

5. NATURE AND EXTENT OF COPCS IN MILL SOILS, RESIDENTIAL SOILS, AND FRESHWATER SEDIMENTS

This section presents the results of the RI field investigations and evaluates these data to determine the nature and extent of COPCs in the Uplands Environment of the Site. This section is divided into three parts: Mill Property Soils, Offsite Residential Soils, and Freshwater Sediments. The nature and extent of chemicals in groundwater is presented in Section 6. During the Work Plan development, the SMT identified specific data gaps and RI objectives. For each media, these specific objectives and data gaps are discussed below. The data collected during the RI and, when appropriate, data collected during the EPA ESI (E&E 1998) are presented, compared to appropriate criteria, and discussed.

5.1 Mill Property Soils

The primary objective of the soil investigation was to collect sufficient additional data to define the nature and extent of chemical concentrations in Site soil. The first section below discusses the general physical characteristics of the soils on the Site based on the soil borings performed during the RI. Subsequent sections discuss the chemical levels found in the soils at the various source areas previously identified on the Site (E&E 1998, Integral 2004).

Source areas were identified during the ESI based on the records review of the mill, knowledge of the mill operations, and an understanding of the hazardous substance waste streams. Eight source areas on this Site were defined:

- Bone yard (storage site for used equipment)
- Chlorine dioxide generator and pre-fab building
- Log yard
- Wood mill
- Hog-fuel pile
- Sump sediments
- Spent sulfite liquor lagoon
- Main process area.

The hog fuel pile and the sump sediments were addressed as part of interim actions, and are not discussed here. In addition, some ESI soil sample locations from the finishing room area, which is located in the main process area, were addressed as part of interim actions and are not discussed further. In addition to the soil samples collected in the remaining six areas (above), ecological samples were collected at various locations around the Site.

Within the main process area, spills and leaks resulting from the operation of equipment and activities around the following buildings were identified as potential sources:

- Finishing room and machine room

- Air pollution and control equipment
- Recovery boiler room
- Blowpits
- Transformer building
- Digester building
- Acid plant
- Bleach plant
- Laboratory area
- Screen room
- Automotive repair area (referred to as Buck's shop in some reports)
- Log yard transformer area
- Sawmill transformer area.

Additionally, emissions from various stacks located around the mill would have released PCDD/Fs, PAHs, and inorganic substances. The emissions sources are discussed as a specific source type in Sections 5.1.2.9 and 5.2.

5.1.1 Physical Properties of Site Soils

Data collected during the RI soils investigation included descriptions of the physical properties of materials encountered and chemical analyses of soil samples collected during the sampling effort. Soils encountered in the soil borings were described in accordance with ASTM Method D-1586 at each of the locations where soil samples were collected. Soil logs generated from these descriptions are presented in Appendix D. The logs describe the materials encountered from the Site surface to, or just below, the groundwater table surface of the shallow fill aquifer. In a few cases, the boreholes were terminated at shallower depths when perched groundwater was encountered.

The materials observed during the RI soils investigation are consistent with previous observations at the Site. Typically, sand and gravel materials were encountered, consisting primarily of beach and fill deposits. Because much of the shallow subsurface at the Site consists of fill materials and has been reworked by Site activities (such as grading), the distribution of materials varies across the Site.

In general, fill materials comprised a greater majority of the upper soil column in borings completed along the western margin of the property (e.g., in the log yard and wood mill areas) and central and northern portions of the main process area. These materials were frequently sands and gravelly-sands, although wood debris and crushed limestone were also encountered. Fill materials were also present across the surface in the southern regions of the main process area. Native beach sands, as evidenced by the presence of well-sorted, uniform materials, tended to be encountered more frequently in boreholes located closer to the coastal bluff (e.g., locations AP20, MS20, and SR22). Similarly, the thickness of fill materials tended to decrease in boreholes in the vicinity of Ennis Creek,

where apparent native sand and silt layers were encountered at relatively shallow depths (e.g., 5 ft bgs).

The three boreholes completed on the eastern end of the Site (SL20 – 22) showed similar patterns, with a 3.5- to 6.5-ft thick layer of gravelly-sand fill layer overlying beach sands. Materials logged during sample collection in the bone yard, located in the southeastern portion of the Site, tended to have a gravelly fill layer (~4 ft thick) overlying silty sand materials characteristic of the till layer that underlies the shallow fill Site aquifer.

Visual and olfactory observations of petroleum hydrocarbons were collected during the soil sampling. This information is provided in the borehole logs in Appendix D and summarized below.

Location	Depth (ft)	Description
LY21	2-5	strong petroleum odor, oily sheen on water, black streaks on sampler
LY22	4-4.5	asphalt or oil stained?*
LY23	4-5	oil smell, organics*
SR22	1-2	slight petroleum odor*
CS20	2-9	strong petroleum*/liquor odor
DB21	11.3	oily water in excavation, petroleum odor and sheen on water
RB21	8.5-9.5	petroleum odor, sheen on water and sampler

*See comments below

The Uplands RI Management Plans (Integral 2004) stated that field screening methods would be used to determine if additional analyses were required. The need for additional analyses for the presence of petroleum hydrocarbons was determined as follows:

- **Boring LY21:** Samples from this location were analyzed for petroleum hydrocarbons (see Section 5.1.2.6.4).
- **Boring LY22:** Field sampling staff determined the material present was asphalt and not indicative of a petroleum release. In addition, samples from deeper intervals did not show petroleum impacts and this location is distant from any known or suspected sources of petroleum hydrocarbons. Therefore, analyses for petroleum hydrocarbons were not requested.
- **Boring LY23:** Field sampling staff found the petroleum odors at LY23 to be minor and did not observe any staining of the soil. In addition, this location is distant from any known or suspected sources of petroleum hydrocarbons. Therefore, analyses for petroleum hydrocarbons were unwarranted.

- **Boring SR22:** A slight petroleum odor was noted in a gravel layer at the 1-2 foot interval by field staff, but was absent from deeper soils at this location. Furthermore, this location is distant from any known or suspected sources of petroleum hydrocarbons. Therefore, analyses for petroleum hydrocarbons were not requested.
- **Boring CS20:** Field sampling staff concluded that the material in CS20 was pulp liquor and not petroleum. Similar material and odors were noted in nearby boring PC20. Therefore, analyses for petroleum hydrocarbons were not requested.
- **Boring DB21:** This boring was located in an area containing treated wood pilings and beams. During trenching, treated wood was unavoidably disturbed and some pieces fell into the excavation. Field sampling staff believed that this introduced wood debris was the proximate source of the odor and sheen. Boring DB21 is removed from known or suspected sources of petroleum hydrocarbons. Since petroleum hydrocarbons were not suspected of being present in soil at this location prior to excavation, additional analyses were not requested.
- **Boring RB21:** As with boring DB21, boring RB21 was located in an area containing treated wood pilings. Field sampling staff believed that wood debris unavoidably introduced into the excavation was the proximate source of the odor and sheen. Since petroleum hydrocarbons were not suspected of being present in soil at this location prior to excavation, additional analyses were not requested.

5.1.2 Chemical Properties of Site Soils

The complete chemical data set for the RI soil samples is provided in a series of tables in Appendix E; the chemical data are presented by chemical class (e.g., PCDD/Fs, inorganic chemicals, SVOCs). Appendix F reports the data quality review for this data. Attachment 1 of Appendix F contains the tribal split data. Appendix G is attached on CD ROM and contains the laboratory data packages. Each of the chemical results is screened against available and applicable criteria in the Appendix E tables. These criteria are discussed in Section 5.1.2.1. RI data are discussed based on the source areas in the subsequent sections.

5.1.2.1 Criteria Used to Evaluate Chemicals in the Soils at the Site

Risk-based Criteria. In this report, chemical concentrations are compared to values calculated and provided by Ecology from a tool known as Cleanup Levels and Risk Calculations (CLARC), which are based on Equations 740-1, 740-2, 745-1, and 745-2, contained in Sections 740 and 745 of MTCA (WAC 173-340). These values are referred to as Method B and C values. For any given chemical, the Method B and Method C values are those chemical concentrations that would pose an acceptable risk level to people who may come into contact with soils. Method B is calculated based on exposures consistent with residential land use activities. Method C is calculated based on exposures consistent with activities and frequencies of an industrial worker scenario. In this report, Method B values for each chemical are referred to as unrestricted criterion, and Method C values for each chemical are referred to as industrial criterion.

Although the values used in this report are based on MTCA Method B and Method C formulas, they may not constitute the final soil cleanup level for a hazardous substance because they do not account for other requirements for establishing soil cleanup levels under MTCA, such as consideration of other exposure pathways or additive risk. Final cleanup levels will be determined as part of the feasibility study and cleanup action plan, which are the next steps in the RI/FS process.

When Method B (unrestricted use) and Method C (industrial use) criteria are not available, Method A levels are used to evaluate chemical concentrations. Method A levels differ from Methods B and C in that they may not be risk-based, but rather are based on a review of appropriate regulations and could include other considerations, such as aesthetics or the potential for the chemical to leach to groundwater. Method A levels are considered applicable to sites that have few hazardous substances.

CLARC does not provide concentrations for all chemicals evaluated. For these chemicals, values provided by EPA (2004) and referred to as Risk Based Screening Levels (RBSLs) are used. Like the CLARC criteria, the EPA RBSLs are calculated based on residential and industrial exposure scenarios. While EPA notes these are not intended to be cleanup levels, they represent a common range of values associated with acceptable risk.

MTCA provides two specific methods for evaluating the effects of mixtures of carcinogenic PAHs (cPAHs). In the first method, each of the seven cPAHs can be assumed to be as toxic as benzo(a)pyrene. Alternately, TEFs can be applied to evaluate cPAH mixtures. TEFs for cPAHs compare the relative carcinogenic potencies of the six other cPAHs with the potency of benzo(a)pyrene. The TEFs referenced in MTCA were used to calculate TEQs for cPAHs. The sum of the adjusted soil concentrations is called a benzo(a)pyrene toxicity equivalents concentration (cPAH TEQ). The RI report uses both methods for reporting cPAH results.

TEQ cPAHs must also consider how nondetected values for individual compounds within the cPAH groups are calculated. In this report, two commonly-used methods accounting for this situation are used. One is to assign a reporting limit value of zero to an individual cPAH compound. The other method is to assign a reporting limit value of one-half the analytical detection limit for the individual cPAH compound. Both methods have been used in the evaluations of sampling results. In most cases, the reporting limit method does not affect the evaluation of TEQ results against the screening criteria. Where the difference between the two reporting limit methods does affect the screening evaluation, it is noted in the text.

Background. Risk assessment methods incorporate findings from several scientific disciplines into simplified algebraic equations. Each of these variables has uncertainty associated with it. The uncertainty involved with each variable has been taken into account by assigning conservative values to the variables, and thus overestimating risk. As a result of this approach, it is often possible to have risk-based criteria that are below background concentrations of that chemical. To evaluate the chemical concentrations

found onsite, inorganic chemicals are compared to background concentrations found in the region as developed and published by Ecology (1994).

Globally Distributed Substances. Many SVOCs that are persistent in the environment, such as PCDD/Fs and PAHs, are found globally at low levels from both natural and anthropogenic sources. PCDD/Fs emitted into the atmosphere have been transported and deposited throughout the world and are found in air, soil, water, sediment, and biota (USEPA 2000).

Typical levels of PCDD/Fs have been evaluated relative to land uses (USEPA 2000; Ecology 1999). EPA (2000) estimated the typical mean rural soil background TCDD TEQ to be 2.8 parts per trillion (ppt) and the typical mean urban soil background concentration to be 9.4 ppt.⁶ Typical levels of PCDD/Fs stated below were reported as TCDD TEQ by Ecology (1999) in its assessment of metals and dioxins in fertilizers and soils in Washington State.

Data from Ecology's study have been used to provide an initial assessment of typical concentrations of PCDD/Fs that might be encountered in the Port Angeles area. Ecology's study sampled soils from 30 locations distributed across the state in areas under three land uses. PCDD/Fs were detected in all 30 soil samples. TCDD TEQs for the complete study data set ranged from 0.033 to 19 ppt⁷. The average TCDD TEQ was 2.8 ppt, the median value was 1.2 ppt, and the geometric mean was 0.98 ppt. The study also presented the data broken down by the types of land use of the areas sampled:

- **Urban** – Soil samples were collected from 14 randomly selected public sites, such as parks and other grass-covered landscapes, because these areas are generally not in industrial areas or close to point sources of PCDD/Fs. Selected urban areas included Seattle, Spokane, Tacoma, and the Tri-Cities. TCDD TEQs in urban area samples ranged from 0.13 ppt to 19 ppt⁷. The average TCDD TEQ was 4.1 ppt, the median value was 1.7 ppt, and the geometric mean was 1.9 ppt.
- **Open** – Soil samples were collected from eight open area locations defined as historically nonforested, nonagricultural, and located away from large urban areas. Four of the eight samples were collected from grazed land and four from nongrazed conservation areas and reserves. TCDD TEQs in open areas ranged from 0.040 ppt to 4.6 ppt. The average TCDD TEQ was 1.0 ppt, the median value was 0.27 ppt, and the geometric mean was 0.24 ppt.
- **Forested** – Soil samples were collected from eight forested areas defined by the presence of an extensive canopy of primarily mature trees. Four samples were collected from forests managed for timber production, and four samples were collected from forests located on state and federal lands not managed for timber production (i.e., parks, wilderness areas). TCDD TEQs in forested areas ranged from 0.033 ppt to 5.2 ppt. The average TCDD TEQ was 2.3 ppt, the median value was 2.2 ppt, and the geometric mean was 1.2 ppt.

⁶ Calculated assuming that non-detected values are equal to zero.

⁷ Ecology's study calculated TCDD TEQs assuming that non-detected values for individual congeners are equal to zero.

The study also provided TCDD TEQs calculated assuming that nondetected values for individual congeners are equal to one-half of the analytical detection limit. Using that assumption, the minimum and maximum TCDD TEQ values for the complete data set were 0.64 ppt and 22 ppt, respectively.

To supplement the statistics reported in Ecology's study, 90th percentile values were calculated for this RI as additional points of comparison to PCDD/F concentrations found onsite. When the nondetected values are assumed to equal zero, the 90th percentile value for the complete study data set is 5.24 ppt. When nondetected values are assumed to equal one-half the detection limit, the 90th percentile value is 6.39 ppt. These values may be compared to TCDD TEQs calculated for RI samples in Appendix E-2.

Ecology does not provide statewide or regional background concentrations for PAHs. Several authors have published background PAH levels (LaGoy and Quirk 1994). One of the most comprehensive assessments (Bradley et al. 1994) evaluated PAH concentrations in three urbanized areas in New England. The study collected 62 samples collected from areas of parks, open lots, roads, and sidewalks, but away from areas directly influenced by industrial sites. Carcinogenic PAHs were detected in 61 of the samples. The cPAH TEQ concentrations detected in the assessment ranged from a minimum of 0.257 parts per million (ppm) to 21.31 ppm. The average value was 2.437 ppm. These values are used as points of comparison for cPAH TEQ concentrations found onsite.

5.1.2.2 The Bone Yard (Used Equipment Storage)

The bone yard is an unpaved area, about 150 by 200 ft, located on the southeast portion of the Site (Figure 5-1). This area was used to store equipment that had been taken out of service but was still functional. Anecdotal evidence suggested that transformers, which may have contained PCBs, may have been stored in this area. Potential release of chemicals into the soils could have resulted from leakage and washing of various equipment stored onsite. However, field logs noting the types and condition of equipment storage are not available, and no documents exist to indicate any releases of hazardous substances from this equipment.

The Site soils are predominantly gravelly sand, from 0 - 4.5 ft and silty sand below 4.5 ft. Some metal shavings, wood debris, and portions of brick were observed in the 0 - to 4-ft layer.

ESI sampling at the bone yard evaluated five locations (E&E 1998). Four locations were sampled at 0- to 2-ft intervals and 2- to 4-ft intervals for a total of eight samples. At one additional location, samples were collected from 0 to 10 ft in 2-ft intervals for a total of five samples. Groundwater was detected at 10 ft bgs. All of these samples were analyzed for a suite of chemicals.

None of the chemicals analyzed in soil samples collected during the ESI exceeded industrial criteria. Arsenic and various PAHs were detected at concentrations above the unrestricted criteria. During the ESI, an arsenic concentration of 27.5 ppm was reported at location BY02 in the surface soil. This is above the 90th percentile Washington State background concentration (regional background) of 7.3 ppm (Ecology 1994).

Subsequent analyses for arsenic at Stations BY02 and BY20 during the RI yielded concentrations ranging from 0.7 to 6.10 ppm, below regional background.

The lower concentrations of arsenic found during the RI sampling could have resulted for several reasons. Among these are:

1. The samples collected during the RI were at different depth intervals. This could have resulted in the difference in concentrations. However, the upper 4 ft of the soil profile is consistent according to the boring logs (Appendix D).
2. The higher level of arsenic could have been a laboratory or field contaminant, or some other outlier in the process.
3. The higher level could have resulted from a small piece of solid waste in the original sample (e.g., ash, asphalt).
4. The sample locations may have been different, suggesting a highly localized elevation in arsenic concentration. The E&E (1998) report noted that accurately locating some stations was not possible due to interferences. Thus, the position of the sample for BY02 as given by the GPS coordinates in the 1998 report did not match the location noted on the report figures. Because the accuracies of the GPS instruments were noted as compromised in the 1998 report, the actual resample location at BY02 was selected in the field by consulting the E&E (1998) maps and aerial photos, as well as speaking with people that were present at the time the sampling was conducted.

No samples had repeatable levels of arsenic above regional background, consistent with Ecology guidance for screening chemical concentrations (Ecology 1994). Thus, based on the available data, the nature and extent of arsenic for this source area is considered to be consistent with background soil conditions within the Puget Sound region of Washington State.

Equipment storage activities are unlikely to be a primary source of PAHs in the environment. However, this area is downwind of the stack emissions and thus could have been impacted by PAHs from particulate deposition. The surface sample exceedences from PAHs are discussed in Section 5.1.2.9, which addresses stack emissions.

5.1.2.3 Chlorine Dioxide Generator and Prefab Building

The chlorine dioxide generator was located between Ennis Creek and the primary clarifier. It produced chlorine dioxide for use in the pulp bleaching processes. The area around the generator is paved except on the south, toward the pre-fab area. The pre-fab area is about 400 by 400 ft, contained several buildings, and was used as a storage area and parking lot.

ESI sampling (E&E 1998) was conducted at three locations in a triangular pattern around the chlorine dioxide generator. Two of these locations were sampled at 0- to 2-ft and 2- to 4-ft intervals bgs, and the third location at 2-ft intervals to 8 ft bgs, where groundwater was encountered (Figure 5-2). Samples were also collected at three locations in the prefab

area, from 0- to 2-ft intervals bgs and 2 to 4 ft bgs. An additional location in the prefab area was sampled in 2-ft intervals to 18 ft bgs, where groundwater was encountered.

Of the chemicals analyzed in soil samples collected during the ESI, only copper exceeded its industrial criterion and only at a single location (PF02; Figure 5-2). This sample may have contained metallic copper (e.g., from miscellaneous wires) that was inappropriately included in the sample, as there was no discoloration of the soil⁸. With the exception of arsenic, copper and chrysene, no chemicals were detected at levels exceeding unrestricted criteria. Arsenic levels were below regional background (Ecology 1994). Chrysene was detected in one sample at a level (0.16 ppm) that is slightly above the unrestricted criterion (0.14 ppm). This surface sample was collected below asphalt, and it is likely a result from drilling through asphalt and the presence of asphalt particles. It is unlikely that this PAH concentration is from past activities because no other sample contained significant concentrations of PAHs.

Additional RI sampling focused on physically inspecting the area in the vicinity of the elevated copper concentration (PF02) and resampling to verify or refute the presence of an elevated concentration. Inspection of the area showed no unusual discoloration. The resample result collected during the RI was 43.6 ppm, below the unrestricted criterion. Given this, the chlorine dioxide generator and pre-fab area are not considered to have elevated chemical concentrations.

5.1.2.4 Spent Sulfite Liquor Lagoon (East Side of Mill)

As part of the operation of the mill, SSL was produced during the pulping process and either recovered for reuse or recycled as a fuel to power the plant operations. As part of the recovery process, SSL was temporarily pumped to and stored in the SSL lagoon prior to burning in the recovery boiler. The SSL lagoon was constructed in 1974 with a permeable clay liner initially, and later with a 60-mil, HDPE floating cover. This area was not sampled during the ESI. Rayonier collected samples from the clay liner, the berm, and the residual material in the SSL lagoon in 1997, and reported the data in the Work Plan (Integral 2004). No chemicals were detected above industrial criteria, and only arsenic was found above its unrestricted criterion. However, arsenic levels were below regional background (7.3 ppm; Ecology 1994).

In 2001, the material in the SSL lagoon was removed to the Mt. Pleasant Landfill as part of the landfill closure activities. The clay liner and associated stained soils located above the groundwater table were excavated, and the excavation was backfilled and compacted with soil from the berm. Areas of discoloration were noted on the floor of the excavation before it was backfilled. Therefore, surface and subsurface samples were collected during the RI in the SSL lagoon at station SL22 (Figure 5-3). The soil samples were analyzed for metals, PAHs and PCDD/F congeners. The subsurface soil sample is considered to be representative of the soil not removed during the excavation.

⁸ Soil discoloration would be expected at this elevated concentration if copper was present as a copper compound.

To evaluate the possibility that the pipeline that transferred SSL to the lagoon may have leaked, two subsurface soil samples (SL21 and SL20) were collected from 3-inches bgs to groundwater and analyzed for metals and PAHs. The surface soil at these two locations was also analyzed for PCDD/F to characterize potential deposition from stack emissions.

In both the surface and subsurface samples from location SL22, and the subsurface samples from SL20 and SL21, arsenic was the only chemical that exceeded its unrestricted criterion (Figure 5-3). However, levels were below regional background (Ecology 1994).

The results of PCDD/Fs from locations SL20 and SL21 are discussed in the subsequent section evaluating aerial deposition sources and chemical concentrations on the east side of the Site.

5.1.2.5 Wood Mill

Samples were not collected during the ESI from the wood mill area (E&E 1998). Two locations (WM20 and WM21) were identified for sampling during the RI (Figure 5-4). Soil samples were collected from 0 to 3 inches bgs and 3 inches bgs to groundwater. Surface samples were analyzed for PAHs, metals, PCBs, petroleum hydrocarbons [gas-range organics (GRO), diesel-range organics (DRO), residual-range organics (RRO)] and PCDD/Fs. Subsurface samples were analyzed for the same chemicals, plus an additional suite of SVOCs.

Chemical concentrations in samples from WM21 did not exceed unrestricted criteria, except for arsenic at 3.5 ppm in the surface sample and 3.2 ppm in the subsurface sample. These values are below regional background (Ecology 1994).

Chemical concentrations in samples collected at WM20 exceeded criteria for several chemicals in both the surface and subsurface samples (Figure 5-4). Most of the chemicals and chemical groups that exceed criteria are indicative of petroleum. RRO (heavy oils) exceeded the industrial criterion (2,000 mg/kg) in both the surface (2,800 ppm) and subsurface (2,600 ppm) samples. Several PAHs that are often affiliated with RRO were also present at levels exceeding unrestricted criteria. Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded the unrestricted criterion (0.137 ppm), with concentrations ranging from 1.1 to 9.1 ppm. Similarly, the same seven PAHs exceeded the unrestricted use criterion in the subsurface sample, with concentrations ranging from 0.32 to 1.9 ppm.

The surface sample collected at WM20 also exceeded the unrestricted criterion for Aroclor 1260 (0.5 ppm), with a level of 2.40 ppm, but was well below its industrial criterion (Figure 5-5). The unrestricted criterion and the Ecology background level were also exceeded for arsenic in both surface and subsurface samples (33.4 ppm and 14.9 ppm, respectively), but levels were below the industrial criterion.

Six PCDD/F congeners exceeded the unrestricted criteria in the WM20 surface soil sample. A slightly different mixture of six congeners also exceeded the unrestricted

criteria in the subsurface sample (Figure 5-6). PCDD/Fs are not believed to be associated directly with the wood mill operations, and particulate air deposition did not substantially influence this area. These levels may have resulted from the fill or ash used for fill material.

5.1.2.6 Log Yard

The log yard, approximately 300 by 600 ft, was located at the southwest corner of the Site and included both paved and unpaved areas (Figure 5-7). During operations, the log yard was used to store logs prior to processing. Additionally, a section of the paved area near the concrete retaining wall was used to temporarily store boiler ash prior to transport and disposal offsite.

During the ESI, 29 discrete samples were collected from 16 locations. The soil borings in this area encountered large rock fill at shallow depths, which made soil boring and sampling difficult. Six locations were sampled from the 0- to 2-ft interval, six locations were sampled at 2-ft intervals from 0 to 4 ft, two locations were sampled at 2-ft intervals from 0 to 6 ft bgs, one location was sampled at 2-ft intervals from 0 to 8 ft bgs, and one location was sampled at 10 ft bgs only. All samples were analyzed for a suite of 150 chemicals. Arsenic, lead, and PCDD/Fs were detected at concentrations above the unrestricted criteria. No chemicals were detected above the industrial criteria.

During the RI, log yard soil samples were collected from seven locations at depth intervals, 0 to 3 inches bgs and 3 inches bgs to groundwater, and one location at 0 to 20 cm bgs. Samples were analyzed for a suite of chemicals to better characterize spatial extent.

Several PCDD/Fs congeners, PAHs, arsenic, lead, DRO, and RRO had concentrations above the unrestricted criteria. In addition, four PAHs, DRO, and RRO had concentrations above the industrial criteria.

5.1.2.6.1 Metals

Arsenic concentrations in samples collected during the ESI and RI (Figure 5-7) were below regional background (Ecology 1994) except for two samples collected during the ESI: one located at GB08 (9.2 ppm; 2-4 ft interval) and one located at LY21 (7.7 ppm; 0- to 30-inch interval). Boiler ash was handled in this area, and may contribute to some of the arsenic found in soil samples from the log yard. However, since the highest detected concentration of arsenic (9.2 ppm) falls within the range of natural background (1.45 - 17.2 ppm), arsenic at the log yard may be from naturally occurring sources.

Lead levels in surface soil samples collected from unpaved areas were generally low, suggesting that offsite point and nonpoint sources and stack emissions from the mill were not significant sources (Figure 5-8). Ecology (2001) does not provide unrestricted (Method B) or industrial (Method C) criteria for lead. Therefore, lead was compared to the MTCA Method A unrestricted (250 ppm) and industrial (1,000 ppm) criteria. Although most samples had lead concentrations within the range of natural background (2.12 -36.2 ppm; Ecology 1994), two samples had concentrations greater than the Method

A unrestricted criterion and a single sample exceeded the Method A industrial criterion. Lead was detected at 8,610 ppm at the 2- to 4-ft interval at location GB08, which was sampled during the ESI. Location GB08 was resampled during the RI, and lead was detected at 5.9 ppm at the 0- to 3-inch interval and 31.1 ppm at the 3-inch to groundwater interval.

Two possible reasons may contribute to the lower lead concentrations found during the RI sampling at location GB08. First, the samples were collected from different depth intervals during the RI. The RI subsurface sample was collected from the 3-inch to groundwater interval, which is more representative of potential exposure to workers who might come into contact with subsurface soil during excavation activities. A second reason for the lower lead levels found in the RI samples from GB08 is that the ESI sample may have included a piece of metal or ash containing lead, which would not be representative of soil in the area.

The second sample with a lead concentration above the unrestricted criterion, but below the industrial criterion, occurred at RI location LY21 (429 ppm at the 0- to 3-inch interval). Hog fuel boiler ash was handled in the area. Although no data characterizing the metals concentration of boiler ash from the Rayonier mill are available, Ecology (1999) conducted a study that included the analysis of Fort James NutriLime, which was characterized as fly ash from the Fort James hog fuel boiler. The concentration of lead in the NutriLime samples collected in 1997 and 1998 ranged from 89.3 to 171 ppm. Since the lead concentrations in hog fuel boiler fly ash are below the highest levels in soil samples from the log yard, it seems unlikely that the boiler ash is the source of the elevated lead concentrations. Lead has been used in a variety of products, including solder for pipes and cans, batteries, paint, leaded gasoline, ammunition in the form of shot and bullets, and electrical equipment (ATSDR 1999b). The high lead concentration found in the surface soil sample at location LY21 was likely associated with fragments of decommissioning debris.

5.1.2.6.2 PAHs

For ESI data, cPAH TEQ concentrations⁹ were below the unrestricted criterion when nondetected values were assumed to equal zero¹⁰ (Figure 5-9). Four RI samples collected at three locations (LY21: 0- to 3-inch and 3-inch to groundwater; LY24: 0- to 3-inch; LY25: 0- to 3-inch intervals) had cPAH TEQ concentrations above the unrestricted criterion. The cPAH TEQ for the sample collected from the 0- to 3-inch depth interval at LY21 also exceeded the industrial criterion. The sample collected at LY21 over the 3-inch to groundwater interval exceeded the industrial criterion for two individual cPAHs.

⁹ As specified in MTCRA regulations (WAC 173-340-708), carcinogenic PAH (cPAH) concentrations are expressed as a benzo(a)pyrene toxic equivalency quotient, which were calculated by 1) assuming nondetected values equal zero, and 2) assuming nondetected values equal one-half the detection limit (rl = 1/2).

¹⁰ Reporting limits for PAH analyses conducted during the ESI were high, which biased the cPAH TEQ calculation when using rl = 1/2. However, an examination of raw data (E&E 1998) shows that detected concentrations of cPAHs were well below the reporting limits. Therefore, it is reasonable to conclude that cPAH TEQ concentrations are not seriously underestimated using the rl = 0 assumption.

LY21 is located adjacent to a former fuel oil tank. RI field logs indicate that there was a petroleum odor associated with the soil at LY21 and that a sheen was present on the groundwater encountered at a depth of 5 ft bgs. DRO and RRO were also detected at elevated levels in the surface and subsurface soil samples at location LY21. Therefore, petroleum associated with the former fuel oil tank may be the source of cPAHs at location LY21.

The cPAH TEQ concentrations at locations LY24 and LY25 that were above the unrestricted criterion were limited to the surface soil sampled at the 0- to 3-inch interval. Both of these locations were covered by asphalt at the time of sampling. However, the historical nature of the soil cover over these sample locations is uncertain and may have included periods when the soil was exposed. Possible sources of the cPAHs in the surface soil at locations LY24 and LY25 include aerial deposition from offsite point and nonpoint sources, handling of boiler ash, and the overlying asphalt.

5.1.2.6.3 PCDD/Fs

1,2,3,4,6,7,8-HpCDD exceeded the unrestricted criterion at location ECO35. 1,2,3,6,7,8HxCDD; 1,2,3,7,8,9-HxCDD; 1,2,3,7,8-PeCDD; 2,3,4,7,8-PeCDF; and 2,3,7,8-TCDD exceeded unrestricted criteria in the subsurface soils at location LY21 (Figure 5-10). Most of the PCDD/F congeners exceeded unrestricted criteria in the surface soil samples of LY21. No individual congener exceeded industrial criteria.

Possible sources of the PCDD/Fs in these surface soil samples are boiler ash handling, deposition of mill stack emissions, and deposition from offsite point and nonpoint sources. PCDD/Fs levels in the surface and subsurface soil sample at LY21 were greater than the levels reported in the hog fuel boiler ash sample from the mill area, suggesting that hog fuel boiler ash may not be the source. A fuel oil tank was located adjacent to sample location LY21, and elevated levels of cPAHs and petroleum mixtures were detected there. However, the association between petroleum mixtures and PCDD/Fs is unclear.

5.1.2.6.4 Petroleum (DRO and RRO)

Petroleum mixtures were analyzed at a single location (LY21) because of its proximity to a historical fuel oil tank. Ecology (2001) does not provide unrestricted criteria (Method B) and industrial criteria (Method C) for petroleum mixtures, but it does provide Method A values that can be used for comparative purposes. DROs were detected in surface and subsurface soil samples at concentrations above the Method A industrial criterion of 2,000 ppm (Figure 5-11). RROs were detected in surface soil samples at concentrations above the Method A industrial criterion of 2,000 ppm. RI field logbooks indicate that there was a petroleum odor associated with the soil at LY21 and that a sheen was present on the groundwater encountered at a depth of 5 ft bgs. The source of the petroleum mixtures in soil samples is likely to be the former fuel oil tank located just west of location LY21.

5.1.2.7 Ecological Samples

The riparian corridor along Ennis Creek, the forested areas along the east and west coastal bluffs, and forested areas along the entrance to the Site contain habitat suitable for the species of the region. These four areas were the focus of the onsite ecological sampling. In addition, three locations within the industrialized area of the Site contained sufficient habitat and biota to be sampled during the RI. Ecological sampling was conducted during the RI with the objective of providing site-specific data on which to base the terrestrial ecological evaluation under MTCA (WAC 173-340-7490 through 7494). Samples were collected from 15 locations on the Site. Sampling was stratified over five areas, and co-located soil and biota (plants and earthworms) samples were collected from each area (Table 5-1).

Each soil and biota sample consisted of a five-point composite collected from a contiguous area ranging in size from approximately 50 to 450 square yards. All samples were analyzed for the presence of metals and PCDD/Fs, which were identified as chemicals of potential ecological concern. In addition, conventional soil parameters were analyzed at each soil sampling location. Metals and PCDD/Fs are known to be associated with pulp mill stack emissions and may have been deposited onto areas of higher habitat quality located along the coastal bluffs and Ennis Creek corridor. In addition, the three samples from the industrial area were analyzed for the presence of PCBs, which were also identified as chemicals of potential ecological concern that were associated with some industrial operations on the Site (e.g., hydraulic fluid in the finishing room). The analytical results for the ecological soil samples are presented in Appendix E. Results of plant and earthworm tissue sampling are shown in Appendix E and discussed in the ecological risk assessment report (in preparation).¹¹

Ecological soil samples from locations ECO33 and ECO34 consisted of sandy-textured fill material with no natural soil structure or horizons. The soil sample from ECO35 located on the west side of the industrial portion of the mill was more of a loamy soil and may have been natural material. The remaining ecological soil samples from the coastal bluffs and Ennis Creek corridor were of natural origin containing distinct soil horizons.

Of the eight metals analyzed, only arsenic was detected at a concentration above its unrestricted criterion. However, all of these locations were at or below regional background (Figure 5-12).

1,2,3,6,7,8-HpCDD exceeded its unrestricted criterion at ECO33, ECO34, and ECO35. Seven other PCDD/F congeners exceeded unrestricted criteria at ECO33 (Figure 5-13). OCDD exceeded its unrestricted criterion at ECO34. No PCDD/F concentrations were above the industrial criteria.

5.1.2.8 Main Process Area

The main process area was largely built on fill material. Groundwater occurs at between 1 to 6 ft bgs, with groundwater becoming shallower moving from south to north. The area

¹¹ MTCA does not provide ecological criteria for plant and earthworm tissue.

was covered by buildings or pavement during most of the operational life of the mill. A variety of the industrial processes performed at the mill were conducted in the main process area. An underground piping system conveyed mill effluents to five shoreline outfalls prior to installation of the primary treatment system in 1972 (Foster Wheeler 1997). Process liquids were also conveyed around the mill by a system of pipes.

Soil sampling of the main process area during the ESI (E&E 1998) focused on characterization of chemical concentrations in surface soil. RI soil sampling in the main process area had two objectives: 1) characterize the spatial extent of arsenic, lead, and PCDD/F concentrations in and around ESI locations that had high concentrations, and 2) characterize petroleum hydrocarbon concentrations, subsurface soil concentrations of metals, and SVOCs not addressed during the ESI (E&E 1998).

5.1.2.8.1 Surface Soil Overview

Surface soil samples (0- to 3-inch interval and 0- to 2- foot interval) were collected during the ESI from 49 locations within the main process area that were not paved or otherwise obstructed by foundations, and areas accessible under buildings. Seven sample locations in the finishing room (FR05 – FR11) were removed as part of an interim action conducted in 1998 (SECOR 1999). Ten locations in the hog fuel pile (HF01 – HF10) were removed during the excavation of wood residue performed by Rayonier in 2001. Chemical data from locations that were the subject of removals or interim actions are excluded from the characterization of the nature and extent of chemicals in the main process area presented in this section. Each sample was analyzed for a suite of 150 chemicals. Arsenic, lead, several PCDD/F congeners were detected above the unrestricted criteria. 1,2,3,4,6,7,8-HpCDD exceeded their industrial criteria at location FR02.

During the RI, surface soil samples were collected from 26 locations within the main process area. Concentrations of arsenic, lead, all PCDD/Fs were above the unrestricted criteria at various locations throughout the Site. None were detected above industrial criteria.

5.1.2.8.2 Subsurface Soil Overview

Subsurface soil was characterized at two locations during the ESI (E&E 1998): RB03 at the 8- to 10-ft interval and RB04 at the 4- to 6-ft and the 8- to 10-ft intervals. Each sample was analyzed for a suite of 150 chemicals. All detected concentrations were below the industrial criteria. Only arsenic was detected at a concentration above the unrestricted criterion of 0.67 ppm, but concentrations were below regional background.

During the RI, subsurface soil samples were collected from 24 locations. Metals, PCDD/Fs, pesticides, PCBs, PAHs, SVOCs, and petroleum hydrocarbons were analyzed in subsurface soils. The analytic suite varied, depending upon the type of source area being characterized. No chemicals were detected above the industrial criteria. Seventeen chemicals were detected above the unrestricted criteria.

Detected chemicals with concentrations above unrestricted criteria are discussed in the following sections.

5.1.2.8.3 Arsenic

All detected arsenic concentrations were above the unrestricted criterion, and five samples (7 percent) had concentrations above the industrial criterion (Figure 5-14). Ecology (1994) determined the natural soil background concentration of arsenic to be an average of 7.3 ppm, with a range of 1.45 to 17.2 ppm. Twelve samples (17 percent) had arsenic concentrations above the maximum background concentration of 17.2 ppm. The five samples with arsenic concentrations above the industrial criterion (AP02, AP03, AP04, DB02, and RB01) were all collected during the ESI (E&E 1998).

ESI sample location RB01 (0- to 3- inch interval) had an arsenic concentration of 250 ppm, above the industrial criterion of 87.5 ppm (Figure 5-14). Arsenic concentrations in and around RB01 were characterized further during the RI. Location RB01 was resampled during the RI, and the surface soil sample (0- to 3-inch interval) had an arsenic concentration of 4.7 ppm. The RI subsurface soil sample (3-inch to groundwater) from RB01 had an arsenic concentration of 6.3 ppm. RI samples were also collected from locations north (RB21) and south (RB20) of RB01 to characterize arsenic concentrations in the area. Arsenic concentrations in surface and subsurface soil samples from locations RB20 and RB21 ranged from 2.7 to 15.1 ppm. Concentrations of arsenic in surface and subsurface samples collected from the recovery boiler during the RI (sample locations RB01, RB20 and RB21) and ESI (sample locations RB02, RB03 and RB04) fall within the range of natural background (1.45 to 17.2 ppm) (Ecology 1994). Therefore, the arsenic levels in soils at the recovery boiler do not appear to be elevated above background. The cause of the elevated arsenic level in the ESI sample from location RB01 is not known.

Sample locations AP02, AP03, AP04, and DB02 are located at the acid plant and digester building. Sulfur dioxide, ammonia, and water were mixed in the acid plant to form fortified ammonium bisulfite cooking liquor, which was combined with wood chips and treated at high pressure and temperature in nine large vessels in the digester building. Cellulose fibers and water-soluble noncellulose wood residues were emptied into the blowpits under pressure and then transferred to red stock washers, where the digestion chemicals were washed from the pulp. Data characterizing metal concentrations in SSL at the Rayonier mill are limited to TCLP method analysis (Foster Wheeler 1997), which is not suitable for characterizing total metals concentrations. However, samples of the liner, subgrade, and sludge from the SSL lagoon (Landau 1998c) provide a conservative estimate of arsenic concentrations in the SSL itself. Results showed that the arsenic concentrations in samples from the SSL lagoon ranged from 3 to 5 ppm. Since the arsenic concentrations in soil samples at the acid plant and digester building range up to 260 ppm, it seems unlikely that SSL was the source.

5.1.2.8.4 Cadmium

Cadmium was not detected at a concentration above the industrial criterion of 3,500 ppm in any sample. However, one surface soil sample (ESI sample MR01) had a cadmium

concentration of 140 ppm, which was above the unrestricted criterion of 80 ppm. The next highest concentration was 7.5 mg/kg in ESI sample MR03. The range of cadmium detected in natural background soil samples is 0.1 to 5.0 ppm (Ecology 1994).

Cadmium is not known to be used in the pulping process (Rydholm 1965). Cadmium concentrations in soil samples from the machine room, with the exception of ESI sample MR03, were below the unrestricted criterion. Therefore, it does not appear that the machine room is a source of cadmium. The major uses of cadmium in the U.S. are as active electrode materials in nickel-cadmium batteries (70%), pigments used mainly in plastics, ceramics, and glasses (12%); stabilizers for polyvinyl chloride (PVC) against heat and light (17%); engineering coatings on steel and some nonferrous metals (8%); and components of various specialized alloys (2%) (ATSDR 1999a). Since cadmium concentrations across the main process area are consistent with natural background levels, the source of the elevated concentration in sample MR01 is likely the inclusion of a fragment of cadmium-containing material either contained in the fill material brought onto the mill property or associated with mill operations.

5.1.2.8.5 Chromium

While no chromium concentrations were above the industrial criterion of 10,500 ppm, two ESI surface soil samples (PC01 = 327 ppm, DB02 = 357 ppm) had concentrations above the unrestricted criterion of 240 ppm. These levels were also above the maximum natural background concentration of 235 ppm (Ecology 1994).

Chromium is not known to be directly associated with the pulp-making industry (Rydholm 1965). Chromium concentrations in all soil samples from the air pollution control equipment area and digester building, with the exception of ESI samples PC01 and DB02, were below the unrestricted criterion. Therefore, it does not appear that the air pollution control equipment area and digester building are sources of chromium. The current uses of chromium in the U.S. are wood preservation (52%), leather tanning (13%), metals finishing (13%), pigments (12%), refractory industry (3%), and other uses (7%) (ATSDR 2000b). Typically, chromium in stainless-steel and chromium alloys ranges from 11.5 to 30 percent by weight (ATSDR 2000b). It is possible that fill brought to the mill property included materials that contained chromium.

5.1.2.8.6 Lead

ESI samples AP03, DB02, and MR03 had lead concentrations greater than 750 ppm (Figure 5-15), and were investigated further during the RI. Locations AP03, DB02, and MR03 were resampled during the RI, and samples were collected at locations AP20, SR23, and MR20 to bound the extent of lead at these locations. Concentrations of lead in RI surface samples (0-to 3-inch interval) from locations AP03, DB02, and MR03 showed a marked decrease when compared to the ESI results (Figure 5-15). Lead concentrations in RI samples from locations AP03 and MR03 were below the Method A unrestricted criterion (250 ppm), while the lead concentration at location DB02 decreased from 2,060 ppm in the ESI sample to 374 ppm in the RI sample. The lead concentration in the subsurface soil sample (3-inch to groundwater) from location AP03 (355 ppm) was also below the Method A industrial criterion. The lead concentration in the subsurface soil

sample from location MR03 (35.4 ppm) was below the Method A unrestricted criterion. Surface and subsurface soil samples from bounding locations AP20, SR23, and MR20 had lead concentrations below the Method A unrestricted criterion. Two surface soil samples were collected from location AP20 during the RI. One sample was collected from the surface of the concrete rubble that was placed over the area during decommissioning, and the other was collected from the surface of the fill material below the concrete rubble. The surface sample at location AP20 that was collected from the top of the concrete rubble had a lead concentration (270 ppm) below the Method A unrestricted criterion.

The decrease in lead concentrations between ESI and RI samples from locations AP03, DB02, and MR03 could be caused by several factors. First, the soil may be heterogeneous in terms of the presence of lead. Particles of material containing lead (e.g., solder, industrial linings) may be present in the fill material brought onto the Site or site-related operations may have introduced particles of lead into the soil. A soil sample that included a fragment of lead-containing material would bias the analytical results and would not be representative of soil lead concentrations at that sample location. Second, a certain amount of instrument error is inherently associated with sample positioning. It is possible that a small positional change in the reoccupation of EPA sample locations could result in a change in the concentrations of lead in the soil sample, particularly if the presence of lead in the soil was heterogeneous. Since the RI sampling results best represent current site conditions, lead concentrations in the surface soil at location AP03 and MR03 are considered to be below the Method A unrestricted criterion, while the lead concentration in surface soil at location DB02 is considered to be below the Method A industrial criterion.

Lead was analyzed in 79 soil samples from the main process area. Assuming the resampling results of the RI represent current Site conditions, no concentrations of lead were above the Method A industrial criterion of 1,000 ppm. Concentrations of lead at 12 locations were above the Method A unrestricted criterion of 250 ppm. The frequency of detections above the unrestricted criteria arranged by source area within the main process area were:

- Finishing room: 1 of 5
- Recovery boiler: 1 of 10
- Machine room: 3 of 15
- Screen room: 1 of 11
- Acid plant: 5 of 8
- Digester building: 1 of 3.

Lead is not used directly in the pulping process (Rydholm 1965). However, lead has been used in a variety of products including solder for pipes and cans, batteries, paint, leaded gasoline, ammunition in the form of shot and bullets, and electrical equipment (ATSDR 1999b). Several of these products (e.g., solder, electrical equipment) were probably used on the Site. Fragments of material containing lead may have either been included in the

fill material brought onto the property or may have been introduced into the soil through mill operations. Elevated lead concentrations appear to be more frequent around the acid plant and digester building. Lead linings were used historically by the pulp industry to control corrosion of digesters, but digesters were later lined with ceramic bricks (Rydholm 1965). The digesters at Rayonier were lined with ceramic brick held in place with lead-containing mortar. Lead piping was used to cool sulfur dioxide gas in the acid plant prior to the late 1980s.

5.1.2.8.7 Thallium

Seventy soil samples were analyzed for thallium in the main process area, and this metal was detected in 26 of the samples. All detected concentrations were below the industrial criterion of 245 ppm. A single sample, ESI surface sample RB01 (7 ppm), had a thallium concentration above the unrestricted criterion of 5.6 ppm. Ecology (1994) did not establish a natural background concentration for thallium in Washington State soils; however, a common range of thallium in surface soil of the U.S. is 0.02 – 2.8 mg/kg (Kabata-Pendias and Pendias 1984). Although thallium was not analyzed in the RI surface soil sample from location RB01, it was analyzed in the subsurface sample, which had a thallium concentration of 0.05 ppm.

Thallium is not known to be directly associated with the pulp-making industry (Rydholm 1965). All soil samples from the recovery boiler, with the exception of ESI sample RB01, had thallium concentrations below the unrestricted criterion. Therefore, it does not appear that the recovery boiler is a source of thallium. Approximately 65 percent of the thallium currently used in the U.S. is used in the production of semiconductors (ATSDR 1992a). The remainder is used primarily by the pharmaceutical industry. Other current and historical uses include a floatation enhancer for ore refining, glass and artificial gem production, pesticides (banned in 1972), and a chlorination catalyst. The source of thallium in the surface soil at location RB01 is unknown.

5.1.2.8.8 Vanadium

Vanadium was analyzed in 70 samples from the main process area and detected in all samples. While no concentrations were above the industrial criterion of 24,500 ppm, the concentration in a single sample, RI sample BP20 (3-inch to groundwater interval; 1,400 ppm), was above the unrestricted criterion of 560 ppm. Although Ecology (1994) did not provide a natural background concentration for vanadium in soils in Washington State, the U.S. Geological Survey (Shacklette and Boerngen 1984) reported the geometric mean vanadium concentration in soils of the western U.S. to be 80 ppm, with a range of 7 to 500 ppm. Therefore, the vanadium concentration at BP20 appears elevated above background.

Vanadium is not used directly in the pulp-making process (Rydholm 1965). Vanadium concentrations in all soil samples from the bleach plant, with the exception of RI sample BP20, were below the unrestricted criterion. Therefore, it does not appear that the bleach plant is a source of vanadium. Approximately 83 percent of the vanadium consumed in the U.S. is used in steel production (ATSDR 1992b). It is possible that the elevated vanadium concentration found in the subsurface soil sample at RI location BP20 is

associated with fragments of metal debris either included in fill material brought onto the Site or from activities at the mill.

5.1.2.8.9 Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate (BEHP) was detected in 49 of the 68 soil samples from the main process area. All detected concentrations were below the industrial criterion of 9,375 ppm. The BEHP concentration of one sample, RI sample MS20 (3-inch to groundwater interval; 1,800 ppm), was above the unrestricted criterion of 71.43 ppm. BEHP was detected at 0.19 ppm in the surface sample at the same location.

BEHP is not used directly in the pulp-making process (Rydholm 1965). The single RI maintenance shop sample location was primarily targeted to evaluate a potential petroleum source. Approximately 95 percent of the BEHP consumed in the U.S. is used as a plasticizer in the production of flexible PVC products (ATSDR 2002). BEHP is a ubiquitous laboratory contaminant, which can result in false positive results. Since the laboratory QA report did not identify any systemic laboratory contamination issues, it is assumed that the elevated BEHP concentration reported for RI sample MS20 is associated with the inclusion of a fragment of PVC in the sample.

5.1.2.8.10 Pentachlorophenol

Pentachlorophenol (PCP) was detected in 14 of 58 samples from the main process area. Detected concentrations were all below the industrial criterion. ESI surface soil sample SR03 had a PCP concentration of 15 ppm, which is above the unrestricted criterion of 8.33 ppm. The surface soil at location SR03 was resampled during the RI, and PCP was not detected (< 0.16 ppm).

PCP was one of the most widely used biocides in the U.S. with 80 percent being used for wood preservation (ATSDR 2001). Two reasons may account for the decrease in PCP concentrations in surface soil at location SR03 between the ESI sampling in 1997 and the RI sample in 2003. First, the PCP concentrations in the soil may have declined due to natural processes such as photolysis and biodegradation, which can result in a PCP half-life in soil of 2 to 4 weeks (ATSDR 2001). Second, the soil may be heterogeneous in terms of the presence of PCP. Particles of material containing PCP (e.g., PCP-treated wood) may either have been present in the fill material brought onto the Site or may have been introduced into the soil through the use of PCP-treated wood at the mill. A soil sample that included a fragment of this material would bias the analytical results and would not be representative of soil PCP concentrations at that sample location. Since the RI sampling results represent the most current Site conditions, the PCP concentration in the surface soil at location SR03 is considered to be below the unrestricted criterion.

5.1.2.8.11 Pyrene

Pyrene was detected in 50 of 72 soil samples from the main process area. Detected concentrations of all samples were below the industrial criterion. A single sample (ESI surface sample TB02 = 14,000 ppm) had a detected concentration above the unrestricted criterion of 2,400 ppm.

Pyrene is a PAH, which are ubiquitous in the environment having both natural and manmade sources (ATSDR 1995). PAHs are natural components of petroleum and are generated during grass/forest fires and volcanic activity. As a combustion product, they are generated by internal combustion engines, power plants, and boilers. Typically, PAHs co-occur, and if one PAH in a sample is elevated, many other PAHs in that sample should also be elevated. Detected concentrations of the other 14 PAHs in sample TB02 ranged from 0.130 to 6.10 ppm, which is considerably less than the 14,000 ppm reported for pyrene. This comparison suggests that the pyrene concentration reported for sample TB02 may be anomalous. In addition, pyrene concentrations in other soil samples from the transformer building and adjacent finishing room and machine room were below the unrestricted criterion.

5.1.2.8.12 PAHs

PAHs were detected in 41 samples from the main process area (Figure 5-16). No detected cPAH TEQ concentrations were above the industrial criterion of 17.98 ppm. cPAH TEQ (rl=0) concentrations in 18 samples and cPAH TEQ (rl=1/2) concentrations in 30 samples were above the unrestricted criterion of 0.137 ppm. The detection limits for cPAHs reported for the ESI data (E&E 1998) were above the unrestricted criterion, which accounts for the greater number of samples with elevated cPAH TEQs. Sample locations with detected concentrations of cPAH TEQ above the unrestricted criterion are distributed throughout the main process area and do not appear to be closely associated with any particular source area.

Concentrations of individual PAHs are provided in Appendix E. Chrysene shows the highest frequency of detected concentrations above the unrestricted criterion (23 of 31 samples) and dibenzo(a,h)anthracene the lowest (2 of 31 samples).

PAHs are ubiquitous in nature (Eisler 1987) having many natural (e.g., forest fires, volcanoes, crude oil) and anthropogenic (e.g., motor vehicles, wood-burning stoves and furnaces, industrial smoke or soot) sources (ATSDR 1995). The boilers on the mill property were a source of PAHs. However, results of particulate deposition modeling show that deposition rates were highest east of the digester building, and deposition west of the digester building was negligible. The distribution of surface soil samples with cPAH concentrations above unrestricted criteria does not show a strong relationship with the particulate deposition modeling results, suggesting the mill boilers may not be a significant source of cPAHs on the Site. Five samples located at potential petroleum release sites in the main process area (DK20, MS20, RB01, RB20, and RB22) had GRO, DRO, and RRO concentrations less than the unrestricted criteria, suggesting these sites were not sources of cPAHs.

5.1.2.8.13 PCDD/Fs

At least one PCDD/F congener was detected above the unrestricted criteria in 27 of the 32 surface soil samples from the main process area (Figure 5-17a). The concentration of 1,2,3,4,6,7,8-HpCDD exceeded their industrial criteria at Station FR02 during the ESI sampling, but not during the RI. In contrast to the surface soil samples, at least one

PCDD/F congener was detected above unrestricted criteria in only five of the 21 subsurface soil samples (Figure 5-17b).

ESI (E&E 1998) samples from FR02 and SR03 had elevated PCDD/F concentrations and were resampled during the RI. RI sampling results showed substantially lower PCDD/F concentrations in the surface soil at location FR02, but little change at location SR03. Concentrations in the subsurface soil were lower than in the surface soil at both locations. The decrease in PCDD/F concentrations between the ESI sampling in 1997 and the RI sampling in 2003 at location FR02 may be an actual decrease or may reflect differences due to the heterogeneity of PCDD/F concentrations in the soil. Sample locations with detected concentrations of PCDD/F congeners above the unrestricted criteria occurred across the main process area and do not appear to be closely associated with any particular source area.

If an aerial deposition source was responsible for the PCDD/Fs present in the soil samples from the main process area, concentrations of PCDD/Fs would be expected to be higher in surface soil samples than in subsurface soil samples. PCDD/Fs deposited on the soil surface from aerial sources tend to bind with the soil organic matter and are rather immobile (USEPA 2000). The effect of sampling depth on PCDD/F concentrations was evaluated statistically by comparing TCDD TEQ¹² data from the RI for surface soil (0- to 3-inch interval) and subsurface soil (3-inch to groundwater interval) samples. Test results show the TCDD TEQ concentrations to be significantly greater ($p < 0.05$) in surface samples compared to subsurface samples (Table 5-2). Figure 5-18 shows the relationship of TCDD TEQ (rl=0) concentrations between the surface and subsurface soil samples, which shows a highly significant linear correlation ($r = 0.79^{**}$, $n = 18$). This suggests that the presence of higher TCDD TEQ concentrations in the surface soil is consistent with an aerial deposition source.

5.1.2.9 Surface Soils on the East Side of the Site

Aerial deposition modeling from stack sources indicated portions of the east side of the Site were strongly influenced by particulate deposition from stacks in the main process area (Appendix H). The COPCs related to stack emissions are metals, PAHs, and PCDD/Fs. Twenty-four samples were collected on the east side of the Site at 22 locations. The following chemicals were detected in at least one sample at concentrations above unrestricted criteria:

- Arsenic
- Chromium
- PCDD/Fs
- Carcinogenic PAHs.

¹² TCDD TEQs were calculated following MTCA (WAC 178-340-708).

Most samples exceeded the unrestricted criterion for arsenic, but only one sample exceeded regional background (Figure 5-19). This sample was discussed previously in the discussions of the bone yard, and the concentration was not reproduced during the RI.

No samples exceeded the industrial criterion for chromium (Figure 5-20). One sample at location RS20 had a concentration of 307 ppm, which marginally exceeded the unrestricted criterion. All other samples on the east side of the Site were at or near regional background (Ecology 1994).

Based on these results, soils on the east side of the Site do not appear to have been significantly impacted by aerial depositions. Metal concentrations in soils are generally below unrestricted criteria or regional background.

cPAHs were generally undetected on the east side of the Site (Figure 5-21). Two locations had cPAH TEQ concentrations slightly above the unrestricted criterion: BY03 at the 2- to 4-ft interval and BY05 at the 0- to 2-ft interval. The cPAH TEQ concentrations at both of these locations were below the industrial criterion. Appendix E reports the individual carcinogenic chemical concentrations [i.e., benzo(a)pyrene] at each location.

PCDD/Fs were analyzed in 12 samples from 10 locations on the east side of the Site (Figure 5-22). Individual PCDD/F congeners exceeded unrestricted criteria in surface soil samples at two locations (ECO33, SL21). However, no samples exceeded the industrial criteria. No subsurface soil samples exceeded the unrestricted criteria.

5.2 Offsite Residential Soil

Residential areas near the mill were sampled during the ESI (E&E 1998). The rationale for the selection of the sample locations was not presented in either the work plan or the final report. ATSDR performed a public health evaluation based in part on the information from these samples and concluded none of the chemical concentrations detected in offsite soil would be expected to produce adverse health effects in potentially exposed residents (ATSDR 2004).

To evaluate the data further for compliance with MTCA, the section below compares the chemical concentrations collected during the ESI (E&E 1998) in offsite areas to criteria. Chemicals with concentrations in at least one sample that were greater than the unrestricted criteria are:

- Arsenic
- Heptachlor epoxide
- Lead
- PCDD/Fs
- PAHs.

5.2.1 Atmospheric Deposition Modeling

Atmospheric dispersion and deposition of particulates from the former mill is the primary pathway of chemical migration from the Site to offsite properties. The Rayonier mill operated from 1930 to its closure in 1997. To supply power for mill operations, hog fuel, dewatered wastewater treatment sludge, and fuel oil were burned in boilers at the Site. PCDD/Fs were likely formed during the combustion of sludge that contained chlorinated materials as well as bark from logs that had been stored in seawater.

Air deposition modeling of emission sources at the mill was performed as a component of the RI's effort to identify patterns of aerial deposition surrounding the former mill (Kennedy/Jenks Consultants 2003; Appendix H). The Industrial Source Complex Short Term (ISCST3) and ISC Prime air models were used to estimate depositional patterns around the Site based on emissions data for several stacks formerly operated at the facility, specifically, the recovery boiler, power boiler No. 4, power boiler No. 5, hog fuel boiler No. 6 at the electroscrubber inlet, hog fuel boiler No. 6 at all three stacks, and the hog fuel boiler baghouse. Stack-specific data and local meteorological and topographical data were used in the model to predict long-term deposition patterns. The model is fully described and discussed in Appendix H.

The soil sampling programs for both the ESI and the RI were not specifically designed to validate air model predictions. However, the ISCST3 model does provide a context for the highest particulate deposition rates, and thereby identifies areas that would have been impacted by emissions from the Site. Since particulate depositions were dominated by the hog fuel boiler prior to installation of the electroscrubber in 1981, the subsequent discussion focuses on the mill emissions prior to 1981. During this time, the model predicted the highest rates of off-property deposition along the bluff in the area between Ennis and Morse creeks, east of the mill property (Figure 5-23). In particular, sample locations GLR and JNR, which correspond to model-predicted particulate deposition rates of approximately 20 and 30 grams per square meter-year ($\text{g}/\text{m}^2/\text{yr}$), respectively, are found along this bluff. Continuing along this bluff to the west or south of these sample locations, predicted deposition rates decline considerably. For instance, deposition rates of approximately $5 \text{ g}/\text{m}^2/\text{yr}$ and $1\text{-}2 \text{ g}/\text{m}^2/\text{yr}$, correspond to sample locations ZMR and MSR (Figure 5-23).

The deposition rate for the location of each specific surface soil sample from the ESI and the RI was interpolated using ARCVIEW GIS. Using Statgraphics for Windows, the cluster analysis procedure was used to create 10 clusters from the 160 surface soil samples collected on- and offsite based on the predicted deposition rate ($\text{g}/\text{m}^2/\text{yr}$) at each location. The clusters are groups of observations with similar characteristics. To form the clusters, the procedure began with each observation in a separate group. It then combined the two observations that were closest together to form a new group. After recomputing the distance between the groups, the two groups closest together were combined. This process was repeated until only 10 groups remained. Based on these 10 clusters, data for PAH, PCDD/F, and metals concentrations were averaged. The average chemical concentration for each cluster was then regressed on the mean deposition rate of that cluster.

1. There are several sources of uncertainty associated with the application of these assessment methods to the off-site soils. There is uncertainty around whether observed soil concentrations are influenced by factors other than mill stack emissions. Notable among the possible factors are these: The primary emission sources of particulates and associated chemicals from the hog fuel boiler stack were significantly reduced more than 25 years ago when an electroscrubber was installed on the hog fuel boiler. The soils present during the time prior to the electroscrubber installation may not be represented by the current soils horizon present in the offsite area due to wind and water erosion, residential development activities, and landscaping activities.
2. The chemicals found in the offsite residential areas are consistent with the range of chemicals found in urban environments. This could indicate that chemical contributions resulting from Rayonier mill stack emissions are not quantifiably different than contributions from other urban sources, such as car exhaust, barbecues, fireplaces, oil-burning furnaces and stoves, and fertilizers.
3. A medical waste incinerator which formerly operated at the Olympic Memorial Hospital (OMH) represents another potential significant point source of emissions upgradient of the area sampled in the ESI. EPA identifies such incinerators as the primary sources of PCDD/Fs in some upland environments. This source could have created chemical concentrations of PCDD/Fs that would not correlate with stack emissions at the Site.

Although each of the points noted above are likely to have influenced the contaminants observed in the residential samples, further discussion is warranted relative to the potential source at the OMH. Little documentation exists to evaluate emissions from the incinerator. However, looking at the prevalent wind direction and topography, it can be inferred that deposition from the incinerator might have influenced PCDD/F concentrations observed in samples CTR01, ZMR01, ZMR02, and TBS01. The lack of correlation between PCDD/F concentrations and the predicted deposition model offsite may result from the influence of this source on these samples. The level of PCDD/F at locations ZMR02 and TBS01 near the OMH are as high as those noted for JNR01, which is the point nearest to the area of highest modeled deposition from the mill. However, deposition rates resulting from Rayonier stack emissions are more than 10 times greater at JNR01 relative to ZMR02 and TBS01. Similarly, stations CTR01 and ZMR01/ZMR02, with modeled deposition rates of $1.5 \text{ g/m}^2/\text{yr}$ and $5 \text{ g/m}^2/\text{yr}$ respectively, have higher TCDD TEQs than the concentration found at station GLR01, which has a higher modeled deposition rate for mill emissions ($17 \text{ g/m}^2/\text{yr}$).

Assuming the samples near or west of Ennis Creek have been impacted by other sources and thus, focusing on only those samples nearest the highest areas of deposition from the mill east of Ennis Creek, the PCDD/F concentrations do exhibit trends that are consistent with the deposition model. For example, as shown in Figure 5-24, the highest PCDD/F concentrations found in the residential area east of Ennis Creek are those collected in the locations nearest the areas predicted to have the highest particulate deposition rates.

Another uncertainty in these methods is the accuracy of the model at predicting the actual patterns of particulate deposition. The meteorological data which was used as the model input is considered to be a complete data set with adequate quality controls, but it is from a station located in downtown Port Angeles, and thus in a different topographic regime than the mill site. While a meteorological station produced data at the mill site for several months during mill demolition, the data is incomplete and its quality is difficult to assess. However, a difference in the wind patterns between these two data sets suggests that the selection of data for the model input also introduces some degree of uncertainty into the assessment of the off-site residential soils.

Additional information on the validation of the deposition modeling is presented in Malcolm Pirnie (2005a).

The following sections discuss specific chemicals.

5.2.2 PCDD/Fs

As discussed previously, to supply power for mill operations, hog fuel, dewatered wastewater treatment sludge, and fuel oil were burned in boilers at the Site. PCDD/Fs may have been formed during the combustion of sludge that contained chlorinated effluent as well as bark from logs that had been stored in seawater. Other sources of PCDD/Fs that may influence the offsite residences include:

- Various formulations of 2,4,5-T have been used extensively for weed control on crops and range lands, and along roadways throughout the world. Use of hexachlorophene and the herbicide 2,4,5-T is currently restricted in the United States.
- Combustion of fossil fuels (coal, oil, and natural gas).
- Combustion of wood that had been in contact with seawater.
- During incineration processes (municipal and medical solid waste and hazardous waste incineration).
- Burning of materials that may contain chlorine, such as plastics, wood treated with pentachlorophenol (PCP), pesticide-treated wastes, and other household trash.

The following stations exceeded the unrestricted criteria (Figure 5-24) for individual congeners:

- **JWR-02:** 2,3,7,8-TCDD exceeded unrestricted criterion
- **TBS-01:** 2,3,4,7,8-PeCDF exceeded the unrestricted criterion.

The possible contributions of dioxins and furans by the mill to these samples are evaluated in Malcolm Pirnie (2005b).

5.2.3 Arsenic

Arsenic was observed in the offsite soils at levels above its unrestricted criterion, but below background (Figure 5-25). If arsenic was present in the particulate emissions, it did not elevate levels in the existing offsite soils to levels above those that naturally occur in the environment.

5.2.4 Heptachlor Epoxide

Heptachlor epoxide exceeded its unrestricted criterion at a single location; but was below its industrial criterion (Figure 5-26). Heptachlor epoxide is a breakdown product of heptachlor. Heptachlor is a synthetic chemical that was used in the past for killing insects in homes, buildings, and on food crops. It has not been used for these purposes since 1988. This chemical would not have been associated with emissions from the stacks at the Rayonier facility, but most likely by local use of the pesticide around this residence in the past.

5.2.5 Lead

Lead exceeded the Method A unrestricted criterion at location ENR01. Lead is a mineral commonly occurring in soils from geological processes and was present in many paints applied to houses. Lead exceeded the maximum background concentration naturally occurring in soils (Ecology 1994) at Stations TBS01 and ENR01 (Figure 5-27). These concentrations do not follow any pattern consistent with particulate deposition from the mill, and all samples that were located geographically closer to the mill or closer to areas of higher particulate deposition were well below this concentration. This suggests another source of lead at this location may be influencing this sample.

5.2.6 PAHs

PAHs are chemicals formed during the incomplete combustion of various organic materials. During the operations of the Rayonier mill, PAHs were formed as a result of the combustion of hog fuel, which contained both wood and petroleum. As organic chemicals, PAHs were likely to be adsorbed to the organic particulates emitted from the stacks and then transported offsite via wind to nearby soils. Offsite soils are likely to have received PAHs from several other combustion sources as well. These include:

- Combustion of oil or wood in homes
- Combustion of gasoline or diesel fuel in motor vehicles
- Combustion of garbage or yard waste
- Combustion of charcoal in barbecues
- Use of asphalt in road construction
- Use of crude oil, coal, coal tar pitch, creosote, or roofing tar.

PAHs can also occur naturally in the environment.

The concentration of cPAH TEQ exceeded its unrestricted criterion at a single location, CTR01 (539 ppb; Figure 5-28).¹³ The 17 PAHs evaluated in offsite soils were undetected in the majority of samples, and five were found individually at levels above the unrestricted criterion at one sample location (CTR-01). Concentration distributions for PAHs do not follow any pattern consistent with particulate deposition from the mill. This suggests another source of cPAHs at this location may be influencing this sample.

5.3 Ennis Creek

Ennis Creek, which runs through the mill, is the only source of freshwater sediments within the Site boundary. White Creek converges with Ennis Creek near the southern boundary of the Site. Ennis Creek is a snowmelt creek, which exhibits variable flows throughout the year. The mouth of Ennis Creek is tidally influenced, and the creek discharges directly into Port Angeles Harbor on the Strait of Juan de Fuca. As a result of tidal changes, surface water elevation varies daily at the mouth of Ennis Creek. The section of Ennis Creek that flows through the mill property is confined to a channel lined with large riprap rock, creating a relatively fast-flowing stream during high rainfall events.

Eight freshwater sediment samples were collected from Ennis Creek during the ESI (E&E 1998). Three of the samples were collected upstream of the Rayonier facility, but within the property boundary, and were identified as background samples. Samples EC07SD and EC08SD were located in White Creek above its confluence with Ennis Creek, and sample EC06SD was located in Ennis Creek below the confluence of the two creeks. Sample EC05SD was located in the creek near the parking lot area to characterize potential chemical inputs from runoff from the secondary treatment area drainage ditch. Three sampling stations (EC02SD, EC03SD, and EC04SD) were located near the former finishing room area, which was the site of a hydraulic fluid release. Sample station EC01SD was located just beyond the mouth of the creek. Sediment samples were collected from the 1- to 10-cm interval at each location and analyzed for the presence of up to 150 chemicals.

An interim action was conducted in the Ennis Creek-Finishing Room Area in 2002 (Integral and Foster Wheeler 2003) that resulted in the removal of 1,286 tons of soil from the west bank and the west half of the creek bed. The excavation was backfilled with suitable clean material obtained from an outside source. Chemicals of concern included petroleum hydrocarbons (i.e., DRO, RRO) and PCBs. Sediments associated with ESI sample locations EC02SD and EC03SD, and possibly EC04SD, were removed as part of this interim action.

Sediment samples were collected from one location on Ennis Creek (ECY-20) during the RI and were analyzed for the presence of 52 analytes. This location is upstream of the area addressed by the Ennis Creek-Finishing Room Interim Action (Integral and Foster Wheeler 2003). At location ECY-20, a surface sediment sample was collected from the 0- to 10-cm interval, and a subsurface sample was collected from the 10- to 30-cm interval.

¹³ Seven of the 17 PAHs routinely analyzed are known or suspected carcinogens. As discussed in Section 5.1, these seven PAHs are evaluated as cPAH.

The analytic data for chemicals detected in sediment samples from Ennis Creek during the ESI and RI are presented in Figure 5-29 and Table 5-3. The analytical data are compared to sediment quality benchmark (SQBs) that represent chemical concentrations below which adverse impacts to aquatic organisms are not expected to occur. Since the lower reach of Ennis Creek is influenced by marine water from Port Angeles Harbor, the sediment data were compared to both freshwater and marine SQBs. SQBs were preferentially selected according to the following order:

- Freshwater SQBs
 - Washington State proposed sediment quality values (Ecology 2002)
 - Consensus sediment quality values (McDonald et al. 2002)
 - NOAA screening values (Buchman 1999)
 - EPA ECO UPDATE Ecotox Thresholds (USEPA 1996)
 - Ontario sediment quality guidelines (Persaud et al. 1993)
- Marine SQBs
 - Washington State sediment quality standards (WAC 173-204)
 - NOAA screening values (Buchman 1999).

The analytical data are also compared to samples EC06SD, EC07SD, and EC08SD which EPA (1998) used as background for the ESI, and Ecology (1994) background concentrations for metals in soil.

Concentrations of six metals (aluminum, barium, cobalt, manganese, nickel, and vanadium) were above the SQBs. With the exception of manganese in sample ECY20 (0-10 cm; 559 ppm), the detected metal concentrations fell within the range of results for the ESI background locations EC06SD, EC07SD, and EC08SD. However, the manganese concentration in ECY20 was below the 1,200 ppm natural background concentration of manganese in soil in Puget Sound region (Ecology 1994). Calcium, magnesium, potassium, and sodium did not have SQBs because they are essential nutrients and not considered to be toxic at concentrations potentially encountered in environmental media. Thallium does not have an SQB, but was detected at a relatively low concentration (\leq 0.04 ppm).

Detected concentrations of pesticides/PCBs and PCDD/Fs were below SQBs. Four PCDD/F congeners were detected in the samples analyzed for PCDD/Fs. The highest TCDD TEQ (rl=0) occurred at location ECY20 (0-10cm; 0.131 ppt) while the highest TCDD TEQ (rl=1/2) occurred at background location EC07SD (0.575 ppt) (Figure 5-29).

SVOCs were compared to freshwater SQB expressed on a bulk-sediment basis and marine SQB expressed on an organic-carbon-normalized basis (Figure 5-29). SVOCs were infrequently detected, and detected concentrations were below the SQBs in all cases except one. The concentration of dimethyl phthalate at location EC07SD (53 ppb) was above the value of 46 ppb. However, EC07SD is an upgradient location, used as

background for the ESI, and sources other than the mill are associated with the occurrence of dimethyl phthalate at this location.

Acetone was only detected at location EC01SD. Because acetone has a short half-life and is highly volatile, it is unlikely that the detection was associated with a release from historic mill operations. Rather, the likely source of this chemical detection was from the field laboratory sampling methodology. Acetone is commonly used in both the field and laboratory as a decontaminant.

In summary, the RI samples compared favorably with the ESI samples and do not substantially differ from the concentrations measured in the ESI background samples. Furthermore, none of the chemicals detected in the RI samples had concentrations that exceed the freshwater SQB guidance values or ESI background concentrations.