCs were detected in the soil in AOC 5. The VOC analytical results are presented in Appendix D, Tables D-2 and D-3, and SVOC analytical results are presented in Tables D-4 and D-5. The VOC occurring at the highest concentration is xylene at a concentration of 0.0763 mg/kg in soil boring SB-712(P).

6.5.2 Ground Water

Ground water was not identified as a media of concern in this AOC based on ground-water samples collected from temporary well points.

6.5.3 LNAPL

No LNAPL was identified in AOC 5.

6.5.4 Storm Water

Storm water was not identified as a media of concern in this AOC. Surface water infiltrates.

6.5.5 Sediment

Sediment was not identified as a media of concern in this AOC.

6.5.6 Air

Air was not identified as a media of concern in this AOC.

7.0 IRAMS UNDERTAKEN AS PART OF THE RI

Members of the Astoria Area-Wide PRP Group have developed and implemented specific IRAMs to control and mitigate releases resulting from past operations at the Astoria Area-Wide site. The IRAMs were selected by factoring in effectiveness, long-term reliability, implementability, implementation risk, and reasonable cost. Information obtained during previous investigations and this RI was used in developing and evaluating IRAM alternatives.

7.1 OVERVIEW OF REMEDIAL ACTIVITIES

The scope of the IRAMs conducted at the Astoria Area-Wide site as part of the RI is discussed in this section. Certain activities, such as the installation of an absorbent boom in Slip 2 and upgraded HVAC (heating, ventilation, and air-conditioning) system in the Port office building continue to operate in order to mitigate the effect of petroleum hydrocarbons in the environment. Interim remedial actions conducted during the RI include the following.

Remedial Measures	Year Initiated
Soil Removal – AOC 3	2002
LNAPL Recovery – AOC 2 & 4	2003
Storm Sewer Reroute – AOC 4	2004
Absorbent Boom Replacement – AOC 4	2004
Pipeline Decommissioning – AOC 1 & 4	2004
UST Removal – AOC 4	2004
HVAC Upgrades – AOC 4	2004
Soil and Pipeline Removal – AOC 2	2005
Development IRAM – AOC 4	2005
AST and UST Removal – AOC 2	2002 – 2006

7.1.1 Soil Removal – AOC 3

This IRAM was performed independent of the PRP group in anticipation of proposed development on the former Chevron/McCall bulk plant. The July 26, 2002, Interim Remedial Action Measures Work Plan, Former McCall Oil Bulk Facility, presents the work plan for this IRAM. As mentioned in Section 1.5, a previous subsurface investigation identified Bunker C waste and elevated petroleum hydrocarbon and metals concentrations in the shallow soil on site. Approximately 6,800 tons of contaminated soil were removed from the former Chevron/McCall bulk plant in 2002. Soil was delineated both laterally and vertically. Confirmatory closure samples were collected to verify that the contaminated soil had been removed. The lateral and vertical extent of the contaminated soil was defined visually in shallow test pits and further defined by advancing soil borings. The borings were part of the overall Astoria Area-Wide soil investigation. The soil was excavated using backhoes and either temporarily stockpiled on the property pending transport, or loaded directly into trucks for transport to Hillsboro landfill. The IRAM was finalized by placing clean fill consisting of crushed concrete derived from demolition of the structure on Pier 3 to return to level grade conditions. A previously unknown UST was also decommissioned and removed from the former Chevron/McCall bulk plant along with related contaminated soil. Development occurred on the former Chevron/McCall bulk plant property in 2005. Englund Marine constructed a new retail facility, service shop, and a parking area.

7.1.2 LNAPL Recovery – AOC 2 and 4

The removal of LNAPL from the monitoring wells as part of the RI at the Astoria Area-Wide site began in July 2003. Product removal was initially performed using a disposable bailer. The bailer was lowered into the well just far enough to recover product while limiting the amount of ground water removed. The removal technique was subsequently changed from using a bailer to using a peristaltic pump. The peristaltic pumping method was more efficient and continued to be the preferred method through December 2004. LNAPL was pumped from each well until the thickness of product in the well was minimal. LNAPL recovery generally

occurred monthly. This LNAPL recovery was completed in association with monthly monitoring and quarterly ground-water sampling.

In March 2005, absorbent socks were inserted into monitoring wells containing LNAPL. Table 7-1 includes a listing of those wells with absorbent socks. LNAPL recovery by absorbent socks is on-going and each month the socks are removed and weighed as a measure of the quantity of LNAPL recovered during the past month. The February 2005 and March 2005 Progress Reports submitted to DEQ (*EnviroLogic Resources* 2005b and 2005c) document the contracting and implementation of this activity to Cowlitz Clean Sweep of Astoria. A table summarizing the volume of LNAPL recovered is included as Table 7-1.

7.1.3 Storm Sewer Reroute – AOC 4

In May 2004, part of an existing storm water system was rerouted in accordance with the DEQ-approved Hydrocarbon Seep IRAM Specifications Work Plan, dated December 22, 2003. By rerouting this section of the storm water system, a possible preferential pathway for petroleum hydrocarbons was removed. This section of the storm water system ran between the Port office and Port maintenance buildings, through a storm water catch basin (Outfall #2 sampling point) and to Outfall #2. The storm sewer line also ran through an area where free-phase hydrocarbons had been observed. The exact discharge point of Outfall #2 could not be located although the general area of the discharge point was determined during a dye test. The new sewer line was specifically designed with an elevation profile that is above the maximum observed ground-water elevations in the area at the head of Slip 2 (Figure 2-4).

The abandoned pipes and existing lines inside of the catch basin were plugged with cement grout. The bottom of the catch basin was also sealed with grout. The new piping system starts at the storm water catch basin located between the two buildings, is routed through a new manhole, and discharges into Slip 2 at the new Outfall #2 location. Another section of pipe was installed from the reconstructed catch basin to the new manhole.

7.1.4 Absorbent Boom Replacement – AOC 4

In 2004, a new enhanced absorbent boom system was installed in Slip 2 to replace the former boom system in accordance with the DEQ-approved Hydrocarbon Seep IRAM Specifications Work Plan, dated December 22, 2003. Initially, the boom system was inspected weekly to confirm that the boom was moving freely with the fluctuating water surface and that the boom segments are in proper positions to function effectively. If the boom was not functioning effectively it was adjusted to reestablish proper performance. Once the boom was functioning properly the inspection frequency changed to monthly. Currently the boom is on a monthly inspection schedule. The absorbent boom is changed out periodically as it fills or is damaged by storms.

In 2008, an enhanced absorbent boom was installed, consisting of an absorbent sweep boom near the bank and an absorbent snare between the absorbent sweep and the existing absorbent/hard boom. The absorbent sweep boom consists of a sheet of absorbent material 19 inches wide that collects LNAPL as it leaves the bank. The absorbent snare boom is located off-shore from the sweep boom, and consists of pom-poms that collect LNAPL that is not absorbed by the sweep boom.

7.1.5 Pipeline Decommissioning – AOC 4

Pipeline investigation and decommissioning activities occurred in March and April 2004 in accordance with the DEQ-approved Historical Shell/Niemi Oil/Mobil Petroleum Pipeline Investigation and Decommissioning Work Plan, dated December 18, 2003. Four test pit excavations were completed along pipelines jointly operated by Shell and Mobil/Niemi Oil in the past as part of this investigation. The purpose of the excavations was to expose the historical pipelines at likely junctions, elbows, and suspected current inland termini; assess soil conditions and the condition of the pipelines at these points; and decommission the pipelines in place by grout sealing if not previously decommissioned.

The exposed pipelines at each excavation location were inspected for indications of historical releases and historical abandonment/decommissioning activities. One section of pipeline investigated appeared to be previously decommissioned (e.g., pipelines were cut and capped, grout present inside the line, etc). The other three investigated sections did not show indications of having been decommissioned. As documented in the July 30, 2004, Technical Memorandum, Historical Shell/Niemi/Mobil Petroleum Pipeline Investigation and Decommissioning Report, although petroleum related compounds were detected, no indications of historical pipeline releases were observed in explorations.

7.1.6 UST Removal – AOC 4

As presented in the December 23, 2004, IRAM Work Plan, (*EnviroLogic Resources*, 2004l) and February 9, 2005, IRAM Work Plan Addendum (*EnviroLogic Resources*, 2005a) for the former ExxonMobil/Niemi Oil bulk plant, two underground storage tanks (USTs) were removed from beneath the former ExxonMobil/Niemi Oil bulk plant in November 2004. This included the removal of an underground heating oil storage tank and an UST for secondary containment in connection with the former overhead petroleum truck loading rack. The heating oil was historically used to heat the office building on site.

The tanks were decommissioned by removal. The heating oil tank was 340-gallon capacity while the second UST was a 2,000-gallon capacity tank used for secondary containment. After removal the tanks were transported to a metals recycling facility. Confirmation samples were collected from beneath each end of the tanks. The UST excavations were backfilled with clean backfill. No impacted soils were removed from the property.

Due to an oversight the samples were sent to a laboratory not previously utilized for soil analysis as part of the Astoria Area-Wide project. The soil samples were not subject to the same QA/QC protocol. The analytical results are presented in Table D-1 and sample locations are included in Section 6 – AOC 4 figures. The confirmation samples from the heating oil tank excavation detected diesel range hydrocarbons at a concentration of 41,000 mg/kg (north end 6 foot depth) and 27,000 mg/kg (south end 6 foot depth). The two confirmation samples

from the secondary containment UST were submitted for hydrocarbon identification and only diesel range hydrocarbons were detected in one sample. Follow up analysis did not detect diesel range hydrocarbons above the method reporting limit.

7.1.7 HVAC Upgrades – AOC 4

Soil vapor data were reviewed and it was determined that the Port office building represented the most at-risk structure for vapor intrusion impacts because of the presence of free-phase petroleum hydrocarbons in ground-water monitoring wells near the Port office building. Soil vapor monitoring samples were collected from four monitoring points near the Port office building to assess the potential intrusion of subsurface hydrocarbon vapors into indoor air. Soil vapor points were installed during September 2004 and samples were collected in September and December 2004. As presented in the Technical Memorandum, Vapor Intrusion Pathway Assessment, Port of Astoria Office Building, dated April 25, 2005, the soil vapor results indicated the concentrations of benzene in two of the samples might exceed calculated site-specific soil vapor RBCs in a portion of the Port office building. The Port office building HVAC system was upgraded in 2005 to maintain a positive pressure inside the building during working hours. The purpose of maintaining a positive pressure is to limit the potential for soil vapors to migrate through the foundation and enter the breathing zone of the workers inside the building. With the upgrade, 500 cubic feet per minute (cfm) of air now flows through the HVAC system inside the Port office. Five new programmable thermostats were installed during this upgrade. During non working hours the system is off. The implementation of this IRAM is documented in an October 25, 2005, letter to DEQ.

The methods used during the sub slab investigation are provided in the Subsurface Vapor Intrusion to Indoor Air Investigation, Port of Astoria Office Building (*EnviroLogic Resources* and GeoSyntec Consultants, 2005f). A differential pressure micromanometer was set up to monitor the pressure across the foundation during two test events conducted in July 2005 and February 2006. The difference in pressure of the indoor air and the sub slab was measured in order to confirm the HVAC upgrades are working to create a positive pressure inside the building. Testing implied that when windows and doors were left open the IRAM

effectiveness was negligible. The IRAM was effective in maintaining a small positive interior cross-slab pressure difference during the February 2006 testing when a special effort was made to keep perimeter doors (not necessarily exterior) and windows from being left open or ajar for extended time periods. Figure 7-1 presents a graph showing the differential pressure measured for the February 2006 test event.

7.1.8 Soil and Pipeline Removal – AOC 2

During site development activities in 2005 related to construction of a new Bornstein Seafood plant upland of Slip 1, heavy oil/Bunker C was encountered in a catch basin that had been buried with soil. It is unclear whether this material was waste from a nearby bulk plant/pipeline or deposited for some other reason. The heavy oil/Bunker C contaminated soil, and pipes were removed from the site. Confirmation samples showed the soil remaining in the excavation was not impacted by petroleum hydrocarbons. No work plan was developed for this IRAM as the catch basin was found during ongoing development activities. Sampling results are included in Section 6.0.

7.1.9 Development IRAM – AOC 4

A work plan was submitted for an IRAM at the former Mobil/Niemi Oil bulk plant in December 2004. DEQ approved the work plan in March 2005. The work plan addresses the environmental issues to be managed during the redevelopment of the former Mobil/Niemi Oil bulk plant site. The IRAM work plan enabled the Port (property owner) to redevelop and commercially lease the former bulk plant site before completion of the RI and baseline human health risk assessment. The goals of this IRAM are to:

- Reduce potential human exposure to petroleum hydrocarbons and other contaminants in the environment that could result in an unacceptable risk.
- Reduce potential migration of contaminants through subsurface soil and ground water to the Columbia River.

- Provide specific guidelines and requirements regarding petroleum contamination for preparation of engineering and land use plans associated with the proposed commercial redevelopment of the former Mobil/Niemi Oil bulk plant.
- Utilize remedies that are expected to be consistent with the potential final remedial actions for the Astoria Area-Wide site.

The tasks to be performed as part of the proposed former Mobil/Niemi Oil bulk plant IRAM included implementing remedies consisting of a passive soil venting system and vapor barrier for the identified areas of hydrocarbon impact. The redevelopment IRAM included development of a contaminated media management plan for the protection of development contractors as well as the design and installation of a vapor barrier and passive vapor extraction system beneath the new building constructed at the former Mobil/Niemi Oil bulk plant. Redevelopment work including grading and stockpiling of contaminated media began in May 2006. The engineering design for the passive soil venting system was submitted to DEQ in January 2007. Installation of the sub-slab portions of the vapor barrier were completed in April 2008 with installation of the final elements still pending.

7.1.10 UST Removal – AOC 2

Although a formal IRAM work plan was not submitted to DEQ, UST and AST removal at the former Val's Texaco service station and AST removal at the former Delphia bulk plant has occurred. These removal activities were not conducted by the PRP group. Four ASTs were removed from the west tank farm at the former Delphia bulk plant between 2002 and 2006 and one diesel UST and associated piping was removed at the former Val's Texaco property in 2006. The fueling dispenser islands and product piping from the gasoline ASTs to the dispenser islands were also removed from the former Val's Texaco site in 2006.

7.2 EFFECTIVENESS OF IRAMS

The IRAMs undertaken at the Astoria Area-Wide site have been generally effective in helping to minimize the impact of petroleum hydrocarbon constituents in the environment. The extent of petroleum hydrocarbons has been reduced with the removal of the potential sources from

areas of concern and underground tanks and pipelines. The remaining residual petroleum hydrocarbon constituents within the locality of the facility (LOF) were evaluated in the human health and ecological risk assessments and if warranted, will be addressed as part of the feasibility study process.

The various IRAMs implemented have had varying degrees of effectiveness in reducing the levels of petroleum hydrocarbon constituents on the site. Soil removal, storm sewer rerouting, pipeline decommissioning, and UST removal are IRAMs that had goals of reducing mass of petroleum hydrocarbons or removing potential sources of the release of petroleum hydrocarbons. These IRAMS also provided additional site characterization information that has been incorporated into the RI.

Currently LNAPL recovery is performed by using absorbent socks in select monitoring wells. LNAPL discharging to the surface water in Slip 2 is contained within the absorbent boom. The effectiveness of the absorbent boom is qualitatively evaluated by the lack of a sheen on the off-shore side of the boom. The effectiveness of the absorbent socks is evaluated by monitoring the LNAPL mass recovered in the socks.

8.0 FATE AND TRANSPORT

In order to determine chemical fate and transport, the physical and chemical properties of the compound and the surrounding environment must be evaluated. Factors that are considered include the mobility, persistence, and stability of the chemical. Additionally, physical, chemical, and biological processes that may affect a constituent are also considered. The following factors may influence the fate and transport of an organic compound in an aquifer system and subsurface soils:

Physical Factors:

- Physical loss processes, such as volatilization, photolysis, and sorption;
- Transport processes, such as dilution, advection, and dispersion; and
- Ground-water flow factors, such as characteristics of the porous media, hydrogeologic boundaries, and aquifer-recharge capacity.

Chemical Factors:

- Organic and inorganic matter composition and concentration of the soils;
- Ground-water temperature, specific conductance, cation and anion concentrations, and pH; and
- Chemical processes; e.g. hydrolysis, acid-base reactions, oxidation-reduction ("redox") reactions, ion pairing or complexes, and/or photochemical degradation.

Biological Factors:

- Variety of species and strains of microorganisms present; and
- Aerobic and anaerobic microbiological processes.

8.1 FACTORS AND PROCESSES AFFECTING FATE AND TRANSPORT

The fate and transport of a compound varies based on degree of persistence, physical and chemical properties such as density, solubility, volatility, and whether the compound can be

degraded naturally or only under induced conditions. Fate and transport properties of COI are described in the following sections.

8.1.1 Fate and Transport for Aqueous-Phase Chemicals

The fate of aqueous-phase chemicals in the subsurface needs to be examined to provide insight into their potential migration. The migration or transport of organic compounds depends significantly on the physical and chemical properties of the specific compounds. Important properties for predicting the behavior of the compounds detected at the Astoria Area-Wide site are presented in Table 8-1. Some of the more important factors affecting the transport of dissolved chemicals reported in Table 8-1 are aqueous solubility, octanol/water partition coefficient (k_{ow}), and molecular weight. In general, lower molecular weight compounds, such as benzene, toluene, and naphthalene are more soluble and have lower octanol/water partition coefficients than higher molecular weight compounds such as phenanthrene. Higher molecular weight compounds, such as benzo(a)pyrene and dibenz(a,h)anthracene generally exhibit lower solubility and mobility characteristics. Consequently, lower molecular weight compounds may be subject to greater leaching or dissolution in ground water than more hydrophobic compounds that tend to have low mobilities. Several of the processes important to assessing the distribution of aqueous-phase chemicals are discussed below.

8.1.1.1 Advection

The process that transports chemicals by the motion of flowing ground water is known as advection. Because of advection, nonreactive chemicals are carried with ground water at a rate equal to the average linear velocity of ground water. Advection is the dominant process involved in the transport of chemicals at the Astoria Area-Wide site and is the reason chemicals are found downgradient of their sources. Horizontal migration of chemicals in ground water is generally a function of the chemicals' solubility; chemicals with low solubilities have a low potential for migration. Additionally, solubility decreases with increasing molecular weight. Diesel-range hydrocarbons and associated constituents generally

have lower solubilities than gasoline-range hydrocarbons and are therefore not expected to migrate in ground water as far as gasoline-range hydrocarbons would.

It is important to note that dissolved petroleum constituents move more slowly than the ground water, because of sorption to organic material on the soil particles and biodegradation. Because their water solubilities are low, dissolved petroleum constituents partition between the dissolved phase and soil particles surfaces, especially in soils with high organic content like that found at the Astoria Area-Wide site. Sorption to soil and desorption back into the dissolved phase is a continual process that retards the movement of the dissolved phase, the amount of retardation depending mainly on the organic content of the soil. Typical retardation factors in sandy soil range from 2.4 for dissolved benzene (ground water moves 2.4 times faster than benzene) to 6.2 for dissolved xylene (ASCE, 1999).

8.1.1.2 Dispersion

The individual molecules of a dissolved chemical tend to spread out from the path they would be expected to follow according to the advective hydraulics of the flow system. This spreading phenomenon, called hydrodynamic dispersion, causes dilution of the chemical. It occurs because of mechanical mixing during fluid advection. It is an effect similar to turbulence in surface water. For porous media, the concepts of average linear velocity and longitudinal dispersion are closely related. Longitudinal dispersion is the process whereby some of the water molecules and chemical molecules travel more rapidly than the average linear velocity and some travel more slowly. The chemical, therefore, spreads out in the direction of flow and declines in concentration. Spreading in directions perpendicular to the flow is called transverse dispersion. Longitudinal dispersion is normally much larger than transverse dispersion, but the ratio between longitudinal dispersion and transverse dispersion is dependent on the velocity of ground-water flow. In areas where the average linear velocity of ground water is modified by tidal influences, transverse dispersion can become more pronounced than in upgradient portions of a plume.

8.1.1.3 *Molecular Diffusion*

Diffusion is a dispersion process of importance only at low ground-water flow velocities. Diffusion is the process whereby molecular constituents move in the direction of their concentration gradient. Diffusion occurs in the absence of any bulk hydraulic movement of ground water. If ground water is flowing, diffusion is a mechanism, along with mechanical dispersion, that causes mixing with potential for subsequent chemical dilution. Diffusion ceases only when equilibrium is reached and concentration gradients are zero. Diffusion affects the transport of chemicals in the shallow water-bearing zone most where tidal influences cause the hydraulic gradient to flatten only to the extent that it adds to the dispersive process.

8.1.1.4 *Chemical Precipitation and Dissolution*

Precipitation is the transformation of a material from a solute in solution phase to a separate liquid or solid phase. When the concentration of a chemical in aqueous solution exceeds its effective solubility, precipitation occurs. The solubility is defined as the maximum amount of a chemical that can be dissolved in a given amount of solvent under specified conditions. A solution that has reached its solubility limit is a saturated solution. Organic chemicals usually form a separate liquid phase during precipitation, whereas inorganic chemicals will typically precipitate as a solid.

Dissolution is the process in which a chemical undergoes transformation from a solid or separate phase to an aqueous phase because the concentration of the chemical in aqueous solution is below its solubility limit. Precipitation and dissolution reactions are usually reversible, depending on the solubility of the chemicals. Environmental factors or conditions such as temperature, pH, K_{oc}, and partition coefficient of a compound between organic compound and water (K_{ow}) will influence the aqueous solubility of organic compounds.

COI at the Astoria Area-Wide site have variable aqueous solubilities (Table 8-1). Their presence in a mixture of hydrocarbons affects how they solubilize to water. Dissolution from

the separate liquid phase has occurred through time causing a dissolved-phase plume with petroleum-related constituents in the shallow water-bearing zone.

8.1.1.5 Volatilization

Volatilization of a compound is the transformation from the aqueous, liquid, or solid phase to a gas. At the Astoria Area-Wide site the petroleum-related compounds were initially in the liquid phase. Chemicals with high vapor pressures and low solubility may be affected by this process (USEPA, 1979). The Henry's Law Constant parameter characterizes the partitioning between aqueous and gas phases. Organic compounds with Henry's Law Constants in the 10^{-2} to 10^{-3} atmospheres-cubic meter per mole (atm-m^3/mol) range or larger are considered volatile.

Table 8-1 shows that Henry's Law Constants for COI range between 1.47E-8 and 0.7 atm-m^3/mol. Some COI have a Henry's Law Constant of less than 10^{-3} atm-m^3/mol (mostly semi-volatile organic compounds), indicating that these compounds are not volatile. Many of the COI at the Astoria Area-Wide site also have high K_{oc} values, confirming that these compounds sorb strongly to the soil and do not readily escape to the atmosphere.

8.1.1.6 Photolysis

Photolysis is the process whereby certain organic compounds are chemically changed in the presence of light. This process is insignificant in the ground-water system, but may be very significant in degrading compounds present in shallow soils and surface waters. Photolysis decreases as soil depth increases due to lack of sunlight. There are limited areas at the Astoria Area-Wide site where organic compounds are present in surface soils. Organic compounds are present in surface water in the location of the hydrocarbon seep in Slip 2.

Limited photolysis research is available for the COI. Information that is available indicates that photolysis is significant for PAHs present in surface soil, surface water and sediment. For example, Zepp and Schlotzhauer (1979) calculated the half-life for sunlight photolysis of

naphthalene in water at latitude 40°N at mid-day in the summer to be 71 days. Photolysis has probably had some effect on concentrations of photodegradable chemicals in the location of the hydrocarbon seep, sediment, and surface soils.

8.1.1.7 Hydrolysis

Hydrolysis is the splitting of a compound into fragments through reaction with a water molecule. The information available in the literature (Olsen and Davis, 1990) indicate that hydrolysis may be important for chlorinated organic compounds, however no specific information was found in literature concerning the COI at the Astoria Area-Wide site.

8.1.1.8 Acid-Base Reactions

Acid-base reactions influence the pH of a solution. In general, an acid is any substance which, when added to water, increases the hydrogen ion concentration. Substances that increase the hydroxide ion concentration when added to water are called bases. The hydrogen ion concentration is measured by the pH, an important factor that affects the transport mechanisms of many chemical compounds. Solubility, sorption capacity, redox potential, and biodegradation capabilities are typically influenced by a pH change.

The pH of the shallow water-bearing zone beneath the Astoria Area-Wide site generally ranges between 6.5 and 7.2. Under these conditions, COI would tend to exist as a negatively charged ion and would not be subject to as complete adsorption as in an acidic system. The transport of metals is more significantly affected by pH change than organic compounds.

8.1.1.9 Redox Reactions

Redox (oxidation-reduction) reactions are defined as electron transfer reactions. Reducing agents provide electrons, and oxidizing agents accept electrons (Stumm and Morgan, 1970). Microorganisms catalyze nearly all important redox reactions that occur in ground water (Freeze and Cherry, 1979). The oxidizing or reducing capability is measured by redox

potential (Eh). Olsen and Davis (1990) reported that PAHs such as naphthalene are oxidized by free radicals. Oxidizing agents, such as oxygen, enhance abiotic oxidation by accepting electrons from organic compounds.

8.1.1.10 Sorption and Desorption

Sorption is a term that designates processes that tend to remove chemicals from the aqueous environment by binding the constituent to soil particles or into separate liquid phases. The reversed process is termed desorption. Sorption may involve the interphase accumulation or concentration of substances at a surface or interface; sorption in this case is also called adsorption. The sorption process can occur at an interface between any two phases, such as liquid-liquid, gas-liquid, gas-solid, or liquid-solid interfaces. If charged ions are involved in the adsorption where one ion type replaces another ion type on the soil surface, the process may be called an ion-exchange reaction. Adsorption is a major mechanism for immobilization of charged organic compounds.

The primary force controlling the sorption process is the affinity of the solute for either the solvent or the solid surface. The affinity for the solvent can be described in terms of solubility, and the affinity for the solid surface can be described in terms of attractive forces. There are three attractive forces: electrical; van der Waals, which govern physical adsorption; and chemical, in the form of covalent, hydrogen, or other chemical bonds which govern chemisorption.

Soil materials that are important to sorption include organic colloids, clays, metal oxides and hydroxides, and free lime ($CaCO_3$). For some solutes though, solid affinity for the solute can play a role subordinate to the affinity of the aqueous solvent. Organic dipoles and large organic ions are preferentially accumulated and seek positions at the interface to a larger extent than easily hydrated ions (Stumm and Morgan, 1970).

The distribution of chemicals between water and the adjoining solid matrix is often described by the soil-water distribution coefficient (K_d). Several methods have been used to evaluate K_d.

For example, K_d has been shown to be proportional to the fraction of organic carbon in the solid matrix and the octanol/water partition coefficient (K_{ow}):

$K_d = (f_{oc})\ (K_{oc})$ Schwarzenback and Westall, 1981

$K_d = (0.63)\ (f_{oc})\ (K_{ow})$ Karickhoff and others, 1979

where: f_{oc} = fraction of organic carbon

K_{oc} = organic carbon partitioning coefficient

K_{ow} = octanol/water partitioning coefficient

Table 8-1 contains values for K_{oc} and K_{ow} that were obtained from the literature for COI at the Astoria Area-Wide site. Bulk weight and moisture and organic content for selected samples obtained during the RI are shown in Table 8-2. Dry unit weights in samples collected from borings range between 84.9 pounds per cubic foot (pcf) and 107.5 pcf. Moisture content in the same samples ranges between 6.6% and 65.5%. Organic content in the same samples ranges between 0.2% and 6.5%.

8.1.1.11 Biological Transformation

Bioaccumulation, biodegradation, and biotransformation are biological processes that can cause changes in the chemical quality of ground water. Bioaccumulation is defined as a process by which living organisms retain chemicals in cell tissues. The rate or amount of bioaccumulation is generally related to the body fat content of the organisms and the solubility of the chemical. Biodegradation is a term used to describe the breakdown of organic constituents by microorganisms. Biotransformation describes the change of organic constituents into other organic or inorganic constituents by biological activity. Biodegradation of an organic chemical into simpler forms could result from the biotransformation and the bioaccumulation of that organic chemical by microorganisms, which cause an enzyme-catalyzed breakdown of a chemical into simpler forms.

The biological processes through bioaccumulation, biodegradation, and biotransformation in water and soil environments are carried out primarily by microorganisms. The effects of macrobiota are generally considered insignificant to the subsurface environment. The following processes are performed or mediated by microorganisms in soil and water:

- Degradation of organic constituents;
- Depletion of available oxygen supplies;
- Participation in redox changes involving oxidation and reduction reactions;
- Production of CO_2 that subsequently forms carbonic acid (H_2CO_3);
- Production of a variety of organic acids;
- Production of large and/or small organic molecular species upon which other constituents can be sorbed and removed from the water phase; and
- Assimilation and removal of the chemical constituents by incorporating these constituents in the biomass.

Chemical factors influencing the biodegradability of constituents include:

- Moisture content;
- Temperature;
- Chemical structure;
- Solubility, volatility, hydrophobicity, octanol-water partition coefficient, etc.;
- Presence of other chemicals and their concentrations;
- Organic matter content of the soil;
- Amount and type of clay minerals in the soil;
- Water and soil pH; and
- Water and soil oxygen levels.

8.2 FATE AND TRANSPORT OF NONAQEOUS-PHASE LIQUIDS

The transport of non-aqueous (immiscible) phase chemicals, or free product, is governed by a balance of capillary pressure, gravitational forces, and viscous forces as described by Villaume and others (1983) and by Schwille (1988). Given the appropriate conditions, immiscible phase chemicals can migrate to greater depths through macropores and/or fractures in the geologic media. LNAPL has been identified at the Astoria Area-Wide Site. LNAPL floats on the water table and migrates following the potentiometric surface.

An insight into the potential for non-aqueous phase migration in different soil types can be obtained with a knowledge of the density, interfacial tension, and wetting or contact angle against a solid surface in the presence of water. Under hydrostatic conditions, immiscible-phase migration will only occur when a globule or stringer accumulates sufficient mass to overcome capillary pressures (Villaume, 1985; Schwille, 1988). More mass is required to penetrate finer-grained soil materials. Grain-size distribution of the subsurface soils has a profound affect on non-aqueous phase chemical migration.

With time, the composition of petroleum hydrocarbons in the subsurface changes due to weathering and the remaining constituents are increasingly enriched in those components that resist the loss mechanisms (volatilization, dissolution, and biological transformation). The remaining petroleum constituents become more and more firmly fixed in the subsurface soil, continually releasing its more soluble components in slowly decreasing concentrations to the ground water.

8.3 CHEMICAL CHARACTERISTICS

Chemical characteristics are discussed in the following sections for LNAPL, PAHs, VOCs, and metals.

8.3.1 Light Nonaqueous-Phase Liquids

LNAPL detected at the Astoria Area-Wide site include diesel and gasoline-range hydrocarbons. Constituents associated with these LNAPL include PAHs, VOCs, and metals, all from different chemical classes. PAHs, VOCs, and metals are discussed in the following sections. Petroleum hydrocarbons have varying structural configurations that are divided into two families: aliphatics and aromatics (TPHC Working Group, 1998). Aliphatics are further divided into other classes called alkanes, alkenes, and cycloalkanes. Aliphatics include chemicals such as benzene, ethylbenzene, toluene, xylenes, and other VOCs. Aromatics include chemicals such as acenaphthene, benzo(a)anthracene, pyrene, and other PAHs. The aromatics are generally heavier than aliphatics. Gasoline has a typical composition of alkanes

(4-8%), alkenes (2-5%), isoalkanes (25-40%), cycloalkanes (3-7%), cycloalkenes (1-4%), and aromatics (20-50%). Diesel fuels predominantly contain a mixture of aliphatics (64%), alkenes (1-2%), and aromatics (35%) (ATSDR, 1995).

The composition of either of these products varies on the refining process, weathering, and/or biological modification after release into the environment. LNAPL in the environment is dependent on the number of liquids present, relative strength of attraction between the fluids and the solids, geometry of the pore system, and the history of the system (EPA, 2004). Based on subsurface modeling studies by the EPA (2004), it was concluded that water is more attracted to solids than LNAPL; LNAPL occupies larger pores and pore openings than water; and that in a three-phase system (water/NAPL/air), LNAPL forms films and small lenses between the water and air.

In addition to the presence of LNAPL in the subsurface of areas of the Astoria Area-Wide site, a petroleum hydrocarbon seep is located at the head of Slip 2. LNAPL has been observed in the surface water (generally as a sheen) and sediment in the vicinity of the petroleum hydrocarbon seep. Constituents associated with the LNAPL seep have also been detected in both the sediments and surface water in the vicinity of the seep. Due to the age of the releases, a significant portion of the LNAPL encountered at the Astoria Area-Wide site is trapped in the soil pore spaces making it relatively immobile. When the water table rises and falls, the LNAPL is moved vertically, "smearing" NAPL into a region thicker than the LNAPL thickness, where residual NAPL can become immobilized. A large percentage of the LNAPL upland of the Slip 2 hydrocarbon seep appears to be trapped beneath the water table during most of the year. The term "immobile" is used loosely and really means that some mobility may still occur but it will move very slowly compared to the time frame of interest. The Slip 2 hydrocarbon seep has been characterized as a petroleum sheen on the surface of water entering the slip and not as a measurable thickness of LNAPL.

8.3.2 Polycyclic Aromatic Hydrocarbons

PAHs are major components of diesel and heavier oil-range petroleum hydrocarbons. The fate and transport of PAHs in the environment are dependent on their individual physical and chemical properties. The physical and chemical properties of the PAHs of potential concern at the Astoria Area-Wide site are shown in Table 8-1. In soil, the fate of PAHs is dependent on the organic carbon content and particle size; sorption to particles increases with the increasing presence of organic carbon (EPA, 2004). PAHs generally tend to sorb strongly to soil particulates and have low aqueous solubilities and mobility (Table 8-1; Hickok and others, 1982). As a result, PAHs with lower molecular weight are more likely to be transported through soils to ground water by leaching. Physical mass transport of PAH-impacted soil particulates is possible for surface soil and sediment through surface water processes. Volatilization of the lower molecular weight PAHs may also occur in soils. Through root uptake, PAHs can assimilate in plants. PAHs can break down by reacting with sunlight and other chemicals in the air, over a period of days to weeks. Following release to surface water, PAHs will undergo rapid photolysis whereas biodegradation and biotransformation are the ultimate fate process for PAHs in soil and aquifer materials.

PAHs with two or three rings (relatively low molecular weights; LPAHs) such as naphthalene, have relatively rapid loss rates due to volatility levels, water solubility, and biodegradability. Alternatively, PAHs with four or more rings such as benzo(a)pyrene (high molecular weight, HPAHs), have increased hydrophobicity and chronic toxicity due to relatively slower degradation/volatilization rates compared to LPAHs, thus having lower loss rates within the environment (ATSDR, 1995). For example, phenanthrene (molecular weight 178 g/mol) is more soluble in water than pyrene (molecular weight 202 g/mol).

For a PAH compound to be degraded biologically under field conditions, certain criteria must be met. First, an appropriate microbial community must be present. The ability to degrade unique carbon sources is often associated with prior exposure of microbial communities to the chemical or to similar chemicals (Mueller and others, 1989). Second, substrate availability and organism-substrate interaction are required. Lastly, environmental parameters such as

temperature, pH, redox potential, oxygen and nutrient availability, and moisture must be conducive to growth of the requisite organisms (Mueller et al., 1989; EPA, 2004).

PAHs are readily bioaccumulated; however, they are also rapidly metabolized and excreted (Niimi and Palazzo, 1986), such that bioaccumulation is not a long-term situation. There is evidence that the clearance rates for most PAHs are rapid, with half-lives of nine days or less (Niimi and Dookhran, 1989). The dominant transport process for PAHs is associated with sorption to soil particles, suspended particulates, and sediments; once sorbed to soil particles and sediments, transport of PAHs would be limited. (EPA, 2003)

8.3.3 Volatile Organic Compounds

VOCs are a major component of gasoline hydrocarbons. Similar to PAHs, fate and transport of VOCs in the environment are dependent on their individual chemical properties. The physical and chemical properties of the VOCs of potential concern at the Astoria Area-Wide site are shown in Table 8-1. In part, dissolved VOCs in soil, ground water, and surface water are a result of the chemical degradation of the LNAPL. The dominant fate processes associated with the presence of VOCs in the environment are volatilization of VOCs throughout the soil column, volatilization of VOCs from ground water to and throughout the soil column, and volatilization from both soil and LNAPL into the interstitial spaces (soil vapor). In ground water, VOCs are transported through advection and dispersion. According to a USGS study (Squillace et al., 2005), dissolved oxygen concentrations in ground water generally affected both the detection and concentration of VOCs; higher detection and concentration of VOCs were found to be associated with anoxic ground-water conditions.

By-products of microbial metabolism are also processes associated with the breakdown of VOCs. For example, BTEX under anaerobic conditions will transform to carbon dioxide. Plants can also remove contaminants dissolved in ground water or soil.

8.3.4 Metals

Metals are also constituents of gasoline and diesel fuel. Metal COPC at the Astoria Area-Wide site include arsenic, chromium, and lead. Arsenic combined with naturally occurring elements (e.g., sulfur, nitrogen) is inorganic arsenic. Arsenic combined with carbon and hydrogen is referred to as organic arsenic, which is usually less harmful than the inorganic forms. In soil, many arsenic compounds tend to partition to soil or sediment under oxidizing conditions, therefore reducing the affinity for leaching to great soil depths (ATSDR, 2005). Among the various studies, iron content within the soil appears to be the most influential parameter affecting arsenic adsorption (ATSDR, 2005). Arsenic that is adsorbed to iron and manganese oxides may be released under reduced conditions in sediments (ATSDR, 2005), which is one of the affected media in AOC 4. In addition, microbial action can also result in dissolution of arsenic. Biotic and abiotic processes control the fate of arsenic in soil (ATSDR, 2005). There are several oxidation states and chemical species that are dependent on the soil pH and oxidation-reduction potential. In water, arsenic can undergo several transformations via oxidation-reduction, ligand exchange, precipitation, and biotransformation with the following influencing parameters (ATSDR, 2005): Eh; pH; metal sulfide and sulfide ion concentrations; iron concentrations; temperature; salinity; distribution and composition of biota; season; and nature and concentration of natural organic matter.

In addition, microbial action can also result in dissolution of arsenic. Arsenic present in ground water, in oxidizing and mildly reducing conditions is usually controlled by adsorption as opposed to mineral precipitation (ATSDR, 2005).

Chromium has several oxidation states ranging from chromium -2 to chromium +6. Chromium II is relatively unstable and readily oxidizes to trivalent chromium (III). Trivalent chromium is the most stable state with hexavalent chromium (VI) as the second most stable in the environment (ATSDR, 2000). Hexavalent chromium is the most toxic of the oxidation states. Hexavalent chromium may exist in aquatic ecosystems in a dissolved state, although in soil it is expected to be reduced by organic matter to the trivalent form (EPA, 1998).

Lead strongly adsorbs to inorganic solids with its mobility affected by soil type, pH, organic carbon content, cation exchange capacity, the form of lead, and the presence of metal oxides, aluminum silicates, and carbonates. Especially in clays and silty clay soils, mobility is generally low (EPA, 2004). In addition, leaching of lead in soil to ground water is slow due to its affinity to adsorb. In water, lead and its associated compounds tend to concentrate in the water surface microlayer in three forms including dissolved, dissolved bound, and particulate (EPA, 2004). Lead is most soluble and bioavailable in water with low pH, low organic content, and other low nutrients.

9.0 BENEFICIAL LAND AND WATER USE

As part of evaluating the possible risk posed to human health or the environment by petroleum compounds encountered at the site, beneficial land and water uses within the RSA are identified. In addition to risk assessment, the beneficial use determinations are critical in selecting protective and appropriate remedial options (interim and final) at the site. Current and reasonably likely future land and water uses for the Astoria Area-Wide site and the surrounding area were reviewed as part of the Beneficial Land and Water Use Survey. The results of the survey were originally presented in the Technical Memorandum, Beneficial Land and Water Use Surveys (*EnviroLogic Resources*, 2003b). This section incorporates the findings from the original survey and incorporates known changes to land use since the original survey was completed.

9.1 LAND USE DETERMINATION

The Astoria Area-Wide site and surrounding area is within the Port of Astoria Sub-area Plan in the Astoria Comprehensive Plan (City of Astoria, 1998). The July 2003 updates to the Astoria Comprehensive Plan were reviewed and the updates were not related to the zoning designations within the RSA. The allowable land uses for the zoning designations are defined in the Astoria Development Code. The 2002 updated development code for uses permitted in each zone were reviewed and is attached in Appendix F.

The designated zonings for land uses at the Astoria Area-Wide site are Shoreland-Marine Industrial (S-1), Shoreland-General Development (S-2), and General Commercial (C-2 and C-3) (Figure 9-1). Since the Beneficial Land and Water Use Survey was completed, a portion of the Shoreland-Marine Industrial (S-1) zone between Portway and Industry Street was changed to a Shoreland-General Development (S-2) zone.

Most of the properties within the southeast portion of the Astoria Area-Wide site are zoned Commercial (C-3). The area south of West Marine Drive, southeast and upgradient from the LOF is zoned High-Density Residential (R-3). In the marine industrial area, which includes

the properties north of Industry Street and the piers, uses currently include the Port of Astoria office and shop buildings, the Oregon State Police station, Bergeson Construction, Englund Marine and Bornstein Seafoods. At the time the RI process began vacant land in this area was used as storage areas for commercial fishing supplies. The vacant land once housed a veneer warehouse and a steel-works plant. Southwest of this area was the former ExxonMobil/Niemi Oil bulk plant that has now been removed. Riverland, LLC, is currently redeveloping the vacant land and former ExxonMobil/Niemi Oil bulk plant areas into commercial structures that will house P&L Johnson, Inc., storage garages, and other tenants. In the area of the Riverland development Portway Street was renamed to Gateway Avenue. Bergeson Construction has also redeveloped its land. The redevelopment did not include any known change in use, just new facilities. Figure 9-2 shows recent development changes in relation to the LNAPL.

Along Industry Street is the trolley line with the trolley barn across from Qwest on the northeast side of Industry Street. West of Hamburg Street is the former Chevron/McCall bulk plant that was vacant land during the beneficial land and water use survey and is now the Englund Marine facility.

The general commercial area southeast of Industry Street and northwest of West Marine Drive includes the former Delphia bulk plant, Niemi Oil Cardlock, Qwest vehicle service center, ILWU Local 50 (one building), Youngs Bay Texaco with a carwash facility, vacant land, Chevron Lube and Oil, and the former Val's Texaco. There is one mixed use building with first story commercial (Fast Lube & Oil at former Harris/Van West) and potential second story residential occupancy. At the beginning of the RI process the second floor residential unit was occupied; at the time of an April 2008 site visit it was not apparent that it was still occupied. A portion of the land between Youngs Bay Texaco and the former Harris/Van West property was occupied by a small apartment building. The apartment building was removed in 2006 and in April 2008 the land was still vacant with no indication of construction activity. Also at the time of the April 2008 site visit it was noted that Youngs Bay Texaco was no longer operating as a service station. The car wash was still active, but the service station building had been converted into a restaurant and fish market.

Outside of the Astoria Area-Wide site to the west are Do-It Best/Darigold Feed Store, Astoria Mini Storage, and the Bayshore Motor Inn. To the south and west across Marine Drive are more small commercial businesses including Johnson's One Stop gas station. To the east is the Portway Tavern and Red Lion Hotel, both on the east side of Portway Street. The Red Lion Hotel borders along the shoreline of the West Mooring Basin. The tavern, hotel and these commercial/retail businesses are not within the LOF.

New offices for marine operations and other tenants are under construction on Pier 1. Pier 1 is where cruise ships berth when stopping in Astoria. The Marine Spill Response Corporation, Astoria Pacific Foods, and West Bay Sardine and Seafood Producers currently occupy Pier 2. Piers 1 and 2 also provide berthing for vessels calling at the Port of Astoria. Pier 3 is currently used as a boatyard with a boat haul out facility and for storage of dredged sediments. ented on Figure 9-1 presents a proposed riverwalk trail located at the Port of Astoria.

Although local zoning and the Port Charter do not explicitly prohibit residential structures, the reasonably likely future land use of the RSA and more specifically the Astoria Area-Wide site is expected to be similar to current uses. Parts of the Astoria Area-Wide site are currently undergoing redevelopment, and all of the new developments support commercial and industrial operations.

9.2 CURRENT AND REASONABLY LIKELY FUTURE BENEFICIAL WATER USES

Existing water resources at the Astoria Area-Wide site include the City of Astoria municipal water supply, ground water, and surface water. The city water supply is readily available in and around the Astoria Area-Wide site and users in the area rely exclusively on the municipal water system to meet drinking and other water needs. Municipal water in and adjacent to the Astoria Area-Wide site is currently used for drinking and domestic, industrial (e.g., industrial process water uses), and engineering (e.g., heat exchange, fire suppression) uses. The municipal water supply system will continue to be the reasonably likely future water source for users in the LOF and surrounding areas.

Based upon a well survey, there are no ground-water supply wells within the RSA. The well survey is described in more detail in Section 9.4. The Astoria Area-Wide site and adjacent areas do not currently use ground water to meet drinking and other water needs and ground water is not likely to be a water source in the future because all water is supplied by the City of Astoria.

Surface waters bordering the RSA include the Columbia River on the east and northwest and Youngs Bay to the west and south. Beneficial surface water uses include commercial navigation, commercial and recreational fishing, aquatic life/habitat, recreation, and aesthetic quality. The river and sediment pore water serve as or contribute to habitat for aquatic life, including mammals, birds, fish, macroinvertebrates, and benthic organisms. Slips 1 and 2 are used primarily for commercial/marine use. Boats dock at Piers 1, 2, and the West Mooring Basin. Aquatic features of the RSA include deep waters off the Port piers and the West Mooring Basin. Much of the aquatic habitat is considered to be degraded due to Port and mooring basin use. The area is almost entirely developed for Port facilities. The only shoreland vegetation consists of upland grasses, scotch broom, and other shrubs located on and adjacent to Pier 3.

Near shore surface waters in or near the RSA are zoned Aquatic Development (A-1, A-2, and A-2A) within the slips, west of Pier 3, and east of the West Mooring Basin; Aquatic Conservation Area (A-3), west of Pier 3; and Aquatic Natural (A-4) southwest of Pier 3. The City of Astoria code defines the different aquatic zoned areas as:

- A-1, A-2, and A-2A: "Development Aquatic areas are designated to provide for navigation and other identified needs for public, commercial, and industrial water-dependent uses. The objective of the Development Aquatic designation is to ensure optimum utilization of appropriate aquatic areas by providing for intensive development. Such areas include deepwater adjacent to or near shoreline, navigation channels, sub-tidal areas for in-water disposal of dredged material, areas of minimal

biological significance needed for uses requiring alteration of the estuary, and areas that are not in Conservation or Natural designations" (City of Astoria, 1998).

- A-4: "Natural Aquatic areas are designated to assure the protection of significant fish and wildlife habitats; of continued biological productivity within the estuary; and of scientific, research, and educational needs. These areas are managed to preserve natural resources in recognition of dynamic, natural, geological, and evolutionary processes. Natural Aquatic areas include all major tidal marshes, tide flats, and seagrass and algae beds. The designation is relatively free of human influence" (City of Astoria, 1998).

- A-3: "Conservation Aquatic areas are designated for long-term uses of renewable resources that do not require major alterations of the estuary, except for the purpose of restoration. They are managed for the protection and conservation of the resources found in these areas. The Conservation Aquatic designation includes areas needed for the maintenance and enhancement of biological productivity, recreational resources, aesthetic features and aquaculture. The Conservation Aquatic designation includes areas that are smaller or of less biological importance than Natural Aquatic areas. Areas that are partially altered possess the resource characteristics of other aquatic areas are also included in this designation" (City of Astoria, 1998).

No current water diversions from the Columbia River have been identified in the RSA. A former water tower existed on the Astoria Area-Wide site. This 10,000-gallon water tank, which was used to store Columbia River water for on site fire suppression, was removed in April 2002.

9.3 WATER SUPPLIER

According to Mike Caccavano of the City of Astoria Public Works engineering department, the source of drinking water in and near the locality of the facility is the City water system. All residences and commercial buildings within and near the Astoria Area-Wide site are

connected to the city water supply. From the 1880s to the present, the City of Astoria has received its principal water supply from the Bear Creek Basin, a forested watershed on the west slopes of Wickiup Mountain. This watershed is capable of and will continue to be the City of Astoria's water supply in the foreseeable future. The City does not operate ground-water supply wells or surface-water diversions/intakes within or near the RSA. The City does not have any water right points of diversion in or near the RSA. The RSA is part of the municipal service area.

9.4 WELL SURVEY

This beneficial use evaluation included a ground-water well survey. A water well log search was performed using the Ground-water Resource Information Distribution (GRID) database provided on the Oregon Water Resources Department (WRD) website to determine if there is a record of beneficial uses of ground water in the RSA. Instead of using a radius from a point to do the well survey, the survey included any section that was part of the RSA. The results of the GRID search are presented in Appendix G. The area searched includes Sections 7 and 18, Township 8 North, Range 9 West, and Sections 12 and 13, Township 8 North, Range 10 West, Willamette Base and Meridian. No water-supply wells were identified within the RSA. Because there are no water-supply wells in the RSA, and all property owners have access to City water, a door-to-door/postcard survey was not performed. No agricultural land use requiring ground water currently exists in the RSA and will not likely occur in the future. The only wells located within the RSA and adjacent areas are ground-water monitoring wells used to assess ground-water quality and hydrologic parameters. Ground-water supply is not likely to become a water-supply source in the foreseeable future because all water is supplied by the City of Astoria.

9.5 WATER RIGHTS

A water rights search was performed on the Water Right Information System (WRIS) on the WRD website. The area searched includes Township 8 north, Range 10 west, Sections 12 and 13; and Township 8 north, Range 9 west, Sections 7 and 18. The RSA is included within this

broader area. The only water rights identified were for the City of Astoria. Four water-right permits (S-27092, S-31880, S-31881, and S-13424) were listed as belonging to the City of Astoria. The water sources for these rights include Youngs River and Youngs River Reservoir, Bear Creek and Reservoir, and Cedar Creek. These points of diversion water rights are not within or near the locality of the facility of the Astoria Area-Wide site. The water right search is included as Table J-5.

9.6 DEVELOPMENT TRENDS AND PATTERNS

Parts of the Port of Astoria property at the Astoria Area-Wide site are currently being redeveloped. Historically the property has been primarily industrial with commercial business. The trend appears to be toward more commercial/marine with less emphasis on industrial development. Recent development proves this to be true. Structures have been built at the former Chevron/McCall bulk plant, at the head of Slip 1, and on Pier 1. The businesses at these sites include Englund Marine, Bornstein Seafoods, and marine offices. Site preparation for construction of a new commercial development at the former ExxonMobil/Niemi Oil bulk plant and properties to the east began in April 2006.

According to the City of Astoria Comprehensive Plan (1998), "major Port development will be encouraged at the existing Port docks." The water supply for these future developments is reasonably likely to remain municipal, and the City of Astoria's sources are capable of providing for this development. The City of Astoria Land Use and Zoning Map (City of Astoria, 1998) shows the land area around the Astoria Area-Wide site is primarily zoned for commercial and industrial uses along with aquatic development within the Slip and river areas.

For a variety of reasons, shallow ground water at the Astoria Area-Wide Site is unlikely to be used as a future source of industrial water. Yield from the shallow ground-water aquifer or the Astoria Formation appears to be insufficient to meet large-scale industrial process water demands. Also, it is likely that sustained pumping of shallow ground water would lead to intrusion of salt water into the shallow aquifer. Given these constraints, it is likely that

hypothetical future industrial processes would use the relatively readily available municipal water supply that is already in place.

10.0 CONCEPTUAL SITE EXPOSURE MODEL

This section presents the conceptual site exposure model (CSM) and describes the various exposure scenarios identified at the Astoria Area-Wide site. The CSM describes potential chemical sources, release mechanisms, environmental transport processes, exposure routes, and receptors. The primary purpose of the CSM is to describe pathways by which human or ecological receptors may be exposed to COI. The human health CSM is shown on Figure 10-1. The ecological CSM is shown on Figure 10-2. The areas of the Astoria Area-Wide site where each exposure scenario is relevant for human health are shown on Figure 10-3. The intertidal habitat is shown on Figure 10-4. Processes that control the fate and transport of petroleum in the environment were discussed in Section 8.0 and potential exposure scenarios are discussed below. This discussion is summarized from the Human Health Risk Assessment Work Plan (Maul, Foster & Alongi, 2005), the Human Health Risk Assessment (HHRA) (Maul, Foster & Alongi, 2007), the Ecological Risk Assessment (ERA) Work Plan (Kennedy/Jenks Consultants, 2005), and the Level III Ecological Risk Assessment Report (Kennedy/Jenks Consultants, 2006c). The HHRA is included as Appendix G and the ERA is included as Appendix H.

10.1 PRIMARY SOURCES

Petroleum impacts to soil and ground water at the Astoria Area-Wide site have resulted from releases at a number of petroleum-storage and handling facilities. Likely sources include USTs, ASTs, pipes, and dispensers. Releases may have occurred from leaks in tanks or pipes, and during petroleum transfers. Section 5.0 presents a detailed discussion of potential sources.

10.2 FATE AND TRANSPORT

The primary mechanisms that affect fate and transport of released petroleum products include leaching from soil to ground water, volatilization from soil to ground water to air, advection and dispersion in ground water, sorption to the soil matrix, and natural degradation processes. These processes have been discussed extensively in Section 8.0.

Gasoline and diesel are the primary petroleum products that have been released at the Astoria Area-Wide site. In order to generate free phase gasoline or diesel (LNAPL) on the water table there must be a release of sufficient volume to result in gravity-driven downward migration through the soil. The downward migration of LNAPL through soil is typically constrained by the water table. This is because gasoline and diesel have a density less than that of water and they are immiscible with water. These properties also result in little tendency for LNAPL to migrate deep into the shallow water-bearing zone.

Once the released LNAPL encounters the capillary fringe above the water table, the weight of LNAPL will cause it to gradually displace pore water until equilibrium conditions are reached. The relatively high water content of the capillary fringe will result in low permeability to LNAPL, and at this point the downward gradient caused by gravitational forces will diminish. If there is a sufficient volume of released product, the driving hydraulic head will result in lateral migration of LNAPL until steady-state conditions are met (American Petroleum Institute [API], 2002). Once equilibrium conditions have developed and lateral migration of LNAPL has diminished, LNAPL plumes typically are stable. Unless new product is added to the system or other significant changes occur, there will be no further significant lateral movement of product.

Much of the Astoria Area-Wide site is covered with permeable surfaces such as gravel, and it is likely that precipitation that falls in these areas percolates through the vadose zone and interacts with LNAPL or petroleum compounds that have been adsorbed into soil. Chemicals with relatively high solubility may leach from soil to pore water, and dissolved chemicals may be transported downward to local ground water. Also, when the water table rises and interacts with product or petroleum that is adsorbed into soil, some constituents will partition into water.

Once in ground water, dissolved contaminants may be transported by diffusion and advection in ground water horizontally away from the original source. Horizontal migration with ground water is expected to be significantly more extensive than vertical migration. It is most likely

that the only significant mechanisms that would allow for downward vertical migration of petroleum constituents are diffusion and dispersion and these processes result in orders of magnitude reductions in waterborne concentrations over relatively short distances from the source (API, 2002). In general, the potential for a chemical to migrate in ground water increases as a function of chemical solubility. Many petroleum constituents have relatively low solubility and a low likelihood of extensive migration in ground water.

Dispersion, retardation, and biodegradation act to reduce dissolved concentrations of petroleum constituents in ground water downgradient of the source area. Some volatile contaminants that are either adsorbed to soil or dissolved in ground water may volatize to soil pore spaces. Chemical vapors in pore spaces may eventually migrate through the soil matrix and enter outdoor air. Once in outdoor air, mixing with ambient air is expected to reduce airborne chemical concentrations rapidly and substantially. If buildings are located over impacted ground water, it is possible that vapors may eventually enter indoor air by penetrating cracks in a building floor or foundation.

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

10.3 EXPOSURE SCENARIOS

Properties at the Astoria Area-Wide site are generally used for commercial and industrial purposes. There is one mixed use building with first story commercial (Fast Lube & Oil at former Harris/Van West) and second story residential occupancy. A previously existing small apartment building located on the north side of West Marine Drive was demolished in the fall of 2006. It is likely that properties at the Astoria Area-Wide site will continue to be used for commercial and industrial purposes for the foreseeable future. Various workers will have the greatest potential to contact contaminated soil or ground water. These workers may include

on-site occupational workers, occasional excavation workers, and construction workers. Relevant default DEQ (2003) potential exposure scenarios are presented on Figure 10-1 of the Human Health Risk Assessment Work Plan (Maul, Foster & Alongi, 2005). The scenarios are briefly discussed below for both soil and ground water.

10.3.1 Soil

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

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

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

Petroleum hydrocarbons have been observed in subsurface, saturated soil at several locations. In general, there is little potential for people to contact petroleum hydrocarbons trapped in soil below the water table. Indirect exposure to petroleum constituents in saturated soil is unlikely because soil that is saturated with water has little air-filled pore space, and this prevents volatile chemicals from partitioning into air and migrating to the soil surface. Although it may be possible for excavations to expose soil containing petroleum hydrocarbons below the water table, it is unlikely that workers would occupy such an excavation without substantial dewatering.

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

No single-family residences are present at the Astoria Area-Wide site and, given land-use plans for the area, it is unlikely that single-family residences will be developed in the foreseeable future. Assuming similar land use and land use allowed under current zoning, any residential occupants are assumed to have potential exposures similar to urban residents, not single-family residents (DEQ, 2003). As a result, it is assumed that urban residents could have direct contact with surface soil (0 to 3 feet bgs). Also, it is assumed that volatile chemicals in vadose zone soil located within 50 feet of the former apartment complex could migrate to indoor air and be inhaled by urban residents.

Although chemicals in soil may leach to ground water, soil leaching models will not be used to evaluate soil conditions in the risk assessment. Soil RBCs for the leaching pathway are estimated using models that simulate partitioning of chemicals from soil to ground water, and

they are designed to protect ground water that is used for drinking purposes (DEQ, 2003). Ground water at the Astoria Area-Wide site is not used for drinking purposes. Also, empirical data regarding ground-water quality are available to evaluate risks associated with exposure to impacted ground water. As a result, model estimates of chemical concentrations in ground water that may result from leaching are not necessary for the risk evaluation because actual ground-water quality data can be used for this purpose.

10.3.2 Ground Water

The City of Astoria supplies municipal drinking water to facilities in and near the Astoria Area-Wide site. Ground water at the site is not used for drinking purposes, and this is unlikely to change. As a result, human receptors such as occupational workers are unlikely to ingest or directly contact site-related chemicals in ground water.

It is assumed that occupational workers could be exposed to volatile hydrocarbons that migrate from ground water to indoor or outdoor air. It is also assumed that excavation workers could have direct contact with chemicals in ground water if an excavation were developed below the water table in the northern part of the Astoria Area-Wide site. Excavations are required to be dewatered before entry, and therefore it is unlikely that workers will have substantial direct contact with chemicals in ground water.

10.3.3 Surface Sediment and Surface Water

Petroleum constituents have impacted sediment and surface water near the seep at the base of Slip 2. The identified potentially complete ecological exposure pathways are direct contact of constituents to benthic receptors residing in surface sediments and direct contact in surface water to resident pelagic receptors (Kennedy/Jenks Consultants, 2006b). A complete discussion of the potential risks associated with exposure to petroleum near the seep is discussed as part of the ecological risk assessment (Kennedy/Jenks Consultants, 2006c).

The human receptors that appear to have the greatest potential to contact sediment and surface water of the Columbia River are recreationalists such as fishers and boaters. The seep area in Slip 2 is located in part of the Astoria Area-Wide site that is actively used for industrial purposes and that is likely to remain an industrial-use area for the foreseeable future. Given the industrial nature of the Astoria Area-Wide site, recreational fishing, clamming, or crabbing in Slip 2 would be unsafe. As a result, it is unlikely that people will have significant direct contact with impacted sediment.

Dissolved chemicals may migrate from ground water or sediment near the hydrocarbon seep to surface water. Given the small-scale and localized nature of the seep, the relatively small volume of LNAPL that discharges, and the substantial flow of ambient water over the seep area, chemical concentrations in surface water are expected to be low. Section 6.4.6 describes the results of surface water sampling in the area of the hydrocarbon seep. Due to mixing in the ambient water, it is likely that elevated chemical concentrations in surface water would only be found immediately adjacent to impacted sediment. It is unlikely that people would have significant exposure to elevated concentrations of petroleum constituents in surface water.

Several PAHs with relatively high molecular weights are present in impacted sediment. It is possible that some of these PAHs can accumulate in the tissues of some aquatic organisms. Vertebrates, including fish, can metabolize PAHs, and these hydrocarbons have little propensity to accumulate in tissues of vertebrates. As a result, it is unlikely that people who catch and consume fish near the Astoria Area-Wide site would have significant exposure to site-related chemicals. However, some invertebrates may accumulate some PAHs in tissues. For several reasons, it is unlikely that recreational fishers would have significant exposure to site-related chemicals in tissues of vertebrates.

Direct-contact exposures with impacted sediment and surface water are considered potentially complete, but insignificant, exposure pathways. Similarly, indirect exposure to site-related PAHs that may accumulate in tissues of invertebrates that are harvested and consumed by fishers is also considered an insignificant exposure pathway.

11.0 HUMAN HEALTH RISK ASSESSMENT

This section summarizes key findings of the human health risk assessment (HHRA) for the Astoria Area-Wide Petroleum Site in Astoria, Oregon. The purpose of the HHRA was to characterize potential risks that site-related chemicals in soil and ground water may pose to human health. To focus the HHRA on chemicals with potential to pose unacceptable human health risk, the list of COI detected at the site was evaluated and reduced to develop the chemicals of potential concern (COPC). COPC at the Astoria Area-Wide site consist primarily of petroleum-related hydrocarbons. With the exception of a few metals, all of the COPC in soil and ground water were petroleum mixtures or petroleum constituents. Although some metals were identified as COPC, there is no evidence of significant metals contamination in soil or ground water. For a complete understanding of the assessment of risk to human health at the Astoria Area-Wide site, the HHRA report is provided as Appendix G.

The HHRA was performed consistent with methods outlined in the HHRA Work Plan (Maul Foster & Alongi, 2005) and in subsequent correspondence with the DEQ (DEQ, 2005b, 2006b; Maul, Foster & Alongi, 2006). The assessment was performed using methods outlined in the DEQ (2003) *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites*. Risk estimates were made by comparing concentrations of chemicals in soil and ground water with applicable generic DEQ risk based concentration (RBCs). A RBC is an estimate of the concentration of a chemical in soil, ground water, or air that would not pose unacceptable risks to humans with a reasonable maximum exposure (RME) to the impacted medium. DEQ has developed generic RBCs for the most common scenarios by which humans may contact chemicals at a site. By design, generic DEQ RBCs are conservative. DEQ has not developed generic RBCs for all the COPC identified, and some site-specific RBCs were developed for some COPC.

11.1 CONCEPTUAL SITE MODEL

Mechanisms by which people may be exposed to COI are detailed in Section 10. Various workers are the human receptors with the greatest potential to contact COI in soil or ground water. These workers include occupational workers, occasional excavation workers, and construction workers. Ground water at the Astoria Area-Wide site is not used as a source of drinking water and is unlikely to be used as a water-supply source in the foreseeable future. Potential exposure scenarios evaluated in the HHRA include:

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

A change to the CSM occurred between when the HHRA work plan was approved and when the draft HHRA was submitted. A four-unit apartment complex where the urban resident exposure pathway was assumed to be complete in the HHRA work plan was demolished in the fall of 2006. Also, a previously unknown apartment was identified on the second story of a mixed use building with first story commercial space (Fast Lube & Oil at former Harris/Van West), but the apartment appears to no longer be occupied. No residences are present at the Astoria Area-Wide site, and given land-use plans and development trends, it is not likely that residences will be developed in the foreseeable future. Therefore, it is not reasonably likely that the urban resident exposure scenario will be complete in the foreseeable future. However, at the request of DEQ, all soil and ground-water data were compared with RBCs for urban residents in the HHRA. The pathways screened with urban resident RBCs included direct contact with surface soil (0 to 3 feet bgs), indirect exposure to volatile chemicals in vadose-zone soil that migrate to outdoor air, and indirect exposure to volatile chemicals in vadose-

zone soil that migrate to indoor air. The results of comparisons with urban resident RBCs are presented as part of the HHRA in Appendix G.

11.2 RISK CHARACTERIZATION

The Astoria Area-Wide site has been divided into five general AOC. Petroleum-related chemicals in AOC 3 and AOC 5 are not expected to pose unacceptable risks to potential human receptors. Risk estimates for AOC 1, AOC 2, and AOC 4 are discussed below. Figure 11-1 shows the areas of the Astoria Area-Wide site where potentially unacceptable risks have been inferred.

11.2.1 AOC 1

Along the eastern boundary of AOC 1, in the north and central area of the Niemi Oil Cardlock facility, the concentrations of benzene in subsurface soil are above the generic DEQ vapor-intrusion RBC (Figure 11-1). Although there currently are no buildings near this location, it is assumed that a building could be developed over benzene-impacted soil in this area at some time in the future. As a result, it is assumed that the benzene-impacted soil has the potential to pose unacceptable risks to indoor workers of a hypothetical building in the north central portion of the facility.

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

Shallow ground water beneath some portions of the Niemi Oil Cardlock facility has concentrations of 1,2,4-trimethylbenzene, naphthalene, or hydrocarbons identified in TPH-G

range above excavation-worker RBCs. Also, ground water from monitoring-well MW-30(A) located on Port property north of the Burlington Northern railroad tracks had concentrations of naphthalene and TPH-G-range hydrocarbons above excavation-worker RBCs.

11.2.2 AOC 2

One soil sample collected in AOC 2, at the former Delphia Oil Val's Texaco facility had a concentration of benzene above the generic occupational vapor-intrusion RBC (Figure 11-1). There are no buildings commonly occupied by workers within 50 feet of this sample location.

The concentration of TPH-D-range hydrocarbons in one soil sample collected at the former Shell bulk plant site (sample location SB-904(S)) slightly exceeded the corresponding generic DEQ construction worker RBC. However, this sample was collected at 12 feet bgs, below the typical depth of most foundation or utility excavations in the area; and the TPH-D concentrations in shallower soil at this location were well below the corresponding generic DEQ RBC. Additionally, TPH concentrations in adjacent explorations were below the corresponding generic DEQ RBCs. Based on multiple lines of evidence, the TPH-D-range hydrocarbons in soil at the SB-904(S) location are not expected to pose an unacceptable risk to potential future construction workers.

11.2.3 AOC 4

Petroleum-related chemicals in the portion of AOC 4 with LNAPL may pose unacceptable risks to potential workers (Figure 11-1). Concentrations of benzene in several subsurface soil samples collected in what appears to be the LNAPL smear zone were above the generic DEQ vapor-intrusion RBC protective of occupational workers. Similarly, concentrations of benzene in soil-gas samples collected over the LNAPL zone were above soil-gas RBCs protective of workers who may inhale benzene in indoor air. At present, the Port office building is the only existing building overlying the LNAPL plume that routinely houses workers. The subslab-vapor investigation concluded that sub-slab gas concentrations at the Port of Astoria office building do not pose an unacceptable human health risk due to chronic

exposures. However, in the portion of AOC 4 with LNAPL, it is assumed that volatile chemicals in the subsurface can pose unacceptable risks to workers in a future building. The complete results of the sub-slab soil gas intrusion assessment are included as Appendix H.

In addition to exceedances of vapor-intrusion RBCs, concentrations of diesel-range hydrocarbons in soil samples collected from the smear zone in the northeast portion of the inferred LNAPL plume were above the construction-worker RBC (Figure 11-1). Also, ground-water samples collected from monitoring wells in the general area where LNAPL is present on ground water had concentrations of benzene, 1,2,4-trimethylbenzene, naphthalene, or TPH-G that were above the construction-worker RBC.

A surface-soil sample collected near the Port maintenance building had concentrations of benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene that were above occupational- and construction-worker RBCs (Figure 11-1). The source of PAH impacts at this location is likely different from the source(s) of LNAPL in AOC 4.

11.3 HOT SPOTS

Under Oregon's environmental cleanup rules, the balancing factors used in remedy selection are weighted differently for areas considered hot spots of contamination compared to areas that are not hot spots.

11.3.1 Soil Hot Spots

Based on available data, no highly concentrated hot spots were identified for soil. Highly concentrated soil hot spots are defined as areas where site-related chemicals are present at levels exceeding RBCs corresponding to 100 times the acceptable risk level for human exposure to each individual carcinogen, and ten times the acceptable risk level for human exposure to each individual noncarcinogen (DEQ, 1998b).

11.3.2 LNAPL Hot Spots

The DEQ typically assumes that direct exposure to LNAPL represents an unacceptable risk, and that zones with a significant volume of LNAPL represent "highly mobile" hot spots. LNAPL is present in sediment near a seep in Slip 2 near the shoreline and a petroleum sheen has been observed on the water surface near the seep. A zone of LNAPL is present in AOC 4, and LNAPL has been identified in monitoring-well MW-15(A) at the former Delphia bulk plant. These zones of LNAPL may be considered highly mobile hot spots.

11.3.3 Ground-Water Hot Spots

The criteria for determining ground-water hot spots differ from those for other media (DEQ 1998). For ground water, a hot spot exists if a hazardous substance has a significant adverse effect on the beneficial uses of that resource, and if restoration or protection of the beneficial use can occur within a reasonable amount of time. Because it must be feasible to treat areas of contaminated ground water before they are considered hot spots, ground-water hot spots will be characterized as part of the FS. Ground-water samples collected from four monitoring wells (MW-26(A), MW-28(A), MW-29(A), and MW-30(A)) in AOC 1, and from three monitoring wells (MW-40(A), MW-42(A), and MW-44(A)) in AOC 4, had concentrations of at least one COPC that were above an applicable construction-worker RBC. These two zones of ground-water contamination are considered preliminary hot spots.

11.4 UNCERTAINTY ANALYSIS

Uncertainty is inherent in many aspects of the risk-assessment process. Risk estimates are calculated by combining site data, assumptions about human exposures to impacted media, and toxicity data. The uncertainties in a risk assessment can be grouped into the following main categories:

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

With few exceptions, when substantial uncertainty was associated with a variable used in modeling or risk estimation, health-protective approximations of this variable were employed in the HHRA. As a result, risks are likely to be overestimated.

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

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

12.0 ECOLOGICAL RISK ASSESSMENT

This section presents a summary of the ecological risk assessment (ERA) completed for the Astoria Area-Wide site. The purpose of the ERA is to evaluate the potential for adverse impacts to the environment attributable to exposure to site-related petroleum constituents. The receptors and potential exposure pathways requiring evaluation at this site are presented in the CSM for ecological receptors as summarized in Section 10.0 and presented in detail in the ERA Work Plan (Kennedy/Jenks Consultants, 2005). The following summary presents the results of the Level I through Level III ERA activities conducted at the site. The complete Level III Ecological Risk Assessment Report is provided as Appendix I of this RI report (Kennedy/Jenks Consultants, 2006b).

12.1 LEVEL I SCOPING ECOLOGICAL RISK ASSESSMENT

Per DEQ ERA guidance, a Level I ERA was completed in August 2004 (Hart Crowser, 2004b). The study area for the Level I ERA was previously described as bounded on the north by Slip 2 (approximately 600 feet from the shore toward the Columbia River), on the east by Portway, on the south by West Marine Drive, and on the west by the western property boundary of the former Chevron/McCall Oil bulk plant property. The ERA study area encompassed a portion of the Columbia River within Slip 2 at the Port of Astoria, as shown on Figure 12-1. The ongoing IRAM consists of a floating boom and free product absorbent system to contain petroleum hydrocarbons presently seeping into the Columbia River from the filled shoreline at the head of Slip 2. Further upland investigations have also been completed to address the source(s) of the hydrocarbon seep.

On August 20, 2004, DEQ issued its finding in agreement with the Level I ERA that no ecologically important species and/or habitats were present in the upland portion of the Astoria Area-Wide site (DEQ, 2004). In its August 20, 2004, memorandum, DEQ was not prepared to "discount the near-water and in-water portions of the site as low quality habitat". Thus, according to DEQ ERA guidance, additional ecological risk assessment steps were required for the in-water portion of the site within Slip 2.

12.2 PRELIMINARY LEVEL II SCREENING ECOLOGICAL RISK ASSESSMENT

A preliminary Level II screening assessment consisting of two surface sediment samples collected from the southeast corner of Slip 2 was conducted in November 2003 (*EnviroLogic Resources*, 2003d). One sediment sample was collected inside the containment boom area, while the other was collected outside the boom area. The sediment samples were analyzed for TPH and PAHs.

The sediment sample collected from inside the boom area had higher concentrations of diesel and heavy oil range hydrocarbons than the sample collected outside the boom. The Level II screening of the sediment chemical data identified several PAHs that exceeded their respective DEQ marine sediment screening level values (SLVs), including acenaphthene, anthracene, benz(a)anthracene, chrysene, fluoranthene, pyrene, and total light and heavy molecular weight PAHs. Additionally, an extended list of constituents was analyzed by the laboratory to help identify the types of potential sources of PAHs in the sediments by comparing pyrogenic and petrogenic PAHs. Pyrogenic PAHs are derived from combustion (i.e., has been burned) and petrogenic PAHs are generally from a noncombusted petroleum product. The sediment sample collected from inside the boom had a larger contribution of petrogenic PAHs, and the sample collected outside the boom had a higher proportion of pyrogenic PAHs.

12.3 LEVEL III BASELINE ECOLOGICAL RISK ASSESSMENT RESULTS

Based on the results of the preliminary Level II screening, a Level III baseline ERA work plan was prepared to evaluate potential risks to ecological receptors within Slip 2 from site-related petroleum constituents in sediment and surface water (Kennedy/Jenks Consultants, 2005). The assessment endpoints chosen for the ERA were the protection of the benthic invertebrate community and resident pelagic organisms from reproductive impairment caused by site constituents. Measurement endpoints included comparison of test sediment bioassay results to reference and control sediment bioassay results for benthic toxicity, and comparison of surface water chemistry data to appropriate surface water screening criteria.

12.3.1 Additional Sampling and Bioassay Testing

Five test sediment samples were collected within Slip 2 - three from inside the boom area, and two from outside the boom area in the southeast corner of the slip as shown on Figure 12-2. Additionally, two reference sediments were collected from the East Boat Basin (REF-EBB) at the Port of Astoria and from Youngs Bay (REF-YB), west of the site and south of the Skipanon Channel. These sample locations are shown on Figure 12-3. All sediment samples were analyzed for the full set of analytes per the Washington State Sediment Management Standards. Sampling of these reference locations was coordinated with the U.S. Army Corps of Engineers, which has done extensive sediment sampling and bioassay testing in the Lower Columbia River and Astoria region, and approved by the DEQ in their April 6, 2006, letter to *EnviroLogic Resources* (DEQ, 2006). To address potential risks to pelagic receptors, five surface water samples were collected from the mid-water column within Slip 2 and analyzed for petroleum constituents (PAHs and BTEX). In addition to chemistry analyses on the sediment samples, the standard suite of three marine/estuarine bioassay tests was conducted on the five test sediments and two reference sediments.

12.3.2 Results and Discussion

The results of surface water and sediment sampling are discussed in the context of ecological risk in the following paragraphs.

12.3.2.1 Surface Water

Surface water chemical analytical results were compared to EPA ambient water quality criteria (AWQC) final chronic values (FCVs) for chronic toxicity of individual PAHs in water exposures (EPA, 2003). Because no AWQC are available for BTEX, surface water concentrations for these chemicals were compared to DEQ aquatic SLVs. The objective of the surface water sampling and evaluation program was to evaluate whether petroleum constituents in the seep or sheen observed in Slip 2 may pose an ecological risk to pelagic

(water column) aquatic receptors. No exceedances of any FCVs or SLVs were observed in any of the surface water samples analyzed. Therefore, it was concluded that the chemical constituents in the water column at the Astoria Area-Wide site pose no risk to aquatic ecological receptors.

12.3.2.2 Sediment

Sediment chemical analytical results were compared to DEQ marine/estuarine SLVs. Several sediment samples contained levels of multiple analytes exceeding DEQ marine/estuarine sediment SLVs. All samples collected had exceedances of SLVs for copper, likely due to high naturally occurring background concentrations in sediments. Both reference samples had slight exceedances of the DEQ SLV for mercury. Four of the five sediment samples collected from Slip 2 contained levels of petroleum constituents that exceeded DEQ marine SLVs for various light and heavy molecular weight PAHs. Sediment sample SD-104 collected from outside the absorbent boom, in the central near shore area of Slip 2, and furthest away from Pier 2, only exceeded the DEQ marine SLVs for copper and slightly for mercury. The majority of the exceedances corresponding were from samples collected inside the containment boom area.

The suite of proposed marine/estuarine biological tests, selected according to the Dredged Material Evaluation Framework (DMEF) (Corps et al. 1998) for the Lower Columbia River Management Area (LCRMA), was as follows:

- Acute 10-day Eohaustorius estuarius amphipod mortality test;
- Chronic 20-day juvenile *Neanthes arenaceodentata* polychaete survival/growth test; and
- Acute 48-hour larval *Mytilus galloprovincialis* bivalve mortality/abnormality test.

Based on physical and chemical analytical results, REF-EBB was selected as the reference sediment sample for use in bioassay testing. Selection of this reference sample was conducted based on consensus reached at the June 2, 2006, meeting with the DEQ.

The results of the three marine/estuarine bioassay tests are summarized below and presented in detail in Tables 5 through 7 of the Level III ERA report that is included as Appendix I.

Amphipod Mortality Test: Test samples SD-100, SD-101, and SD-102 (all located within the absorbent boom) resulted in 100 percent amphipod mortality, test sample SD-103 (located outside the absorbent boom near the pier) yielded 61 percent mortality, and SD –104 (located outside the absorbent boom furthest from the pier) yielded 24 percent mortality. Of the three marine/estuarine tests run, the amphipod mortality test results best correlated to the relative PAH concentration gradient found in the southeast corner of Slip 2. Levels of PAHs decreased rapidly moving out beyond the containment boom, particularly at sample SD-103 and beyond to the northwest (SD-104).

The performance criterion for the selected reference sample REF-EBB was not met for mortality, according to the guidance in the LCRMA DMEF. Mean mortality in REF-EBB exceeded mean mortality in the negative control sample plus 20 percent (Corps et al. 1998) by 3 percent. As discussed during the June 2, 2006, meeting the use of REF-EBB was agreed upon as an appropriate reference sediment for test comparison, based upon similar grain size characteristics and very low levels of non-target contamination. Therefore, samples SD-100, SD-101, SD-102, and SD-103 resulted in "one-hit" failures compared to REF-EBB, based on the LCRMA DMEF (Corps et al. 1998). Sample SD-104 passed the amphipod mortality bioassay when compared to REF-EBB.

Polychaete Survival/Growth Test: For the chronic 20-day polychaete survival and growth test, none of the test samples showed significantly decreased individual survival or growth rate compared with reference sediment REF-EBB. Therefore, all test samples passed the "one-hit" criterion for mean survival and growth. The performance criterion was not met for survival/growth for the selected reference sample REF-EBB, i.e., the mean growth rate for

REF-EBB was less than 80 percent of the negative control mean growth rate. However, at the June 2, 2006, meeting, DEQ agreed to use REF-EBB for statistical comparison purposes within the ERA. The results of the polychaete survival and growth test indicate the polychaete was not sensitive to the PAH constituents found in the test samples. Individual growth rates did not appear to show a dose-response relationship relative to observed PAH concentrations in sediment within the containment boom and moving out into Slip 2.

Larval Bivalve Mortality/Abnormality Test: Results for the larval bivalve mortality and abnormality test were the most confounding of the three bioassays. The acute 48-hour larval bivalve mortality and abnormality test indicated that the normalized combined mortality and abnormality (NCMA) for the five test samples ranged from 56.4 to 87.3 percent. Reference sample REF-EBB had a NCMA of 61.8 percent. Both reference samples performed poorly with little explanation for the source of larval abnormalities. Although initial interstitial salinity in the bulk test and reference sediments was low, this particular larval test mixes a small aliquot of sediment with typical salinity seawater and is thoroughly shaken (similar to an elutriate test for potential leaching of contaminants during dredging) prior to addition of the larvae. Therefore, low salinity cannot explain the poor NCMA performance of the reference sediments. Furthermore, test sediment SD-102, which contained the highest levels of PAH constituents of any sample, had the lowest percentage of NCMA (56.4 percent), i.e., the least amount of larval mortality/abnormality, and outperformed the "cleaner" reference sample REF-EBB (61.8 percent).

Personal discussion with Mr. Mark Siipola of the Portland District U.S. Army Corps of Engineers indicated that other dredged material characterization projects recently conducted in the vicinity of the site also found similar low salinity and similar issues with the polychaete growth and acute larval bioassays (Kennedy/Jenks, 2006). The marine/estuarine sediment bioassay protocols developed in Puget Sound may not perform as well in the Lower Columbia River estuary because of its unique hydrodynamics. Low sediment interstitial salinities have been observed within the vicinity of the site that pose unique bioassay testing challenges within the Lower Columbia River.

12.3.3 Conclusion

Petroleum constituents within a small area of sediment in the southeast corner of Slip 2, encompassing the area just outside the containment boom and the shoreline, appeared to be causing mortality and adverse toxicity to benthic organisms. Unacceptable amphipod mortality indicated unacceptable toxicity in the three sediment samples collected inside the boom and one sample collected just outside the boom. A second sample outside the boom passed the amphipod mortality "one-hit" criteria test. Results of the juvenile polychaete bioassay indicated the concentrations of petroleum constituents found in Slip 2 sediments were not at sufficient levels to affect the sublethal or chronic growth endpoint. None of the test organisms failed the juvenile polychaete survival/growth bioassay test.

The larval bivalve mortality/abnormality bioassay results were the most inconclusive of the three tests. None of the test organisms failed the bioassay, but the combined mortality/abnormality results did not trend with the PAH concentrations in sediment. Both the juvenile polychaete and larval bivalve tests had poor performance issues with the reference sediments. These issues were similarly encountered at other bioassay testing sites around the Lower Columbia River estuary, as experienced by the U.S. Army Corps of Engineers and the DEQ.

13.0 CONCLUSIONS

The detailed evaluation of conditions at the Astoria Area-Wide site undertaken by the PRP group has resulted in a compilation of the site history, identification of potential sources, characterization of the hydrostratigraphy and hydraulic system, characterization of the distribution of petroleum hydrocarbons in soil and ground water, storm water, sediment, and soil gas, and refinement of the CSM of chemical fate and transport. The purpose of this evaluation was to gather sufficient information to assess the risks to human health and the environment and evaluate potential remedial alternatives.

13.1 SOURCE CHARACTERIZATION

The operational history of the Astoria Area-Wide site was reviewed by analyzing aerial photographs, Sanborn Fire Insurance Maps, DEQ file information, and other historical documents. Individual PRPs contributed facility operations information. The historical information review identified the former retail and bulk petroleum distribution facilities and ancillary equipment as potential sources of petroleum hydrocarbons identified at the Astoria Area-Wide site.

The PRP group initiated soil and ground-water characterization in 2002 to delineate potential sources and the source of the hydrocarbon seep located in the southeast corner of Slip 2. The specific source of the hydrocarbon seep at the base of Slip 2 is an upland LNAPL plume consisting of petroleum hydrocarbons. The extent of the LNAPL plume is shown on Figure 11-1. The portion of the LNAPL plume located beneath the former ExxonMobil/Niemi Oil bulk plant, Portway, and south of the former McCall petroleum pipelines is primarily gasoline with some diesel. The portion of the LNAPL plume north of the former McCall petroleum pipelines, beneath a portion of the Port office building and adjoining paved areas is predominately diesel with some gasoline. The source characterization identifies former facilities at the former ExxonMobil/Niemi Oil bulk plant and the McCall diesel pipeline release as two sources of hydrocarbons in the LNAPL plume in AOC 4.

Other petroleum hydrocarbons were identified in environmental media in association with other facilities. Other LNAPL identified at the site includes gasoline-range hydrocarbons at the former Delphia bulk plant and gasoline-range hydrocarbons near the southeastern portion of the former ExxonMobil/Niemi Oil bulk plant, does not appear to be contiguous with the upland LNAPL plume. Historically, LNAPL has been identified on other portions of the Astoria Area-Wide site as discussed in Section 6.0.

13.2 HYDROGEOLOGIC CHARACTERIZATION

The hydrostratigraphy beneath the Astoria Area-Wide site has been characterized to depths up to 50 feet. Characterization was completed by gathering information during exploration activities. These activities included advancing soil probe borings and soil borings, monitoring well installation, test pit excavation, soil and ground-water sampling, CPT-ROST® explorations, ground-water and LNAPL monitoring, LNAPL sampling, water level information collection, and aquifer characterization.

The results of these activities identified three hydrostratigraphic units of interest beneath the site. These units, comprising the shallow water-bearing zone, are the dredge sand fill, native alluvial deposits, and to a limited degree, the upper Astoria Formation. The vadose zone beneath the Astoria Area-Wide site is generally comprised of a dredge sand fill, gravel base rock, and fill debris. The shallow water-bearing zone is primarily in the dredge sand fill. The dredge sand fill is comprised of fine sands with lenses of silt and clay as well as gravel, wood, and other organics. The known occurrences of petroleum hydrocarbons in soil and ground water are generally within the dredge sand fill unit.

Data suggest the three units and the adjacent surface water bodies (Youngs Bay and the Columbia River) are hydraulically connected. The water table beneath most of the site generally fluctuates between 7 and 11 feet bgs. Water levels beneath the site are subject to tidal influences, with ground-water level fluctuations due to tidal cycles ranging from about 0.5 feet near the shoreline decreasing to a few hundredths of a foot several hundred feet

inland. The shallow ground-water flow direction beneath most of the site is generally to the north/northwest.

13.3 COPC CHARACTERIZATION

The COPC are present in the vadose zone soils and soil gas, as LNAPL on the ground-water surface in select locations, as dissolved constituents in ground water in the saturated zone, as a sheen on surface water in Slip 2, and in shallow sediments within the southeast corner of Slip 2. Vertical dispersion of the COPC and development of a smear zone have occurred at varying depths. Interpretation of CPT/ROST data indicates lateral dispersion of COPC occurs on a localized level because of the presence of fine-grained lenses within the dredge sand fill. These lenses are generally limited in extent and the overall influence of these fine-grained lenses on the lateral distribution of the COPC is interpreted to be minor.

The depth interval where water-table fluctuations have occurred contain residual petroleum hydrocarbons and residual LNAPL. It is important to note that the greatest LNAPL thicknesses were generally measured in wells following prolonged periods of inactivity (August 2002) and subjected to numerous changes in water levels. Under these conditions the well casing tends to accumulate a LNAPL thickness exceeding the surrounding formation because the absence of resistance in the well results in LNAPL rising above the true elevation in the formation. Wet season monitoring records indicate that when the water table rises the residual petroleum hydrocarbons and LNAPL move into the wells and greater thicknesses of LNAPL on the water table are observed. The remobilization of LNAPL does not necessarily translate into higher concentrations of dissolved constituents. Because the historical release sources have been removed and several IRAMs have been implemented, further migration of the LNAPL and dissolved phase plumes will be limited due to hydrocarbon mass removal over time by natural attenuation processes and the ongoing product recovery and seep containment IRAMs.

Concentrations of COPC occur in soil vapor associated with LNAPL. Specific investigations of soil gas in areas beneath the Port office building indicate that soil gas concentrations are

attenuating between a depth of five feet bgs and the depth of the building slab. Volatile COPC are detected at significant concentrations over a much smaller area just below the slab than at deeper depths.

13.4 EFFECTIVENESS OF IRAMS

Two early (Pre-RI) IRAMS included a ground-water treatment and LNAPL recovery system and a containment boom for the hydrocarbon seep in Slip 2. The remedial pumping program to cleanup ground water and remove LNAPL was active at the site in 1995. The remedial ground-water/LNAPL system was considered essentially unsuccessful. The original containment boom was replaced with an absorbent containment boom in 2004 and in 2008 an enhanced absorbent boom system was installed. The purpose of the absorbent containment boom is to contain and remove petroleum hydrocarbons that are released to surface water in Slip 2. Sediment and surface water sampling conducted in association with the ecological risk assessment indicate that the absorbent containment boom is very effective in containing the petroleum hydrocarbon seep.

The IRAMs undertaken at the Astoria Area-Wide site during the RI process have been generally effective in helping to minimize the impact of petroleum hydrocarbon constituents in the environment. The extent of petroleum hydrocarbons has been reduced with the removal of the potential sources from areas of concern and underground tanks and pipelines.

The various IRAMs implemented have had varying degrees of effectiveness in reducing the levels of petroleum hydrocarbon constituents on the site. Soil removal, storm sewer rerouting, pipeline decommissioning, and UST removal are IRAMs that had goals of reducing mass petroleum hydrocarbons or removing potential sources of the release of petroleum hydrocarbons. These IRAMS also provided additional site characterization information that has been incorporated into the RI.

Currently LNAPL recovery is performed by using absorbent socks in select monitoring wells. LNAPL seeping to the surface water in Slip 2 is contained within a system of absorbent

booms described in Section 7.1.4. The absorbent booms are monitored and replaced when full. The effectiveness of the absorbent boom is qualitatively evaluated by the lack of a sheen on the off-shore side of the boom. The effectiveness of the absorbent socks is evaluated by monitoring the LNAPL mass recovered in the socks.

The HVAC upgrade performed at the Port office building is another IRAM that is currently in effect. The Port office building HVAC system was upgraded in 2005 to maintain a positive pressure inside the building during working hours. Effectiveness of the IRAM was evaluated in July 2005 and February 2006. Testing implied that when windows and doors were left open the IRAM effectiveness was negligible. The IRAM was effective in maintaining a small positive interior cross-slab pressure difference during the February 2006 testing when a special effort was made to keep perimeter doors (not necessarily exterior) and windows from being left open or ajar for extended time periods.

13.5 HUMAN HEALTH RISK ASSESSMENT

The results of the HHRA identified several areas within the Astoria Area-Wide site where there is a potential risk from site-related chemicals in soil and ground water to human health. Specifically, these areas were identified in AOC 1, 2, and 4. Hot spots were also identified at the Astoria Area-Wide site. These areas and hot spots are summarized below.

AOC 1: Benzene in subsurface soil is present beneath the Niemi Oil Cardlock facility within AOC 1 above the generic DEQ vapor-intrusion to buildings RBC. There is no building in this location and there is no unacceptable risk under the current use.

Shallow ground water beneath some portions of the Niemi Oil Cardlock facility has concentrations of 1,2,4-trimethylbenzene, naphthalene, or hydrocarbons identified in TPH-G range above excavation-worker RBCs. Also, ground water from monitoring-well MW-30(A) located on Port property north of the Burlington Northern railroad tracks had concentrations of naphthalene and TPH-G range hydrocarbons above excavation-worker RBCs.

AOC 2: One soil sample collected in AOC 2, at the former Val's Texaco property had a concentration of benzene above the generic vapor-intrusion RBC (Figure 11-1). There are no buildings commonly occupied by workers within 50 feet of this sample location. One soil sample collected at depth from the former Shell bulk plant site slightly exceeded the generic TPH soil RBC. However, the risk assessment concluded TPH at this location does not pose an unacceptable risk.

AOC 4: Petroleum-related chemicals in the portion of AOC 4 with LNAPL may pose unacceptable risks to potential workers. Concentrations of benzene in several subsurface soil samples collected in what appears to be the LNAPL smear zone were above the generic DEQ vapor-intrusion RBC protective of occupational workers. Similarly, concentrations of benzene in soil-gas samples collected over the LNAPL zone outside the Port office building were above site-specific soil-gas RBCs for occupational exposures. At present, the Port office building is the only existing building overlying the LNAPL plume that routinely houses workers. The sub slab vapor investigation concluded that sub slab gas concentrations at the Port of Astoria office building do not pose an unacceptable human health risk due to chronic exposures. New buildings overlying the LNAPL in AOC 4 are being constructed with vapor barriers.

In addition to exceedances of vapor-intrusion RBCs, concentrations of diesel-range hydrocarbons in soil samples collected from the smear zone in the northeast portion of the inferred LNAPL plume were above the construction-worker RBC (Figure 11-1). Also, ground-water samples collected from monitoring wells in the general area where LNAPL is present on ground water had concentrations of benzene, 1,2,4-trimethylbenzene, naphthalene, or TPH-G that were above the construction-worker RBC. New development in AOC 4 has been conducted under a DEQ-approved Contaminated Media Management Plan to limit the potential for construction workers to be exposed to unacceptable risks.

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

occupational- and construction-worker RBCs (Figure 11-1). The source of PAH impacts at this location is likely different from the source(s) of LNAPL in AOC 4.

HOT SPOTS: A zone of LNAPL and a seep are present in AOC 4, and LNAPL has been identified in monitoring-well MW-15(A) at the former Delphia bulk plant. These zones of LNAPL may be considered potential highly mobile hot spots. Because it must be feasible to treat areas of contaminated ground water before they are considered hot spots, ground-water hot spots will be characterized as part of the FS. Ground-water samples collected from four monitoring wells (MW-26(A), MW-28(A), MW-29(A), and MW-30(A)) in AOC 1, and from three monitoring wells (MW-40(A), MW-42(A), and MW-44(A)) in AOC 4, had concentrations of at least one COPC that were above an applicable construction-worker RBC.

13.6 ECOLOGICAL RISK ASSESSMENT

The surface water sampling and evaluation program concluded the chemical constituents analyzed in the Slip 2 water column at the Astoria Area-Wide site dot not pose an unacceptable risk to aquatic ecological receptors.

Petroleum constituents within a small area of sediment in the southeast corner of Slip 2, encompassing the area just outside the absorbent boom and the shoreline, appeared to be causing mortality and adverse toxicity to benthic organisms. Unacceptable amphipod mortality indicates unacceptable toxicity in the three sediment samples collected inside the boom and one sample collected just outside the boom. A second sample from outside the boom passed the amphipod mortality test. Results of the juvenile polychaete bioassay indicated the concentrations of petroleum constituents found in Slip 2 sediments were not at sufficient levels to affect the sublethal or chronic growth endpoint. None of the test organisms failed the juvenile polychaete survival/growth bioassay test.

The larval bivalve mortality/abnormality bioassay results were the most inconclusive of the three tests. None of the test organisms failed the bioassay, but the combined mortality/abnormality results did not trend with the PAH concentrations in sediment. Both the

juvenile polychaete and larval bivalve tests had poor performance issues with the reference sediments. These issues were similarly encountered at other bioassay testing sites around the Lower Columbia River estuary, as experienced by the U.S. Army Corps of Engineers and the DEQ.

13.7 SUMMARY

The data and interpretations provided in this RI report are intended to provide the information necessary for assessment of risk and development of remedial alternatives. The stratigraphy and hydraulics of the aquifer system have been defined, which allows for evaluation of exposure pathways and comparison of ground-water cleanup scenarios. The distribution of petroleum related hydrocarbons in soil and ground water has been defined. This allows for calculation of the risk to human health and the environment through the exposure pathways controlled by the hydrostratigraphy and, evaluation of remedial alternatives in terms of processes and technologies that may be available to address the unacceptable risk at the Astoria Area-Wide site.

The human health risk assessment (included as Appendix G and summarized in Section 11.0) determined petroleum constituents within AOC 1, 2 and 4 could present an unacceptable risk to human health during certain exposure scenarios and that highly mobile hot spots have been identified at the site.

The ecological risk assessment (included as Appendix I and summarized in Section 12.0) determined petroleum constituents within a small area of sediment in the southeast corner of Slip 2, encompassing the area just outside the containment boom and the shoreline, appeared to be causing mortality and adverse toxicity to benthic organisms.

14.0 REFERENCES

Applied Geotechnology, Inc., 1992, Soil Excavation and Groundwater Sampling, Decommissioning Chevron Station No. 60095872, 490 West Marine Drive, Astoria, Oregon, DEQ File No. 04-91-0250: consultant Report dated November 10, 1992.

Coppel, W., 1996, Request for Closure, DEQ File 04-90-392, Former Shell Service Station, 460 West Marine Drive, Astoria, Oregon: consultant letter report dated February 29, 1996.

Coppel, W., 1997, Technical Memorandum: consultant letter dated November 11, 1997.

Coppel, W.M., 1999, Limited Site Investigation, Johnson One Stop, 469 West Marine Drive, Astoria, Oregon: consultant letter report dated December 20, 1999.

City of Astoria, Astoria Comprehensive Plan, May, 1998.

City of Astoria, Astoria Development Code, January 2002.

Delta Environmental Consultants, Inc., 1993, Quarterly Monitoring Report, First Calendar Quarter 1993, Chevron Facility No. 9-5872, 490 West Marine Drive, Astoria, Oregon, Oregon DEQ File No. 04-91-0250, Delta Project No. 43-93-714: consultant Report dated May 4, 1993.

Delta Environmental Consultants, Inc., 1993, Quarterly Monitoring Report Second Calendar Quarter 1993, Chevron Facility No. 9-5872, 490 West Marine Drive, Astoria, Oregon, Oregon DEQ File No. 04-91-0250, Delta Project NO. 43-93-714: consultant report dated July 26, 1993.

Delta Environmental Consultants, Inc., 1993, Quarterly Monitoring Report, Third Calendar Quarter 1993, Chevron Facility No. 9-5872, 490 West Marine Drive, Astoria, Oregon, Oregon DEQ File No. 04-91-0250: consultant Report dated October 12, 1993.

Delta Environmental Consultants, Inc., 1993, Quarterly Monitoring Report, Fourth Calendar Quarter 1993, Chevron Facility No. 9-5872, 490 West Marine Drive, Astoria, Oregon: consultant Report dated December 30, 1993.

Ecology and Environment, Inc., 1987, Preliminary Assessment Report, McCall Oil Marine Terminal, Astoria, Oregon: consultant report dated September 1987.

EMCON Northwest, Inc., 1992, Underground Storage Tank Closure Assessment, Chevron U.S.A. Products Company, Facility 60095872, 490 West Marine Drive Astoria, Oregon: consultant report dated April 27, 1992.

EnviroLogic Resources, Inc., 2002a, RI/FS and IRAM Development Proposal, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated January 21, 2002.

EnviroLogic Resources, Inc., 2002b, RI/FS and IRAM Development Work Plan, Phase 1, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated July 15, 2002.

EnviroLogic Resources, Inc., 2003a, Technical Memorandum, Phase 1 Source/Soil Characterization, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated January 30, 2003.

EnviroLogic Resources, Inc., 2003b, Technical Memorandum, Beneficial Land and Water Use Surveys, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated February 21, 2003.

EnviroLogic Resources, Inc., 2003c, Storm Water Monitoring Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated March 26, 2003.

EnviroLogic Resources, Inc., 2003d, Technical Memorandum, Sediment Sampling, Remedial Investigation/Feasibility Study/Interim Removal Action Measures. Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated November 6, 2003.

EnviroLogic Resources, Inc., 2003e, Phase 1 Ground-Water Assessment, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated July 2, 2003.

EnviroLogic Resources, Inc., 2003f, RI/FS Work Plan Addendum, Phase 2 Soil Characterization, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated July 28, 2003.

EnviroLogic Resources, Inc., 2003g, Technical Memorandum, Remedial Investigation/Interim Removal Action Measures, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated August 5, 2003 (relating to sediments).

EnviroLogic Resources, Inc., 2003h, Technical Memorandum, Geophysical Investigation, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated November 25, 2003.

EnviroLogic Resources, Inc., 2003i, Vapor Inhalation Pathway Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated December 12, 2003.

EnviroLogic Resources, Inc., 2004a, Technical Memorandum, Storm Water Sampling – Third Quarter 2003, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated January 28, 2004.

EnviroLogic Resources, Inc., 2004b, Technical Memorandum, Quarterly Ground-Water Monitoring, Fourth Quarter 2003 – 1st Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated March 15, 2004.

EnviroLogic Resources, Inc., 2004c, Technical Memorandum, Storm Water Sampling – Fourth Quarter 2003, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated March 17, 2004.

EnviroLogic Resources, Inc., 2004d, Technical Memorandum, Quarterly Ground-Water Monitoring, First Quarter 2004 – 2nd Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Site, Astoria, Oregon, dated April 23, 2004.

EnviroLogic Resources, Inc., 2004e, Technical Memorandum, Phase 1, Monitoring Well Installation, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated April 30, 2004.

EnviroLogic Resources, Inc., 2004f, Technical Memorandum, Storm Water Sampling – First Quarter 2004, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated May 20, 2004.

EnviroLogic Resources, Inc., 2004g, RI/FS Work Plan Addendum, Slip 2 Hydrocarbon Seep Interim Action Removal Measures Work Plan, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated August 5, 2004.

EnviroLogic Resources, Inc., 2004h, Technical Memorandum, Quarterly Ground-Water Monitoring, Second Quarter 2004 – 3rd Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Site, Astoria, Oregon, dated August 12, 2004.

EnviroLogic Resources, Inc., 2004i, Technical Memorandum, Phase 2, Soil Characterization, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated November 1, 2004.

EnviroLogic Resources, Inc., 2004j, Technical Memorandum, Quarterly Ground-Water Monitoring, Third Quarter 2004 – 4th Round, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated November 23, 2004.

EnviroLogic Resources, Inc., 2004k, Technical Memorandum, Storm Water Sampling – Fourth Quarter 2004, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated December 20, 2004.

EnviroLogic Resources, Inc., 2004l, IRAM Work Plan, Port of Astoria Property Redevelopment, Former Mobil/Niemi Oil Bulk Plant, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated December 23, 2004.

EnviroLogic Resources, Inc., 2005a, IRAM Work Plan Addendum, Port of Astoria Property Redevelopment, Former Mobil/Niemi Oil Bulk Plant, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated February 9, 2005.

EnviroLogic Resources, Inc., 2005b, Progress Report – February 2005, Remedial Investigation/Feasibility Study/Interim Removal Action Measures, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated March 15, 2005.

EnviroLogic Resources, Inc., 2005c, Progress Report, Remedial Investigation/Feasibility Study/Interim Removal Action Measures, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated April 14, 2005.

EnviroLogic Resources, Inc., 2005d, Technical Memorandum, Vapor Intrusion Pathway Assessment, Port of Astoria Office Building, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated April 29, 2005.

EnviroLogic Resources, Inc., 2005e, Work Plan for Sub-Slab Site-Specific Assessment of Subsurface Vapor, Intrusion to Indoor Air, Port of Astoria Office Building, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated June 9, 2005.

EnviroLogic Resources, Inc., and GeoSyntec Consultants, 2005f. Vapor Intrusion Pathway Assessment, Port of Astoria Office Building, Astoria Area-Wide Petroleum Site, Astoria, Oregon: technical memorandum dated June 13, 2005.

EnviroLogic Resources, Inc., 2005g, Technical Memorandum, Slip 2 Hydrocarbon Seep Interim Removal Action Measures, Upland Data Collection. Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated June 14, 2005.

EnviroLogic Resources, Inc., 2005h, Work Plan for Additional Upland Data Collection, Slip 2 Hydrocarbon Seep Interim Removal Action Measures, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated June 30, 2005.

EnviroLogic Resources, Inc., 2005i, Technical Memorandum, Slip 2 Hydrocarbon Seep Interim Removal Action Measures, Upland Data Collection. Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated August 19, 2005.

EnviroLogic Resources, Inc., 2005j, Progress Report, Remedial Investigation/Feasibility Study/Interim Removal Action Measures, Astoria Area-Wide Petroleum site, Astoria, Oregon, dated December 14, 2005.

Environmental Data Resources, Inc., 2002, EDR NEPA Check, Port of Astoria: Report dated January 14, 2002.

Environmental Data Resources, Inc., 2002, EDR Sanborn Map Report, Port of Astoria: Report dated January 14, 2002.

Environmental Data Resources, Inc., 2002, The EDR Radius Map with GeoCheck, Port of Astoria: Report dated January 14, 2002.

Environmental Data Resources, Inc., 2002, The EDR-Historical Topographic Map Report, Port of Astoria: Report dated January 15, 2002.

EPA. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures. EPA/600/R-02/013. U.S. Environmental Protection Agency. Narragansett, Rhode Island, Duluth, Minnesota, and Newport, Oregon, November 2003.

Ferris, J.G., 1963, Cyclic Water-Level Fluctuations as a Basis for Determining Aquifer Transmissibility, in R. Bentall (compiler), Method of Determining Permeability, Transmissibility, and Drawdown, U.S. Geological Survey Water-Supply Paper 1536-I, Washington, D.C., pp 3305-318.

First Strike Environmental, 1997, Initial Sampling Results and UST Decommissioning Plan: consultant report dated September 4, 1997.

First Strike Environmental, 1997, Site Contamination Investigation: consultant report dated December 16, 1997.

First Strike Environmental, 1997, UST Decommissioning Project at US WEST Astoria Garage Site, 481 Industry Street, Astoria, Clatsop County, Oregon 97103: FSE Project #: 97-04-26, DEQ Facility ID#: 6293 ~ DEQ Case#: 046D-97-87~LUST#: 04-97-0735: consultant report dated December 10, 1997.

Frank, F.J., 1970, Ground-water resources of the Clatsop Plains sand-dune area, Clatsop County, Oregon: US Geological Survey, Water Supply Paper 1899-A, 41 p.

Freeze, R.A., and Cherry, J.A., 1979: Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall.

GeoSyntec Consultants, 2007, DRAFT Sub-Slab Soil Gas Intrusion Assessment, Port of Astoria Office Building, Astoria Area-Wide Petroleum Site, Astoria, Oregon DEQ ECSI File #2277: consultant report, July 2007

Hahn & Associates, 1994, Storm Sewer Line Investigation: McCall Oil and Chemical Corporation, Port of Astoria Facility, Astoria, Oregon; Work Plan for Site Assessment Report: consultant letter dated July 28, 1994.

Hahn and Associates, Inc., 1993, Subsurface Investigation, McCall Oil and Chemical Corporation, Port of Astoria Facility, Astoria, Oregon: consultant report dated October 21, 1993.

Hahn and Associates, Inc., 1996, Data Package For Site Investigation Activities, June 1994 Through April 1996, Port of Astoria Fuel Facility, Foot of Hamburg Road, Astoria, Oregon: consultant report dated July 26, 1996.

Hahn and Associates, Inc., 1997, Groundwater Treatment System Operation Summary, Port of Astoria Fuel Facility, Foot of Hamburg Road, Astoria, Oregon: consultant report dated February 26, 1997.

Hart Crowser, 2003, Historical Shell/Niemi/Mobil Petroleum Pipelines Investigation and Decommissioning Work Plan, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated December 18, 2003.

Hart Crowser, 2004a, Historical Shell/Niemi/Mobil Petroleum Pipeline Investigation and Decommissioning Report. Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated July 30, 2004.

Hart Crowser, 2004b, RI/FS Technical Memorandum, Level 1 Ecological Risk Assessment, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, dated August 12, 2004.

Hydrodynamic Process and Ecosystems Group, Civil and Environmental Engineering Department, Portland State University, undated. http/web.cecs.pdx.edu/~jaylab/group/orton/salt_intrusion.html

JCR Consultants, Inc., 1986a, Closure Plan, Astoria Oil Services, Inc., Astoria, Oregon: consultant report Dated April 21, 1986.

JCR Consultants, Inc., 1986b, Closure Plan, Field and Laboratory Test Results, Astoria Oil Services, Inc., Astoria, Oregon: consultant report Dated July 31, 1986.

JCR Consultants, Inc., 1986c, Final Closure, Waste Management Area, Astoria Oil Services, Inc., Astoria, Oregon: consultant report Dated November, 1986.

Kennedy/Jenks Consultants, 2005, RI/FS Work Plan, Ecological Risk Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated September 22, 2005.

Kennedy/Jenks Consultants, 2006 Personal communication between Taku Fuji and Mark Siipola, Portland District U.S. Army Corps of Engineers), May4, 1006.

Kennedy/Jenks Consultants, 2006a, Preliminary Results for Sediment, Water Column Sampling, and Bioassay Results. Ecological Risk Assessment. Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated May 15, 2006.

Kennedy/Jenks Consultants, 2006b, Level III Ecological Risk Assessment Report, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated October 16, 2006.

LCFRB. 2004. Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan. Volume II – Subbasin Plan, Chapter A – Lower Columbia Mainstem and Estuary. Lower Columbia Fish Recovery Board. December 2004.

http://www.nwcouncil.org/fw/subbasinplanning/lowerColumbia/plan/Vol%20ll%20A--Col%20Estuary%20mainstem.pdf

Maul, Foster & Alongi, 2005, RI/FS Work Plan Addendum, Human Health Risk Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated October 10, 2005.

Maul, Foster & Alongi, 200,. Letter (re: Response to DEQ Comments Regarding Human Health Risk Assessment Work Plan for the Astoria Area-Wide Petroleum Site) to T. Calabrese, EnviroLogic Resources, Inc., Portland, Oregon: consultant letter dated February 14, 2006.

Millham, N.P. and B.L. Howes, 1995, A Comparison of Methods to Determine K In a Shallow Coastal Aquifer: Ground Water, vol. 33, no. 1, pp. 49-57.

Montgomery, J. H. 1991. Groundwater Chemicals Field Guide. Chelsea, MI.: Lewis Publishers, Inc.

Neil Shaw Consulting Geologist, Inc., 1996, Underground storage tanks decommissioning at Val's Shell, formerly Portway Texaco, 452 West Marine Drive, Astoria, Oregon, DEQ Facility 6312: consultant report prepared for Delphia Oil, Inc., dated October 2, 1996.

Neil Shaw Consulting Geologist, Inc., 1993a, Investigation and Cleanup of Underground Storage Tank Related Diesel Release to Soil Near Port Office, 1 Portway, Astoria, Oregon, DEQ File No. 04-93-062: consultant report dated July 9, 1993.

Neil Shaw Consulting Geologist, Inc., 1993b, Investigation and Cleanup of Underground Storage Tank Related Diesel Release to Soil and Groundwater Located Near Eastern Boundary of Port of Astoria Property, 1 Portway, Astoria, Oregon, DEQ File No. 04-93-062: consultant report dated July 11, 1993.

Niem, A.R., and Niem, W.A., 1985, Oil and Gas Investigation of the Astoria Basin, Clatsop and northernmost Tillamook Counties, Northwest Oregon: State of Oregon Department of Geology and Mineral Industries, Oil and Gas Investigation OGI-14, maps and text.

Niem, A.R., and Van Atta, R.O., 1973, Cenozoic stratigraphy of northwestern Oregon and adjacent southwestern Washington, in Beaulieu, J.D., 1973, Geologic field trips in northern Oregon and southern Washington: Oregon Department of Geology and Mineral Industries, Bulletin 77, p. 75 - 92.

NOAA, Tide Tables for Tongue Point, November and December 2004.http://tidesandcurrents.noaa.gov/get_predictions.shtml?year=2004&stn=1038+Astoria

Northwestern Aquatic Sciences Division, 1988, Toxicity of Dredge Site Sediments for Port of Astoria: consultant report dated August 11, 1988.

Olsen, R.L., and Davis, Andy, 1990, Predicting the fate and transport of organic compounds in ground water, pt. 1 of Hazardous Materials Control, V. 3.

Olympus Environmental, Inc., 1992, On-Site Soil Aeration Report, Decommissioned Chevron Station No. 60095872, 490 West Marine Drive, Astoria, DEQ File No. 04-91-0250: consultant letter report dated November 13, 1992.

Oregon Department of Environmental Quality, 1991a, Order Requiring Removal Actions and Access, Harris Oil and Flying Dutchman: Order dated April 2, 1991.

Oregon Department of Environmental Quality, 1991b, Second Order Requiring Removal Actions and Access, Harris Oil and Flying Dutchman: Order dated 1991.

Oregon Department of Environmental Quality, 1992b, Groundwater Monitoring Well Drilling, Construction, and Decommissioning: Oregon Department of Environmental Quality, Portland, OR, August 24.

Oregon Department of Environmental Quality, 1997a, Waste management and cleanup environmental cleanup statues and rules: Oregon Department of Environmental Quality, June 1997.

Oregon Department of Environmental Quality, 1998a, UST cleanup manual, cleanup rules for leaking petroleum UST systems: Oregon Department of Environmental Quality, October 1998.

Oregon Department of Environmental Quality, 1998b, Guidance for conduct of deterministic human health risk assessments: Oregon Department of Environmental Quality.

Oregon Department of Environmental Quality, 1998-2001, Guidance for ecological risk assessment: Levels I, II, III, IV: Oregon Department of Environmental Quality, April 1998-March 2001.

Oregon Department of Environmental Quality, 1999a, Risk-based decision making [RBDM] for the remediation of petroleum-contaminated sites: Oregon Department of Environmental Quality, September 1999.

Oregon Department of Environmental Quality, 2002, McCall Oil and Chemical Company, National Pollutant Discharge Elimination System Waste Discharge Permit 1550A: File #108588.

Oregon Department of Environmental Quality, 2003, Risk-based decision making [RBDM] for the remediation of petroleum-contaminated sites: Oregon Department of Environmental Quality, September 2003.

Oregon Department of Environmental Quality, 2004, Memorandum to Tom Calabrese re: Remedial Investigation/Feasibility Study/Interim Removal Action Measures, Level 1 Ecological Risk Assessment, Astoria Area-Wide Petroleum Site, Astoria, Oregon, ECSI Number 2277, Order ECSR-NWR-01-11. Oregon Department of Environmental Quality. August 20, 2004.

Oregon Department of Environmental Quality, 2005b, Comments on RI/FS Work Plan Addendum, Human Health Risk Assessment Work Plan, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, DEQ ECSI File #2277. Oregon Department of Environmental Quality. December 8, 2005.

Oregon Department of Environmental Quality, 2006, Letter to Tom Calabrese re: Bioassay Reference Sample Selection, Ecological Risk Assessment, Astoria Area-Wide Petroleum Site, Astoria, Oregon, DEQ ECSI File # 2277. Oregon Department of Environmental Quality. April 6, 2006.

Oregon Department of Environmental Quality, 2006b, Response to Comments on RI/FS Work Plan Addendum, Human Health Risk Assessment Work Plan, and Sub-Slab Sampling Results, Port of Astoria Office Building, Remedial Investigation/Feasibility Study, Astoria Area-Wide Petroleum Site, Astoria, Oregon, DEQ ECSI File #2277, letter dated May 9, 2006.

Oregon State Fire Marshal, Hazardous Material Emergency Incident Report, June 5, 1997.

Oregon Water Resources Department, 1995, Administrative rules for construction, maintenance and abandonment of monitoring wells and other holes in Oregon. Oregon Administrative Rules: Chapter 690, Division 240, July.

Orr, E.L., and Orr, W.N., 1999, Geology of Oregon [Fifth Edition]: Debuque, Iowa, Kendall/Hunt Publishing Company, p. 167-202.

Pacific Environmental Group, Inc., 1993, Environmental Site Assessment Chevron Station 9-5872, 490 West Marine Drive, Astoria, Oregon, DEQ File #04-91-250: consultant report dated June 29, 1993.

Pacific Environmental Group, Inc., 1994, Well Abandonment Report, Chevron Station #9-5872: consultant report dated April 26, 1994.

Pacific Environmental Group, Inc., 1996, Site Assessment Report, Former Astoria Bulk Facility, 585 Hamburg Road, Astoria, Oregon, ECSI File 73: consultant report dated December 5, 1996.

Pacific Northern Environmental, 1993a, Soil Treatment Project: letter report dated October 20, 1993.

Pacific Northern Environmental, 1993b, Vandermay/Harris, Volume II, Waste Oil UST Decommissioning Report, 460 West Marine Drive, Astoria, Oregon: consultant report dated November 1993.

Pacific Northern Environmental, 1993c, Soil Treatment Project: consultant letter report dated December 15, 1993.

Pacific Northern Environmental, 1994a, Proposed Underground Storage Tank Site Assessment & Disposal in Place Plan: consultant report prepared for Delphia Oil Inc. dated March 1994.

Pacific Northern Environmental, 1994b, Delphia Oil – Portway Texaco Underground storage tank closure in-place plan addendum: Letter to Mr. Richard Rose, Oregon Department of Environmental Quality from Pacific Northern Environmental, April 5, 1994.

Pacific Northern Environmental, 1994c, Quarterly Groundwater Monitoring and Soil Matrix Cleanup Report (April - June 1994): consultant report dated October 11, 1994.

Pacific Northern Environmental, 1994d, Quarterly Groundwater Monitoring Report, 460 West Marine Drive, Astoria, Oregon, DEQ File No. 04-90-392: consultant report dated March 1994.

Pacific Northern Environmental, 1995, Letter to DEQ, Proposed Future Actions at Van West Oil: letter to DEQ dated January 9, 1995.

Pacific Northern Environmental, 1996, DEQ File No. 04-90-392, 460 West Marine Drive, Astoria, Oregon: consultant letter to DEQ dated September 17, 1996.

Petroleum Services Unlimited, Inc., 1990, Pressure Line Tests at Astoria West Shell Station.

PNG Environmental, Inc., 1996, Work Plan for Initial Site Characterization, Niemi Oil Company Cardlock, 455 Industrial, Astoria, Oregon, File No. 04-90-496: consultant letter report dated October 24, 1996.

PNG Environmental, Inc., 1997, Report of Subsurface Investigation, Niemi Oil Cardlock, Astoria, Oregon, DEQ LUST NO. 04-90-496: consultant report dated April 17, 1997.

PNG Environmental, Inc., 1998, Focused Environmental Site Assessment, Niemi Oil Card Lock Facility, 455 Industry Street, Astoria, Oregon: consultant report dated September 25, 1998.

PNG Environmental, Inc., 2002, Interim Remedial Action Measure Work Plan, Former McCall Oil Bulk Facility, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated July 26, 2002.

Priest, G.R., 2002, Coastal Program Director, Oregon Department of Geology and Mineral Industries, verbal communication.

Rankin, D.K., 1983, Holocene geologic history of the Clatsop Plains Foredune Ridge Complex: Portland State University, master's thesis.

Reckendorf, F., Peterson, C., and Percy, D., 2001, The dune ridges of Clatsop County; Interactive Dune Map: Oregon DOGAMI Open-File report 2001-07, http://nwdata.geol.pdx.edu/coastal-studies/dunes/default.html.

Reiter, R, 1998, Areawide Petroleum Issues – Astoria: Memorandum to Mike Rosen, Voluntary Cleanup/Site Assessment, dated February 12.

Rittenhouse-Zeman & Associates, Inc., 1990a, Final Report on Subsurface Investigation, Chevron Service Station #9-5872, 490 W. Marine Drive: consultant report dated June 1990.

Rittenhouse-Zeman & Associates, Inc., 1990b, 20-Day Release Report, 460 West Marine Drive, Astoria Oregon: consultant report dated December 28, 1990.

Rittenhouse-Zeman & Associates, Inc., 1991a, 45-Day Release Report, 460 West Marine Drive, Astoria, Oregon: consultant report dated March 1991.

Rittenhouse-Zeman & Associates, Inc., 1991b, Second Quarter, 1991 Monitoring of Groundwater, 705 West Marine Drive, Astoria, Oregon: letter report dated July 2, 1991.

RSV Engineering, 2003a, Hydrocarbon Seep Interim Remedial Action Measure Work Plan, Astoria Area-Wide Site, Astoria, Oregon: consultant report dated September 11, 2003.

RSV Engineering, 2003b, Hydrocarbon Seep IRAM Specifications, Astoria Area-Wide Petroleum Site, Astoria, Oregon: consultant report dated December 22, 2003

RSV Engineering, 2004, IRAM As-Built Drawings, Hydrocarbon Seep IRAM at Slip 2. October 28, 2004.

Schlicker, H.G., Deacon, R.J., and Beaulieu, J.D., 1972, Environmental geology of the coastal region of Tillamook and Clatsop Counties, Oregon: Oregon Department of Geology and Mineral Industries, Bulletin 74, scale 1:62,500.

Schwille, Frederich, 1988, Dense chlorinated solvents in porous and fractured media: Chelsea, Michigan, Lewis Publishers.

SEACOR, 1992a, Corrective Action Plan Report, Flying Dutchman Enterprises, Inc., Former Service Station. 460 West Marine Drive, Astoria, Oregon: consultant report dated October 8, 1992.

SEACOR, 1992b, Subsurface Investigation Report, Flying Dutchman Enterprises, Inc., Former Service Station, 460 West Marine Drive, Astoria, Oregon: consultant report dated June 17, 1992.

SEACOR, 1994, Groundwater Monitoring Report, First Quarter 1994, Former Chevron Facility No. 9-5872, 490 West Marine Drive, Astoria, Oregon: consultant report dated March 9, 1994.

Shell Global Solutions, 2004, Forensic Analysis of Samples of Separate-Phase Hydrocarbon from the Astoria Area-Wide Petroleum Site, Astoria, Oregon (2003 and 2004 Samples): letter report dated June 17, 2004.

SRH Group, 1991, Supplement to RZA 45-Day Release Report, Harris Oil Site, 460 West Marine Drive, Astoria, Oregon: consultant letter report dated April 19, 1991.

Sweet, R., 1977, Carrying Capacity of the Clatsop Plains Sand Dune Aquifer: prepared for Clatsop County Planning and Development, 36 p.

Sweet-Edwards/EMCON Northwest, Inc., 1991, Subsurface Environmental Site Assessment, Chevron U.S.A., Inc., Facility 60095872, 490 W. Marine Drive, Astoria, Oregon: consultant report dated April 27, 1992.

Terra Dolce Consultants, Inc., 2005, Preliminary Geotechnical Evaluation West Bay Marketing Inc., Proposed New Building Pier 2. Port of Astoria, Astoria, Oregon: consultant report dated February 18, 2005.

Tolan, T.L., 1982, The stratigraphic relationships of the Columbia River Basalt Group in the Lower Columbia River Gorge of Oregon and Washington: Portland State University, master's thesis.

US EPA, 1980, Interim guidelines and specifications for preparing quality assurance project plans. U.S. Environmental Protection Agency, Office of Research and Development, Office of Monitoring Systems and Quality Assurance, QAMS-005/80.

US EPA, 1986a, Test methods for evaluating solid waste, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, SW-846, September (update 1, July 1992; update 2a, August 1993; update 2, September 1994; update 2b, January 1995).

US EPA, 1986b, RCRA groundwater monitoring technical enforcement guidance document (TEGD): U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Waste Programs Enforcement.

US EPA, 1987, Data quality objectives for remedial response activities, development process: U.S. Environmental Protection Agency.

US EPA, 1988, Guidance for conducting remedial investigations and feasibility studies under CERCLA, interim final: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington DC, EPA/540/G-89/004, October.

US EPA, 1989a, Risk assessment guidance for Superfund, Volume 1: human health evaluation manual (Part A), interim final: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington DC, EPA/540/1-89/002, July.

US EPA, 1989b, Exposure factors handbook: U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington DC, EPA 600/8-89/043, July.

US EPA, 1991a, Human health evaluation manual, supplemental guidance: standard default exposure factors: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington DC, OSWER Directive 9285.6-03, March.

US EPA, 1991b, Supplemental risk assessment guidance for Superfund: U.S. Environmental Protection Agency, Region 10, Seattle, WA, August.

US EPA, 1991c, Risk assessment guidance for Superfund, Volume 1: human health evaluation manual (Part B), development of risk-based preliminary goals: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington DC, OSWER Directive 9285.7-01B, December.

US EPA, 1992a, Guide to management of investigation-derived waste, Office of Solid Waste and Emergency Response: Superfund Docket FTS 260-3046, January.

US EPA, 1992b, Framework for ecological risk assessment: U.S. Environmental Protection Agency, Risk Assessment Forum, Washington DC., EPA/630/R-92/001, February.

US EPA, 1994, USEPA contract laboratory program national functional guidelines for organics data review, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response: EPA 540/R-94/012, February.

US EPA, 1995, Draft ecological risk guidelines: U.S. Environmental Protection Agency, EPA/630/R-95/002, October 13.

US EPA, 1996, Drinking Water Regulations and Health Advisories, United States Environmental Protection Agency, Office of Water: EPA 822-B-96-002, October.

US EPA, 1997, EPA Region 10, Supplemental ecological risk assessment guidance for Superfund sites: U. S. Environmental Protection Agency, EPA 910-R-97-005.

US EPA, 1999, Letter (re: Region 9 Preliminary Remediation Goals (PRGs) 1999) to PRG table mailing list from Stanford J. Smucker, USEPA Region IX: U.S. Environmental Protection Agency. October 1.

US EPA, 2000a, Drinking water standards and health advisories: U.S. Environmental Protection Agency, Office of Water, EPA 822-18-00-001, Summer 2000.

US EPA, 2000b, Memorandum regarding Region 9 preliminary remediation goals (PRGs) to PRG table mailing list from S. Smucker: U.S. Environmental Protection Agency, November 2000.

US Geological Survey, 2002, Mean daily streamflows: http://water.usgs.gov/waterwatch/

Verschueren, K., 2001, Handbook of Environmental Data on Organic Chemicals: Fourth Edition, John Wiley & Sons, Inc., Hoboken, New Jersey.

Villaume, J.F., Lowe, P.C., and Unites, D.F., 1983, Recovery of coal gasification wastes, An Innovative Approach: Proceedings of The Third National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Water Well Association, Worthington, Ohio.

Villaume, J.F., 1985, Investigations at sites contaminated with dense, non-aqueous phase liquids (NAPLs): Ground-Water Monitoring Review, v. 5, no. 2.

Weather Underground, 2002, http://www.wunderground.com/US/OR/Astoria.html

Wells, R.E., Niem, A.R., MacLeod, N.S., Snavely, P.D. Jr., and Niem, W.A., 1983, Preliminary geologic map of the west half of the Vancouver 1□x 2□ Quadrangle, Oregon: US Geological Survey, Open-file Report 83-591.