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Human Health and Ecological Risk Assessment for the Southern Wood Piedmont Site, Wilmington, North Carolina

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Part I:

Human Health Risk Assessment

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EXECUTIVE SUMMARY

ChemRisk®, the human health and ecological risk assessment division of McLaren/Hart Environmental Engineering Corporation, was retained by Southern Wood Piedmont (SWP) to prepare human health and ecological risk assessments which evaluate current and future risks associated with environmental conditions at SWP's former wood treatment facility, located in Wilmington, North Carolina.

The Human Health Risk Assessment (HHRA) followed conservative agency guidance and, consequently, the risk estimates presented herein very likely overstate true risks posed by residual constituents in Site surface and subsurface soil, sediments, surface water, and groundwater. It is also important to consider that resultant risk estimates represent upper bound estimates - true risks are likely to be less or even zero. A summary discussion of the significant conclusions drawn from the HHRA is presented below.

The Ecological Risk Assessment (ERA) represents a conservative screening-level analysis of potential impacts from Site constituents on benthic and key higher trophic organisms. Conservative agency guidance was also followed in the construct and analysis of potential ecological impacts. Summary details of this analysis are presented below.

Part I: Human Health Risk Assessment

In the HHRA, theoretical upper-bound incremental lifetime cancer risks and noncancer hazards were evaluated for three hypothetical future use scenarios at the Site:

- construction/utility repair worker;
- adolescent trespasser; and,
- recreational angler.

These theoretical exposure populations were selected based on a review of land use surrounding the facility, and upon visual inspection of the site in March 1996.

Following EPA exposure assessment guidelines, chronic intakes were estimated for the typical and high end exposed individuals. In both cases, a series of upper-bound, generic exposure factors and assumptions were used to estimate exposures. The typical and high end exposures differ to the extent that the high end exposures used several parameter values that are taken from the high end of the range of parameter values, whereas for the typical exposed individual, values nearer the mean of the range of values were used to evaluate exposures. For each exposure pathway, most parameter values used in the HHRA to estimate exposure were upper-bound values which, when combined in the exposure equations, result in exposure estimates that are likely not realistic and most certainly overestimate actual exposures (if any).

Results of the evaluation indicated that all noncancer hazards were below the noncancer hazard index risk benchmark of 1, indicating that Site-related constituents do not pose a noncancer human health hazard. Carcinogenic risks for the typical exposed individual were estimated to be within the range of 3.0×10^{-6} to 1.5×10^{-5}, and risks for the high end exposed individual were estimated within the range of 7.2×10^{-6} to 6.6×10^{-5}. Comparison with EPA's acceptable cancer risk range of 1×10^{-6} to 1×10^{-4} at CERCLA sites indicates that human health risks associated with the Site are insignificant.

Part II: Ecological Risk Assessment

Part II of the SWP Wilmington Site Risk Evaluation contains a screening-level ERA. The ERA concludes that the sampling efforts conducted at the Site have sufficiently characterized the nature and extent of chemicals in various environmental media. Moreover, the results indicate that chemicals of potential ecological concern (COPC) are limited to sediment PAHs, as summarized below:

- Concentrations of organic compounds and metals in surface waters were consistently non-detect, or, in the few instances where they were detected, were either below, or slightly above AWQC values.

- Sediment metal concentrations in the ditch/Creek system were also consistently below sediment quality benchmarks. Cape Fear River sediments had metal levels

that infrequently exceeded benchmarks, and were largely within the background range of concentrations.

- The presence of petrogenic (petroleum-related) and pyrogenic (combustion-related) PAHs were ubiquitous in sediments throughout the Study Area. A preliminary evaluation of the type and pattern of sediment PAH suggested that other sources of these compounds may be present. Thus, the Site is not likely to represent the sole source of PAH to the surrounding environs.

A comprehensive evaluation of the local ecological habitat and communities identified several differences between the ditch/Creek system and the Cape Fear River, which influence potential exposure of resident or migratory biota. Collectively, observations during this evaluation conclude that:

- Although several rare species have been identified within approximately one mile of the Site, these species have limited exposure to the ditch/Creek system sediments because: (a) they are currently not present at the Site; (b) they occupy more terrestrial, wetland, or lake habitat than available in the ditch/Creek system; and (c) their access is physically limited as a result of the Greenfield Lake dam, or the Greenfield Creek tidal gate.

- In addition to rare species, the indigenous, commercially, and recreationally important fish and invertebrate communities of the Cape Fear River are not exposed to sediments in the ditch/Creek system due to the presence of the Greenfield Creek tidal gate.

- As a result of the tidal gate, current water quality and biological observations indicate that the ditch/Creek system is predominately freshwater, has only a limited benthic community, and does not provide habitat to support a balanced, indigenous fish community.

Ecologically significant exposure pathways at the Site are a result of: (a) the bioavailability of COPC in sediments; (b) direct contact and ingestion of biota with sediments; and (c) bioaccumulation through consumption of potentially contaminated prey. It is clear from evaluating these exposure pathways that:

- Overall, the factors controlling bioavailability of sediment metals appear sufficient in reducing availability and, subsequently, risk to aquatic organisms. However, in the Cape Fear River, lead and zinc concentrations at the background station may be toxic to aquatic organisms as a result of their relatively high bioavailability potential compared to other metals at that station.

- The bioavailability of sediment PAHs to aquatic organisms in the ditch/Creek system and Cape Fear River is reduced at several locations, thereby reducing potential exposure to aquatic organisms.

- The ability of most aquatic organisms to metabolize PAHs suggests that these chemicals are not likely to impact higher trophic level communities through the consumption of potentially impacted prey.

Based on the results of the screening-level ERA, it is apparent that potential risks from PAH exposure via bioaccumulation are insignificant for higher trophic organisms. However, hazard quotients calculated for benthic macroinvertebrates indicate potential risks to this community via direct contact and ingestion of sediment PAH. Upon further examination, several lines of evidence suggest that potential risks to these organisms may be overstated, as indicated by the following observations: (a) the presence and composition of a functional benthic macroinvertebrate community throughout the drainage ditch and Greenfield Creek; (b) the recognition that the hazard quotient calculations do not account for factors which control PAH bioavailability; and (c) the indication that sediment total organic carbon at some stations appears to be at sufficient concentration to reduce the risk of PAH bioavailability (and therefore toxicity) to benthic organisms. Finally, potential risks calculated in this assessment consider the contribution of multiple sources of PAH into the ecosystem, and are therefore not specific to sources restricted to the Site (i.e., do not distinguish background sources from potential Site sources).

1.0 INTRODUCTION

ChemRisk®, the human health and ecological risk assessment division of McLaren/Hart Environmental Engineering Corporation, was retained by the Southern Wood Piedmont Company (SWP) to conduct a human health and ecological risk assessment of SWP's former wood treatment Site located in Wilmington, North Carolina. The purpose of this risk assessment is to evaluate potential upper bound health risks associated with current Site conditions (i.e., baseline risks) as well as potential risks related to the Site's likely future industrial use.

The human health risk assessment (HHRA) was performed considering the following U.S. Environmental Protection Agency (EPA) guidance, including, but not limited to:

- EPA. 1995a. *Supplemental Guidance to RAGS: Region 4 Bulletin. Human Health Risk Assessment.* U.S. Environmental Protection Agency, Region 4, Waste Management Division, Atlanta, Georgia. November.

- EPA. 1995b. *Exposure Factors Handbook.* U.S. Environmental Protection Agency, Exposure Assessment Group, Washington, DC. June. EPA/600/P-95/002A.

- EPA. 1995c. *Guidance for Risk Characterization.* U.S. Environmental Protection Agency, Science Policy Council, Washington, DC. February.

- EPA. 1992a. *Guidelines for Exposure Assessment.* U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC. Federal Register Vol. 57, No. 104, pp. 22888-22938, May 29.

- EPA. 1992b. *Guidance for Data Useability in Risk Assessment (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. April.

- EPA. 1989a. *Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A).* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. December. EPA/540/1-89/002.

- EPA. 1987. *Risk Assessment Guidelines of 1986.* U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC. August. EPA/600/8-87/045.

The framework for the HHRA is organized according to that originally developed by the National Academy of Sciences (NAS, 1983) and subsequently adopted by the EPA (1987a) and includes the following sections:

- Hazard Identification (Section 2.0);
- Toxicity Assessment (Section 3.0);
- Exposure Assessment (Section 4.0); and,
- Risk Characterization (Section 5.0).

In addition to the guidance documents cited above, site-specific data, data from the peer-reviewed scientific literature, and other government documents were used as resources in the conduct of the HHRA. The full citation for all resources utilized in this assessment may be found under References (Section 6.0).

2.0 SITE CHARACTERIZATION AND DATA EVALUATION

The purpose of the Site Characterization and Data Evaluation is to describe the history of the Site, the nature of chemical constituents on the Site, the useability of analytical data compiled for the Site, and to identify those chemicals that may be of potential concern to human health.

2.1 SITE CHARACTERIZATION

The SWP Site is located parallel to Front Street in downtown Wilmington, New Hanover County, North Carolina. The Site consists of fifty-two acres of vacant land on the Cape Fear River waterfront (Refer to Site aerial photograph, next page). Thirty-five acres comprising the northern portion of the Site are currently owned by the City of Wilmington while the remaining seventeen acres is owned by the North Carolina State Ports Authority. The Site has been cleared of surface structures, storage tanks, and railroad sidings and most of the Site is covered with either short grass or remnant sections of concrete or pavement. Two storage facilities, the Amerada Hess Bulk Petroleum Storage Facility and the Pactank Bulk Chemical Storage Facility border the Site on the north and south respectively. A residential area, separated by a buffer zone of trees, commercial property, and Front Street, borders the Site on the east while the Cape Fear River borders the property on the west (Figure 2.1)

The site geology has been identified as a part of the Peedee Formation, primarily consisting of unconsolidated, dark green to grey, clay-rich marine sand. Beneath this upper sand and clay unit lies a dark brown to black clayey peat to peaty clay with varying amounts of wood and root fragments (ViroGroup, 1994). The climate in this area is considered subtropical with an average January temperature in excess of 48°F and an average July temperature in excess of 80° F. Mean annual precipitation is 51 inches per year and mean annual lake evaporation is 42 inches; thus, net precipitation for the area is approximately 9 inches per year. A two year, 24-hour rainfall maximum in the area has been reported to be 5.0 inches (Geraghty & Miller, 1993).

Aerial photograph of Site Study Area (within red boundry). Note: Hess Petroleum Bulk Storage Facility at top of photo, and PacTank Chemical Storage Facility at bottom of photo. Cape Fear River is to left of photo.

The dominant direction of shallow groundwater flow appears to be to the south, parallel to the Cape Fear River. However, tidal influences may temporarily alter or reverse groundwater flow directions. Runoff from the Site is also expected to flow in a south-southeasterly direction towards the wetlands and the drainage ditch on the eastern edge of the Site. This drainage ditch drains to the Cape Fear River via Greenfield Creek. Greenfield Creek flows in a westerly direction from Greenfield Lake, then along the southern border of the Site to the Cape Fear River. In past years, the River, Creek, and drainage ditch were tidally influenced; however, a new tidal gate installed during 1992/1993 prevents significant volumes of river water from entering the creek or drainage ditch. Additional details on the geology and hydrology of the Site can be found in two recent documents (NCDEHNR, 1995; ViroGroup, 1994).

The SWP Site was used from 1935 to 1983 to treat and store wood products. Creosote was the only wood preservative used at the Site prior to 1972. From 1972-1980 chromated copper arsenate (CCA) was also used as an alternative wood preservative. In 1980, part of the facility was modified to use pentachlorophenol (PCP) as a wood preservative. Chemical constituents used in these wood treatment processes represent the vast majority of site-related compounds of interest (NCDEHNR, 1995).

SWP began its first closure procedures in 1975 by covering a southeast drainage ditch containing creosote sludges with fill. Wood treatment operations ceased in May 1983 and plant equipment removal began at this time. During the mid-to-late 1980s, SWP excavated an estimated 672,000 cubic feet of creosote contaminated soils from various on-Site locations and Landfarmed these soils in the northern half of the Site, referred to as Landfarm areas LF1 and LF2. Based on arsenic content, CCA-contaminated soils were either transported to an off-site hazardous waste landfill in Pinewood, South Carolina or were stabilized with cement and reburied during excavation with clean sandy-clay fill from off-site areas. All Site activities were concluded in April 1990 (NCDEHNR, 1995).

Landfarm soil samples collected in 1990 and 1991 were found to contain residual creosote constituents. In particular, benzo(a)pyrene and PCP concentrations exceeded benchmark soil screening concentrations (NCDEHNR, 1995). Various polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) were also detected in Landfarm area soils, but there are uncertainties about their quantification (NCDEHNR, 1995), and their concentrations, on a TEQ basis, only slightly exceeded the EPA's PCDD/F clean-up criteria for residential soils of 0.001 mg/kg (Geraghty

& Miller, 1993). Although benchmark soil screening concentrations were exceeded for several constituents, a site-specific risk assessment for the Landfarm areas, conducted by Geraghty & Miller (1993), concluded that these locations did not pose a significant health risk. Furthermore, the NCDEHNR concluded that soil constituent levels at the Site were acceptable for future industrial land use, groundwater constituents did not appear to threaten any public drinking water supplies, and there was no indication that constituents had migrated from the five-acre Landfarm area to groundwater (NCDEHNR, 1993).

To ensure that the status of potential risks associated with Landfarm constituent concentrations measured in 1996 did not differ from those presented by Geraghty & Miller in 1993, this HHRA reassessed potential human health risks for the Landfarm area based on the most recent data.

In 1991, soil and groundwater contamination was investigated in the two non-treated wood storage areas (NTA and NTB) and one of the treated wood storage areas (TWSA). Non-aqueous and aqueous phase semi-volatile organic compounds (SVOCs) were detected in groundwater and soils beneath three of the four wood storage areas (NCDEHNR, 1995). PCP and related compounds have not been detected in groundwater. SVOCs, and in particular benzo(a)pyrene, have been detected in areas that were formerly used for outdoor storage of treated wood (NCDEHNR, 1995). Arsenic has been detected at concentrations that exceed its benchmark screening concentration in all of the treated wood storage areas (NCDEHNR, 1995). There does not appear to be a significant vapor or particulate respiratory hazard to individuals on or near the Site primarily because of the predominantly non-volatile nature of wood-preserving materials and the present vegetated surface conditions at the Site (NCDEHNR, 1995). Elevated concentrations of inorganic chemicals, such as arsenic, have been identified only in groundwater monitoring wells adjacent to the former CCA storage area (NCDEHNR, 1995).

The presence of SVOCs in on- and off-Site sediment suggests the possible migration of constituents via surface water runoff to the drainage ditch, Greenfield Creek, and the Cape Fear River. However, the presence of SVOCs in River and Creek sediments may also be related to other industrial activities along the River such as petroleum storage (NCDEHNR, 1995).

Data from the most recent investigation of the Site, Greenfield Creek, and Cape Fear River, conducted in 1996, are discussed in the following sections.

2.2 DATA EVALUATION

Data evaluation is the process of compiling and evaluating Site analytical data for the purpose of determining the usefulness of the data for risk assessment. The primary objectives of the data evaluation are to (a) determine which data are most appropriate for use in the risk assessment, and (b) compile a preliminary list of chemicals of potential concern (COPC) for human receptors. The EPA (1989a) has identified nine steps in the data evaluation process:

(1) Compile all Site analytical data and sort by medium;
(2) Evaluate analytical methods;
(3) Evaluate sample quantitation limits;
(4) Evaluate data quality with respect to data qualifiers;
(5) Evaluate data quality with respect to quality assurance samples such as field and laboratory blanks;
(6) Evaluate tentatively identified compounds;
(7) Compare potential Site-related constituent concentrations with background levels;
(8) Develop a preliminary set of data for use in the risk assessment;
(9) Further refine the list of chemicals of potential concern through the evaluation of essential nutrients, grouping of chemicals by class, evaluation of the frequency of detection, and use of a concentration-toxicity screen.

The evaluation of Site data is presented in the following sections.

2.2.1 Data Sources and Compilation

Sources of information on Site-related constituents considered in this assessment include:

- A total of 92 soil borings completed in the NTA, NTB, and TWSA areas in 1991. Of these 92 borings, 48 samples (35 surface and 13 subsurface) from 35 locations were selected for chemical analysis. Samples were analyzed for arsenic, copper, chromium, and SVOCs (Geraghty & Miller, 1993; ViroGroup, 1994).

- A total of 78 soil borings (18-inch depth) completed in 1996 in the Production Area and Treated Wood Storage Area B (TWSB). Of these 78 borings, 26 were randomly selected for sampling

and analysis. Two samples were collected from each of 26 borings at defined depths for a total of 52 samples. All samples were analyzed for arsenic, copper, chromium, SVOCs, and VOAs (Savannah Laboratories, 1996; ViroGroup, 1996).

- A total of 36 groundwater samples collected from locations throughout the Site in 1992. All samples were analyzed for arsenic, copper, chromium, lead, SVOCs, and VOAs (ViroGroup, 1994).

- Eleven sediment samples collected in 1992 from the on-site drainage ditch and along the north bank of Greenfield Creek as part of the Phase II Groundwater Quality Assessment. All samples were analyzed for arsenic, copper, chromium, lead, SVOCs, and VOAs (ViroGroup, 1994).

- A total of 13 sediment samples collected in 1996 from a southern tributary to Greenfield Creek and the Cape Fear River. All samples were analyzed for arsenic, copper, chromium, SVOCs, and VOAs (ViroGroup, 1996).

- A total of 57 surface water samples collected semi-annually between 1985 and 1993 from the Cape Fear River at the U.S. Highway 74 bridge and the old slip, Greenfield Creek, and the Ports Authority. All samples were analyzed for arsenic, copper, chromium, and SVOCs (ViroGroup, 1994).

- Nine surface water samples collected in 1996 from Greenfield Creek and the Cape Fear River. All samples were analyzed for arsenic, copper, chromium, VOAs, and SVOCs (ViroGroup, 1996).

The data sets described above are summarized in Table 2-1. As described in the following section, these data sets were evaluated to determine their useability for risk assessment.

2.2.2 Evaluation of Data Useability

Analytical methods and reported detection limits are presented in Table 2-2. A comparison of analytical methods and detection limits for the various investigations conducted at the Site and in Greenfield Greek and the Cape Fear River, indicate that analytical methods and detection limits are comparable for all data sets. An evaluation of data qualifiers indicates that all data are useable for

risk assessment purposes. Quality assurance samples (i.e., field, trip, and laboratory blanks) were free of chemical contamination. A single tentatively identified compound, trichloromethanethiol, was reported to be present in some Site samples. This chemical is discussed in more detail in Sections 2.3 (Selection of Chemicals of Potential Concern [COPC]) and 3.1 and Appendix A (Toxicity Profiles). Comparison of inorganic chemicals to background concentrations, evaluation of frequency of detection, and identification of COPC is presented in Section 2.3.

Two sets of samples were eliminated from the analyses because they were determined to be temporally inapplicable to current and future Site conditions. These are the single sediment sample collected in 1985 from the Cape Fear River and the 57 surface water samples collected from the Cape Fear River between 1985 and 1994. Because of the dynamic nature of the Cape Fear River, these samples are not representative of current or future River conditions. All other data were evaluated for the purpose of identifying COPC. It should be noted that benzo(k)fluoranthene (BKF) was measured as an individual chemical in the 1996 investigation, but was measured as the combination of BKF and benzo(b)fluoranthene (BBF) in the 1991 investigation. Because BBF has a higher cancer slope factor than BKF, it was conservatively assumed that the concentration of BKF + BBF measured in 1991 was all BBF.

2.3 Selection of Chemicals of Potential Concern

Screening for COPC was performed following EPA (1995d) guidance using all available chemical data for surface and subsurface soils, groundwater, and surface water, except as noted in Section 2.2.2. Chemical concentrations in sediment were used to estimate fish tissue concentrations, as described in the Part II Ecological Risk Assessment, for the purpose of comparing to EPA (1995d) risk-based concentrations (RBC) for fish. As detailed below, compounds were retained as COPC if: a) detected in more than 5% of the samples in a particular medium (for n greater than or equal to 20) or detected at any frequency (for n less than 20); and b) present at a level exceeding Site-specific background concentrations (inorganics only); and c) present at a concentration exceeding the corresponding EPA (1995d) RBC. Further discussion of these screening steps follows below.

Evaluation of Frequency of Detection

In accordance with EPA (1989a, 1995d), chemicals that were infrequently detected at the site were not retained for further analysis in the human health risk assessment. For datasets of 20 or more samples, chemicals were eliminated if detected in less than 5% of the samples. For datasets

containing less than 20 samples, a chemical was only eliminated if it was not detected in any sample from a specific medium. As no constituents were detected in Greenfield Creek and Cape Fear River surface waters, this medium was excluded from further consideration in the human health risk assessment.

Comparison to Background

EPA (1989a, 1995d) states that inorganic chemicals present at naturally occurring levels may be eliminated from the risk assessment. For this assessment, inorganic chemicals whose maximum concentrations did not exceed average background concentrations were eliminated from further consideration. Site-specific background concentrations for inorganic chemicals were identified using soil samples collected by Geraghty & Miller (1993) from the NTA. All of the results for arsenic, chromium, and copper (the inorganic chemicals that had been detected in at least 5% of Site samples) were averaged to arrive at an estimate of a site-specific background concentration for these constituents. Because industrial practices generally did not take place at the NTA, this area is believed to be relatively free of Site-related constituents, and provided a reasonable approximation of background concentrations for naturally occurring inorganic chemicals. The background concentrations derived in this fashion were generally lower than similar industrial values reported by some other states. New Jersey, for example, reports higher background concentrations for each of these three chemicals (NJDEP, 1993).

Comparison of Maximum Concentrations to EPA (1995d) RBCs

Consistent with EPA (1995d) guidance, maximum concentrations of the remaining chemicals were compared with EPA (1995d) RBCs as a final step in the COPC selection process. The RBCs are conservative, screening-level, media-specific chemical concentrations developed for the purpose of identifying chemicals of potential concern. Chemicals exceeding their respective EPA (1995d) RBC values, or those that lack an RBC, were retained as COPC in the assessment.

COPC retained in the HHRA are summarized in Tables 2-3 through 2-8 (located at the end of section). For on-Site surface and subsurface soils outside of the landfarm areas, in the case of the hypothetical construction/utility worker scenario, data were compared with industrial RBCs to select representative COPC; for the hypothetical trespasser scenario, surface soil and sediment data were compared with residential RBCs. For landfarm surface soils, COPC for the hypothetical construction/utility worker scenario were determined by comparing data from this location with

industrial RBCs. Finally, RBCs for tap water were used to select COPC for groundwater, and RBCs for fish consumption were used to select COPC for the recreational angler scenario.

As described in the Part II Ecological Risk Assessment for the Site, the food web model used to calculate whole body fish concentrations is only valid for organic chemicals. For inorganic chemicals, it is not currently possible to estimate chemical concentrations in aquatic organisms from concentrations in sediment using a mechanistic model. In addition, there are no empirical bioaccumulation factors (BAFs) published for inorganic chemicals. There are several reasons for this, most notably because of the large number of physicochemical factors associated with chemical complexation in sediments and organisms, and the substantial variation of metal sequestration in various organisms or phylogenic groups makes the modeling of such factors a very complex exercise.

In the absence of site specific data describing the potential uptake and accumulation of inorganic chemicals (i.e., arsenic, chromium, copper), the COPC screen was conducted using the 95th UCL sediment concentration from the Cape Fear River. This methodology conservatively assumes that 100 percent of the chemical in the sediment accumulates in the fillet. Using this approach, concentrations of both chromium and copper were below the Region III RBC's for fish tissue. Arsenic exceeded the RBC screen; however, it was not considered a COPC. Data on the toxicity of arsenic clearly indicates that inorganic arsenic taken up by fish is methylated to arsenobetaine, which is readily excreted (Kuroiwa et al., 1994; Lunde, 1973, 1977; Penrose, 1977). Research on human metabolism also indicates that between 75 to 85 percent of all arsenobetaine in humans is absorbed systemically and excreted unmetabolized within five days (Vahter et al., 1983). In addition, the chemical structure of arsenobetaine supports the conclusion that methylated forms of arsenic are almost toxicologically inert. The new EPA screening value for arsenic in fish tissue supports these conclusions. Based on EPA data, arsenic accumulated in fish tissues is not considered a carcinogen (IRIS, 1995).

The spot concentrations for organic chemicals (i.e., PAHs and VOCs) evaluated in the COPC screen for the recreational angler (Table 2-7) were calculated from the whole body concentrations predicted by the food web model. For PAHs, a fillet concentration was calculated assuming that 25 percent of the whole body concentrations remains in the muscle tissue. A review of the literature by Hellou (1996) indicates that a majority of the PAHs taken up by fish are stored in the liver. Ratios comparing liver to muscle tissue concentrations range from 2 to 75 (Hellou, 1996). Based on this

data, 25 percent accumulation in the fillet was considered a conservative assumption. A similar reduction in VOCs to account for differences between whole body and fillets concentrations was not incorporated into the human health risk assessment; however, all VOCs were still below Region III RBC's for fish tissue.

Table 2-1. Summary of Sample Data for the SWP Wilmington Site

	Site[a]			Cape Fear River		
	Number of Samples	Date Sampled	Reference	Number of Samples	Date Sampled	Reference
Surface Soil	35[b]	1991	Geraghty & Miller, 1993			
	26[c]	1996	ViroGroup, 1996			
Subsurface Soil	13[b]	1991	Geraghty & Miller, 1993			
	26[c]	1996	ViroGroup, 1996			
Groundwater	36	1992	ViroGroup, 1994			
	31	1993	ViroGroup, 1994			
Sediment	11[d]	1992	ViroGroup, 1994	1	1985	ViroGroup, 1996
	1	1993	ViroGroup, 1994	11	1996	ViroGroup, 1996
	2[e]	1996	ViroGroup, 1996			
Surface Water	5	1996	ViroGroup, 1996	61	1985-1994	ViroGroup, 1994
				4	1996	ViroGroup, 1996

a. Excluding the landfarm areas.
b. NTA, NTB, and TWSA areas only.
c. TWSB and Production areas only.
d. Samples are from Greenfield Creek and the on-site drainage ditch.
e. Samples are from a southern tributary to Greenfield Creek.

Table 2-2. Analytical Methods and Detection Limits Summary for Samples Collected from the SWP Wilmington Site[a] and Cape Fear River

Sampling Date	Media	SVOAs	VOAs	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
1996	Surface Water	EPA 8270	EPA 8240	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/l)	0.01 - 0.05		0.01	NA	0.01	0.025	NA	NA	NA
1996	Soil	EPA 8270	EPA 8240	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/kg)	0.33-1.7	0.005-0.01	1.0	NA	1.0	2.5	NA	NA	NA
1996	Sediment	EPA 8270	EPA 8240	EPA 7060	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010	EPA 6010
	DL (mg/kg)	0.33-1.7	0.005-0.01	1.0	0.072	1.0	0.36	0.72	0.58	0.29
1994	Surface Water	EPA 8270	NA	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/l)	0.01 - 0.05	NA	0.01	NA	0.01	0.025	NA	NA	NA
1993	Sediment	EPA 8270	EPA 8240	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/kg)	0.33-1.7	0.005-0.01	1.0	NA	1.0	2.5	NA	NA	NA
1993	Groundwater	EPA 8270	EPA 8240	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/l)	0.01 - 0.05	0.005-0.01	0.01	NA	0.01	0.025	NA	NA	NA
1985-1993	Surface Water	EPA 8270	NA	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/l)	0.01 - 0.05	NA	0.01	NA	0.01-0.05	0.01-0.025	NA	NA	NA
1992	Groundwater	EPA 8270	EPA 8240	EPA 7060	NA	EPA 6010	EPA 6010	EPA 6010	NA	NA
	DL (mg/l)	0.01 - 0.05	0.001-0.005	0.005-0.01	NA	0.006-0.01	0.006-0.025	0.005-0.25	NA	NA
1992	Sediment	EPA 8270	EPA 8240	EPA 7060	NA	EPA 6010	EPA 6010	EPA 6010	NA	NA
	DL (mg/kg)	0.33-1.6	0.001-0.005	1.2	NA	0.75	0.75	5.0	NA	NA
1991	Soils	EPA 8270	NA	EPA 7060	NA	EPA 6010	EPA 6010	NA	NA	NA
	DL (mg/kg)	0.33-1.6	NA	1.2	NA	0.75	0.75	NA	NA	NA

a. Excluding the Landfarm areas
NA - Not applicable

Table 2-3. COPC Screen for Surface Soils (mg/kg)[a]

Compound	Number of Samples	Frequency of Detection (%)	Maximum Concentration	Background Concentration	Region III RBC (Residential)[b]	Region III RBC (Industrial)[b]	> 5% Detect?	Maximum Exceeds Background?	Maximum Exceeds Region III RBC or None Available?	COPC?
Acenaphthene	61	3.0	0.93	NA	4,700	120,000				
Acenaphthylene	61	15	2.5	NA	NSA	NSA	Y		Y	Y
Anthracene	61	46	84	NA	23,000	610,000	Y			
Arsenic	61	84	1300	5.9	0.43	3.80	Y	Y	Y	Y
Benzo(a)anthracene	61	72	59	NA	0.88	7.80	Y		Y	Y
Benzo(a)pyrene	61	66	28	NA	0.088	0.78	Y		Y	Y
Benzo(b)fluoranthene	61	87	60	NA	0.88	7.80	Y		Y	Y
Benzo(k)fluoranthene	61	33	30	NA	8.8	78	Y		Y	Y
Carbazole	61	31	7.8	NA	32.0	290	Y			
Chromium	61	100	1200	5.4	390.0	10,000	Y	Y		
Chrysene	61	87	68	NA	88	780	Y			
Copper	61	82	1600	30.4	3,100	82,000	Y	Y		
Dibenzo(a,h)anthracene	61	8.0	2.4	NA	0.088	0.78	Y		Y	Y
Fluoranthene	61	92	97	NA	3,100	82,000	Y			
Indeno(1,2,3-cd)pyrene	61	48	10	NA	0.88	7.80	Y		Y	Y
m&p-Xylene	26	12	0.011	NA	160,000	1,000,000	Y			
Naphthalene	61	8.0	0.99	NA	3,100	82,000	Y			
Phenanthrene	61	44	54	NA	NSA	NSA	Y		Y	Y
Tetrachlorophenol	61	2.0	2.8	NA	2,300	61,000				

a. Chemicals not detected in any sample were not evaluated.
b. EPA, 1995d
NA - Not applicable
NSA - No standard available

Table 2-4. COPC Screen for Subsurface Soils (mg/kg)[a]

Compound	Number of Samples	Frequency of Detection (%)	Maximum Concentration	Background Concentration	Region III RBC (Industrial)[b]	> 5% Detect?	Maximum Exceeds Background?	Maximum Exceeds Region III RBC or None Available?	COPC?
Acenaphthene	39	13	2000	NA	120,000	Y			
Anthracene	39	23	3400	NA	610,000	Y			
Arsenic	39	67	110	5.9	3.80	Y	Y	Y	Y
Benzo(a)anthracene	39	46	800	NA	7.80	Y		Y	Y
Benzo(a)pyrene	39	39	290	NA	0.78	Y		Y	Y
Benzo(b)fluoranthene	39	46	690	NA	7.80	Y		Y	Y
Benzo(k)fluoranthene	39	33	36	NA	78	Y			
Carbazole	39	8.0	930	NA	290	Y		Y	Y
Chromium	39	97	380	5.4	10,000	Y	Y		
Chrysene	39	49	740	NA	780	Y			
Copper	39	56	120	30.4	82,000	Y	Y		
Dibenzo(a,h)anthracene	39	3.0	0.6	NA	0.78				
Ethylbenzene	26	3.8	0.22	NA	200,000				
Fluoranthene	39	59	3700	NA	82,000	Y			
Indeno(1,2,3-cd)pyrene	39	23	88	NA	7.80	Y		Y	Y
m&p-Xylene	26	23	0.44	NA	1,000,000	Y			
Naphthalene	39	8.0	2100	NA	82,000	Y			
o-Xylene	26	4.0	0.2	NA	1,000,000				
Phenanthrene	39	26	4400	NA	NSA	Y		Y	Y

a. Chemicals not detected in any sample were not evaluated.
b. EPA, 1995d
NA - Not applicable
NSA - No standard available

Table 2-5. COPC Screen for Greenfield Creek Sediments (mg/kg)[a]

Compound	Frequency of Detection (%)	Maximum Concentration	Region III RBCs (Residential)[b]	>5% Detect?	Max Exceeds Region III RBCs or None Available?	COPC?
Inorganics						
Arsenic	50	5.2	0.43	Y	Y	Y
Cadmium	60	1.0	39	Y		
Chromium	93	14	390	Y		
Copper	100	46	3100	Y		
Lead	100	290	NSA	Y	Y	Y
Nickel	40	2.8	1600	Y		
Zinc	100	160	23000	Y		
SVOCs						
Acenaphthene	64	44	4700	Y		
Anthracene	36	49	23000	Y		
Benzo(a)anthracene	79	730	0.88	Y	Y	Y
Benzo(a)pyrene	64	680	0.088	Y	Y	Y
Benzo(b)fluoranthene	43	1800	0.88	Y	Y	Y
Benzo(k)fluoranthene	43	4.9	8.8	Y		
Carbazole	21	18	32	Y		
Chrysene	79	920	88	Y	Y	Y
Dibenzo(a,h)anthracene	14	3.7	0.088	Y	Y	Y
Fluoranthene	79	1300	3100	Y		
Indeno(1,2,3-cd)pyrene	36	680	0.88	Y	Y	Y
Naphthalene	14	44	3100	Y		
Phenanthrene	43	70	NSA	Y	Y	Y
VOCs						
Ethylbenzene	7.1	0.15	7800	Y		
Toluene	29	0.016	16000	Y		
cis-1,3-Dichloropropene	43		3.7	Y		
o-Xylene	21	0.069	1600	Y		

a. Chemicals not detected in any sample were not evaluated.
b. EPA, 1995d
NSA - No standard available

Table 2-6. COPC Screen for Groundwater (mg/l)[a]

Compound	Number of Samples	Frequency of Detection (%)	Maximum Concentration	>5% Detect?	Region III RBC (Tap Water)[b]	Maximum Exceeds Region III RBC or None Available?	COPC?
Inorganics							
Arsenic	36	64	0.14	Y	0.00005	Y	Y
Chromium	28	100	0.67	Y	0.180	Y	Y
Copper	32	100	0.40	Y	1.50		
Lead	31	84	0.39	Y	NSA	Y	Y
SVOCs							
2,4-Dimethylphenol	67	9	0.37	Y	0.730		
Acenaphthene	67	45	3.0	Y	2.2	Y	Y
Anthracene	67	19	0.94	Y	11		
Benzo(a)anthracene	67	10	0.42	Y	0.000092	Y	Y
Benzo(a)pyrene	67	10	0.11	Y	0.0000092	Y	Y
Benzo(b)fluoranthene	98	9	0.21	Y	0.000092	Y	Y
Benzo(k)fluoranthene	36	3	0.056				
Carbazole	67	24	0.36	Y	0.0034	Y	Y
Chrysene	67	16	0.34	Y	0.0092	Y	Y
Dibenzo(a,h)anthracene	67	2	0.011				
Fluoranthene	67	25	2.7	Y	1.50	Y	Y
Indeno(1,2,3)pyrene	67	6	0.035	Y	0.000092	Y	Y
Naphthalene	67	27	14.0	Y	1.5	Y	Y
VOCs							
Benzene	67	13	0.10	Y	0.00036	Y	Y
Ethylbenzene	67	28	0.11	Y	1.3		
M,P-Xylene	67	28	0.09	Y	0.520		
o-Xylene	36	14	0.04	Y	1.4		
Toluene	67	16	0.05	Y	0.750		
Trichloromethanethiol	31	16	0.00	Y	NSA	Y	Y

a. Chemicals not detected in any sample were not evaluated.
b. EPA, 1995d
NSA - No standard available

Table 2-7. COPC Screen in Spot (*Leiostomus xanthurus*) (mg/kg)[a]

Compound	Modelled[b] Spot Concentration (mg/kg)	Region III RBC's for Fish Tissue[c]	COPC?
Acenaphthene	0.079	81	
Anthracene	0.13	410	
Benzo(a)anthracene	0.043	0.0043	Y
Benzo(a)pyrene	0.021	0.00043	Y
Benzo(b)fluoranthene	0.036	0.0043	Y
Benzo(k)fluoranthene	0.0052	0.043	
Carbazole	0.037	0.16	
Chrysene	0.059	0.43	
Fluoranthene	0.20	54	
Naphthalene	0.014	54	
Phenanthrene	0.13	NA	
1,2-Dichloropropane	0.0084	0.046	
Ethylbenzene	0.0835	140	
m/p-xylene	0.03965	2700	
o-xylene	0.02764	2700	
Arsenic	0.010	0.0018	Y
Chromium	0.046	6.8	
Copper	0.0473	50	

a. Modelled as described in Part II (Ecological Risk Assessment for this Site). Only those chemicals detected in sediment were evaluated.

b. PAH concentration in spot fillet; VOC concentration in whole body; Inorganic concentration equal to sediment concentration (See text for more detail)

c. EPA, 1995d.

d. Arsenic not considered a COPC due to lack of toxicological properties in fish.

NA - an RBC is not available for this compound.

Table 2-8. COPC Screen for Landfarm Soils (mg/kg)[a]

Compound	Number of Samples	Frequency of Detection (%)	Maximum Concentration	Background Concentration	Region III RBC (Industrial)[b]	> 5% Detect?	Maximum Exceeds Background?	Maximum Exceeds Region III RBC or None Available?	COPC?
Anthracene	6	50	10	NA	610,000	Y			
Arsenic	6	100	22	5.9	3.80	Y	Y	Y	Y
Benz(g,h,i)perylene	6	67	6.2	NA	NSA	Y		Y	Y
Benzo(a)anthracene	6	67	7.0	NA	7.80	Y			
Benzo(a)pyrene	6	67	9.2	NA	0.78	Y		Y	Y
Benzo(b)fluoranthene	6	83	15	NA	7.80	Y		Y	Y
Benzo(k)fluoranthene	6	67	5.7	NA	78	Y			
Benzo(b,k)fluoranthene	6	83	21	NA	NSA	Y		Y	Y
Carbazole	6	17	2.2	NA	290	Y			
Chromium	6	67	2.6	5.4	10,000	Y			
Chrysene	6	83	8.7	NA	780	Y			
Copper	6	67	8.3	30.4	82,000	Y			
Fluoranthene	6	83	11	NA	82,000	Y			
Indeno(1,2,3-cd)pyrene	6	67	7.4	NA	7.80	Y			
Phenanthrene	6	83	4.2	NA	NSA	Y		Y	Y

a. Chemicals not detected in any sample were not evaluated.
b. EPA, 1995d
NA - Not applicable
NSA - No standard available

3.0 TOXICITY ASSESSMENT

Toxicity assessment is defined by the EPA (1989a) as an evaluation of the inherent toxicologic potential associated with exposure to a chemical. It is the process of determining whether human exposure to an agent could cause an increase in the incidence of an adverse health effect (cancer, birth defect, etc.) (NAS, 1983). This process involves a review of the relevant biological and chemical information as well as a characterization of the nature and strength of the evidence of causation in order to determine whether a hazard actually exists. In the absence of definitive data on health effects in humans, effects in laboratory animals or other test systems are typically examined to determine whether the chemical poses a hazard to humans. Information from short-term *in vitro* tests and structural similarity to known chemical hazards may, in certain circumstances, also be considered adequate for toxicity assessment.

When individual epidemiologic studies fail to demonstrate a causal relationship between exposure to an agent and a disease endpoint, such a relationship may be established by evaluating the total weight-of-evidence from numerous studies of similarly exposed populations. When a specific endpoint is consistently observed in multiple studies, and when all other cause-effect criteria have been satisfied (strength of association, dose-response relationship, temporally correct association, specificity of the association, and biological plausibility), then a causal relationship can be inferred (Hill, 1965; Mausner and Kramer, 1985; OSTP, 1985; Kelsey et al., 1986; IARC, 1987). Sufficient evidence for carcinogenicity in humans, as described in the EPA's *Guidelines for Carcinogen Risk Assessment*, requires the establishment of a causal relationship between the agent and cancer (EPA, 1986a). The nature and strength of causation are characterized by the EPA according to the "weight–of–evidence" carcinogen classification system (EPA, 1989a). This classification system is summarized in Table 3-1.

Once it has been determined that a relationship exists between chemical exposure and adverse effects in humans, it becomes necessary to determine quantitatively the magnitude or probability of effects occurring at varying levels of exposure, specifically at the low levels humans might be expected to contact as a result of environmental exposure. This quantitative process is referred to as dose-response assessment. Dose-response assessment is a quantitative analysis of the relationship between the magnitude of the dose received and the observed toxicologic responses within an exposed population (EPA, 1989a). In other words, dose-response assessment is the process whereby the relationship between the dose of an agent administered or received and the anticipated incidence of an adverse health effect in an exposed population is characterized.

Ideally, actual human data would be used quantitatively to characterize the potential occurrence of adverse effects. In most instances, however, such data are not available. Therefore, the scientific understanding of the dose-response relationship is largely based on data collected from animal studies (usually rodent bioassays) and hypotheses about what might occur in humans. Because the degree of exposure to environmental contaminants is typically several orders of magnitude below the doses used in animal studies, mathematical models are typically used to estimate the possible responses in humans at levels far below those tested in animals. These models contain several limitations which should be considered when risk estimates are evaluated (EPA, 1989a). Primary among these limitations is the uncertainty inherent in extrapolating results obtained in animal research to humans (cross-species extrapolation) and the shortcomings in extrapolating responses obtained from high-dose research studies to estimate human responses at very low doses (high dose to low dose extrapolation). Consequently, we have a limited ability to use the results of standard rodent bioassays to understand the actual human biological hazard or cancer risk posed by typical levels of exposure (Crump et al., 1976; Sielken, 1985; Paustenbach, 1989). Limitations considered in this assessment are discussed in greater detail in the Uncertainty Evaluation (Section 5.3).

Oftentimes, the availability of new scientific information on the toxicology of a chemical warrants the re-evaluation of the dose-response relationship of the chemical. Such a dose-response assessment may be included in the risk assessment. For the COPCs selected in this risk assessment, it was determined that no new toxicological or epidemiological data were available that would change the outcome of previous dose-response assessments conducted by the EPA. Therefore, dose-response assessments for individual COPCs are not included in this risk assessment.

The relevant toxicological and environmental fate and transport information for each COPC identified in this risk assessment was evaluated and is summarized in Section 3.1. Information used to evaluate chemical hazards for each COPC was obtained from one or more of the following sources: the EPA's Integrated Risk Information System (IRIS), the Health Effects Assessment Summary Tables (HEAST) (EPA, 1995e), the EPA (1995d) Region III COC Screening Table, toxicological profiles published by the Agency for Toxic Substances and Disease Registry (ATSDR), and the scientific literature.

The IRIS database contains descriptive and quantitative toxicity information and is considered to be the most authoritative source of verified EPA toxicity values, including cancer slope factors (CSFs) and reference doses (RfDs), for use in human health risk assessments (EPA, 1989a). Although IRIS values are recommended by the Agency to ensure consistency in risk assessments, it is important to note that alternative toxicity values may also be used in Superfund risk assessments if they are based upon more recent, credible, or relevant toxicological data (EPA, 1993a). For the purpose of this human health risk assessment, however, EPA-derived toxicity values were used for all chemicals. Toxicological values not found in IRIS were obtained either from the HEAST or from the EPA (1995d) Region III Screening Table.

The HEAST is prepared annually by EPA's Environmental Criteria and Assessment Office (ECAO) and provides information on chemicals commonly found at both Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites. In addition to verified toxicity values, HEAST lists interim CSFs and RfDs. For this assessment, information contained in IRIS superseded all other sources of information and other sources were consulted only when information was not available in IRIS. Consistent with EPA (1989a) guidance, EPA criteria documents (i.e., EPA, 1991a; 1995e) were also consulted as sources of toxicity information for chemicals without toxicity values published in IRIS and HEAST.

Background information on the toxicity and physical and chemical properties of each COPC was obtained from the ATSDR and the scientific literature, and is presented in the Toxicity Profiles (Section 3.1 and Appendix A). Toxicity values used in this risk assessment to evaluate the human health risks for each COPC are presented in Section 3.2.

3.1 TOXICITY PROFILES

Toxicity Profiles have been prepared for all Site COPCs, and are located in Appendix A of this HHRA. These profiles contain an analysis of the scientific literature, a reporting on physical and chemical properties, environmental fate and transport, as well as the acute and chronic effects associated with exposure to the compound, in addition to providing an overview of the potential hazards to human health. In cases where a group of chemicals share similar physical, chemical, and/or toxicologic properties, such as PAHs, a single toxicity profile was prepared for all the chemicals belonging to that group.

3.2 TOXICITY VALUES

The toxicity values associated with each COPC are summarized in Table 3-2 through 3-5. As discussed earlier, CSFs established by EPA were used to assess the potential carcinogenic risks to hypothetically exposed populations. Chemical-specific CSFs are presented in Tables 3-2 and 3-3.

Tables 3-4 and 3-5 present the health criteria used to evaluate noncarcinogenic effects resulting from oral and inhalation exposures. For the purposes of this human health risk assessment, the oral and inhalation reference doses established by EPA were used as the basis for assessing the potential noncarcinogenic chronic health hazards for the hypothetically exposed populations.

Table 3-1. EPA Weight-of-Evidence Classification System for Carcinogenicity

Group	Description
A	Human carcinogen
B1 or B2	Probable human carcinogen
	B1 indicates that limited human data are available
	B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

Source: EPA, 1989a.

Table 3-2. Oral Toxicity Values for Potential Carcinogenic Effects

Chemical	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Absorbed or Administered	EPA Weight of Evidence Classification	Type of Tumor	Method of Administration	Source
VOCs						
Benzene	2.90E-02	Administered	A	Nonlymphocytic leukemia	Inhalation	EPA, 1996
Trichloromethanethiol	NA	NA	ND	NA	NA	NA
SVOCs						
Acenaphthene	NA	NA	ND	NA	NA	EPA, 1996
Acenaphthylene	NA	NA	D	NA	NA	EPA, 1996
Benzo(a)anthracene[a]	7.30E-01	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1995d
Benzo(b)fluoranthene[a]	7.30E-01	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1995d
Benzo(k)fluoranthene	7.30E-02	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1995d
Benzo(a)pyrene	7.30E+00	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1996
Carbazole	2.00E-02	Administered	B2	Liver tumors	Diet	EPA, 1995d
Chrysene[a]	7.30E-03	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1995d
Dibenzo(a,h)anthracene[a]	7.30E+00	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1995d
Fluoranthene	NA	NA	D	NA	NA	EPA, 1996
Indeno(1,2,3-c,d)pyrene[a]	7.30E-01	Administered	B2	Forestomach squamous cell papillomas and carcinomas	Diet	EPA, 1995d
Naphthalene	NA	NA	D	NA	NA	EPA, 1996
Phenanthrene	NA	NA	D	NA	NA	EPA, 1996
Inorganics						
Arsenic	1.50E+00	Administered	A	Skin tumors	Drinking water	EPA, 1996
Chromium VI	ND	NA	A	NA	NA	EPA, 1996
Lead	ND	NA	B2	NA	NA	EPA, 1996

NA - Not applicable
ND - Not determined
a. The cancer slope factor for this chemical is based on the carcinogenicity of benzo(a)pyrene

Table 3-3. Inhalation Toxicity Values for Potential Carcinogenic Effects

Chemical	Inhalation Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk Value (ug/m^3)	EPA Weight of Evidence Classification	Type of Tumor	Method of Administration	Source
VOCs						
Benzene	2.90E-02	8.30E-06	A	Leukemia	Inhalation	Oral Value
Trichloromethanethiol	NA	NA	ND	NA	NA	NA
SVOCs						
Acenaphthene	NA	NA	ND	NA	NA	EPA, 1996
Acenaphthylene	NA	NA	D	NA	NA	EPA, 1996
Benzo(a)anthracene	6.10E-01	ND	B2	ND	ND	EPA, 1995d
Benzo(b)fluoranthene	6.10E+00	ND	B2	ND	ND	EPA, 1995d
Benzo(k)fluoranthene	6.10E-02	ND	B2	ND	ND	EPA, 1995d
Benzo(a)pyrene	6.10E+00	ND	B2	ND	ND	EPA, 1996
Carbazole	2.00E-02	ND	B2	ND	NA	Oral value
Chrysene	6.10E-03	ND	B2	ND	NA	EPA, 1995d
Dibenzo(a,h)anthracene	6.10E+00	ND	B2	NA	NA	EPA, 1995d
Fluoranthene	NA	NA	D	NA	NA	EPA, 1996
Indeno(1,2,3-c,d)pyrene	6.10E-01	ND	B2	NA	NA	EPA, 1995d
Naphthalene	NA	NA	D	NA	NA	EPA, 1996
Phenanthrene	NA	NA	D	NA	NA	EPA, 1996
Inorganics						
Arsenic	5.00E+01	4.3E-03[a]	A	Lung cancer	Inhalation	EPA, 1996
Chromium VI	4.10E+01	1.20E-02	A	Lung cancer	Inhalation	EPA, 1996
Lead	NA	NA	B2	NA	NA	EPA,1996

NA - Not applicable

ND - Not determined

a. The unit risk value should not be used if air concentrations for this compound exceed 2 mg/cm^3, since above this concentration the unit risk value may not be appropriate (EPA, 1995).

Table 3-4. Oral Toxicity Values for Potential Noncarcinogenic Effects

Compound	Chronic Oral RfD (mg/kg-day)	Absorbed or Administered	Confidence Level	Critical Effect	Method of Administration	Combined Uncertainty and Multiplying Factors	Source
VOCs							
Benzene	1.71E-03	NA	NA	No effects reported	NA	NA	Inhalation RfD
Trichloromethanethiol	NA	NA	NA	ND	NA	NA	NA
SVOCs							
Acenaphthene	6.00E-02	Administered	Low	Hepatotoxicity	Gavage	300	EPA, 1996
Acenaphthylene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(a)anthracene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(b)fluoranthene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(k)fluoranthene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(a)pyrene	NA	NA	NA	ND	NA	NA	EPA, 1996
Carbazole	NA	NA	NA	ND	NA	NA	EPA, 1996
Chrysene	NA	NA	NA	ND	NA	NA	EPA, 1996
Dibenzo(a,h)anthracene	NA	NA	NA	ND	NA	NA	EPA, 1996
Fluoranthene	4.00E-02	Administered	Low	Nephropathy, increased liver	Gavage	3000	EPA, 1996
Indeno(1,2,3-cd)pyrene	NA	NA	NA	ND	NA	NA	EPA, 1996
Naphthalene	4.00E-02	NA	NA	No effects reported	NA	NA	EPA, 1995d
Phenanthrene	NA	NA	NA	ND	NA	NA	EPA, 1996
Inorganics							
Arsenic	3.00E-04	Administered	Medium	Hyperpigmentation, keratosis and possible vascular complications	Drinking water	3	EPA, 1996
Chromium VI	5.00E-03	Administered	Low	No effects reported	Drinking water	500	EPA, 1996
Lead	NA	NA	NA	ND	NA	NA	EPA, 1996

NA - Not applicable
ND - Not determined

Table 3-5. Inhalation Toxicity Values for Potential Noncarcinogenic Effects

Chemical	Chronic Inhalation RfD (mg/kg-day)	Reference Concentration (mg/m^3)	Confidence Level	Critical Effect	Method of Administration	Combined Uncertainty and Multiplying Factors	Source
VOCs							
Benzene	1.71E-03	NA	NA	No effects reported	NA	NA	EPA, 1995d
Trichloromethanethiol	NA	NA	NA	ND	NA	NA	NA
SVOCs							
Acenaphthene	6.00E-02	NA	NA	ND	NA	NA	Oral value
Acenaphthlylene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(a)anthracene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(b)fluoranthene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(k)fluoranthene	NA	NA	NA	ND	NA	NA	EPA, 1996
Benzo(a)pyrene	NA	NA	NA	ND	NA	NA	EPA, 1996
Carbazole	NA	NA	NA	ND	NA	NA	EPA, 1996
Chrysene	NA	NA	NA	ND	NA	NA	EPA, 1996
Dibenzo(a,h)anthracene	NA	NA	NA	ND	NA	NA	EPA, 1996
Fluoranthene	4.00E-02	NA	NA	ND	NA	NA	Oral RfD
Indeno(1,2,3-c,d)pyrene	NA	NA	NA	ND	NA	NA	EPA, 1996
Naphthalene	4.00E-02	NA	NA	ND	NA	NA	Oral RfD
Phenanthrene	NA	NA	NA	ND	NA	NA	EPA, 1996
Inorganics							
Arsenic	3.00E-04	NA	Medium	Hyperpigmentation, keratosis and possible vascular complications	Diet	NA	Oral RfD
Chromium VI	5.00E-03	NA	Low	No effects reported	Drinking water	500	Oral RfD
Lead	NA	NA	Low	ND	Drinking water	NA	EPA, 1996

NA - Not applicable
ND - Not determined

4.0 EXPOSURE ASSESSMENT

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human exposure to substances present in the environment. The exposure assessment includes the identification of potentially exposed populations, analysis of exposure pathways, definition of exposure points, and estimation of exposure point concentrations (EPCs) in order to develop exposure scenarios and estimate potential dose rates under current and future uses of the Site. The dose rate estimates are then combined with the toxicity values described in Section 2.0 (Toxicity Assessment) to estimate the theoretical risks associated with hypothetical current and future exposures, as part of the risk characterization discussed in Section 5.0.

The exposure assessment is a critical component of the Site assessment process, as it qualitatively and quantitatively describes the potential contact between the COPCs and human receptors potentially affected by the COPCs. There are two important steps to an exposure assessment: (1) the development of exposure profiles and (2) the quantitative estimates of exposure based on those profiles. An exposure profile is a narrative description of the exposures that may occur at the Site based on the nature of chemical contamination on the Site and the characteristics of the exposure setting. The quantification of exposure translates the narrative exposure profile into a series of exposure equations resulting in numerical estimates of dose rates. These numerical estimates are subsequently used in the risk calculations.

Since the time of the EPA's original (1987) risk assessment guidance, the EPA has further revised and clarified its policies for performing exposure and risk assessments. Announced by the EPA on February 26, 1992 and discussed in the *Final Guidelines for Exposure Assessment* (EPA, 1992a) and in the *Policy for Risk Characterization* (EPA, 1995c), these references provide a basis for consistency and comparability in risk assessment and increase confidence in professional scientific judgment.

Consistent with EPA guidance, ChemRisk evaluated risks to both high end exposed individuals, as well as typically exposed individuals in the human health risk assessment. High end exposures were assessed such that the upper bound estimates of the concentration in Site media were combined with conservative chemical intake parameters to arrive at maximal quantitative estimates of potential COPC intake. Typical exposures, on the other hand, were evaluated using average concentrations, and more reasonable intake parameters, to quantify risks that would likely be incurred by the majority of individuals exposed to Site chemicals (if any).

For the purpose of this risk assessment, receptor subpopulations were characterized, in accordance with EPA (1989a) guidance, as those groups of individuals whose activities (described by the frequency and duration of their likely actions) represented full and unrestricted future use of the Site (considering the likely current and future uses identified) and who were assumed to be most susceptible to exposure from Site-related chemicals.

In the following sections, the exposure setting for the Site and surrounding area is characterized, exposure pathways and subpopulations with the greatest potential for exposure are identified, and typical and high end exposure estimates are quantified for these respective exposure groups.

4.1 CHARACTERIZATION OF EXPOSURE SETTING

As previously discussed in Section 2.1 (Site Characterization), several investigations conducted between 1985 and 1996 have reported Site-related constituents in groundwater, sediment, surface soil, and subsurface soil. Chemicals associated with past Site activities include selected VOCs, SVOCs, and metals, including chromium, copper and arsenic. COPCs for each Site media were identified in Section 2.3. (Selection of Chemicals of Potential Concern). Selected SVOCs, VOCs, and inorganic chemicals were identified as COPCs in all media, with the exception of fish, for which only three SVOCs were identified as COPCs; no VOCs or inorganic chemicals were identified as COPCs in fish.

Selected SVOCs, VOCs, and inorganic chemicals were identified as COPC in groundwater beneath the Site. Groundwater studies suggest that some of these constituents have migrated through a peat layer to two deeper, semiconfined sand units. These overburden units are not used as a drinking water source (NCDEHNR, 1995), and are separated from bedrock by a tight, apparently continuous, clay layer two feet thick. Although the sandy limestone formation beneath this clay layer is a principal aquifer in the region, groundwater use is limited within two miles of the Site and no

groundwater supply wells are located within four miles of the Site (NCDEHNR, 1995). The nearest domestic well is approximately 1.6 miles west of the Site. It is estimated that 2,129 people use groundwater within four miles of the Site (NCDEHNR, 1995). The NCDEHNR (1995) previously concluded that Site-related chemicals in groundwater beneath the Site do not threaten public drinking water supplies. Moreover, no surface water intakes were identified for public water supplies operating within 15 miles upstream or downstream of the Site, primarily because of the brackish nature of the water (NCDEHNR, 1995).

In addition, selected SVOCs, VOCs, and inorganic chemicals were also identified as COPC in surface and subsurface soils from the NTA, NTB, TWSA, TWSB, and Production areas. There is no evidence that Site soil contamination has directly affected any off-Site areas, other than the possibility that surface water runoff from the Site has contributed to surface water and sediment concentrations at the drainage ditch and Greenfield Creek, and sediment along the Cape Fear River proximate to the Site.

Composite soil samples collected in 1996 from the landfarm area indicate the presence of relatively low levels of various PAHs, site metals (arsenic, chromium, and copper), and dioxins and furans.

The Cape Fear River system is an established commercial and sport fishery. According to fisheries officials, the section of the River adjacent to the City of Wilmington serves as a nursery for blue crab, eel and shrimp, which are commercially harvested within 15 miles downstream of the Site (NCDEHNR, 1995). Area fishermen typically catch transient American shad, hickory shad, herring, resident largemouth and striped bass, flathead and blue catfish, redbreast sunfish, and spot (NCDEHNR, 1995). An analysis of the Cape Fear River food web indicates that spot, a common recreationally fished species, has the greatest potential for exposure to sediment-bound constituents through the food web (refer to the Part II Ecological Risk Assessment for details).

Three SVOCs were identified as COPC in Cape Fear River fish (presented earlier in Table 2-7). The identification of these COPC in fish from the Cape Fear River is strictly theoretically based on the conservative assumption that certain SVOCs are potentially bioaccumulative in fish. SVOCs are rarely found as constituents in fish due to the high rate with which they are metabolized by fish.

No residents or workers are currently present at the Site. Although the Site is secured by a vehicle gate at the entrance, the area is accessible on foot or by boat. Historic vandalism has occurred on-Site; however, during recent surveys and ChemRisk's visit to the Site observations were made that

suggest trespassing is minimal (NCDEHNR, 1995). The nearest residences are approximately 400 feet east of the Site. The nearest school and daycare are located 0.45 and 0.2 miles from the Site, respectively. A sports field (Optimist Park) is located directly southeast of the Site but is separated by a railroad grade, thick vegetation and the existing on-Site drainage ditch. The total population residing within 0.25 miles of the Site is estimated at 527, whereas 51,914 people reportedly reside within four miles of the Site (NCDEHNR, 1995).

4.2 PATHWAYS ANALYSIS

The objective of the pathways analysis is to identify those potential pathways of exposure that are likely to be complete pathways. According to the EPA (1989b), a complete exposure pathway requires the following three criteria:

(1) a source or chemical release from a source;
(2) an exposure point where contact can occur; and,
(3) an exposure route by which contact and uptake can occur.

The process of pathway analysis involves the identification of sources and receiving media, evaluation of fate and transport mechanisms, identification of exposure points and exposure routes, and the development of exposure pathways based on this information.

For impacted Site media, one or more possible routes of exposure may exist including ingestion, dermal contact, and/or inhalation of dust and vapors. Fish could represent an exposure medium if site-related chemicals are assimilated in edible (fillet) portions. The various routes of exposure that are relevant to a given environmental media, when evaluated together, define the exposure pathway.

Whether or not each of these pathways represent complete exposure scenarios is contingent upon potential current and future uses and activities occurring at the Site. For example, due to the Site's likely industrial redevelopment, access to currently impacted media would be greatly reduced or even eliminated due the presence of buildings or other permanent structures. It is recognized, however, that the property redevelopment activities could in and of themselves result in construction or utility worker exposures to Site wide COPC in surface and subsurface soils and groundwater, and to constitutents in landfarm soils. It is also possible that certain areas of the Site, such as the drainage ditch and Greenfield Creek, might remain intact and thus could be accessed by trespassers at the Site. Finally, a recreational angler could potentially be exposed to Site-related bioaccumulative chemicals

in fish and shellfish from the Cape Fear River, irrespective of the Site development plans. Accordingly, the construction/utility repair worker, child trespasser, and recreational angler have all been retained as potential receptors at this Site.

The media-specific exposure routes for each scenario are summarized in the conceptual site model presented in Figure 4-1. The scenarios identified in this HHRA were conservatively selected to represent situations that might pose the greatest potential for exposure to future workers, trespassers, and anglers.

4.3 QUANTIFICATION OF EXPOSURE

In the exposure assessment, estimates of the concentrations of Site-related chemicals are combined with a series of intake parameters that serve to quantify the exposure of a hypothetical receptor. Such parameters include, soil ingestion rates, inhalation rates, and exposed skin surface area, among others. This risk assessment relied upon point estimates of key exposure values in calculating an overall chemical intake rate. Exposure parameter values are described in Tables 4-1 through 4-3.

4.3.1 Description of Exposure Scenarios

As described above, three exposure scenarios (construction/utility worker, trespasser, and recreational angler) were selected for this assessment based upon Site-specific information and professional judgement. The degree to which individuals may be exposed to Site chemicals under any of these scenarios is primarily determined by the frequency and duration of the exposure event, and/or the conservatism of the point estimate exposure factors.

Construction/Utility Repair Worker (excluding Landfarm)
Under the construction/utility repair worker scenario for the Site as a whole (with the exception of the landfarm), ChemRisk conservatively assumed that this hypothetical exposure group could be exposed to Site COPC via ingestion and dermal contact with surface and subsurface soils; inhalation of surface and subsurface soil particles, inhalation of surface and subsurface soil vapors, dermal contact with groundwater, and inhalation of COPC volatilized from groundwater.

Construction/Utility Repair Worker (Landfarm only)

Hypothetical construction/utility repair workers in the landfarm area were evaluated based on the dermal contact, soil ingestion, and inhalation of dust pathways. Because soil sampling in the landfarm area was represented by composite samples, soil as an exposure medium could not be divided between the surface and subsurface.

Trespasser

Under the trespasser scenario, exposures to COPC are assumed to occur among adolescents (age seven through 16) via ingestion of, and dermal contact with, Greenfield Creek and drainage ditch sediments; dermal contact and ingestion of surface soils, and inhalation of surface soil particles (dust) and vapors. It is assumed that trespassers will contact both sediments and surface soils concurrently. For this reason, several intake parameters were divided between the two media. These parameters are discussed in greater detail in Section 4.3.3.1.

Recreational Angler

Exposures under the adult recreational angler scenario are limited to the consumption of fish from the Cape Fear River. Exposure parameters common to each of these scenarios, as well scenario specific parameters, are discussed further in the following sections.

4.3.2 Estimation of Exposure Point Concentrations

The exposure point concentration (EPC) is an estimate of the concentration of a chemical in the media under consideration to which a hypothetical individual could be exposed. The EPC should represent concentrations to which receptors may be exposed. The common convention in risk assessment is to rely upon the mean concentration when assessing typical exposures and the 95th upper confidence limit (UCL) on the mean concentration to assess high end exposures. Consistent with EPA Region IV guidance, the data set for each chemical was tested for normality and/or lognormality. In most instances, the data were neither normally nor lognormally distributed. Under these circumstances, the data were conservatively assumed to be lognormally distributed, except when the 95th UCL of the log transformed data exceeded the mean. In this case, the 95th UCL was calculated assuming the data were normally distributed.

In this assessment, EPCs were calculated only for COPCs which were screened from the analytical data as described in Tables 2-3 through 2-6. In deriving the mean and upper 95th UCL, one-half the limits of detection were used for non-detected concentrations. Consistent with EPA (1995d), the smaller of either the 95th UCL concentration, or the maximum concentration, was selected as the EPC for site COPC when assessing risks to high end exposed individuals. For typically exposed individuals, the arithmetic average was used. EPCs for all Site media are presented in Tables 4-4 through 4-8.

Consistent with EPA (1991a) guidance, EPCs for vapor-phase COPC volatilized from groundwater during a hypothetical excavation phase of the construction/utility worker scenario were derived for compounds with a molecular weight of 200 or less, and a Henry's Law Constant greater than 1.0E-5 atm-m^3/mole (Table 4-4). The vapor-phase concentrations of groundwater COPC found to meet these criteria were determined first by calculating the flux of each chemical from the surface of the exposed groundwater layer, and then applying the flux rates to a simple box model. Each of these steps is described below.

Following EPA (1995d) guidance for estimating gaseous emissions from a non-aerated surface impoundment containing solubilized COPC in water pooled at soil surfaces, the flux from the pooled groundwater was estimated. The model employed is a two-phase resistance model which accounts for the liquid- and gaseous-phase resistances at the interface between the two media (EPA, 1995d). The resistances are expressed in terms of the liquid phase and gaseous phase mass transfer coefficients which are subsequently used to derive the overall mass transfer coefficient for the system. The flux model uses the overall mass transfer coefficient, the concentration of chemical in groundwater, and the area of the pool to estimate the flux of chemical into the overlying air. For the purposes of this evaluation, ChemRisk assumed that the dimensions of the pooled area were similar to the dimensions used to estimate soil-to-air volatilization factors (EPA, 1991a).

Upon calculation of the flux rates, a box mixing model was developed to conservatively estimate the air concentration above the excavated area. This model assumes that a box with known dimensions is placed over the pooled water from which the chemical vapors are emitted. Furthermore, it is assumed that two ends of the box are open and wind is free to pass through the box. As a result, the chemical concentration within the box, (C_{ai}) is a function of both input (flux rate from the pooled water) and output (dilution from wind). The C_{ai} term, therefore, is equal to the mass rate entering

the box divided by the volumetric rate of air that flows through the box. The results of the gaseous emissions model and the box model are summarized in Table 4-4.

The fish species selected for the derivation of a fish tissue EPC under the adult recreational angler scenario was spot, a popular gamefish that accounted for approximately 46% of all recreational landings in North Carolina in 1994 (NCDEP, 1995). The derivation of the EPC was conducted using a model that considers both the estimated concentration in the fish resulting from direct uptake from the water column, as well as indirect uptake from feeding on contaminated organisms. (The concentrations in organisms were modeled in the Part II Ecological Risk Assessment, based upon Cape Fear Sediment data). Because there were no detected analytes in the Cape Fear River water samples, the model for this assessment incorporated feeding of impacted organisms as the only uptake parameter. Unlike EPCs derived for other Site media in the human health risk assessment, only a single conservative fish tissue concentration for each detected sediment analyte was derived, based on the 95th UCL of the sediment data. The model parameters used in the derivation of the fish tissue concentrations, as well as the sediment data upon which they are based, are described in detail in the Part II Site Ecological Risk Assessment.

4.3.3 Description of Exposure Equations

This section describes the exposure equations that estimate an individual's potential intake resulting from the exposure pathways identified in Section 4.2. For the purpose of this assessment, seven exposure pathways were identified, including 1) incidental ingestion of soils and sediments; 2) dermal contact with soils and sediments; 3) dermal contact with groundwater; 4) inhalation of soil particles; 5) inhalation of soil vapors; 6) inhalation of groundwater vapors; and, 7) fish consumption. When calculating potential carcinogenic risk, the chronic dose rate is modeled as the lifetime average daily dose intake (LADI), whereas potential noncarcinogenic risk is modeled as the average daily dose intake (ADI). The difference between the two lies in the use of the carcinogenic or non-carcinogenic averaging times discussed below. Both the LADI and ADI are expressed in units of milligrams of chemical per kilogram body weight per day (mg/kg-day). The exposure equations for estimating either the LADI or ADI for each specific exposure pathway follow. Definitions for variables that remain constant across pathways are provided for the first pathway only. Parameters that are unique to a pathway are defined for that specific pathway. The derivation of the concentrations of COPC in each media are discussed in detail in Section 4.3.4. Unless explicitly

stated otherwise, exposure parameters used in assessing high end verses typically exposed individuals are the same.

4.3.3.1 Incidental Ingestion of Soils and Sediments

Dose rate (mg/kg-day) = Cs x Ir x Bf x Ef x Ed x Cf x 1/Bw x 1/At

where,

Cs = Soil/sediment concentration (mg/kg)
Ir = Ingestion rate (mg/day)
Bf = Bioavailability factor (unitless)
Ef = Exposure frequency (days/yr)
Ed = Exposure duration (yrs)
Bw = Body weight (kg)
At = Averaging time (days)
Cf = Conversion factor (kg/mg)

Soil Ingestion Rate

Soil ingestion rates used in this assessment were derived based upon studies that determined intake by measuring residual quantities of elemental soil tracers (such as silicon, titanium, and aluminum, among others) in the fecal output of study participants (Hawley, 1985; Calabrese et al., 1989; Davies, 1990; Van Wingen, 1990). Because these rates are derived such that the overall quantity of soil ingested is considered (regardless of any indirect pathways), it is not necessary to add the subsequently ingested fraction of inhaled particles described below in Section 4.3.3.4 (under Lung Deposition Fraction) to the selected soil ingestion rate. The soil ingestion rates selected under each of the exposure scenarios for the high end and typically exposed individuals have been adopted by EPA (1995a,b).

In assessing high end exposures under the trespasser scenario, ChemRisk used an upper bound soil ingestion rate of 100 mg/day recommended by EPA (1989a) for assessing risks to a child under a residential scenario. Considering that adolescents evaluated under the trespasser scenario would likely be exposed to both impacted soils and sediments while playing in Greenfield creek, ChemRisk divided the soil ingestion rate evenly between both Site media, so that the soil and sediment rates were set at 50 mg/day each.

In the evaluation of the typically exposed trespasser, a total soil ingestion rate of 50 mg/day was used which is based upon tracer studies conducted by Hawley (1985) and Calabrese et al. (1989). This rate is recommended for use in evaluating soil ingestion in individuals over the age of 6 by the EPA (1995b). As was the case under the high end exposure scenario, this ingestion rate was divided evenly between soil and sediment, for a resultant rate of 25 mg/day for each media.

Two soil ingestion rates were used in assessing risks under the construction/utility repair worker scenario, corresponding to surface soil and subsurface soil exposures, respectively. For typical exposures to surface soils, ChemRisk used the adult default soil ingestion rate of 50 mg/day discussed above (EPA, 1995b). For the evaluation of high end exposures, this value was increased to 100 mg/day, the value previously cited by EPA for use in assessing soil exposures among adults (EPA, 1989b). In evaluating subsurface soil exposures, ChemRisk used an enhanced soil ingestion rate of 480 mg/day (Hawley, 1985). This value, (which represents soil ingestion per event, rather than an annual average) is cited in both the 1989b, and 1995b Exposure Factors Handbooks as an upper bound ingestion rate to be used in "conjunction with a short term exposure frequency and duration". This enhanced rate was used under the assumption that exposure to subsurface soils would likely occur during activities related to soil excavation, which would result in increased ambient concentrations of airborne soil particles, and an increased overall potential for intake. Given the magnitude of the soil ingestion rate, it was not considered necessary to evaluate both high end and typical exposures under the subsurface soil ingestion pathway.

Bioavailability

Bioavailability describes the extent to which a substance is capable of being absorbed and available to interact with the metabolic processes of an organism (EPA, 1992a). It is a function of a compound's chemical properties, the physical state of the medium to which an organism is exposed, and the ability of the organism to physiologically take up the chemical. Bioavailability is a chemical- and pathway-specific parameter that is typically represented by a unitless coefficient that describes the percentage of the compound absorbed through either a dermal, pulmonary, or gastrointestinal membrane prior to systemic distribution. ChemRisk conservatively assumed complete absorption of COPC following incidental ingestion of soil and sediments under the trespasser and construction/utility repair worker scenarios, and consumption of fish under the adult recreational angler scenarios (ie. bioavailability factors were set equal to 1.0).

Exposure Frequency

An exposure frequency of 18 days per year was derived for the trespasser scenario under the assumption that an adolescent trespasser could play in the creek two days per month during the warm weather months (there are approximately 9 months per year that ambient temperatures in the Wilmington area reach 70 degrees Fahrenheit (Southeast Regional Climate Center, 1996)).

Under the construction/utility repair worker scenario, a hypothetical worker was assumed to be in contact with Site-related media for an exposure frequency of 250 days (corresponding to a work week of 5 days for a total of 50 weeks). A 220 day fraction of the total frequency was assumed to entail exposures to surface soils only, during routine maintenance activities that would not involve digging below the surface soil layer (0-6 inches). The remaining 30 days was assumed to involve exposures to subsurface soils via ingestion, inhalation (particles and vapors) and dermal contact pathways, and groundwater via dermal contact and inhalation of volatilized COPC during excavation and construction activities.

The exposure frequency used in the calculation of risks to the recreational angler is 365 days per year, based upon the recommendation of the EPA, which states that when evaluating risks from long term exposure events (such as fish consumption averaged over a year) a daily exposure frequency should be assumed (EPA, 1989a).

Exposure Duration

Consistent with EPA (1995a), exposures to COPC in sediments and surface soils from Greenfield Creek and the drainage ditch under the trespasser scenario were evaluated assuming a conservative 10 year exposure duration, representative of an adolescent between the ages of seven and sixteen.

The exposure duration selected under the construction/utility repair worker scenario was assumed to be 1 year.

Lastly, an exposure duration of 30 years was used for the adult recreational angler scenario, which represents the 90th percentile of the number of years an individual remains at the same residence (EPA, 1989b).

Body Weight

In accordance with EPA (1995a) guidance, a default body weight of 45 kg was used in assessing risks to adolescents under the trespasser scenario. Under the construction/utility repair and recreational angler scenarios, both of which entail adult receptors, a default body weight of 70 kg was used (EPA, 1989a).

Averaging Time

For carcinogens, consistent with EPA (1991a) guidance, dose rates were averaged over a lifetime of 70 years or 25,550 days for all exposure pathways within each scenario. Conversely, for chronic noncarcinogenic effects, the appropriate averaging period of exposure for each receptor group is equal to the receptor's exposure duration (in years) multiplied by 365 days (per year). In essence, noncancer effects are averaged over the actual period of exposure, not a lifetime of 70 years, e.g. exposure intakes under the trespasser scenario were averaged over 10 years, corresponding to the seven to sixteen year age range of the child receptor, whereas adult exposure intakes under the construction/utility repair and recreational fishing scenarios were averaged over the specific time periods corresponding to the activity under consideration (one year for the occupational scenario, and 30 years under the recreational fishing scenarios).

Exposure frequencies and durations, body weights, and averaging times were held constant when used in assessing the additional pathways under each scenario described below.

4.3.3.2 Dermal Contact with Soil/Sediment

Dose rate (mg/kg-day) = Cs x Sa x Af x Bf x Ef x Ed x Daf x Cf x 1/Bw x 1/At
where,

Sa = Exposed skin surface area (cm^2)
Af = Dermal adherence factor (mg/cm^2)
Daf = Dermal absorption factor (unitless)

Exposed Skin Surface Area

For the purpose of assessing dermal exposures to both creek surface soils and sediments under the trespasser scenario, a total exposed surface area of 3,630 cm^2 was derived. This value includes the

feet, lower legs, hands and forearms of the hypothetically exposed child, (assuming that children who play at the creek are likely to wear shorts, short sleeved shirts, and sandals or bare feet) and represents 33% of the total body surface area (EPA, 1992a).

The exposed skin surface area used to evaluate dermal exposures to surface and subsurface soils under the construction/utility repair worker scenario is 2,700 cm^2. This value includes the hands, forearms, and face of the exposed worker, (assuming that workers will wear long sleeved shirts, pants and work boots) and represents 15% of the total skin surface area of 18,000 cm^2, which is the average total skin surface area for adult males and females (EPA, 1992a).

Dermal Adherence Factors

Adherence of Site soils and sediments to exposed skin is integral to the assessment of dermal exposure to these impacted media. In assessing dermal exposures to high end exposed individuals under the trespasser and construction/utility repair worker scenarios, ChemRisk used the upper end (1.0 mg/cm^2-day) of the range of default soil adherence factors of 0.2 to 1.0 mg/cm^2-day (EPA, 1995b). For the typically exposed individuals within each scenario, the average of the range cited by EPA, (1995b) (0.51 mg/cm^2-d) was used.

Dermal Absorption Factor

Dermal absorption factors are chemical-specific coefficients that describe the percentage of a compound absorbed following contact of the outer skin layer with a contaminated media such as soils or sediments. Consistent with EPA (1995a) guidance, dermal absorption factors of 1.0 for organic compounds, and 0.1 for inorganic compounds were used in this assessment, under both the trespasser and construction/utility repair worker scenarios. For the landfarm, a dermal absorption factor of 0.03 recommended by EPA (1992c) was used to estimate dermal exposure to 2,3,7,8-TCDD by the landfarm worker.

All other exposure parameters are identical to those used under the soil/sediment ingestion pathways described above.

4.3.3.3 Dermal Contact with Groundwater

Dermal Contact with Groundwater

Dose rate (mg/kg-day) = Cgw x Sa x Bf x Ef x Ed x Et x Dpc x Cf x 1/Bw x 1/At

where,

Cgw = Concentration in groundwater (mg/l)

Dpc = Dermal permeability coefficient (cm/hr)

Et = Exposure time (hrs/day)

Exposed Skin Surface Area

In assessing dermal contact with groundwater, it was assumed that only the hands, upper arms, and forearms of the worker would be exposed (representing a total surface area of 3480 cm^2), under the assumption that boots and waders would limit exposures to other parts of the body.

Dermal Permeability Coefficient

Dermal permeability coefficients are chemical specific values that describe the rate at which a chemical passes through skin following exposures via an aqueous media. The rates are driven primarily by the log of the chemicals octanol/water partition coefficient (log Kow), and its molecular weight. The dermal permeability coefficients used in this assessment are proposed for use in conducting exposure assessments to impacted aqueous media by EPA (1992c), and are provided in Table 4-9.

Exposure Time

It was assumed that the exposure time related to groundwater exposure was limited to 2 hrs/day. Although it is unlikely that concurrent exposures to subsurface soils and groundwater would occur (the groundwater would wash off any adhered subsurface soils), the exposure time related to subsurface soil exposure was conservatively not reduced.

All other parameters are identical to those described under the soil/sediment ingestion pathways described above.

4.3.3.4 Inhalation of Soil Particles

Dose rate (mg/kg-day) = Cs x Ihr x Et x Ef x Ed x Bf x Ldf x 1/PEF x /Bw x 1/At
where,

Ihr = Inhalation rate (m^3/hr)
LdF = Lung Deposition Fraction (unitless)
PEF = Particle Emission Factor (m3/kg)

Inhalation Rate

Inhalation of surface soils particles by adolescents under the trespasser scenario was evaluated using an inhalation rate of 15 m^3/d (EPA, 1995a). Under the adult construction/utility repair worker scenario, a rate of 20 m^3/day was used to assess inhalation exposures to soil particles and vapors, as well as COPC volatilized from groundwater (EPA, 1989b). Both rates were converted to hourly intakes, so that adolescent inhalation intakes were expressed as 1.9 m^3/hr, and adult intakes as 2.5 m^3/hr. These hourly intakes were then multiplied by the exposure time (in units of hrs/day) corresponding to the activity under consideration.

Exposure Time

Under the construction/utility repair worker scenario, an exposure time of 8 hrs, corresponding to a full work day, was assumed. Inhalation exposures under the adolescent trespasser scenario, on the other hand, were assessed assuming an exposure time of 4 hrs.

Lung Deposition Fraction

Following inhalation of airborne respirable particles, a portion of the particles will be exhaled and a fraction will be retained in the lungs. Of the fraction inspired, approximately 25 percent of the particles are exhaled, 25% are deposited in the lower respiratory tract (of which half, 12.5 percent, are eliminated from the lungs and swallowed), and 50 percent are deposited in the upper respiratory tract and swallowed (ICRP, 1975; EPA, 1984; Paustenbach et al., 1992). These values result in a lung deposition fraction of 0.125, and an ingestion fraction of 0.625. The ingested fraction of the inhaled respirable particles is accounted for in the soil ingestion rate, as discussed above in Section 4.3.3.1.

Particle Emission Factor

In evaluating inhalation of soil particles under the industrial scenario, the conservative particle emission factor (PEF) of 4.63E+9 m^3/kg was used to relate the constituent concentration in soil with the concentration of respirable particles (Particulate matter $\leq$ 10 microns in size [PM10]) in the air resulting from fugitive dust emissions (EPA, 1991a). The use of this default value is considered conservative, as its derivation assumes surface conditions in which there is minimal vegetative cover, and a "relatively continuous and constant potential for emission over an extended period of time" (EPA, 1991a).

4.3.3.5 Inhalation of Soil Vapors

Dose rate (mg/kg-day) = Ihr x Et x Ef x Ed x Bf x 1/Vf x 1/Bw x 1/At

where,

Vf = Volatilization Factor (m^3/kg)

Volatilization Factor

Chemical-specific volatilization factors (VFs) were used to estimate vapor phase concentrations of subsurface and surface soil COPC. The VFs calculated for each compound are based upon the Hwang and Falco (1986) model developed by EPA's Exposure Assessment Group (EPA, 1991b). The use of the VF is conservative, as it assumes that the constituent concentration in the soil derives from an infinite reservoir that is homogenous in both the surface and subsurface soil columns, and that the contaminated material is not covered by a clean surface layer. Consistent with EPA guidance (1991a), volatilization of soil COPC was only considered for compounds with a molecular weight of less than 200, and a Henry's Law Constant greater than 1.0E-5 atm-m^3/mole.

Inhalation rates and exposure times used in the assessment of inhalation of soil vapors, are identical to those evaluated under the inhalation of soil particle pathway analysis described above.

4.3.3.6 Inhalation of Groundwater Vapors

Inhalation of Groundwater Vapors

Dose rate (mg/kg-day) = Vp x Ihr x Et x Ef x Ed x Bf x 1/Bw x 1/At

where,

Vp = Vapor Concentration (mg/m^3)

The inhalation rate used under the inhalation of groundwater vapors pathway is the same as that used under the inhalation of particles described above. Furthermore, the exposure time is the same as that used under the dermal exposure to groundwater pathway.

4.3.3.7 Fish Ingestion

Fish Ingestion

Dose rate (mg/kg-day) = Cfi x Ir x Ef x Ed x Cf x 1/Bw x 1/At

where,

Cfi = Concentration in fish (mg/kg)
Cf = Conversion factor (kg/g)

Ingestion Rate

Two consumption rates were used in assessing risks from fish ingestion to anglers. For the high end exposed individuals, a rate of 30 g/day was used which represents the average annual fish consumption rate for recreational fishermen based upon the data of Puffer et al. (1981) and Pierce et al. (1981), as cited by EPA (1989a). The rate used to evaluate the typically exposed individuals was 6.5 g/day, which is the value most often used by EPA as the per capita estimate of freshwater and estuarine fish and shellfish consumption by the general population. This estimate is based on the National Purchase Diary Fish Consumption Survey (EPA, 1980; Olsen, 1988).

All other parameter point estimates used in the exposure equation for fish ingestion under the adult recreational angler scenario are discussed further in Section 4.3.3.1.

Figure 4-1. SWP Wilmington HHRA Conceptual Site Model

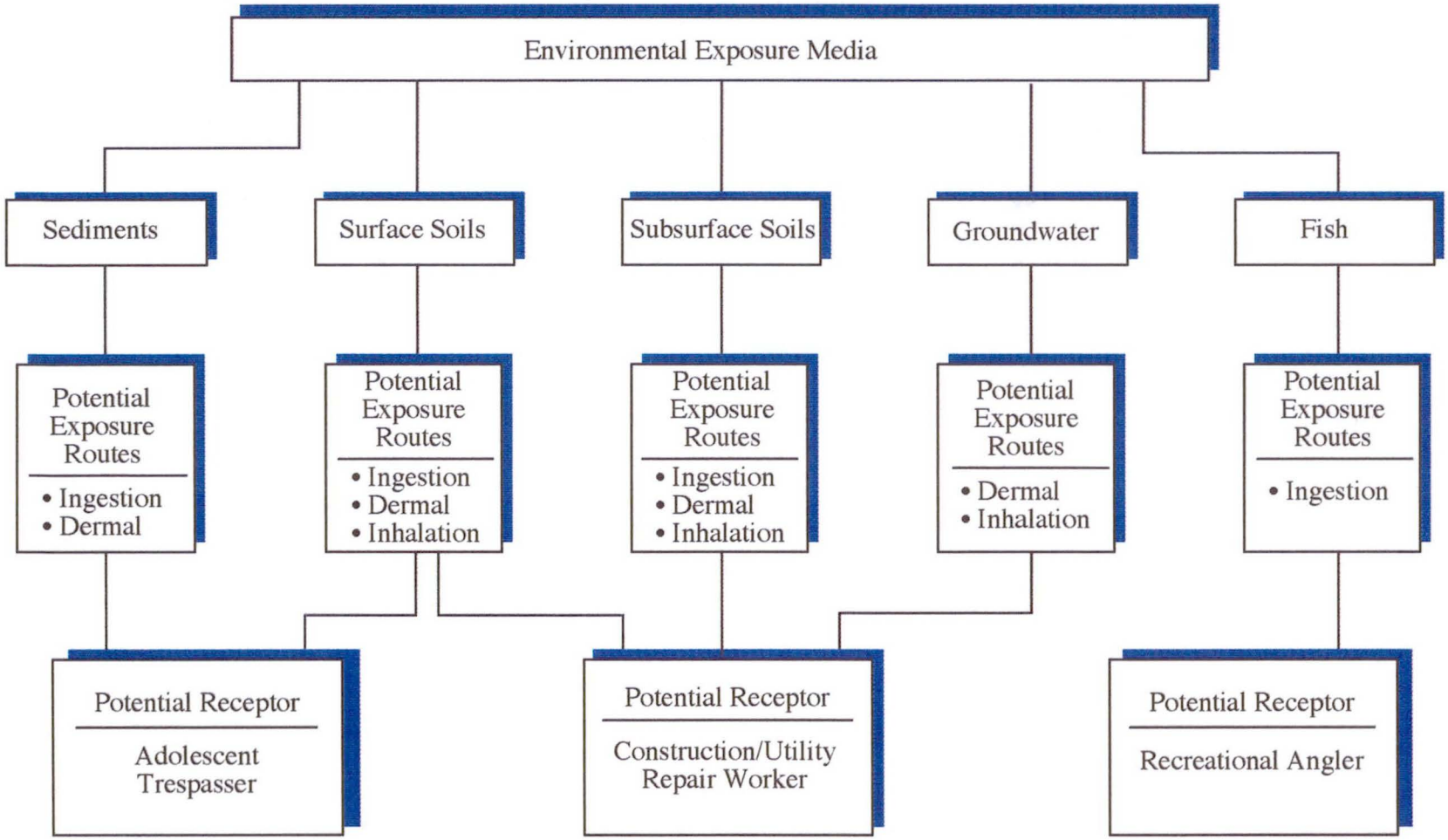

Table 4-1. Point Estimate Exposure Parameter Values for the Adult Construction/Utility Scenario

Pathway	Parameter	Value	Units	Source
All Pathways	Body Weight	70	kg	EPA, 1991a
	Averaging Time, Carcinogen	25550	d	EPA, 1991a
	Averaging Time, Noncarcinogen	365	d	EPA, 1991a
	Exposure Duration	1[a]	yr	Assumed
Ingestion of Surface Soils	Soil Ingestion Rate (High End)	100	mg/d	EPA, 1995a
	Soil Ingestion Rate (Typical)	50	mg/d	EPA, 1995b
	Exposure Frequency	220[a]	d/yr	Assumed
Dermal Contact Surface Soils	Dermal Adherence Factor (High End)	1	mg/cm^2-d	EPA, 1992c
	Dermal Adherence Factor (Typical)	0.51	mg/cm^2-d	EPA, 1992c
	Skin Surface Area	2700[b]	cm^2	EPA, 1989b
	Exposure Frequency	220[a]	d/yr	Assumed
	Absorption Coefficient	Chemical Specific	Unitless	EPA, 1995a
Inhalation of Surface Soil Particles	Inhalation Rate	20	m^3/d	EPA, 1991a
	Particulate Emmission Factor	4.63E+09	mg/m^3	EPA, 1989b
	Exposure Frequency	220[a]	d/yr	Assumed
	Absorption Coefficient	1[a]	Unitless	Assumed
	Lung Deposition Fraction	0.125	Unitless	EPA, 1984
Inhalation of Surface Soil Vapors	Inhalation Rate	20[a]	m^3/d	EPA, 1989a
	Volitilization Factor	Chemical Specific[a]	Unitless	Derived
	Exposure Frequency	220[a]	d/yr	Assumed
	Exposure Time	8	hrs	EPA, 1991a
	Absorption Coefficient	1[a]	Unitless	Assumed
Ingestion of Subsurface Soils	Soil Ingestion Rate	480[b]	mg/d	EPA, 1989b
	Exposure Frequency	30[a]	d/yr	Assumed
Dermal Contact with Subsuface Soils	Dermal Adherence Factor (High End)	1	mg/cm^2-d	EPA, 1992c
	Dermal Adherence Factor (Typical)	0.51	mg/cm^2-d	EPA, 1992c
	Skin Surface Area	2700[b]	cm^2	EPA, 1989b
	Absorption Coefficient	Chemical Specific	Unitless	EPA, 1994
	Exposure Frequency	30[a]	d/yr	Assumed
Inhalation of Subsurface Soil Particulates	Inhalation Rate	20	m^3/d	EPA, 1991a
	Particulate Emmission Factor	4630000000[b]	mg/m^3	EPA, 1989b
	Absorption Coefficient	1[a]	Unitless	Assumed
	Exposure Frequency	30[a]	d/yr	Assumed
	Exposure Time	8	hrs	EPA, 1991a
	Lung Deposition Fraction	0.125	Unitless	EPA, 1984
Inhalation of Subsurface Soil Vapors	Inhalation Rate	20[a]	m^3/d	EPA, 1989b
	Volitilization Factor	Chemical Specific[b]	m^3/kg	EPA, 1989b
	Exposure Frequency	30[a]	d/yr	Assumed
	Exposure Time	8	hrs	EPA, 1991a
	Absorption Coefficient	1[a]	Unitless	Assumed
Dermal Contact with Groundwater	Skin Surface Area	3480[bc]	cm^2	EPA, 1989b
	Dermal Permeability Constant	Chemical Specific	cm/hr	EPA, 1992c
	Exposure Frequency	30[a]	d/yr	Assumed
	Exposure Time	2[a]	hr/d	Assumed
Inhalation of Groundwater	Air Concentration	Chemical Specific[a]	mg/m^3	Modelled
	Inhalation Rate	20[a]	m^3/d	EPA, 1989a
	Exposure Frequency	30[a]	d/yr	Assumed
	Exposure Time	8[a]	hrs	Assumed
	Absorption Coefficient	1[a]	Unitless	Assumed

a. See discussion in text (Section 4.3.2)

b. Hands, forearms, and face (18,000 cm^2 total surface area x 15%)

c. Upper arms, forearms, hands

Table 4-2. Exposure Parameters for the Hypothetical Trespasser (Adolescent 7 - 16 years of age)

Pathway	Parameter	Value	Units	Source
All Pathways	Body Weight	45	kg	EPA, 1995a
	Averaging Time, Carcinogen	25550	d	EPA, 1991a
	Averaging Time, Noncarcinogen	3650	d	EPA, 1991a
	Exposure Frequency	18[a,d]	d/yr	Assumed
	Exposure Duration	10	yr	EPA, 1995a
	Fraction from Contaminated Source	1	Unitless	Assumed
Sediment Ingestion	Sediment Ingestion Rate (High End)	50[c]	mg/d	EPA, 1995a
	Sediment Ingestion Rate (Typical)	25[c]	mg/d	EPA, 1995a
	Absorption Coefficient	1[d]	Unitless	Assumed
Dermal Contact with Soils and Sediments	Dermal Adherence Factor (High End)	1	mg/cm^2-d	EPA, 1992c
	Dermal Adherance Factor (Typical)	0.51	mg/cm^2-d	EPA, 1992c
	Skin Surface Area	3630[b]	cm^2	EPA, 1989b
	Absorption Coefficient	Chemical Specific	Unitless	EPA, 1995a
Soil Ingestion	Soil Ingestion Rate (High End)	50[c]	mg/d	EPA, 1995a
	Soil Ingestion Rate (Typical)	25	mg/d	EPA, 1995b
	Absorption Coefficient	1[d]	Unitless	Assumed
Inhalation of Soil Particles	Inhalation Rate	15	m^3/d	EPA, 1995a
	Particulate Emission Factor	4.63E+09	m^3/kg	EPA, 1989b
	Lung Deposition Fraction	0.125	Unitless	EPA, 1984
	Exposure Time	4[d]	hrs	Assumed
	Absorption Coefficient	1[d]	Unitless	Assumed
Inhalation of Surface Soil Vapors	Inhalation Rate	15	m^3/d	EPA, 1995a
	Volatilization Factor	Chemical Specific	m^3/kg	EPA, 1989b
	Exposure Time	4[d]	hrs	Assumed
	Absorption Coefficient	1[d]	Unitless	Assumed

a. Two days/month, 9 months/year

b. Feet, hands, forearms, lower legs (11,000 cm^2 total surface area x 33%)

c. The soil ingestion rate of 100 mg/day is divided evenly between soils and sediments as it is assumed that approximately half the exposure is to soils (50 mg/day) and half to sediments (50 mg/day)

d. See text for explanation

Table 4-3. Exposure Parameters for the Adult Recreational Angler Scenario

Pathway	Parameter	Value	Units	Source
Fish Consumption	Body Weight	70	kg	EPA, 1991a
	Averaging Time, Carcinogen	25550	d	EPA, 1991a
	Averaging Time, Noncarcinogen	10950	d	EPA, 1991c
	Exposure Frequency	365	d	Assumed
	Exposure Duration	30[a]	yr	Assumed
	Fish Consumption Rate (High End)	30	g/d	EPA, 1989b
	Fish Consumption Rate (Typical)	6.5	g/d	EPA, 1980

a. See text for explanation

Table 4-4. Calculation of EPC's for COPC Volatilized from Groundwater

Chemical Name	Chemical Concentration in Groundwater, C_{Li} (mg/l)		Chemical Concentration in Groundwater, C_{Li} (g/cm^3)		Molecular Wieght, MW	Henry's Law Constant, H_i	Liqud-Phase Mass Transfer Coeeficient, k_{iL}	Gaseous-Phase Mass Transfer Coeeficient, k_{iG}	Overall mass Transfer Coefficient, K_i	Flux of Chemical, i, from water surface, F_i (g/m2-s)		Exposure Point Concentration in Air Above Pool, C_{ai} (mg/m^3)	
	High End	Typical	High End	Typical	(g/gmol)	(atm-m^3/mol)	(cm/s)	(cm/s)	(cm/s)	High End	Typical	High End	Typical
Acenaphthene	4.00E-01	2.00E-01	4.00E-07	2.00E-07	154.2	1.55E-04	9.11E-04	4.06E-01	6.73E-04	2.69E-06	1.35E-06	2.69E-02	1.35E-02
Phenanthrene	2.80E-01	2.60E-01	2.80E-07	2.60E-07	178.2	2.26E-04	8.48E-04	3.86E-01	6.85E-04	1.92E-06	1.78E-06	1.92E-02	1.78E-02
Naphthalene	1.11E+00	6.60E-01	1.11E-06	6.60E-07	128.18	4.60E-04	9.99E-04	4.32E-01	8.90E-04	9.88E-06	5.87E-06	9.88E-02	5.87E-02
Benzene	9.00E-03[a]	6.00E-03	#VALUE!	6.00E-09	78.11	5.43E-03	1.28E-03	5.09E-01	1.27E-03	#VALUE!	7.59E-08	#VALUE!	7.59E-04

a. 95th UCL of log data < mean, assume data normally distributed

Table 4-5. Exposure Point Concentration (EPC) Estimates for Surface Soil (mg/kg)

Constituent	Number of Samples	Frequency of Detection %	Mean Concentration	Maximum Detected Concentration	95th UCL[a]	EPC[b]	
						High End	Typical
Acenaphthylene	61	15	0.27	2.5	0.30[c]	0.30	0.27
Arsenic	61	84	35	1300	41	41	35
Benzo(a)anthracene	61	72	3.4	59	5.3	5.3	3.4
Benzo(a)pyrene	61	66	2.5	28	3.9	3.9	2.5
Benzo(b)fluoranthene	61	87	7.0	60	14	14	7.0
Dibenz(a,h)anthracene	61	8.0	0.23	2.4	0.24	0.24	0.23
Indeno(1,2,3-cd)pyrene	61	48	1.1	10	1.4	1.4	1.1
Phenanthrene	61	44	1.8	54	2.4[c]	2.4	1.8

a. 95th upper confidence limit on arithmetic mean of log transformed data, except where noted below

b. EPC for the high end exposed individual selected as the minimum of either the 95th UCL or the maximum detected concentration. The EPC for the typical exposed individual is the arithmetic mean concentration.

c. 95th UCL of log data < mean, assume data normally distributed

Table 4-6. Exposure Point Concentration (EPC) Estimates for Subsurface Soil (mg/kg)

Constituent	Number of Samples	Frequency of Detection %	Mean Concentration	Maximum Detected Concentration	95th UCL[a]	EPC[b]	
						High End	Typical
Arsenic	39	67	8.6	110	15	15	8.6
Benzo(a)anthracene	39	46	24	800	26	26	24
Benzo(a)pyrene	39	39	10	290	15[c]	15	11
Benzo(b)fluoranthene	39	46	24	690	62	62	24
Carbazole	39	8.0	34	930	5.7	5.7	34
Indeno(1,2,3-cd)pyrene	39	23	2.9	88	4.4[c]	4.4	2.9
Phenanthrene	39	26	230	4400	300	300	230

a. 95th upper confidence limit on arithmetic mean of log transformed data, except where noted below.
b. EPC for the high end exposed individual selected as the minimum of either the 95th UCL or the maximum detected concentration. The EPC for the typical exposed individual is the arithmetic mean concentration.
c. 95th UCL of log data < mean, assume data normally distributed.

Table 4-7. Exposure Point Concentration (EPC) Estimates for Groundwater (mg/l)

Constituent	Number of Samples	Frequency of Detection %	Mean Concentration	Maximum Detected Concentration	95th UCL[a]	EPC[b]	
						High End	Typical
Arsenic	36	64	0.03	0.14	0.07	0.07	0.03
Chromium	20	100	0.08	0.67	0.12	0.12	0.08
Lead	31	84	0.05	0.39	0.11	0.11	0.05
Acenaphthene	67	45	0.20	3.0	0.4	0.4	0.20
Benzo(a)anthracene	67	10	0.02	0.42	0.03[c]	0.03	0.02
Benzo(a)pyrene	67	10	0.009	0.11	0.01[c]	0.01	0.009
Benzo(b)fluoranthene	98	9.2	0.01	0.21	0.02[c]	0.02	0.01
Carbazole	67	24	0.03	0.36	0.05[c]	0.05	0.03
Chrysene	67	10	0.02	0.34	0.03[c]	0.03	0.02
Fluoranthene	67	25	0.12	2.7	0.21[c]	0.21	0.12
Indeno(1,2,3)pyrene	67	6.0	0.006	0.04	0.007[c]	0.007	0.006
Naphthalene	67	27	0.66	14	1.11	1.11	0.66
Phenanthrene	67	39	0.26	5.8	0.28	0.28	0.26
Benzene	67	13	0.006	0.10	0.009[c]	0.009	0.006
Trichloromethanethiol	31	16	0.001	0.004	0.001	0.001	0.001

a. 95th upper confidence limit on arithmetic mean of log transfored data.

b. EPC for the high end exposed individual selected as the minimum of either the 95th UCL, or the maximum detected concentratio: The EPC for the typical exposed individual is the arithmetic mean concentration.

c. 95th UCL of log data < mean, assume data normally distributed.

Table 4-8. Exposure Point Concentration (EPC) Estimates for Greenfield Creek Sediments (mg/kg)

Constituent	Number of Samples	Frequency of Detection %	Mean Concentration	Detected Concentration	95th UCL[a]	EPC[b]	
						High End	Typical
Arsenic	14	50	1.8	5.2	3.6	3.6	1.8
Lead	16	100	45	290	190	190	45
Benzo(a)anthracene	14	79	56	730	800	730	55
Benzo(a)pyrene	14	64	50	680	380	380	50
Benzo(b)fluoranthene	14	43	130	1800	2000	1800	130
Chrysene	14	79	69	920	820	820	69
Dibenzo(a,h)anthracene	14	14	0.47	3.7	0.7	0.70	0.47
Indeno(1,2,3-cd)pyrene	14	36	49	680	220	220	50
Phenanthrene	14	43	15	70	2100	70	15

a. 95th upper confidence limit on arithmetic mean of log transformed data.

b. EPC for the high end exposed individual selected as the lower of either the 95th UCL, or the maximum detected concentration. The EPC for the typical exposed individual is the arithmetic mean concentration.

Table 4-9. Dermal Permeability Coefficients Used Under the Construction/Utility Repair Worker Scenario (cm^2/hr)[a,b,c]

Chemicals	
Acenaphthene	2.6E-01
Arsenic	1.0E-03
Benzo(a)anthracene	8.1E-01
Benzo(a)pyrene	1.2E+00
Benzo(b)flouranthene	1.2E+00
Carbazole	7.97E-02
Chromium	1.0E-03
Chrysene	8.1E-01
Flouranthene	3.6E-01
Indeno(1,2,3)pyrene	1.9E+00
Naphthalene	6.9E-02

a. Used in evaluating dermal exposures to groundwater only.
b. Dermal permeability coefficients only provided for compounds for which either non-carcinogenic or carcinogenic toxicity values were available.
c. All values obtained from EPA, 1992c.

5.0 RISK CHARACTERIZATION

Risk characterization is the process of estimating the incidence of health effects under the various conditions of human exposure described in the exposure assessment (NAS, 1983). A comprehensive risk characterization goes beyond the calculation and reporting of risk estimates and discusses the strength of evidence associated with the relevant hazard and dose-response information and evaluates (both qualitatively and quantitatively) the limitations and uncertainties associated with the exposure assessment (Preuss and Ehrlich, 1987; Paustenbach, 1989).

5.1 Estimation of Carcinogenic Risk

Upper-bound incremental lifetime cancer risks associated with potential human exposure to Site-related chemicals were estimated for each of the three exposure scenarios for which exposure was evaluated in Section 4.0. For each exposure pathway and receptor, risks were calculated by multiplying both typical and high end chemical-specific lifetime average daily intakes (LADIs), presented in Section 4.3.4, by the chemical-specific cancer slope factors (CSFs) described in Section 3.2.

$$\text{Risk} = \text{LADI} \times \text{CSF}$$

Where:

Risk = Lifetime incremental cancer risk (unitless)
LADI = Lifetime average daily intake (mg/kg-day)
CSF = Cancer slope factor $(\text{mg/kg-day})^{-1}$

Pathway- and chemical-specific risk estimates for the typical and high end exposed individuals for each scenario are compiled in Appendix B. Chemical-specific and total risks are summarized in Tables 5-1 and 5-2 for the typical and high end exposed individuals, respectively.

For the site wide construction/utility repair worker (excluding landfarm area), total theoretical cancer risks ranged from 1.5×10^{-5} (typical) to 1.9×10^{-5} (high end). For the landfarm construction/utility repair worker, total theoretical cancer risks ranged from 3.0×10^{-6} (typical) to 7.2×10^{-6} (high end). For the adolescent trespasser, total theoretical cancer risks ranged from 4.1×10^{-6} (typical) to 6.6×10^{-5} (high end). For the adult recreational angler, total theoretical cancer risks ranged from 8.4×10^{-6} (typical) to 3.9×10^{-5} (high end). These risk estimates all fall within the range of risks deemed by the EPA to be acceptable for CERCLA sites (EPA, 1990).

For the site wide construction/utility repair worker(non-landfarm), adolescent trespasser, and adult recreational angler, benzo(a)pyrene comprises the highest proportion of the risk for both the typical (63-73% of the total risk) and high end (58-77% of the total risk) exposed individuals. For the landfarm construction scenario, 2,3,7,8-TCDD equivalents accounted for 87% of the risk estimate for the typical exposed individual, and 81% for the high end exposed individual.

5.2 Estimation of Noncancer Hazard

The theoretical noncancer hazards associated with potential human exposure to Site-related chemicals were estimated for each of the three exposure scenarios for which exposure was evaluated in Section 4.0. For each exposure pathway and receptor, hazard quotients were calculated by dividing both typical and high end exposures for each COPC, expressed as average daily intakes (ADIs) calculated in Section 4.3.4, by the chemical-specific reference dose (RfD) described in Section 3.2.

$$HQ = ADI / RfD$$

Where:

HQ = Hazard quotient (unitless)
ADI = Average daily intake (mg/kg-day)
RfD = Reference dose (mg/kg-day)

Pathway- and chemical-specific HQs for the typical and high end exposed individuals for each scenario are compiled in Appendix B. Chemical-specific HQs and Hazard Indices (defined as the sum of the chemical-specific HQs for each scenario) are summarized in Tables 5-3 and 5-4 for the typical and high end exposed individuals, respectively.

For the site wide (non-landfarm) construction/utility repair worker, HIs ranged from 1.4×10^{-1} (typical) to 2.8×10^{-1} (high end). For the landfarm construction/utility repair worker, HIs ranged from 1.4×10^{-2} (typical) to 5.9×10^{-2} (high end). For the adolescent trespasser, HIs ranged from 3.6×10^{-3} (typical) to 8.7×10^{-3} (high end). Finally, for the adult recreational angler, noncancer risk estimates were not generated due to the lack of available noncancer health criteria. All of the above HIs are well below the value of one, which is considered by EPA to be the point of departure for evaluating noncancer hazards. Thus, COPC in Site media do not pose a significant noncancer health risk.

5.3 Uncertainty Evaluation

An important facet of the method and use of human health risk assessment concerns the recognition of uncertainties and limitations inherent in the process which arise in connection with dose-response models, animal to human extrapolation, chemical fate and transport, models of potential exposure, and site-specific characteristics. From a regulatory perspective, these uncertainties and limitations may be addressed by developing and employing assumptions which typically overestimate the magnitude of many variables. In this fashion, agencies charged with the protection of public health have often assumed that their mandate would best be met by overestimating potential risks from exposure to environmental constituents (Paustenbach, 1990). However, as our awareness of these uncertainties improves, along with our understanding of how to best characterize them, the result will almost certainly be risk assessments that are more credible and thus more useful to risk managers (Paustenbach, 1990; Keenan et al., 1994). To that end, recent EPA risk assessment guidance incorporates refinements in the treatment of uncertainty (EPA, 1992a). Following are discussions of the major sources of uncertainty associated with the present assessment.

5.3.1 Uncertainty Associated with Toxicity Values

There are a number of uncertainties associated with the toxicity values (RfDs and CSFs) used to estimate noncancer hazard and carcinogenic risk, such as the application of conservative dose response models, use of uncertainty factors, and the assumption that the effects associated with exposure to multiple chemicals is additive for all chemicals. The methods employed by the EPA to account for these uncertainties tend to side with protecting human health, as they should, and are therefore conservative, and more likely to overstate, than understate, actual risks. Following is a brief discussion of the key uncertainties associated with toxicity values.

Reference Doses and Hazard Quotient Estimates

Significant uncertainty is associated with the evaluation of noncarcinogenic effects of chemicals in the environment. Primary sources of uncertainty include the derivation and use of chemical-specific toxicity values and the limitations inherent in the hazard index methodology, such as the assumption of additivity for multiple chemical exposure and the inability of the hazard quotient to predict the likelihood of adverse effects occurring at doses above the RfD.

Toxicity values based on human epidemiological studies are not available for most chemicals, and in general human studies suffer from a lack of exposure data and any number of potential confounding factors, including concomitant exposure to multiple chemicals, recall bias, and lifestyle effects. Therefore, for many chemicals, data from studies of laboratory animals provide the basis for toxicity values. The practice of extrapolating effects observed in experimental animals to predict human toxic response to chemicals is a major source of uncertainty in risk assessment (EPA, 1989a).

An HQ is the ratio of the estimated average daily intake of a chemical to the RfD for that chemical (EPA, 1989a). Since the RfD is established at a dose level at and below which adverse effects would not be expected, an HQ at or below 1 is considered to be a level that would not result in an increased health risk (EPA, 1989a). Given that many environmental contamination situations involve exposure to more than one chemical, the HQs for the individual chemicals may be summed to determine an hazard index for the mixture. Therefore, an HI is typically defined as the sum of HQs for the individual chemicals of concern at the site. This approach assumes that exposures to multiple chemicals may result in adverse effects even if no single chemical exposure exceeds its RfD. As with single constituent exposures, an HI at or below 1.0 is regarded as unlikely to result in an increased health risk even for sensitive populations (EPA, 1989a).

EPA (1989a) guidance, specifying that individual HQs and total site HIs should not exceed a value of 1, represents conservative and health protective regulatory toxicological criteria. That is, an HI value greater than 1 does not necessarily indicate that adverse health effects are likely, because the RfD contains a measure of conservatism to ensure health protection, and as discussed further in this section, the summing of individual HQs assumes that the effects of exposure to multiple chemicals is additive. This is a highly conservative assumption because chemicals with different mechanisms of action or that elicit responses at different target sites may not be additive.

The development of RfDs is also a highly conservative process. RfDs are generally developed by dividing NOAELs from animal studies by "safety factors", to adjust for uncertainties in the

physiological differences between humans and laboratory animals, variation in sensitivity among individuals of human subpopulations, and differences between subchronic and chronic exposures. These safety factors are typically applied in multiples of 10 to NOAELs. Thus, when all three factors are combined, the resultant safety factor is equal to 1,000 (10 x 10 x 10) (Barnes and Dourson, 1988).

However, analysis of toxicological data indicate that a value less than ten for an individual safety factor may be adequate, depending on the relative magnitude of uncertainty associated with the critical study. For example, Lewis et al. (1990) reviewed the data from eighteen laboratory animal studies and found that the average difference between NOAELs based on subchronic exposures and NOAELs based on chronic exposures was a factor of 3.5 or less, not the default value of 10 that is typically applied. Similarly, a factor of 1 for extrapolation from laboratory animals to humans is appropriate if there are adequate data which indicate a likelihood that the test species is significantly more sensitive to the chemical-specific effect than humans.

In cases when the RfD is based on a study which reports a LOAEL but does not report a NOAEL, an additional safety factor is generally applied to the LOAEL to derive an estimated NOAEL. This safety factor may range from 1 to 10, depending upon the study and the severity of the effects observed. When Dourson and Starra (1983) compared LOAELs and NOAELs from a variety of studies that reported both, they found that 96 percent of those studies had LOAEL:NOAEL ratios of 5:1 or less. Based on their evaluation, Dourson and Starra (1983) concluded that a safety factor in the range of 1 to 10 is supportable for extrapolating from a LOAEL to a NOAEL. In addition, Dourson and Starra (1983) suggested that the severity of the effect is a critical determinant in establishing a LOAEL to NOAEL safety factor. For example, for liver necrosis, a relatively severe effect, a high safety factor value (i.e., 10) was suggested. However, for a less severe effect, such as fatty infiltration of the liver, which results in increased liver weight, a factor of 3 was suggested (Dourson and Starra, 1983).

There is regulatory precedent for use of safety factors totaling less than 1,000. For example, in calculating an RfD for 2,4-dichlorophenol, EPA applied an uncertainty (or safety) factor of 100 to the value reported as a NOAEL to account for extrapolation from animal data to humans and for protection of sensitive populations. In their recent derivation of an RfD for Aroclor 1254, the EPA applied a safety factor of 300 to the LOAEL observed in the critical study. EPA justified the safety factor of 300 by reasoning that a 10-fold factor for interspecies differences was unnecessary due to similarities between humans and monkeys; only a "partial factor" was needed to account for use of

a LOAEL because the effect (nail bed changes) was not considered serious, and a "reduced" factor for extrapolation from subchronic to chronic exposure was adequate because the critical effects did not appear to be dependent upon the duration of the study. Thus, the uncertainty factor of 300 applied by EPA in this case was significantly lower than the safety factor of 10,000 which would have resulted if four individual uncertainty factors of 10 had been combined. While there are indications that EPA is moving away from the use of default factors of 10 for addressing uncertainty during the derivation of RfDs, as illustrated in the Aroclor 1254 example, many of the RfDs developed in the past by EPA were based on limited information and analyses. As such, many RfDs are overly conservative and may overstate the noncancer hazard by one or more orders of magnitude (Lewis et al., 1990).

Cancer Slope Factors and Risk Estimates

In establishing cancer slope factors, regulatory agencies implement methods that introduce multiple sources of uncertainty that ultimately increase the overall conservatism inherent to the cancer risk estimates. Major uncertainties exist in the extrapolation from animals to humans and from high doses to low doses (EPA, 1986). For example, species differ substantially in their uptake, metabolism, organ distribution, and target-site susceptibility of carcinogens. While laboratory animals are exposed to controlled concentrations at extremely high doses, humans are typically exposed to lower environmental levels (Crump et al., 1989). In addition, the potency of a chemical is influenced by the size and lifespan of the species experimentally exposed. This has important implications due to the long latency period of many carcinogenic responses. An individual's susceptibility to a carcinogenic compound is also influenced by the variability that exists within human populations. Variables include genetic constitution, diet, occupational and home environments, activity patterns, and other cultural factors (EPA, 1986).

To compensate for these various sources of uncertainty in the dose response assessment, conservatism is incorporated into the derivation of the slope factor. The slope factor represents the upper 95th percent confidence limit on the probability of a carcinogenic response per unit intake of a chemical over a lifetime (EPA, 1989a). In other words, there is only a five percent chance that the probability of a response would be greater than the estimated value. Therefore, slope factors, by definition, overestimate the actual potency of a carcinogen. The accuracy of risk estimates associated with low doses and predicted by the LMS model is unknown, but may in fact be zero (EPA, 1986).

Use of Relative Toxicity Values

As described by EPA (1989a), there is significant uncertainty associated with the use of relative toxicity values, such as toxicity equivalency factors (TEFs), upon which the CSFs for several PAHs are based (EPA, 1993b). For several of these PAHs, it has been assumed that they are carcinogenic because the compound was found to be a component of creosote, which comprises a mixture of PAHs and other organic chemicals, including benzo(a)pyrene. Creosote has been shown to be carcinogenic in laboratory animals. In order to estimate the relative potency of these PAHs, EPA (1993b) derived TEFs for each compound based on its predicted toxicity relative to benzo(a)pyrene. The information used to derive TEFs include primarily structure-activity relationships and results from *in vitro* bioassays used to assess a variety of biochemical responses in cell cultures, such as enzyme induction. Because of the high degree of uncertainty (1) as to whether the compound is actually carcinogenic and (2) associated with the assignment of TEFs based on noncancer endpoints, the CSFs for these PAHs should be viewed as highly conservative.

Additivity of Risk and Hazard

A high level of uncertainty is associated with predicting adverse effects associated with exposure to multiple chemicals. For evaluation of cumulative effects from exposure to multiple chemicals, EPA (1989a) recommends that risks be summed across chemicals for each exposure pathway. This assumption does not account for dissimilarities in mechanisms of action or synergistic or antagonistic effects, but is considered appropriate for screening levels analyses (EPA, 1992a). For certain combinations of chemicals, such as carcinogenic PAHs, this may be appropriate, but for other chemical combinations, such as chromium and PAHs, this is probably not appropriate. Chromium is known to be carcinogenic in humans only through the inhalation route and only in the lungs. Benzo(b)fluoranthene, however, has only produced skin tumors in laboratory animals following direct application. There is no evidence that exposure to benzo(b)fluoranthene causes lung cancer and no evidence that chromium exposure causes skin tumors. Therefore, assuming additivity of these two chemicals may not be appropriate, and is most certainly conservative. In general, assuming additivity for all Site-related chemicals is a highly conservative assumption that most likely overstates the actual risks.

5.3.2 Exposure Parameters and Assumptions

Following EPA (1992a) exposure assessment guidelines, LADIs and ADIs were estimated for the typical and high end exposed individuals. In both cases, a series of upper-bound, generic exposure factors and assumptions were used to estimate exposures. The typical and high end exposures differ

to the extent that the high end exposures used several parameter values that are taken from the high end of the range of parameter values, whereas for the typical exposed individual, values nearer the mean of the range of values were used to evaluate exposures.

Combining a series of upper-bound parameter values in the exposure equations, results in LADI and ADI estimates that are highly conservative and which may overestimate actual exposures. While there is some degree of uncertainty associated with all the exposure parameters used to evaluate exposure to Site chemicals, only those parameters and assumptions used for those exposure pathways that account for the greatest proportion of risk are described below. These include dermal contact with groundwater, soils, and sediments, and incidental ingestion of soils and sediments.

Dermal Contact with Groundwater

Dermal contact with groundwater was only evaluated under the site wide construction/utility repair worker scenario, and accounted for the greatest proportion of the total risk for this scenario, even though the soil EPCs were, in general, significantly higher than groundwater EPCs, and the exposure frequency for groundwater exposure was only 30 days/year as compared to 220 days/year for soil exposure. The principal reason that risks were greatest for dermal exposure to groundwater is the relative difference in water and soil dermal absorption coefficients for individual chemicals. For example, for PAHs, the absorption coefficients for water are about an order of magnitude greater than those for soil. According to EPA (1992c), there may be as much as an order of magnitude of uncertainty associated with these absorption coefficients.

In addition, dermal exposure to groundwater was assumed to occur two hours each day for 30 days. Combined, the total amount of time the skin is immersed in groundwater is 60 hours, all assumed to occur within a 30 day period of time. The skin surface exposed to groundwater during construction/repair activities was assumed to include the upper arms, forearms, and hands. It is highly unlikely that all skin surface assumed for this scenario would be immersed for the entire 60 hours. These assumptions are highly conservative, and as such, likely result in estimated exposures and risks that may not be realistic.

Dermal Contact with Soils and Sediment

The key parameters for assessing dermal contact, for which a high degree of uncertainty exists, are dermal adherence factors as used in combination with the dermal absorption coefficients. Dermal coefficients are generally based on 12 to 24 hour studies of chemical absorption in laboratory animals. In the exposure assessment, it was assumed that an adolescent trespasser may be exposed

to surface soils or sediments for four hours on each of 18 days per year. Use of the dermal adherence factor (mg/cm^2-event) in the exposure formula, assumes that each day is an event, and because a dermal absorption coefficient is used in combination with the dermal adherence factor, the time period of each event is by definition between 12 and 24 hours. As noted above, the total amount of time a trespasser is likely to be on-Site per day is only four hours. It is unlikely that anyone would carry a constant amount a either sediment or soil on their skin for 12 to 24 hours. Soil or sediment may be intentionally washed from the skin or will likely be removed incidently through a variety of mechanisms. For each dermal contact exposure event, actual adherence to the skin is likely to span only an additional two to four hours following initial exposure, for a total of six to eight hours. Therefore, the inherent use of the dermal adherence factor, in combination with the dermal absorption coefficients which are based on 12 to 24 hours studies, is highly conservative and likely to result in exposure estimates that are significantly overstated.

Ingestion of Soils and Sediments

For the construction/utility repair worker scenario, the typical and high end surface soil ingestion rates used were 50 and 100 mg/day, respectively. For subsurface soils, the typical and high end soil ingestion rate was 480 mg/day, as recommended by EPA (1989a) for construction scenarios. For the adolescent trespasser scenario, soil ingestion rates of 50 and 100 mg/day were used for the typical and high end exposures, as recommenced by EPA (1989a; 1995a). The latter two soil ingestion rates are based on elemental soil tracer studies, as described in Section 4.3.3.1, and form a reasonably sound basis for estimating soil ingestion by children and adolescents. However, for adult soil ingestion, there is little information on the amounts of soils that adults actually consume. For example, the rate of 480 mg/day for construction workers is taken from a study by Hawley (1985) who based the estimate on an assumed rate of hand to mouth contact by adults together with an assumption about the amount of soil adhered to the hands of construction workers. EPA (1989b) has indicated that for short exposure durations, this value may be reasonable, however, it is unlikely that soils would be ingested at such a high rate throughout the duration of a construction project. In this assessment, it was assumed that the construction worker/utility repair worker ingested soil at a rate of 480 mg/kg throughout the entire 30 day exposure duration. Use of this soil ingestion rate for the entire exposure duration is therefore conservative and will likely overestimate actual exposures.

Exposure Point Concentrations

There is a high degree of uncertainty associated with the assumption that chemical concentrations in environmental media will remain constant over the entire exposure period. It is likely that

concentrations will decrease over time with natural degradation and attenuation processes. In addition, there is a high degree of variability in the distribution of constituents across the Site, and the probability of exposures to Site constituents at concentrations correlating to the 95% upper confidence limit (UCL) on the mean are small. Random exposure to Site constituents will more likely result in average exposures that reflect concentrations nearer the mean concentration than the 95% UCL concentration. Therefore, use of the 95% UCL to estimate high end exposures is likely to overstate actual exposures.

In summary, for each exposure pathway, most parameter values used to estimate exposure were upper-bound values, which when combined in the exposure equations, result in exposure estimates that may not be realistic and most certainly overestimate actual exposures. When evaluating the results of the risk assessment, these uncertainties must be considered to the extent that for all pathways, it is much more likely that exposures and risks have been overstated, not understated. It is also important to consider what these theoretical risk estimates mean in perspective with the range of risks deemed acceptable by regulatory agencies as well those risk encountered by the general public as a result of everyday activities. These issues are discussed in the following section.

5.4 Perspective on Risk

In the risk assessment and risk management fields, health risks are defined as an estimate of the probability that a given exposure to an agent in a particular environmental setting will result in an adverse health effect (NAS, 1983; Paustenbach, 1989). Adverse health effects may include death (mortality), illness (morbidity), or injury to individuals or a population as a whole (Graham, 1990). Historically, regulatory policy has been directed toward identifying and managing risks posed by carcinogens (EPA, 1986). A key justification for concerns over carcinogens likely stems from the fact that approximately one of every three individuals in the United States will be diagnosed with some form of cancer during their lives (i.e., a cancer incidence rate of 33%) (ACS, 1993). While noncancer effects (e.g., reproductive, immunological, etc.) have been the subject of heightened regulatory concern, carcinogens remain the highest priority.

An individual cancer risk value is an estimate of the probability that an individual member of a population will develop cancer as a result of a lifetime of exposure to a cancer-causing agent. Considering that the cumulative incidence of cancer in the U.S. population is about 33%, or 330,000 cases of cancer in 1,000,000 people (ACS, 1993), an individual exposed to a chemical over the course of his or her lifetime resulting in an estimated incremental cancer risk level of 1 in 1,000,000

is equivalent to stating that the lifetime total cancer risk for this person is not greater than 330,001 chances in 1,000,000 (33.0001%) rather than 330,000 in 1,000,000 (33.000%). Clearly, the significance of 330,001 in 1,000,000 as compared to 300,000 in 1,000,000 is not in itself compelling.

The foundation for risk management decisions is the selection of a cancer risk criterion which is considered to be either acceptable or *de minimis* with respect to the protection of public health and the environment. The term *de minimis* risk is used by risk assessors and regulators to define insignificant risks, or those risks that are not of regulatory concern (Travis et al., 1987). In actuality, a *de minimis* risk should be characterized as one that is judged by society to be of negligible public health concern and too small to justify the expenditure of limited risk management resources (Whipple, 1989). Oftentimes the terms acceptable risk or *de minimus* risk are used interchangeably.

The National Contingency Plan (NCP) under CERCLA establishes a target cancer risk range of 1×10^{-6} to 1×10^{-4} for generally acceptable risks at Superfund sites (EPA, 1990). In establishing this risk range, the EPA rejected the argument that a risk range, rather than a single risk criterion, does not adequately protect health and the environment (EPA, 1990). The EPA noted that, "CERCLA does not require the complete elimination of risk"; rather, remedies comply with CERCLA "when the amount of exposure is reduced so that the risk posed by constituents is very small (i.e., at an acceptable level.) EPA's risk range of 1×10^{-6} to 1×10^{4} represents EPA's opinion on what are generally acceptable levels" (EPA, 1990). The EPA (1990) recommends that, after starting at an incremental cancer risk of 1×10^{-6}, selection of appropriate risks within the range should be based on "consideration of a variety of site-specific or remedy-specific factors." The appropriate factors include, but are not limited to, exposure factors, uncertainty factors, and technical factors (EPA, 1990):

> Included under exposure factors are: the cumulative effect of multiple constituents, the potential for human exposure from other pathways at the site, population sensitivities, potential impacts on environmental receptors, and cross-media impacts of alternatives. Factors related to uncertainty may include: the reliability of alternatives, the weight of scientific evidence concerning exposures and individual and cumulative health effects, and the reliability of exposure data. Technical factors may include: detection/quantification limits for constituents, technical limitations to remediation, the ability to monitor and control movement of constituents, and background levels of constituents.

As discussed in Section 5.3, a high degree of uncertainty is inherent to this risk assessment resulting primarily from the use of conservative exposure assumptions and the use of upper-bound exposure

parameters and toxicity values. As such, exposure and risk estimates must be considered upper-bound estimates because of the multiplicative effect of combining these parameter values and assumptions in the exposure and risk equations. Therefore, estimated risks falling within the range of 1×10^{-6} to 1×10^{-4} should be considered negligible with respect to potential human cancer risk. Given the fact that an incremental risk level of 1×10^{-4} would indicate that a given lifetime exposure would increase the potential lifetime cancer risk from approximately 33% to 33.01%, the range of risks estimated for this risk assessment (3.0×10^{-6} to 6.6×10^{-5}) are clearly insignificant.

5.5 Conclusions

In this risk assessment, theoretical upper-bound incremental lifetime cancer risks and noncancer hazards were evaluated for three hypothetical future use scenarios at the Site: construction/utility repair worker (site wide and landfarm only), adolescent trespasser, and recreational angler. All noncancer hazards were well below a hazard index of 1, indicating that Site-related constituents do not pose a noncancer human health hazard. Carcinogenic risks for the typical exposed individual were estimated within the range of 3.0×10^{-6} to 1.5×10^{5} , and risks for the high end exposed individual were estimated within the range of 7.2×10^{-6} to 6.6×10^{-5}). Exposure and risk estimates were calculated using a series of conservative assumptions and upper-bound exposure and toxicity values. Therefore, these risks should be viewed as upper-bound estimates, and when compared to the range of risks (1×10^{-6} to 1×10^{-4}) deemed acceptable for hazardous wastes by the EPA (1990), it can be concluded that human health risks associated with the SWP Site are negligible.

Table 5-1. Summary of Carcinogenic Risks[a] for the Typical Exposed Individual

	Construction Worker/Utility Repair Worker		Landfarm Worker		Adolescent Trespasser		Adult Recreational Angler	
Chemicals	Risk	Percentage of Total Risk	Risk	Percentage of Total Risk	Risk	Percentage of Total Risk	Risk	Percentage of Total Risk
2,3,7,8-TCDD	-	-	2.6E-06	87	-	-	-	-
Arsenic	4.4E-07	3.0	9.3E-08	3.1	2.3E-07	5.6	-	-
Benzene	7.4E-09	0.051	-	-	-	-	-	-
Benzo(a)anthracene	1.6E-06	11	-	-	3.0E-07	7.3	1.3E-06	15
Benzo(b)fluoranthene	1.2E-06	8.2	4.8E-08	1.6	6.8E-07	17	1.1E-06	13
Benzo(k)fluoranthene	-	-	-	-	3.2E-08	0.78	-	-
Benzo(a)pyrene	1.0E-05	68	2.7E-07	9.0	2.6E-06	63	6.1E-06	73
Carbazole	1.1E-08	0.077	-	-	-	-	-	-
Chromium VI	3.8E-07	2.6	-	-	-	-	-	-
Chrysene	1.4E-08	0.095	-	-	2.0E-09	0.049	-	-
Dibenzo(a,h)anthracene	1.3E-08	0.090	-	-	3.5E-08	0.85	-	-
Indeno(1,2,3-c,d)pyrene	1.0E-06	6.8	-	-	2.5E-07	6.1	-	-
Total Carcinogenic Risk	**1.5E-05**	-	**3.0E-06**	-	**4.1E-06**	-	**8.4E-06**	-

a. Carcinogenic risks derived only for chemicals for which cancer slope factors were available.

Table 5-2. Summary of Carcinogenic Risks[a] for the High End Exposed Individual

	Construction Worker/Utility Repair Worker		Landfarm Worker		Adolescent Trespasser		Adult Recreational Angler	
Chemicals	Risk	Percentage of Total Risk	Risk	Percentage of Total Risk	Risk	Percentage of Total Risk	Risk	Percentage of Total Risk
2,3,7,8-TCDD	-	-	5.8E-06	81	-	-	-	-
Arsenic	9.7E-07	5.1	3.8E-07	5.3	5.6E-07	0.85	-	-
Benzene	1.1E-08	0.058	-	-	-	-	-	-
Benzo(a)anthracene	2.3E-06	12	-	-	7.3E-06	11	5.8E-06	15
Benzo(b)fluoranthene	2.6E-06	14	1.6E-07	2.2	1.8E-05	27	4.8E-06	12
Benzo(k)fluoranthene	-	-	-	-	8.0E-08	0.12	-	-
Benzo(a)pyrene	1.2E-05	61	9.0E-07	13	3.8E-05	58	2.8E-05	72
Carbazole	1.0E-08	0.053	-	-	-	-	-	-
Chromium VI	5.7E-07	3.0	-	-	-	-	-	-
Chrysene	2.1E-08	0.11	-	-	4.7E-08	0.07	-	-
Dibenzo(a,h)anthracene	2.7E-08	0.14	-	-	9.3E-08	0.14	-	-
Indeno(1,2,3-c,d)pyrene	1.2E-06	6.2	-	-	2.2E-06	3.3	-	-
Total Carcinogenic Risk	**1.9E-05**	-	**7.2E-06**	-	**6.6E-05**	-	**3.9E-05**	-

a. Carcinogenic risks derived only for chemicals for which cancer slope factors were available.

Table 5-3. Summary of Hazard Quotients[a] for the Typical Exposed Individual

	Construction Worker/Utility Repair Worker		Landfarm Worker		Adolescent Trespasser		Adult Recreational Angler	
Chemicals	Hazard Quotient	Percentage of Total	Risk	Percentage of Total Risk	Hazard Quotient	Percentage of Total	Hazard Quotient	Percentage of Total
Acenaphthene	1.2E-02	5.0	-	-	-	-	-	-
Arsenic	6.8E-02	29	1.4E-02	100	3.6E-03	100	-	-
Benzene	1.0E-02	4.0	-	-	-	-	-	-
Benzo(a)anthracene	-	-	-	-	-	-	-	-
Benzo(a)pyrene	-	-	-	-	-	-	-	-
Benzo(b)flouranthene	-	-	-	-	-	-	-	-
Chromium VI	1.3E-04	6.0	-	-	-	-	-	-
Flouranthene	8.8E-03	38	-	-	-	-	-	-
Lead	-	-	-	-	-	-	-	-
Naphthalene	4.4E-02	19	-	-	-	-	-	-
Hazard Index	**1.4E-01**	-	**1.4E-02**	-	**3.6E-03**	-	**NA**	**NA**

a. Hazard quotients derived only for chemicals for which reference doses were available.

NA: Not applicable

Table 5-4. Summary of Noncancer Hazard Quotients[a] for the High End Exposed Individual

Chemicals	Construction Worker/Utility Repair Worker		Landfarm Worker		Adolescent Trespasser		Adult Recreational Angler	
	Hazard Quotient	Percentage of Total	Risk	Percentage of Total Risk	Hazard Quotient	Percentage of Total	Hazard Quotient	Percentage of Total
Acenaphthene	2.5E-02	8.0	-	-	-	-	-	-
Arsenic	1.5E-01	72	5.9E-02	100	8.7E-03	100	-	-
Benzene	1.6E-02	7.0	-	-	-	-	-	-
Benzo(a)anthracene	-	-	-	-	-	-	-	-
Benzo(a)pyrene	-	-	-	-	-	-	-	-
Benzo(b)flouranthene	-	-	-	-	-	-	-	-
Chromium VI	2.0E-04	8.0	-	-	-	-	-	-
Flouranthene	1.5E-02	7.0	-	-	-	-	-	-
Lead	-	-	-	-	-	-	-	-
Naphthalene	7.4E-02	7.0	-	-	-	-	-	-
Hazard Index	**2.8E-01**	-	**5.9E-02**	-	**8.7E-03**	-	**NA**	**NA**

a. Hazard quotients derived only for chemicals for which reference doses were available.

NA: Not applicable

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Appendix A

Toxicological Profiles

APPENDIX A

A.1 Arsenic

Arsenic is a naturally occurring element present in earth's crust at concentrations ranging from 1 to 40 mg/kg (O'Neill, 1990). The average soil concentration world-wide is approximately 5 mg/kg (EPA, 1980a). Arsenic, often referred to as a metal, is actually a metalloid that is found in the environment in both organic and inorganic forms. Inorganic arsenic exists in various chemical states, including elemental arsenic (As^0), arsenic trioxide (As_2O_3), and arsenic pentoxide (As_2O_5). Important organic forms of arsenic include the pesticides arsanilic acid (Premix), dimethylarsinic acid (Ansar), sodium dimethylarsinate (Sivisar), sodium methanearsonate (Daconate), and disodium methanearsonate (Methar). Arsenobetaine, commonly referred to as fish arsenic, is the predominate form found in fish tissue (ATSDR, 1993a). The major sources of arsenic in the environment include natural forces such as volcanic activity and weathering of arsenic-containing rocks, and human activity associated with metal smelting, glass manufacturing, pesticide production and use, and fossil fuel combustion (ATSDR, 1993a). Following is a brief summary of the physical and chemical properties of elemental arsenic[a].

Chemical Formula	As^0	ATSDR, 1993a
Molecular Weight	74.92 g/mol	Weast, 1985
Vapor Pressure	1 mmHg @ 372°C	HSDB, 1996a
Boiling Point	613°C Sublimes	Weast, 1985
Melting Point	817°C @ 28 atm	Weast, 1985
Water Solubility	Insoluble	Weast, 1985
Partition Coefficients		
Henry's Law Constant (air/water)	No data	ATSDR, 1993a
log K_{ow} (octanol-water)	No data	ATSDR, 1993a
log K_{oc} (organic carbon-water)	No data	ATSDR, 1993a

a. The physical and chemical properties of the various forms of arsenic are quite variable, and because of the numerous forms of arsenic found in the environment, only those for elemental arsenic are shown.

The relative concentrations of arsenic in various environmental media (i.e., soil, air, and water) is highly dependent upon is its chemical form. For example, in water systems, arsenic acid may be found at elevated concentrations in the dissolved form due to its high solubility in water (3,020 g/L at 12.5°C), whereas inorganic forms are much less soluble and tend to be adsorbed to clays, iron oxides, manganese compounds, and organic material (ATSDR, 1993a). In sediments, arsenic exists primarily as insoluble complexes (Callahan et al, 1979). Because of its low vapor pressure, airborne arsenic (both organic and inorganic forms) is predominately adsorbed to particulate matter (Coles et al., 1979), with negligible levels in the vapor phase. In soils, both inorganic and organic forms of arsenic tend to be adsorbed to soil particles, although leaching of inorganic arsenic to groundwater may occur under certain soil conditions.

The toxicological significance of arsenic can be traced to its widespread use as a poison throughout human history (Doull and Bruce, 1986). Used as a poison, a single dose of 22 mg inorganic arsenic has been shown to be fatal in humans (ATSDR, 1993a). Numerous studies have been conducted to evaluate the toxicity of arsenic in humans and laboratory animals at lower levels of exposure (ATSDR, 1993a). These studies indicate that inorganic arsenic is generally more toxic than the organic forms, and there is evidence that small amounts of arsenic may be beneficial to human health (ATSDR, 1993a). Adverse effects in both humans and laboratory animals associated with low-dose chronic exposure to inorganic arsenic, in the range of 0.014 to 0.1 mg/kg-day, include Blackfoot disease, central fibrosis and cirrhosis of the liver, arterial thickening, thrombosis, Raynaud's disease, functional denervation, paresthesia, mild peripheral neuropathy, and cancer of the skin, liver, bladder, and lung (ATSDR, 1993a).

Strong evidence of carcinogenicity is limited to human studies as the evidence in laboratory animals has generally been inconclusive (IARC, 1980; IRIS, 1996a). Most of the evidence linking arsenic to human cancer is based on studies of lung cancer in workers exposed to airborne arsenic trioxide and arsenate, and studies reporting an increased incidence of skin cancer in populations exposed to arsenic in drinking water (IRIS, 1996a). Because of the strength of this evidence, the EPA has classified inorganic arsenic as a Group A carcinogen (human carcinogen) (IRIS, 1996a).

The EPA (1995) has established an oral CSF of 1.5 $(mg/kg\text{-}day)^{-1}$ for inorganic arsenic, based on an increased incidence of skin cancer in a Taiwanese population exposed to arsenic in drinking water (Tseng, 1977). However, due to uncertainties associated with this value, EPA has acknowledged that risk estimates for oral exposure to arsenic may be overstated by as much as an order of magnitude (IRIS, 1996a). The EPA has also established an inhalation unit risk value (URV) of 0.0043 $\mu g/m^3$ for arsenic based on increased lung cancer mortality observed in occupational populations exposed through inhalation of airborne inorganic arsenic (IRIS, 1996a). For the purposes of this assessment, the inhalation unit risk value is converted to an inhalation CSF of 50 $(mg/kg\text{-}day)^{-1}$ (EPA, 1995a).

The oral RfD for inorganic arsenic of 0.0003 mg/kg-day is based on a study of chronic human exposure to arsenic in drinking water (IRIS, 1996a). Hyperpigmentation, keratosis, blackfoot disease, and possible vascular complications were identified as critical effects (Tseng et al., 1968; Tseng, 1977). The oral RfD was calculated from a NOAEL of 0.0008 mg/kg-day (based on the intake of arsenic from drinking water and sweet potato consumption) and the application of an uncertainty factor of 3 (IRIS, 1996a). This value is currently under reevaluation by EPA (IRIS, 1996a). The Agency has not determined an inhalation RfD value for arsenic. For the purposes of this evaluation, the oral RfD value for arsenic is also used to assess inhalation exposures.

A.2 Benzene

Benzene is used primarily as an intermediate in the manufacture of other chemicals such as ethylbenzene, cumene, cyclohexane, and nitrobenzene (ATSDR, 1995a). It is also employed as a solvent, reactant, and component of gasoline (Brief et al., 1980; Holmberg and Lundberg, 1985; OSHA, 1987). In addition, benzene may be used in such products as paints, rubber cements, adhesives, paint removers, leathers, printing, pesticides, and fumigants OSHA, 1977; ATSDR, 1995a).

Chemical Formula	C_6H_6	HSDB, 1995a
Molecular Weight	78.11	HSDB, 1995a
Vapor Pressure	95.2 mmHg @ 25°C	OHM/TADS, 1990
Boiling Point	80.1°C	HSDB, 1995a
Melting Point	5.5°C	HSDB, 1995a
Water Solubility	1,780 mg/L @ 25°C	Mackay and Leinonen, 1975
Partition Coefficients		
Henry's Law Constant (air/water)	5.5×10^{-3} atm-m^3/mol	Mackay and Leinonen, 1975
log K_{ow} (octanol-water)	2.15	Gossett et al., 1983
log K_{oc} (organic carbon-water)	1.9	HSDB, 1995a

In the environment, benzene volatilizes readily from water and soils to the atmosphere where it exists primarily in the vapor phase (Eisenreich et al., 1981). The primary degradation process for benzene in the atmosphere is reaction with hydroxyl radicals (ATSDR, 1995a). Residence time for benzene has been estimated within a range of 2.1 hours to 8 days based on a vapor phase reaction with photochemically produced hydroxyl radicals (Gaffney and Levine, 1979; Lyman et al., 1982). It may also be removed from the atmosphere via wet deposition, although benzene removed due to this process is likely to revolatilize to the atmosphere (ATSDR, 1995a). Direct photolysis of benzene in the atmosphere is not likely (Bryce-Smith and Gilbert, 1976).

In soil systems, benzene may readily volatilize to the atmosphere, partition to surface water through surface runoff, and leach to groundwater. Tucker et al. (1986) estimated that 67 percent

of benzene released to soil would volatilize while 29 percent would leach to groundwater. Benzene may biodegrade in aerobic soils. Studies have shown that one percent benzene released to soils would biodegrade over a 17-month period (Tucker et al., 1986; ATSDR, 1995a), although the rate of degradation is dependent upon the biological structure and activity of the soils.

Benzene in aquatic systems is readily released to the atmosphere via volatilization. A volatilization half-life of 4.81 hours has been estimated for benzene one-meter deep surface waters at 25°C (Mackay and Leinonen, 1975). Additionally, a half-life of 16.9 days was reported for the photolysis of benzene dissolved in oxygen-saturated deionized water (ATSDR, 1995a). A half-life of 0.71 years has been estimated for benzene following reaction with hydroxyl radicals (Anbar and Neta, 1967). Benzene in surface and groundwater may undergo biodegradation via microorganisms. Reported half-lives for aquatic biodegradation of benzene range from 8 to 28 days (Delfino and Miles, 1985; Vaishnav and Babeu, 1987; Chiang et al., 1989; ATSDR, 1995a). Bioconcentration and biomagnification of benzene within aquatic organisms and foodchains is expected to be minimal (Gossett et al., 1983; Geyer et al., 1984; Ogata et al., 1984; Miller et al., 1985; ATSDR, 1995a; HSDB, 1995a).

A number of studies have reported carcinogenic responses in laboratory animals following exposure to benzene via inhalation and gavage. Maltoni and Scarnato (1979) and Maltoni et al. (1983) reported a dose-related increase in the incidence of mammary tumors, Zymbal gland carcinomas, oral cavity carcinomas, and leukemia in Sprague-Dawley rats administered benzene via gavage at concentrations of 0, 50, 250, or 500 for life. A significantly increased incidence of Zymbal gland carcinomas in rats and mice of both sexes was observed following gavage for 103 weeks at concentrations of 0, 25, 50, 100, or 200. Oral cavity tumors were observed in rats of both sexes, while males also showed increased incidence of skin tumors. Lymphomas and lung tumors were reported for both male and female mice. In general, the effects were considered dose-related (NTP, 1986).

A number of studies have associated carcinogenic effects among humans exposed to benzene. A study of Turkish shoe workers reported an increased incidence of leukemia for individuals employed for 1 to 15 years and subjected to peak exposures of 210 to 650 ppm (Aksoy et al., 1974). A retrospective cohort mortality study of males exposed to benzene in the manufacturing of rubber products also reported a significant increase in the incidence of leukemia (Infante et al., 1977a,b). Likewise, Rinsky et al. (1981) observed a statistically significant increase of leukemia in a subsequent retrospective cohort mortality study with the same study group. Ott et al. (1978) and Wong et al. (1983) have also reported an increased incidence of mortality due to leukemia among chemical workers exposed to benzene.

The EPA has classified benzene as a Group A carcinogen (human carcinogen) based on adequate evidence in humans and animals (IRIS, 1996b). The Agency has established an oral cancer slope factor of 0.029 $(mg/kg\text{-}day)^{-1}$ for benzene based on the results of several studies that have reported

an increased incidence of nonlymphocytic leukemia following occupational exposure to benzene (Aksoy et al., 1974, 1980; Infante, 1977a,b; Ott et al., 1978; Rinsky et al., 1981; Wong et al., 1983), and the increased incidence of tumors in rats and mice exposed via inhalation and gavage (Maltoni and Scarnato, 1979; Maltoni et al., 1983; NTP, 1986). The Agency has not established an inhalation cancer slope factor for benzene. However, the EPA has derived an inhalation unit risk value of 0.0000083 $\mu g/m^3$ (IRIS, 1996b). For the purposes of this assessment, the oral cancer slope factor is used as the inhalation cancer slope factor.

The EPA has not developed an oral or inhalation RfD value for benzene (IRIS, 1996b). In lieu of verified values, a provisional inhalation RfD value of 0.00171 mg/kg-day was applied in this assessment. This value was developed by the EPA (1995b) and is regarded as a provisional value. For the purposes of this assessment, the inhalation RfD value is also used as the oral RfD value.

A.3 Carbazole

Carbazole is a natural component of coal, petroleum, and peat. The incomplete combustion of these materials may result in the release of carbazole to the environment (Smith et al., 1978). Additional sources of carbazole include emissions from waste incineration, tobacco products, wood treatment facilities, and aluminum and rubber manufacturing processes (Graedel et al., 1986; Jacobs and Billings, 1985; Junk and Ford, 1980; Pereira et al., 1987; Smith et al., 1978).

Chemical Formula	$C_{12}H_9$	HSDB, 1996b
Molecular Weight	167.20	HSDB, 1996b
Vapor Pressure	1.37×10^{-6} mmHg @ 25°C	Boublik et al., 1984
Boiling Point	355°C	Budavari, 1989
Melting Point	245°C	Budavari, 1989
Water Solubility	Insoluble	Budavari, 1989
Partition Coefficients		
Henry's Law Constant (air/water)	8.65×10^{-8} atm-m^3/mol	Meylan and Howard, 1991
log K_{ow} (octanol-water)	6.46	Ainsworth et al., 1989
log K_{oc} (octanol carbon-water)	3.72	Hansch and Leo, 1985

In the atmosphere, carbazole is predominantly bound to particles as indicated by its relatively low vapor pressure and high K_{oc}. Vapor-phase carbazole is quickly degraded by reaction with photochemically produced hydroxyl radicals. The estimated half-life of atmospheric carbazole is three hours. Particle-bound carbazole is removed from the atmosphere via wet or dry deposition (Atkinson, 1989; Eisenreich et al., 1981; HSDB, 1996b). The primary removal process for carbazole in soil systems is biodegradation; its low water solubility and high K_{oc} indicate that leaching to groundwater would be minimal. Photolysis occurs to a limited extent in soils, but this

process may be hindered by adsorption of carbazole to soil particles (Grosser et al., 1991; Mueller et al., 1991; Smith et al., 1978).

Carbazole released to aquatic systems is subject to removal via biodegradation and photolysis. Estimated half-lives of carbazole in freshwater systems range from 0.5 to 3 hours due to biodegradation. A half-life of 2.9 hours has also been estimated for the photolysis of carbazole in freshwater ecosystems. The rate of photolysis may be limited, however, if the compound partitions from the water column to sediment and suspended matter (Grosser et al., 1991; Meylan and Howard, 1991; Pereira et al., 1987; Smith et al., 1978).

Toxicity studies of carbazole in laboratory animals are extremely limited. An increased incidence of lesions has been reported in mice fed diets of 0.15%, 0.3% or 0.6% carbazole for 96 weeks. Results of this study reported the presence of neoplastic nodules and hepatocellular carcinomas in the liver, as well as neoplastic lesions in the forestomach, of treated animals (IARC, 1983). In a separate investigation, a group of 10 mice were injected with 10 mg crystallized carbazole. All ten mice were still alive one year after the injection, and no tumors were reported at the injection site (IARC, 1983). In a third study, mice received a total of 120 skin applications of 0.5% carbazole. Results of the study indicated hair removal at the treated area (IARC, 1983).

There are no available studies regarding the potential toxicity of carbazole to humans. The EPA has classified carbazole as a Group B2 carcinogen (probable human carcinogen) based on inadequate evidence of carcinogenicity in humans and sufficient evidence in laboratory animals. The EPA has developed an oral cancer slope factor of 0.02 $(mg/kg\text{-}day)^{-1}$ for carbazole based on the increased incidence of liver tumors in mice administered carbazole in the diet for 96 weeks (EPA, 1995a; IARC, 1983). The EPA has not derived an inhalation cancer slope factor for carbazole. For the purposes of this assessment, however, the oral cancer slope factor will also be used to assess risks assoicated with exposure via the inhalation cancer slope factor. The EPA has not developed an oral or inhalation RfD value for carbazole.

A.4 Chromium

Chromium is used in the plating industry for treating metals for corrosion resistance and decorative purposes and in the manufacture of appliances, tools, and automobiles. It is also employed in the manufacture of alloys such as stainless steel and heat resistant alloys. In addition, chromium compounds are used in printing, leather tanning, pigments, photography, graphics, and other industrial applications. Finally, chromium is an essential nutrient for humans (ATSDR, 1991a). Following is a brief summary of the physical and chemical properties of elemental chromium[a].

Chemical Formula	Cr°	HSDB, 1996c
Molecular Weight	51.996 g/mol	Weast, 1985
Vapor Pressure	1 mmHg @ 1616°C	Weast, 1985

Boiling Point	2672°C	Weast, 1985
Melting Point	1857°C	Weast, 1985
Water Solubility	Insoluble	Weast, 1985
Partition Coefficients		
Henry's Law Constant (air/water)	No data	ATSDR, 1991a
log K_{ow} (octanol-water)	No data	ATSDR, 1991a
log K_{oc} (octanol carbon-water)	No data	ATSDR, 1991a

a. The physical and chemical properties of the various forms of chromium are quite variable, and because of the numerous forms of chromium found in the environment, only those for elemental chromium are shown.

In the environment, chromium is found in one of two valence states: Cr^{3+} (Cr III) and Cr^{6+} (Cr VI). Chromium compounds in the atmosphere are rapidly removed via wet or dry deposition (ATSDR, 1991a). Airborne chromium VI may be reduced to chromium III at a significant rate in the presence of vanadium compounds, Fe^{2+}, HSO^{3-}, or As^{3+}. Conversely, airborne chromium III salts may be oxidized to chromium VI in the presence of manganese oxide (EPA, 1987).

Chromium in soils has limited mobility since it is generally present as insoluble oxide (EPA, 1984). The mean soil concentration world wide is approximately 100 mg/kg (McGuath and Smith, 1990). The mobility of soluble chromium compounds in soils depends largely on the sorption characteristics of the soil such as clay content, Fe_2O_3 content, and organic matter content. Although leaching of chromium from soils to groundwater is expected to be minimal, leaching may occur in highly acidic soils. Cary (1982) reported that chromium translocates only slightly from roots to aboveground portions of plants. Generally, the fate of chromium in soils is dependent on the redox potential and the pH in the soil. The reduction of chromium VI to chromium III is likely to occur in aerobic soils with a low pH or sufficient organic energy sources to initiate the redox reaction (Cary, 1982; EPA, 1987; Saleh et al., 1989).

Most chromium compounds released to aquatic systems are likely to be deposited in sediments. Most of soluble chromium in water exists in ionic form (Cr^{3+} and Cr^{6+}), which constitute a relatively small percentage of total chromium in water. Chromium VI in water is ultimately reduced to chromium III by reducing conditions typically found in sediments rich in organic matter (ATSDR, 1991a). Although chromium compounds in water systems are not expected to biomagnify within aquatic food chains, bioconcentration factors ranging from 1 to 192 have been estimated for chromium VI in rainbow trout, oysters, blue mussels, and soft shell clams (Fishbein, 1981; Schmidt and Andren, 1984; EPA, 1980b, 1984).

Several laboratory studies report the noncarcinogenic effects of chromium VI. The results of an investigation by MacKenzie et al. (1958) suggest a reduction in water consumption among treated rats administered 2.4 mg/kg-day chromium VI via drinking water. Additionally, Anwar et al. (1961) reported no significant effects in female dogs receiving doses up to 0.3 mg/kg in drinking

water for 4 years. Similarly, no effects were recorded for humans consuming approximately 1 mg/L chromium VI for 3 years from a private well (Anwar et al., 1961).

In several studies, chromium VI has been associated with an increased cancer risk to humans exposed to airborne chromium. However, chromium has not been shown to be carcinogenic in laboratory animals exposed via the inhalation route (Baetjer et al., 1959; Steffee and Baetjer, 1965; Nettesheim et al., 1971; Laskin, 1972; EPA, 1984). Two potential factors which may account for this are: (1) animals may be less sensitive to inhaled chromium, or (2) the carcinogenic effects of chromium occur only when humans are co-exposed to other carcinogenic agents such cigarette smoke (ATSDR, 1991a). Several studies have reported an increased incidence in a variety of tumors, including bronchial, intramuscular, and subcutaneous tumors in laboratory animals resulting from exposure to Chromium VI via injection (Furst et al. 1976; Mattoni, 1976; Levy and Martin, 1983).

Inhalation is the primary exposure route of concern for chromium. Evidence from animal studies and human epidemiologic studies indicate that chromium is readily and rapidly absorbed by the lungs (ATSDR, 1991a). Epidemiological studies of chromate industry workers have reported that chronic inhalation of high levels of chromium have been associated with an increased risk of respiratory cancer (IARC, 1980; EPA, 1984; IRIS, 1996c).

The EPA has classified chromium VI as a Group A carcinogen (human carcinogen) based on the results of occupational epidemiologic studies of chromium-exposed workers. Although chromium-exposed workers are exposed to both chromium III and chromium VI compounds, only chromium VI has been determined to be carcinogenic in animals and is, therefore, the only chromium compound to be classified as a human carcinogen (IRIS, 1996c).

The EPA has not established an oral cancer slope factor for chromium VI. The Agency has developed an inhalation unit risk value of 0.012 $\mu g/m^3$ based on the results of epidemiological investigations (Pokrovskaya and Shabynina, 1973; Mancuso, 1975; Axelsson et al., 1980; Langard et al., 1980). The results of these studies are consistent across investigators and study populations and dose-response relationships have been established for chromium exposure and lung cancer (IRIS, 1996c). The EPA has converted this unit risk value to an inhalation cancer slope factor of 41 $(mg/kg\text{-}day)^{-1}$ (EPA, 1995a).

The EPA has also established a chronic oral RfD value of 0.005 mg/kg-day for chromium VI based on a reduction in water consumption and increased tissue concentration among rats receiving drinking water containing up to 25 ppm hexavalent chromium (IRIS, 1996c; MacKenzie et al., 1958). The EPA has not derived an inhalation RfD value for Chromium VI. For the purposes of this assessment, however, the oral RfD value for chromium VI is used as the inhalation RfD value.

A.5 Lead

In the United States, lead is used primarily in lead acid batteries, gasoline additives, and other applications within the transportation industry. It is also employed as a product for construction, ammunition, electronics, television glass, and paint. To a lesser degree, lead is used in ceramics, type metal, ballasts and weights, and tubes. Due to its toxic nature, however, the use of lead has slowly decreased in recent years as alternative materials have been developed (ATSDR, 1991b). Following is a brief summary of the physical and chemical properties of elemental lead[a].

Chemical Formula	Pb°	ATSDR, 1991b
Molecular Weight	207.20	HSDB, 1995b
Vapor Pressure	1.77 mmHg @ 1,000°C	HSDB, 1995b
Boiling Point	1,740°C	HSDB, 1995b
Melting Point	327.4°C	HSDB, 1995b
Water Solubility	Insoluble	HSDB, 1995b
Partition Coefficients		
Henry's Law Constant (air/water)	No data	ATSDR, 1991b
log K_{ow} (octanol-water)	No data	ATSDR, 1991b
log K_{oc} (octanol carbon-water)	No data	ATSDR, 1991b

a. The physical and chemical properties of the various forms of lead are quite variable, and because of the numerous forms of lead found in the environment, only those for elemental lead are shown.

Lead may be found in the environment in a variety of forms, including lead acetate, chloride, chromate, nitrate, oxide, sulfate, and tetraethyl, tetramethyl, and triethyl lead (ATSDR, 1991b). In the environment lead exists primarily as the Pb^{2+} ion. Mean Pb concentrations world wide are approximately 16 mg/kg (Davies, 1990). Lead in the atmosphere exists primarily bound to particles. Ultimately, particle-bound lead is removed from the atmosphere via wet or dry deposition (ATSDR, 1991b).

The fate of lead in soils is dependent on the soil pH, organic matter content, ion-exchange characteristics, and the presence of inorganic colloids and iron oxides (ATSDR, 1991b). Ordinarily, lead is retained in soil, and is unlikely to be transported to groundwater or surface waters (NSF, 1977; EPA, 1986a). Inorganic lead is essentially immobile in soil if bound into crystalline matrices. The transformation of lead complexes and precipitates depends on soil type. Soils with high organic matter content and a pH of 6-8 may form insoluble organic lead complexes, while soils with less organic matter and the same pH may form hydrous lead oxide complexes. Soils with a pH of 4-6, however, may permit the formation of organic lead complexes which are soluble and become subject to leaching or uptake by plants (EPA, 1986a). Conditions that may induce the leaching of lead within soils includes the presence of lead at concentrations

greater than the cation exchange capacity of the soil, the presence of soil constituents capable of forming soluble chelates, and a decrease in the pH of the leaching solution (NSF, 1977).

The amount of lead in water systems is dependent upon the pH and the dissolved salt content. At a pH of less than 5.4 the total solubility of lead is estimated to be 30 µg/L and 500 µg/L in hard and soft water, respectively (EPA, 1979). In river systems, lead may be present as sorbed ions or surface coatings on sediment mineral particles, or it may exist as part of suspended organic matter. Tetraalkyl lead compounds in water may be subject to photolysis and volatilization (ATSDR, 1991b).

Studies of carcinogenicity in laboratory animals following ingestion of lead suggest that renal tumors are the most common carcinogenic response (ATSDR, 1991b; IRIS, 1995d). Azar et al. (1973) reported renal tumors in rats administered lead for two years at doses of 27, 56.5, 105 mg/kg-day. Likewise, renal tubular carcinomas were observed in 81% of the study rats given lead in their drinking water at 37 mg/kg-day for 76 weeks (Koller et al., 1986).

Lead in humans may be stored in bone, kidney, and liver. The major adverse effects in humans associated with lead exposure include alterations in the blood and nervous systems. These effects are generally related to the concentration of lead in blood, not intake. Elevated blood lead concentrations in children and in sensitive adults have been associated with severe, irreversible brain damage, encephalopathy, and possible death. Physiological and biochemical effects associated with low blood lead levels include enzyme inhibition, interference with vitamin D metabolism, cognitive dysfunction in infants, electrophysiological dysfunction, and reduced childhood growth (ATSDR, 1991b).

Exposure to lead has been associated with developmental effects in humans. Effects include reduced birth weight, gestational age, and neurobehavioral deficits or delays. There is no positive association between lead exposure and congenital malformations, suggesting that lead is not teratogenic (ATSDR, 1991b).

There is evidence that exposure to lead can cause genotoxic effects. Lead has been shown in a number of assays to affect processes associated with gene expression (IRIS, 1996d). Lead exposure has also been associated with sister chromatic exchange in workers, and induction of chromosomal aberrations in vivo (Grandjean et al., 1983). Lead acetate has been shown to induce cell transformation in Syrian Hamster embryo cells (DiPaolo et al., 1978).

The EPA has classified lead as a Group B2 carcinogen (probable human carcinogen), based on inadequate evidence of carcinogenicity in humans and sufficient evidence in laboratory animals (IRIS, 1996d). The results of a number of animal studies, including ten rat bioassays and one mouse assay, show a statistically significant increase in renal tumors due to dietary and subcutaneous exposures to soluble lead salts (Van Esch and Kroes, 1969; Azar et al., 1973; Casto

et al., 1979; DiPaolo et al., 1978; Grandjean et al., 1983; Kasprzak et al., 1985; Koller et al., 1986).

The EPA has not established an oral or inhalation cancer slope factor or RfD value for lead (IRIS, 1996d). Since the EPA does not provide guidance on assessing the risks to lead exposure. The lead was not evaluated further in this risk assessment.

A.6 Naphthalene

The primary use of naphthalene is as an intermediate in the production of phthalate plasticizers, resins, dyes, pharmaceuticals, phthaleins, and insect repellents. To a lesser extent, naphthalene is employed in the production of insecticides, leather tanning agents, surface active agents, various organic chemicals, and moth repellents (ATSDR, 1995b).

Chemical Formula	$C_{10}H_8$	ATSDR, 1995b
Molecular Weight	128.19	Weast, 1985
Vapor Pressure	0.087 mmHg @ 25°C	HSDB, 1996
Boiling Point	218°C	Weast, 1985
Melting Point	80.5°C	Weast, 1985
Water Solubility	31.7 mg/L @ 20°C	Weast, 1985
Partition Coefficients		
Henry's Law Constant (air/water)	4.6×10^{-4} atm-m^3/mol	Mabey et al., 1982
log K_{ow} (octanol-water)	3.29	Mabey et al., 1982
log K_{oc} (octanol carbon-water)	2.97	Mabey et al., 1982

In the atmosphere, naphthalene is removed primarily by reaction with photochemically-produced hydroxyl radicals (Howard, 1989). The half-life for naphthalene in the atmosphere has been estimated at less than 1 day (Atkinson et al., 1987). Naphthalene may also be removed from the atmosphere very slowly via wet or dry deposition (Coons et al., 1982).

Naphthalene in soil systems is readily volatilized to the atmosphere with adsorption occurring to a limited extent depending on the organic carbon content of the soil (Karickhoff, 1981; Park et al, 1990; Schwarzenbach and Westall, 1981). Estimated half-lives for naphthalene in soils range from 2 days to 3.6 months (Howard, 1989; Klecka et al., 1990; Park et al., 1990). Biodegradation of naphthalene may also take place in both aerobic and anaerobic soils (Heitzer et al., 1992; Klecka et al., 1990).

Naphthalene released to aquatic systems tends to remain in solution with volatilization to the atmosphere within 1 to 2 weeks (Wakeham et al., 1983; Zoeteman et al., 1980). Naphthalene in water may also be degraded via photolysis and biological processes. Half-lives for the photolysis

of naphthalene range from 22 hours to 550 days (GDCH, 1992; Zepp and Schlotzhauer, 1979). In addition, biodegradation may also be a significant fate process for naphthalene in water (Tabak et al., 1981). Bioconcentration of naphthalene in aquatic organisms is expected to be minimal, and any biomagnification within the food chain occurs only slightly (Banerjee and Baughman, 1991; Geyer et al., 1982; Kenaga, 1980; Thomann, 1989).

Toxicity studies of naphthalene administered to laboratory animals suggest varying effects. Adkins et al. (1986) reported a statistically significant increase in lung adenomas in mice exposed by inhalation to 10 or 30 ppm naphthalene for 6 hours per day, 5 days per week for 6 months. The lung tumor assay results did not indicate a dose-response (Adkins et al., 1986). In a separate investigation, rats administered a single gavage dose of 100 mg/kg naphthalene did not show an increase in the number or size of gamma-glutamyl transpeptidase (GGT) foci compared to controls (Tsuda et al., 1980). Likewise, Schmahl (1955) reported no carcinogenic responses for rats receiving intraperitoneal injections of 20 mg/rat once a week for 40 weeks or for rats fed a diet containing 30 to 60 mg/kg-day until total dose equaled 10 g/rat.

In other animal studies, coal tar-derived naphthalene administered to rats via subcutaneous injection resulted in a slight incidence of lymphosarcomas (Knake, 1956). Also, Knake (1956) reported the presence of leukemia in mice painted with coal tar-derived naphthalene 5 days per week for life. The value of these studies is limited, however, due to the presence of potentially carcinogenic impurities (IRIS, 1996e). The results of other skin-painting studies with naphthalene were negative or inconclusive (Kennaway, 1930; Schmeltz et al., 1978).

Few studies are available which support conclusive evidence of toxicity to humans as a result of exposure to naphthalene. Several investigators report that exposure to mothballs results in various effects including anemia, nausea, vomiting, and abdominal pain (Linick, 1983; Valaes et al., 1963). Likewise, human exposures to naphthalene may result in hepatic, neurological, or ocular effects (Linick, 1983; McMurray, 1977; Valaes et al., 1963).

The EPA has classified naphthalene as a Group D carcinogen (not classifiable as to human carcinogenicity) based on the absence of human data and inadequate data from animal bioassays (IRIS, 1996e). The Agency has not established an oral or inhalation cancer slope factor for naphthalene. The EPA has not formally established an oral or inhalation RfD value for this compound. EPA Region III and developed an oral RfD value of 0.04 mg/kg-day for naphthalene (EPA, 1995b). For the purposes of this assessment, this oral RfD value is also employed as the inhalation RfD value.

A.7 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) comprise a class of hydrocarbons containing two or more benzene rings. In their simplest form, PAHs consist of unsubstituted, fused benzene rings. The more complex PAHs may contain one or more aliphatic substituents. Of the more than 100 different individual PAHs that have been detected in the environment (substituted and unsubstituted) regulatory agencies have generally focused on the 15 unsubstituted PAHs most commonly found at hazardous waste sites.. These are:

Acenaphthene	Benzo(b)fluoranthene	Fluoranthene
Acenaphthylene	Benzo(k)fluoranthene	Fluorene
Anthracene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Benzo(a)anthracene	Chrysene	Phenanthrene
Benzo(a)pyrene	Dibenzo(a,h)anthracene	Pyrene

The major sources of PAHs in the environment include the combustion of fuels and incineration of wastes. To a limited extent, these compounds also occur naturally as a result of brush and forest fires and through their biological synthesis by plants and bacteria (ATSDR, 1993b; 1995c). The chemical and physical properties of selected PAHs identified in this risk assessment as COPCs are listed in Table 3.3.

PAHs generally behave similarly in the environment. They tend to have low water solubilities, low vapor pressures, and have a strong affinity to bind to particles. Therefore, in surface water systems, PAHs tend not to be found in the dissolved phase, but bound to particles, and tend to accumulate in sediments. In soils, PAHs bind strongly to soil particles, and because of their low vapor pressure, their tendency to volatilize from soil is minimal. Thus, airborne PAHs primarily exist bound to particles, not in the vapor-phase. The combination of soil particle binding and low water solubility reduces the potential for PAHs to leach from soil to groundwater. While these general properties can be applied to all PAHs as a group, it should be recognized that there are differences among the various PAHs, and each should be evaluated separately with respect to environmental fate and transport.

There is little evidence of toxic effects of PAHs in humans following chronic exposure other than historical epidemiologic studies linking dermal exposure to PAH-containing coal tars with cancer of the scrotum (Williams and Weisburger, 1986), and reduced lung function, coughing, and throat and chest irritation following exposure to airborne PAHs by rubber factory workers (Gupta et al., 1993; ATSDR, 1995b; 1995c). In laboratory animals, chronic exposure to some PAHs has caused reproductive effects (reduced pregnancy rates, fetal resorption, and reduced birth weights), increased liver weights, hematological effects, and an increased incidence of skin, respiratory, upper digestive tract, and stomach cancer (ATSDR, 1993b; 1995c).

Following are brief summaries of the toxicological properties of those PAHs identified as COPCs in this assessment:

Acenaphthene
Only limited toxicological information is available for acenaphthene (ATSDR, 1995b,c). The EPA (1989) reported increased liver weight in a 13-week study of CD-1 mice orally exposed to acenaphthene at a dose of 175 mg/kg-day. Decreased ovary weights were reported at a dose of 170 mg/kg-day. A review of the scientific did not reveal any additional studies.

The EPA has not classified acenaphthene as to it's carcinogenic potential to humans. Likewise, the EPA has not established an oral or inhalation cancer slope factor for acenaphthene. The Agency has derived an oral RfD value of 0.06 mg/kg-day based on hepatotoxic effects in mice gavaged daily with 350 or 700 mg/kg-day acenaphthene for 90 days (EPA, 1989). The EPA has not developed an inhalation RfD value for acenaphthene. For the purposes of this assessment, the oral RfD value is also used for the inhalation RfD value.

Acenaphthylene
Little data are available on the toxicological properties of acenaphthylene; no studies have been reported specifically for acenaphthylene by ATSDR (1995c). The EPA (1996g) cites a single chronic skin cancer bioassay in mice conducted by Cook (1932) which failed to produce any tumors. The EPA has classified acenaphthylene in Group D (not classifiable as to human carcinogenicity) based on the absence of human data and inadequate data from animal bioassays. In addition, the Agency has not established an oral or inhalation cancer slope factor or RfD value for this compound.

Benzo(a)anthracene
There are no human data which conclusively link exposure to benzo(a)anthracene and human carcinogenicity. Data from laboratory studies, however, are sufficient to suggest a carcinogenic association. In several studies the administration of benzo(a)anthracene caused an increase in the incidence of tumors via gavage, dermal application, and subcutaneous injection (IARC, 1973; Klein, 1963; Steiner and Edgecomb, 1952; Steiner and Faulk, 1951).

The EPA has classified benzo(a)anthracene as a Group B2 (probable human carcinogen) based on the absence of human data and sufficient data from animal assays (IRIS, 1996h). The EPA has established an oral CSF of 0.73 $(mg/kg\text{-}day)^{-1}$ for benzo(a)anthracene based on the application of a TEF of 1.0 for benzo(a)anthracene, to the CSF of 7.3 $(mg/kg\text{-}day)^{-1}$ derived for benzo(a)pyrene (EPA, 1993; IRIS, 1996h). EPA Region III uses an inhalation cancer slope factor of 0.61 $(mg/kg\text{-}day)^{-1}$ for benzo(a)anthracene (EPA, 1995b). This value is also derived by applying a TEF. Finally, The EPA has not derived oral or inhalation RfD values for benzo(a)anthracene (IRIS, 1996h).

Benzo(a)pyrene

Benzo(a)pyrene is probably the most extensively studied of the PAHs. Human exposure to airborne benzo(a)pyrene has been associated with reduced lung function, coughing, and throat and chest irritation (ATSDR, 1995c). In laboratory animals, chronic benzo(a)pyrene exposure has resulted in increased respiratory tract, upper digestive tract, and stomach tumors, squamous cell carcinomas, skin cancer, reduced pregnancy rates, fetal resorption, reduced birth weights, aplastic anemia, and increased production of melanocytes (ATSDR, 1995c).

The EPA has classified benzo(a)pyrene as a Group B2 carcinogen (probable human carcinogen) based on sufficient evidence of carcinogenicity in laboratory animals and inadequate evidence in humans. The EPA has established an oral CSF of 7.3 $(mg/kg\text{-}day)^{-1}$ for benzo(a)pyrene based on the geometric mean of four cancer slope factors derived with the data from two studies. In the first study (Neal and Rigdon, 1967), dietary exposure to benzo(a)pyrene at nine dietary doses ranging from 1 to 250 ppm resulted in squamous cell papillomas and carcinomas of the forestomach in CFW mice (IRIS, 1996i). An upper-bound CSF of 5.9 $(mg/kg\text{-}day)^{-1}$ was generated from the Neal and Rigdon (1967) data by application of a two-stage (modified MVK) model and using historical control data for a related strain of mice. The EPA (1991) calculated two upperbound CSFs of 4.5 and 9.0 $(mg/kg\text{-}day)^{-1}$ using the same data, but by application of a Weibull-type model and the linearized multistage (LMS) model, respectively. In the second study (Brune et al., 1981), dietary doses of 3 and 39 mg/kg-year produced papillomas and carcinomas of the forestomach, larynx, and esophagus in male and female Sprague-Dawley rats. Application of the LMS model to the Brune et al. (1981) data produced an upper-bound CSF of 11.7 $(mg/kg\text{-}day)^{-1}$. The geometric mean of these four CSFs is 7.3 $(mg/kg\text{-}day)^{-1}$ (IRIS, 1996i). In addition, EPA Region III uses an inhalation cancer slope factor of 6.1 $(mg/kg\text{-}day)^{-1}$ for benzo(a)pyrene (EPA, 1995b). This value is derived with the application of a TEF. Finally, The EPA has not derived oral or inhalation RfD values for benzo(a)pyrene (IRIS, 1996i).

Benzo(b)fluoranthene

Other than carcinogenicity data, no other toxicological data are available for benzo(b)fluoranthene (ATSDR, 1995c). Application of 0.01 mg benzo(b)fluoranthene to the skin of CD-1 mice over a period of 20 days resulted in an increased incidence of skin tumors (Weyand et al., 1993). A similar study by LeVole et al. (1993) produced nearly identical results (ATSDR, 1995).

The EPA has classified benzo(b)fluoranthene as a Group B2 carcinogen (probable human carcinogen) based on sufficient data in laboratory animals and no data in humans. The EPA has established an oral CSF of 0.73 $(mg/kg\text{-}day)^{-1}$ based on the application of a TEF of 1.0 for benzo(b)fluoranthene, to the CSF of 7.3 $(mg/kg\text{-}day)^{-1}$ derived for benzo(a)pyrene (EPA, 1993; IRIS, 1996j). EPA Region III uses an inhalation cancer slope factor of 6.1 $(mg/kg\text{-}day)^{-1}$ for benzo(b)fluoranthene (EPA, 1995b). This value is also derived by applying a TEF. Finally, The EPA has not derived oral or inhalation RfD values for benzo(b)fluoranthene (IRIS, 1996j).

Benzo(k)fluoranthene
No human data are available that specifically link exposure to benzo(k)fluoranthene to human cancers. However, benzo(k)fluoranthene is a component of chemical mixtures that have been associated with human cancer. Such mixtures include coal tar, soot, coke oven emissions, and cigarette smoke (EPA, 1996; IARC, 1984). Several laboratory animal studies suggest an association with benzo(k)fluoranthene exposure to cancer incidence. Deutsch-Wenzel et al. (1983) reported the production of tumors after lung implantation in rats. Benzo(k)fluoranthene has also yielded positive results for initiating activity in mouse skin-painting assays (Amin et al., 1985; LaVoie et al., 1982; Van Duuren et al., 1966). In addition, equivocal results have been reported in a lung adenoma assay in mice (LaVoie et al., 1987).

The EPA has classified benzo(k)fluoranthene as a Group B2 carcinogen (probable human carcinogen) based on sufficient data in laboratory animals and no data in humans. The EPA has established an oral CSF of 0.073 $(mg/kg\text{-}day)^{-1}$ based on the application of a TEF of 100 for benzo(k)fluoranthene, to the CSF of 7.3 $(mg/kg\text{-}day)^{-1}$ for benzo(a)pyrene (EPA, 1993; 1996). EPA Region III uses a cancer slope factor of 0.061 $(mg/kg\text{-}day)^{-1}$ for benzo(k)fluoranthene (EPA, 1995b). This value is also derived by applying a TEF. Finally, the EPA has not derived oral or inhalation RfD values for benzo(k)fluoranthene (EPA, 1996).

Chrysene
There are no human data which conclusively link exposure to chrysene and human carcinogenicity. Data from laboratory studies, however, are sufficient to suggest a carcinogenic association. In several studies the administration of chrysene caused an increase in the incidence of tumors via intraperitoneal injection and dermal application (IRIS, 1996k). Mice receiving total doses of 160, 320, or 640 µg/mouse via intraperitoneal injection resulted in an increased incidence of liver tumors, malignant lymphoma, and lung tumors (Buening et al., 1979; Wislocki et al., 1986). Additionally, in mouse skin painting assays chrysene tested positive in both initiation and complete carcinogen studies (Wynder and Hoffman, 1959).

The EPA has classified chrysene as a Group B2 (probable human carcinogen) based on the absence of human data and sufficient data from animal assays (IRIS, 1996k). The EPA has established an oral CSF of 0.0073 $(mg/kg\text{-}day)^{-1}$ for chrysene based on the application of a TEF of 1000.0 for chrysene, to the CSF of 7.3 $(mg/kg\text{-}day)^{-1}$ derived for benzo(a)pyrene (EPA, 1993; IRIS, 1996k). EPA Region III uses an inhalation cancer slope factor of 0.0061 $(mg/kg\text{-}day)^{-1}$ for chrysene (EPA, 1995b). This value is also derived by applying a TEF. Finally, The EPA has not derived oral or inhalation RfD values for chrysene (IRIS, 1996k).

Dibenzo(a,h)anthracene
No toxicological studies on dibenzo(a,h)anthracene were reported by the ATSDR (1995). However, the EPA has classified dibenzo(a,h)anthracene as a Group B2 carcinogen (probable

human carcinogen) based on sufficient data in laboratory animals and no data in humans. Furthermore, the EPA has established an oral CSF of 7.3 (mg/kg-day)$^{-1}$ by application of a TEF of 1.0 to the CSF of 7.3 (mg/kg-day)$^{-1}$ derived for benzo(a)pyrene (EPA, 1993; IRIS, 1996l). EPA Region III uses an inhalation cancer slope factor of 6.1 (mg/kg-day)$^{-1}$ for dibenzo(a,h)anthracene (EPA, 1995b). This value is also derived by applying a TEF. Finally, The EPA has not derived oral or inhalation RfD values for dibenzo(a,h)anthracene (IRIS, 1996l).

Fluoranthene

Only limited data are available on the toxicological effects of fluoranthene. CD-1 mice orally dosed to fluoranthene for 13 weeks had increased liver weights, renal effects, and increased serum globulin levels (ATSDR, 1995c). Warshawsky et al. (1993) reported in increase in the incidence of skin papillomas when fluoranthene was administered to the skin of C3H/HeJ mice in combination with benzo(a)pyrene as a promoter.

The EPA has classified fluoranthene as a Group D carcinogen (not classifiable as to human carcinogenicity) based on the absence of human data and inadequate data from animal bioassays. In addition, the Agency has not established an oral or inhalation cancer slope factor for this compound. The EPA has derived an oral RfD value of 0.04 mg/kg-day based on the results of a 13-week mouse oral subchronic toxicity study which indicate nephropathy, increased liver weights, hematological alterations, and clinical effects in treated animals (EPA, 1988; IRIS, 1996m). The Agency has not derived an inhalation RfD value for this compound. For the purposes of this assessment, however, the oral RfD value is also employed as the inhalation RfD value.

Indeno(1,2,3-cd)pyrene

Little information is available on the toxic effects of indeno(1,2,3-cd)pyrene, other than for carcinogenicity. Rice et al. (1985) administered 100 mg indeno(1,2,3-cd)pyrene to the skin of CD-1 mice over a period of 20 days and reported an increased incidence of skin tumors.

The EPA has classified indeno(1,2,3-c,d)pyrene as a Group B2 carcinogen (probable human carcinogen) based on sufficient evidence of carcinogenicity in laboratory animals and no evidence in humans. The EPA has derived a CSF of 0.73 (mg/kg-day)$^{-1}$ for indeno(1,2,3-cd)pyrene by application of a TEF of 0.1 to the CSF of 7.3 (mg/kg-day)$^{-1}$ for benzo(a)pyrene (EPA, 1993; IRIS, 1996n). EPA Region III uses an inhalation cancer slope factor of 0.61 (mg/kg-day)$^{-1}$ for indeno(1,2,3-c,d)pyrene (EPA, 1995b). This value is also derived by applying a TEF. Finally, The EPA has not derived oral or inhalation RfD values for indeno(1,2,3-cd)pyrene (IRIS, 1996n).

Phenanthrene

Data from toxicity studies of phenanthrene are very limited. No tumor incidence was reported for rats receiving a single oral dose of 200 mg phenanthrene (Huggins and Yang, 1962). Additionally, two skin painting investigations reported the absence of tumors in mice (Kennaway,

1924; Roe and Grant, 1964). However, the results of another skin painting assay did suggest cancer-initiating activity in mice receiving a single dermal application of 1.8 mg phenanthrene in benzene (Scribner, 1973).

The EPA has classified phenanthrene in Group D (not classifiable as to human carcinogenicity) due to inadequate evidence of carcinogenicity in laboratory animals and no evidence in humans. In addition, the EPA has not established oral or inhalation cancer slope factors or RfD values for phenanthrene (IRIS, 1996o).

A.8 Trichloromethanethiol

The EPA has not classified trichloromethanethiol (CCl_3HS) as to potential carcinogenic effects to humans. Additionally, the EPA has not established oral or inhalation cancer slope factors on RfD values. Due to the absence of toxicological data, ChemRisk will not address the potential toxicological significance of this compound.

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Table A-1. Chemical/Physical Data for Selected Polycyclic Aromatic Hydrocarbons

PAH	Chemical Formula[a]	Molecular Weight[a] (Average)	Vapor Pressure[a] (mmHg at 25°C)	Boiling Point[a] °C	Melting Point[a] °C	Henry's Law Constant[a] (atm-m3/mol at 25°C)	Solubility (Water, mg/L)	log Kow[b]	log Koc[b]
Acenaphthene	C12H10	154.21	4.47×10^{-3}[c]	96.2	95	No data	Insoluble	3.98	3.66
Acenaphthylene	C12H8	154.2	0.029[b]	265-275	92-93	1.45×10^{-3}	0.42[f]	4.07	1.4
Benzo(a)anthracene	C18H12	228.29[b]	$2.2 \times 10^{-}$[d]	400[e]	158-159f	1×10^{-6}	0.59[d]	5.61	5.3
Benzo(b)fluoranthene	C20H12[g]	252.3[g]	10^{-8}[b]	No data	168.3[g]	1.22×10^{-5}[b]	0.24[f]	6.04	5.74
Benzo(a)pyrene	C20H12[g]	252.3[g]	5.6×10^{-9}[b]	310-312[h]	179-179.3[h]	4.9×10^{-7}[b]	1.45[f]	6.06	6.74
Chrysene	C18H12	228.3[g]	6.3×10^{-9}[b]	448[g]	256[g]	1.05×10^{-6}[b]	Insoluble	5.61[f]	5.30[b]
Fluoranthene	C16H10[g]	202.26	5.0×10^{-6}[b]	375	111	6.5×10^{-6}[b]	Soluble[i]	4.90[f]	4.58[b]
Dibenzo(a,h)anthracene	C22H14[g]	278.35[f]	1×10^{-1}[b]	269-270	262[f]	7.3×10^{-8}[b]	0.054[f]	6.84	6.52
Indeno(1,2,3-c,d)pyrene	C22H12[g]	276.3[2g]	10^{-10}[b]	530	163.6[g]	6.95×10^{-8}[b]	0.012[f]	6.58	6.2
Phenanthrene	C14H10[g]	178.2[g]	9.6×10^{-4}[b]	340[g]	100[g]	2.26×10^{-4}[b]	0.0027[f]	4.45	4.15

a. HSDB, 1988
b. Mabey et al., 1982
c. EPA, 1988
d. Lyman et al., 1982
e. Weast, 1985
f. Eller, 1984
g. IARC, 1983
h. Weast, 1987
i. Soluble in sea water at 22°C

Appendix B

Risk Profiles

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: INDUSTRIAL Receptor: TYPICAL

Route of Exposure	Total Adult Carcinogenic Risk	Total Adult Hazard Index
Dermal Contact with Groundwater	1.30 E-05	2.6 E-02
Dermal Contact with Subsurface Soil	2.60 E-08	4.6 E-05
Dermal Contact with Surface Soil	5.64 E-08	1.4 E-03
Ingestion of Subsurface Soil	9.99 E-07	1.6 E-02
Ingestion of Surface Soil	4.91 E-07	5.0 E-02
Inhalation of Groundwater Vapors	7.40 E-09	5.0 E-02
Inhalation of Subsurface Soil	4.68 E-12	
Inhalation of Subsurface Soil Vapors		
Inhalation of Surface Soil	1.15 E-10	
Inhalation of Surface Soil Vapors		
Total Risk:	1.46 E-05	1.4 E-01

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Groundwater — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.17 E-04

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 8.17 E-03

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/l	MF** Dermal Permeability	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	2.00 E-01	2.58 E-01	6.03 E-06	NA		4.22 E-04	6.00 E-02	7.04 E-03
Acenaphthylene	–	NR		NA			NA	
Arsenic (inorganic)	3.00 E-02	1.00 E-03	3.50 E-09	1.50 E+00	5.25 E-09	2.45 E-07	3.00 E-04	8.17 E-04
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	2.00 E-02	8.10 E-01	1.89 E-06	7.30 E-01	1.38 E-06	1.32 E-04	NA	
Benzo(a)pyrene	9.00 E-03	1.20 E+00	1.26 E-06	7.30 E+00	9.20 E-06	8.83 E-05	NA	
Benzo(b)fluoranthene	1.00 E-02	1.20 E+00	1.40 E-06	7.30 E-01	1.02 E-06	9.81 E-05	NA	
Carbazole	3.00 E-02	7.97 E-02	2.79 E-07	2.00 E-02	5.58 E-09	1.95 E-05	NA	
Chromium (VI)	8.00 E-02	1.00 E-03	9.34 E-09	4.10 E+01	3.83 E-07	6.54 E-07	5.00 E-03	1.31 E-04
Chrysene	2.00 E-02	8.10 E-01	1.89 E-06	7.30 E-03	1.38 E-08	1.32 E-04	NA	
Dibenz(a,h)anthracene	–	NR		7.30 E+00			NA	
Fluoranthene	1.20 E-01	3.60 E-01	5.04 E-06	NA		3.53 E-04	4.00 E-02	8.83 E-03
Indeno(1,2,3-cd)pyrene	6.00 E-03	1.90 E+00	1.33 E-06	7.30 E-01	9.72 E-07	9.32 E-05	NA	
Lead (and compounds)	5.00 E-02	1.00 E-03	5.84 E-09	NA		4.09 E-07	NA	
Naphthalene	6.60 E-01	6.90 E-02	5.32 E-06	NA		3.72 E-04	4.00 E-02	9.30 E-03
Phenanthrene	2.60 E-01	2.70 E-01	8.20 E-06	NA		5.74 E-04	NA	
Total for Pathway:					1.30 E-05			2.61 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Groundwater Vapors — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 3.35 E-04

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 2.35 E-02

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	1.35 E-02	NR	4.53 E-06	0		3.17 E-04	6.00 E-02	5.28 E-03
Acenaphthylene	–	NR		0			0	
Arsenic (inorganic)	–	NR		5.00 E+01			0	
Benzene	7.59 E-04	NR	2.55 E-07	2.91 E-02	7.40 E-09	1.78 E-05	1.71 E-03	1.04 E-02
Benzo(a)anthracene	–	NR		6.10 E-01			0	
Benzo(a)pyrene	–	NR		6.10 E+00			0	
Benzo(b)fluoranthene	–	NR		6.10 E-01			0	
Carbazole	–	NR		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	–	NR		6.10 E-01			0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	5.87 E-02	NR	1.97 E-05	0		1.38 E-03	4.00 E-02	3.45 E-02
Phenanthrene	1.78 E-02	NR	5.97 E-06	0		4.18 E-04	0	
Total for Pathway:					7.40 E-09			5.02 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Subsurface Soil — TYPICAL

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 2.31 E-08

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 1.62 E-06

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	–	1.00 E-02		NA			NA	
Arsenic (inorganic)	8.56 E+00	1.00 E-03	1.98 E-10	1.50 E+00	2.97 E-10	1.38 E-08	3.00 E-04	4.61 E-05
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	2.44 E+01	1.00 E-02	5.63 E-09	7.30 E-01	4.11 E-09	3.94 E-07	NA	
Benzo(a)pyrene	1.01 E+01	1.00 E-02	2.32 E-09	7.30 E+00	1.69 E-08	1.62 E-07	NA	
Benzo(b)fluoranthene	2.37 E+01	1.00 E-02	5.48 E-09	7.30 E-01	4.00 E-09	3.84 E-07	NA	
Carbazole	3.41 E+01	1.00 E-02	7.88 E-09	2.00 E-02	1.58 E-10	5.52 E-07	NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	–	1.00 E-02		7.30 E+00			NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	2.89 E+00	1.00 E-02	6.68 E-10	7.30 E-01	4.87 E-10	4.67 E-08	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	2.29 E+02	1.00 E-02	5.28 E-08	NA		3.70 E-06	NA	
Total for Pathway:					2.60 E-08			4.61 E-05

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Ingestion of Subsurface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 8.05 E-09

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 5.64 E-07

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/kg	MF**	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	–	NR		NA			NA	
Arsenic (inorganic)	8.56 E+00	NR	6.89 E-08	1.50 E+00	1.03 E-07	4.82 E-06	3.00 E-04	1.61 E-02
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	2.44 E+01	NR	1.96 E-07	7.30 E-01	1.43 E-07	1.37 E-05	NA	
Benzo(a)pyrene	1.01 E+01	NR	8.09 E-08	7.30 E+00	5.91 E-07	5.66 E-06	NA	
Benzo(b)fluoranthene	2.37 E+01	NR	1.91 E-07	7.30 E-01	1.40 E-07	1.34 E-05	NA	
Carbazole	3.41 E+01	NR	2.75 E-07	2.00 E-02	5.50 E-09	1.92 E-05	NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	–	NR		7.30 E+00			NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	2.89 E+00	NR	2.33 E-08	7.30 E-01	1.70 E-08	1.63 E-06	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	2.29 E+02	NR	1.84 E-06	NA		1.29 E-04	NA	
Total for Pathway:					9.99 E-07			1.61 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Subsurface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 9.00 E-15

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 6.31 E-13

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	–	NR		0			0	
Arsenic (inorganic)	8.56 E+00	NR	7.70 E-14	5.00 E+01	3.85 E-12	5.40 E-12	0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	2.44 E+01	NR	2.20 E-13	6.10 E-01	1.34 E-13	1.54 E-11	0	
Benzo(a)pyrene	1.01 E+01	NR	9.00 E-14	6.10 E+00	5.52 E-13	6.34 E-12	0	
Benzo(b)fluoranthene	2.37 E+01	NR	2.14 E-13	6.10 E-01	1.30 E-13	1.50 E-11	0	
Carbazole	3.41 E+01	NR	3.07 E-13	2.00 E-02		2.15 E-11	0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	2.89 E+00	NR	2.60 E-14	6.10 E-01	1.60 E-14	1.82 E-12	0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	2.29 E+02	NR	2.06 E-12	0		1.44 E-10	0	
Total for Pathway:					4.68 E-12			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL | Inhalation of Subsurface Soil Vapors | TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 3.35 E-04

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 2.35 E-02

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	–	NR		0			0	
Arsenic (inorganic)	–	NR		5.00 E+01			0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	–	NR		6.10 E-01			0	
Benzo(a)pyrene	–	NR		6.10 E+00			0	
Benzo(b)fluoranthene	–	NR		6.10 E-01			0	
Carbazole	–	1.16 E-07		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	–	NR		6.10 E-01			0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	2.29 E+02	2.15 E-05	1.65 E-06	0		1.15 E-04	0	
Total for Pathway:					NR			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Surface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.69 E-07

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 1.19 E-05

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	--	NR		NA			6.00 E-02	
Acenaphthylene	2.70 E-01	1.00 E-02	4.57 E-10	NA		3.20 E-08	NA	
Arsenic (inorganic)	3.45 E+01	1.00 E-03	5.85 E-09	1.50 E+00	8.77 E-09	4.09 E-07	3.00 E-04	1.36 E-03
Benzene	--	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	3.43 E+00	1.00 E-02	5.81 E-09	7.30 E-01	4.24 E-09	4.07 E-07	NA	
Benzo(a)pyrene	2.47 E+00	1.00 E-02	4.18 E-09	7.30 E+00	3.05 E-08	2.93 E-07	NA	
Benzo(b)fluoranthene	7.00 E+00	1.00 E-02	1.19 E-08	7.30 E-01	8.66 E-09	8.30 E-07	NA	
Carbazole	--	1.00 E-02		2.00 E-02			NA	
Chromium (VI)	--	NR		4.10 E+01			5.00 E-03	
Chrysene	--	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	2.30 E-01	1.00 E-02	3.90 E-10	7.30 E+00	2.84 E-09	2.73 E-08	NA	
Fluoranthene	--	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	1.12 E+00	1.00 E-02	1.90 E-09	7.30 E-01	1.38 E-09	1.33 E-07	NA	
Lead (and compounds)	--	NR		NA			NA	
Naphthalene	--	NR		NA			4.00 E-02	
Phenanthrene	1.79 E+00	1.00 E-02	3.03 E-09	NA		2.12 E-07	NA	
Total for Pathway:					5.64 E-08			1.36 E-03

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL | Ingestion of Surface Soil | TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 6.15 E-09

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 4.31 E-07

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	2.70 E-01	NR	1.66 E-09	NA		1.16 E-07	NA	
Arsenic (inorganic)	3.45 E+01	NR	2.12 E-07	1.50 E+00	3.18 E-07	1.49 E-05	3.00 E-04	4.95 E-02
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	3.43 E+00	NR	2.11 E-08	7.30 E-01	1.54 E-08	1.48 E-06	NA	
Benzo(a)pyrene	2.47 E+00	NR	1.52 E-08	7.30 E+00	1.11 E-07	1.06 E-06	NA	
Benzo(b)fluoranthene	7.00 E+00	NR	4.31 E-08	7.30 E-01	3.14 E-08	3.01 E-06	NA	
Carbazole	–	NR		2.00 E-02			NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	2.30 E-01	NR	1.41 E-09	7.30 E+00	1.03 E-08	9.90 E-08	NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	1.12 E+00	NR	6.89 E-09	7.30 E-01	5.03 E-09	4.82 E-07	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	1.79 E+00	NR	1.10 E-08	NA		7.71 E-07	NA	
Total for Pathway:					4.91 E-07			4.95 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Surface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 6.60 E-14

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 4.63 E-12

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	2.70 E-01	NR	1.80 E-14	0		1.25 E-12	0	
Arsenic (inorganic)	3.45 E+01	NR	2.28 E-12	5.00 E+01	1.14 E-10	1.60 E-10	0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	3.43 E+00	NR	2.26 E-13	6.10 E-01	1.38 E-13	1.59 E-11	0	
Benzo(a)pyrene	2.47 E+00	NR	1.63 E-13	6.10 E+00	9.94 E-13	1.14 E-11	0	
Benzo(b)fluoranthene	7.00 E+00	NR	4.62 E-13	6.10 E-01	2.82 E-13	3.24 E-11	0	
Carbazole	–	NR		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	2.30 E-01	NR	1.50 E-14	6.10 E+00	9.30 E-14	1.06 E-12	0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	1.12 E+00	NR	7.40 E-14	6.10 E-01	4.50 E-14	5.18 E-12	0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	1.79 E+00	NR	1.18 E-13	0		8.28 E-12	0	
Total for Pathway:					1.15 E-10			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL | Inhalation of Surface Soil Vapors | TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 2.46 E-03

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 1.72 E-01

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	2.70 E-01	2.25 E-04	1.49 E-07	0		1.05 E-05	0	
Arsenic (inorganic)	–	NR		5.00 E+01			0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	–	NR		6.10 E-01			0	
Benzo(a)pyrene	–	NR		6.10 E+00			0	
Benzo(b)fluoranthene	–	NR		6.10 E-01			0	
Carbazole	–	NR		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	–	NR		6.10 E-01			0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	1.79 E+00	2.15 E-05	9.47 E-08	0		6.63 E-06	0	
Total for Pathway:					NR			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: INDUSTRIAL **Receptor: HIGH END**

Route of Exposure	Total Adult Carcinogenic Risk	Total Adult Hazard Index
Dermal Contact with Groundwater	1.61 E-05	4.7 E-02
Dermal Contact with Subsurface Soil	8.16 E-08	1.6 E-04
Dermal Contact with Surface Soil	1.71 E-07	3.2 E-03
Ingestion of Subsurface Soil	1.61 E-06	2.8 E-02
Ingestion of Surface Soil	1.31 E-06	1.2 E-01
Inhalation of Groundwater Vapors	1.11 E-08	8.4 E-02
Inhalation of Subsurface Soil	8.09 E-12	
Inhalation of Subsurface Soil Vapors		
Inhalation of Surface Soil	1.38 E-10	
Inhalation of Surface Soil Vapors		
Total Risk:	1.93 E-05	2.8 E-01

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Groundwater — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.17 E-04

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 8.17 E-03

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/l	MF** Dermal Permeability	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	4.00 E-01	2.58 E-01	1.21 E-05	NA		8.45 E-04	6.00 E-02	1.41 E-02
Acenaphthylene	–	NR		NA			NA	
Arsenic (inorganic)	7.00 E-02	1.00 E-03	8.17 E-09	1.50 E+00	1.23 E-08	5.72 E-07	3.00 E-04	1.91 E-03
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	3.00 E-02	8.10 E-01	2.84 E-06	7.30 E-01	2.07 E-06	1.99 E-04	NA	
Benzo(a)pyrene	1.00 E-02	1.20 E+00	1.40 E-06	7.30 E+00	1.02 E-05	9.81 E-05	NA	
Benzo(b)fluoranthene	2.00 E-02	1.20 E+00	2.80 E-06	7.30 E-01	2.05 E-06	1.96 E-04	NA	
Chrysene	5.00 E-02	7.97 E-02	4.65 E-07	2.00 E-02	9.30 E-09	3.26 E-05	NA	
Chromium (VI)	1.20 E-01	1.00 E-03	1.40 E-08	4.10 E+01	5.74 E-07	9.81 E-07	5.00 E-03	1.96 E-04
Chrysene	3.00 E-02	8.10 E-01	2.84 E-06	7.30 E-03	2.07 E-08	1.99 E-04	NA	
Dibenz(a,h)anthracene	–	NR		7.30 E+00			NA	
Fluoranthene	2.10 E-01	3.60 E-01	8.83 E-06	NA		6.18 E-04	4.00 E-02	1.54 E-02
Indeno(1,2,3-cd)pyrene	7.00 E-03	1.90 E+00	1.55 E-06	7.30 E-01	1.13 E-06	1.09 E-04	NA	
Lead (and compounds)	–	1.00 E-03		NA			NA	
Naphthalene	1.11 E+00	6.90 E-02	8.94 E-06	NA		6.26 E-04	4.00 E-02	1.56 E-02
Phenanthrene	2.80 E-01	2.70 E-01	8.83 E-06	NA		6.18 E-04	NA	
Total for Pathway:					1.61 E-05			4.73 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Groundwater Vapors — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 3.35 E-04

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 2.35 E-02

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	2.69 E-02	NR	9.02 E-06	0		6.32 E-04	6.00 E-02	1.05 E-02
Acenaphthylene	–	NR		0			0	
Arsenic (inorganic)	–	NR		5.00 E+01			0	
Benzene	1.14 E-03	NR	3.82 E-07	2.91 E-02	1.11 E-08	2.68 E-05	1.71 E-03	1.57 E-02
Benzo(a)anthracene	–	NR		6.10 E-01			0	
Benzo(a)pyrene	–	NR		6.10 E+00			0	
Benzo(b)fluoranthene	–	NR		6.10 E-01			0	
Carbazole	–	NR		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	–	NR		6.10 E-01			0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	9.88 E-02	NR	3.31 E-05	0		2.32 E-03	4.00 E-02	5.80 E-02
Phenanthrene	1.92 E-02	NR	6.44 E-06	0		4.51 E-04	0	
Total for Pathway:					1.11 E-08			8.42 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Subsurface Soil — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 4.53 E-08

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 3.17 E-06

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/kg	MF**	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	–	1.00 E-02		NA			NA	
Arsenic (inorganic)	1.50 E+01	1.00 E-03	6.79 E-10	1.50 E+00	1.02 E-09	4.76 E-08	3.00 E-04	1.59 E-04
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	2.60 E+01	1.00 E-02	1.18 E-08	7.30 E-01	8.60 E-09	8.24 E-07	NA	
Benzo(a)pyrene	1.51 E+01	1.00 E-02	6.85 E-09	7.30 E+00	5.00 E-08	4.79 E-07	NA	
Benzo(b)fluoranthene	6.20 E+01	1.00 E-02	2.81 E-08	7.30 E-01	2.05 E-08	1.97 E-06	NA	
Carbazole	5.70 E+00	1.00 E-02	2.58 E-09	2.00 E-02	5.16 E-11	1.81 E-07	NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	–	1.00 E-02		7.30 E+00			NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	4.41 E+00	1.00 E-02	2.00 E-09	7.30 E-01	1.46 E-09	1.40 E-07	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	3.00 E+02	1.00 E-02	1.36 E-07	NA		9.51 E-06	NA	
Total for Pathway:					8.16 E-08			1.59 E-04

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Ingestion of Subsurface Soil — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 8.05 E-09

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 5.64 E-07

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	–	NR		NA			NA	
Arsenic (inorganic)	1.50 E+01	NR	1.21 E-07	1.50 E+00	1.81 E-07	8.45 E-06	3.00 E-04	2.82 E-02
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	2.60 E+01	NR	2.09 E-07	7.30 E-01	1.53 E-07	1.47 E-05	NA	
Benzo(a)pyrene	1.51 E+01	NR	1.22 E-07	7.30 E+00	8.89 E-07	8.52 E-06	NA	
Benzo(b)fluoranthene	6.20 E+01	NR	4.99 E-07	7.30 E-01	3.64 E-07	3.49 E-05	NA	
Carbazole	5.70 E+00	NR	4.59 E-08	2.00 E-02	9.18 E-10	3.21 E-06	NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	–	NR		7.30 E+00			NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	4.41 E+00	NR	3.55 E-08	7.30 E-01	2.59 E-08	2.49 E-06	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	3.00 E+02	NR	2.42 E-06	NA		1.69 E-04	NA	
Total for Pathway:					1.61 E-06			2.82 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — **Inhalation of Subsurface Soil** — **HIGH END**

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 9.00 E-15

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 6.31 E-13

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	–	NR		0			0	
Arsenic (inorganic)	1.50 E+01	NR	1.35 E-13	5.00 E+01	6.75 E-12	9.47 E-12	0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	2.60 E+01	NR	2.34 E-13	6.10 E-01	1.43 E-13	1.64 E-11	0	
Benzo(a)pyrene	1.51 E+01	NR	1.36 E-13	6.10 E+00	8.30 E-13	9.54 E-12	0	
Benzo(b)fluoranthene	6.20 E+01	NR	5.58 E-13	6.10 E-01	3.40 E-13	3.91 E-11	0	
Carbazole	5.70 E+00	NR	5.10 E-14	2.00 E-02		3.60 E-12	0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	4.41 E+00	NR	4.00 E-14	6.10 E-01	2.40 E-14	2.78 E-12	0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	3.00 E+02	NR	2.70 E-12	0		1.89 E-10	0	
Total for Pathway:					8.09 E-12			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL | Inhalation of Subsurface Soil Vapors | HIGH END

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 3.35 E-04

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.35 E-02

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	–	NR		0			0	
Arsenic (inorganic)	–	NR		5.00 E+01			0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	–	NR		6.10 E-01			0	
Benzo(a)pyrene	–	NR		6.10 E+00			0	
Benzo(b)fluoranthene	–	NR		6.10 E-01			0	
Carbazole	–	1.16 E-07		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	–	NR		6.10 E-01			0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	3.00 E+02	2.15 E-05	2.16 E-06	0		1.51 E-04	0	
Total for Pathway:					NR			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Surface Soil — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 3.32 E-07

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 2.32 E-05

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	3.00 E-01	1.00 E-02	9.96 E-10	NA		6.97 E-08	NA	
Arsenic (inorganic)	4.10 E+01	1.00 E-03	1.36 E-08	1.50 E+00	2.04 E-08	9.53 E-07	3.00 E-04	3.18 E-03
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	5.30 E+00	1.00 E-02	1.76 E-08	7.30 E-01	1.28 E-08	1.23 E-06	NA	
Benzo(a)pyrene	3.90 E+00	1.00 E-02	1.30 E-08	7.30 E+00	9.46 E-08	9.07 E-07	NA	
Benzo(b)fluoranthene	1.40 E+01	1.00 E-02	4.65 E-08	7.30 E-01	3.39 E-08	3.25 E-06	NA	
Carbazole	–	1.00 E-02		2.00 E-02			NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	2.40 E-01	1.00 E-02	7.97 E-10	7.30 E+00	5.82 E-09	5.58 E-08	NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	1.40 E+00	1.00 E-02	4.65 E-09	7.30 E-01	3.39 E-09	3.25 E-07	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	2.40 E+00	1.00 E-02	7.97 E-09	NA		5.58 E-07	NA	
Total for Pathway:					1.71 E-07			3.18 E-03

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Ingestion of Surface Soil — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.23 E-08

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 8.61 E-07

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		NA			6.00 E-02	
Acenaphthylene	3.00 E-01	NR	3.69 E-09	NA		2.58 E-07	NA	
Arsenic (inorganic)	4.10 E+01	NR	5.04 E-07	1.50 E+00	7.56 E-07	3.53 E-05	3.00 E-04	1.18 E-01
Benzene	–	NR		2.90 E-02			1.71 E-03	
Benzo(a)anthracene	5.30 E+00	NR	6.52 E-08	7.30 E-01	4.76 E-08	4.56 E-06	NA	
Benzo(a)pyrene	3.90 E+00	NR	4.80 E-08	7.30 E+00	3.50 E-07	3.36 E-06	NA	
Benzo(b)fluoranthene	1.40 E+01	NR	1.72 E-07	7.30 E-01	1.26 E-07	1.21 E-05	NA	
Carbazole	–	NR		2.00 E-02			NA	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	2.40 E-01	NR	2.95 E-09	7.30 E+00	2.16 E-08	2.07 E-07	NA	
Fluoranthene	–	NR		NA			4.00 E-02	
Indeno(1,2,3-cd)pyrene	1.40 E+00	NR	1.72 E-08	7.30 E-01	1.26 E-08	1.21 E-06	NA	
Lead (and compounds)	–	NR		NA			NA	
Naphthalene	–	NR		NA			4.00 E-02	
Phenanthrene	2.40 E+00	NR	2.95 E-08	NA		2.07 E-06	NA	
Total for Pathway:					1.31 E-06			1.18 E-01

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL | Inhalation of Surface Soil | HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 6.60 E-14

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 4.63 E-12

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthene	–	NR		0			6.00 E-02	
Acenaphthylene	3.00 E-01	NR	2.00 E-14	0		1.39 E-12	0	
Arsenic (inorganic)	4.10 E+01	NR	2.71 E-12	5.00 E+01	1.35 E-10	1.90 E-10	0	
Benzene	–	NR		2.91 E-02			1.71 E-03	
Benzo(a)anthracene	5.30 E+00	NR	3.50 E-13	6.10 E-01	2.13 E-13	2.45 E-11	0	
Benzo(a)pyrene	3.90 E+00	NR	2.57 E-13	6.10 E+00	1.57 E-12	1.80 E-11	0	
Benzo(b)fluoranthene	1.40 E+01	NR	9.24 E-13	6.10 E-01	5.64 E-13	6.48 E-11	0	
Carbazole	–	NR		2.00 E-02			0	
Chromium (VI)	–	NR		4.10 E+01			5.00 E-03	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	2.40 E-01	NR	1.60 E-14	6.10 E+00	9.70 E-14	1.11 E-12	0	
Fluoranthene	–	NR		0			4.00 E-02	
Indeno(1,2,3-cd)pyrene	1.40 E+00	NR	9.20 E-14	6.10 E-01	5.60 E-14	6.48 E-12	0	
Lead (and compounds)	–	NR		0			0	
Naphthalene	–	NR		0			4.00 E-02	
Phenanthrene	2.40 E+00	NR	1.58 E-13	0		1.11 E-11	0	
Total for Pathway:					1.38 E-10			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Surface Soil Vapors — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 2.46 E-03

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 1.72 E-01

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/m3	MF** Inverse of VF	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	3.00 E-01	2.25 E-04	1.66 E-07	0		1.16 E-05	0	
Phenanthrene	2.40 E+00	2.15 E-05	1.27 E-07	0		8.89 E-06	0	
Total for Pathway:					NR			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: TRESPASSER **Receptor: TYPICAL**

Route of Exposure		Total Child Carcinogenic Risk	Total Child Hazard Index
Dermal Contact with Sediment		1.56 E-06	1.2 E-05
Dermal Contact with Surface Soil		1.28 E-07	2.3 E-04
Ingestion of Sediment		2.12 E-06	1.7 E-04
Ingestion of Surface Soil		3.13 E-07	3.2 E-03
Inhalation of Surface Soil		5.60 E-11	
Inhalation of Surface Soil Vapors			
	Total Risk:	4.13 E-06	3.6 E-03

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Dermal Contact with Sediment** **TYPICAL**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 2.90 E-07

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.03 E-06

Description of Variables:

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** *bioavailability*	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	–	6.00 E-02		NA			NA	
Arsenic (inorganic)	1.83 E+00	1.00 E-03	5.30 E-10	1.50 E+00	7.96 E-10	3.71 E-09	3.00 E-04	1.24 E-05
Benzo(a)anthracene	5.57 E+01	1.00 E-02	1.62 E-07	7.30 E-01	1.18 E-07	1.13 E-06	NA	
Benzo(a)pyrene	4.99 E+01	1.00 E-02	1.45 E-07	7.30 E+00	1.06 E-06	1.01 E-06	NA	
Benzo(b)fluoranthene	1.30 E+02	1.00 E-02	3.77 E-07	7.30 E-01	2.75 E-07	2.64 E-06	NA	
Benzo(k)fluoranthene	–	6.00 E-02		7.30 E-02			NA	
Chrysene	6.88 E+01	1.00 E-02	1.99 E-07	NA		1.40 E-06	NA	
Dibenz(a,h)anthracene	4.70 E-01	1.00 E-02	1.36 E-09	7.30 E+00	9.94 E-09	9.54 E-09	NA	
Indeno(1,2,3-cd)pyrene	4.92 E+01	1.00 E-02	1.42 E-07	7.30 E-01	1.04 E-07	9.97 E-07	NA	
Lead (and compounds)	4.54 E+01	1.00 E-03	1.32 E-08	NA		9.21 E-08	NA	
Phenanthrene	–	1.00 E-02		NA			NA	
Total for Pathway:					1.56 E-06			1.56 E-06

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Dermal Contact with Surface Soil** **TYPICAL**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 2.90 E-07

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.03 E-06

Description of Variables:

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	2.70 E-01	1.00 E-02	7.83 E-10	NA		5.48 E-09	NA	
Arsenic (inorganic)	3.45 E+01	1.00 E-03	1.00 E-08	1.50 E+00	1.50 E-08	7.00 E-08	3.00 E-04	2.33 E-04
Benzo(a)anthracene	3.43 E+00	1.00 E-02	9.94 E-09	7.30 E-01	7.26 E-09	6.96 E-08	NA	
Benzo(a)pyrene	2.47 E+00	1.00 E-02	7.16 E-09	7.30 E+00	5.23 E-08	5.01 E-08	NA	
Benzo(b)fluoranthene	7.00 E+00	1.00 E-02	2.03 E-08	7.30 E-01	1.48 E-08	1.42 E-07	NA	
Benzo(k)fluoranthene	1.50 E+00	NR	4.35 E-07	7.30 E-02	3.17 E-08	3.04 E-06	NA	
Chrysene	–	NR		NA			NA	
Dibenz(a,h)anthracene	2.30 E-01	1.00 E-02	6.67 E-10	7.30 E+00	4.87 E-09	4.67 E-09	NA	
Indeno(1,2,3-cd)pyrene	1.12 E+00	1.00 E-02	3.25 E-09	7.30 E-01	2.37 E-09	2.27 E-08	NA	
Lead (and compounds)	–	NR		NA			NA	
Phenanthrene	1.79 E+00	1.00 E-02	5.19 E-09	NA		3.63 E-08	NA	
Total for Pathway:					1.28 E-07			1.28 E-07

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Ingestion of Sediment** **TYPICAL**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 3.91 E-09

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.74 E-08

Description of Variables:
- LADI: Lifetime Average Daily Intake
- CDI: Chronic Daily Intake
- Conc.: Chemical Concentration
- MF: Modifying Factor
- HIFcancer: Human Intake Factor, cancer*
- HIFnoncancer: Human Intake Factor, noncancer*
- SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	–	NR		NA			NA	
Arsenic (inorganic)	1.83 E+00	NR	7.16 E-09	1.50 E+00	1.07 E-08	5.01 E-08	3.00 E-04	1.67 E-04
Benzo(a)anthracene	5.57 E+01	NR	2.18 E-07	7.30 E-01	1.59 E-07	1.53 E-06	NA	
Benzo(a)pyrene	4.99 E+01	NR	1.95 E-07	7.30 E+00	1.43 E-06	1.37 E-06	NA	
Benzo(b)fluoranthene	1.30 E+02	NR	5.09 E-07	7.30 E-01	3.72 E-07	3.56 E-06	NA	
Benzo(k)fluoranthene	–	NR		7.30 E-02			NA	
Chrysene	6.88 E+01	NR	2.69 E-07	7.30 E-03	1.97 E-09	1.89 E-06	NA	
Dibenz(a,h)anthracene	4.70 E-01	NR	1.84 E-09	7.30 E+00	1.34 E-08	1.29 E-08	NA	
Indeno(1,2,3-cd)pyrene	4.92 E+01	NR	1.92 E-07	7.30 E-01	1.40 E-07	1.35 E-06	NA	
Lead (and compounds)	4.54 E+01	NR	1.78 E-07	NA		1.24 E-06	NA	
Phenanthrene	–	NR		NA			NA	
Total for Pathway:					2.12 E-06			2.12 E-06

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Ingestion of Surface Soil** **TYPICAL**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 3.91 E-09

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.74 E-08

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	2.70 E-01	NR	1.06 E-09	NA		7.40 E-09	NA	
Arsenic (inorganic)	3.45 E+01	NR	1.35 E-07	1.50 E+00	2.03 E-07	9.45 E-07	3.00 E-04	3.15 E-03
Benzo(a)anthracene	3.43 E+00	NR	1.34 E-08	7.30 E-01	9.80 E-09	9.40 E-08	NA	
Benzo(a)pyrene	2.47 E+00	NR	9.67 E-09	7.30 E+00	7.06 E-08	6.77 E-08	NA	
Benzo(b)fluoranthene	7.00 E+00	NR	2.74 E-08	7.30 E-01	2.00 E-08	1.92 E-07	NA	
Benzo(k)fluoranthene	1.50 E+00	NR	5.87 E-09	7.30 E-02	4.29 E-10	4.11 E-08	NA	
Chrysene	–	NR		7.30 E-03			NA	
Dibenz(a,h)anthracene	2.30 E-01	NR	9.00 E-10	7.30 E+00	6.57 E-09	6.30 E-09	NA	
Indeno(1,2,3-cd)pyrene	1.12 E+00	NR	4.38 E-09	7.30 E-01	3.20 E-09	3.07 E-08	NA	
Lead (and compounds)	–	NR		NA			NA	
Phenanthrene	1.79 E+00	NR	7.01 E-09	NA		4.90 E-08	NA	
Total for Pathway:					3.13 E-07			3.13 E-07

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Inhalation of Surface Soil** **TYPICAL**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 3.20 E-14

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.21 E-13

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	2.70 E-01	NR	9.00 E-15	0		6.00 E-14	0	
Arsenic (inorganic)	3.45 E+01	NR	1.10 E-12	5.00 E+01	5.52 E-11	7.63 E-12	0	
Benzo(a)anthracene	3.43 E+00	NR	1.10 E-13	6.10 E-01	6.70 E-14	7.58 E-13	0	
Benzo(a)pyrene	2.47 E+00	NR	7.90 E-14	6.10 E+00	4.82 E-13	5.46 E-13	0	
Benzo(b)fluoranthene	7.00 E+00	NR	2.24 E-13	6.10 E-01	1.37 E-13	1.55 E-12	0	
Benzo(k)fluoranthene	1.50 E+00	NR	4.80 E-14	6.10 E-02		3.32 E-13	0	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	2.30 E-01	NR	7.00 E-15	6.10 E+00	4.50 E-14	5.10 E-14	0	
Indeno(1,2,3-cd)pyrene	1.12 E+00	NR	3.60 E-14	6.10 E-01	2.20 E-14	2.48 E-13	0	
Lead (and compounds)	–	NR		0			0	
Phenanthrene	1.79 E+00	NR	5.70 E-14	0		3.96 E-13	0	
Total for Pathway:					5.60 E-11			5.60 E-11

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Inhalation of Surface Soil Vapors** **TYPICAL**

Equations for Cancer Effects
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.17 E-03

Equations for Noncancer Effects
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 8.22 E-03

Description of Variables

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF:** *Inverse of VF*	Carcinogenic Effects LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	2.70 E-01	2.25 E-04	7.13 E-08	0		4.99 E-07	0	
Arsenic (inorganic)	–	NR		5.00 E+01			0	
Benzo(a)anthracene	–	NR		6.10 E-01			0	
Benzo(a)pyrene	–	NR		6.10 E+00			0	
Benzo(b)fluoranthene	–	NR		6.10 E-01			0	
Benzo(k)fluoranthene	–	NR		6.10 E-02			0	
Chrysene	–	NR		6.10 E-03			0	
Dibenz(a,h)anthracene	–	NR		6.10 E+00			0	
Indeno(1,2,3-cd)pyrene	–	NR		6.10 E-01			0	
Lead (and compounds)	–	NR		0			0	
Phenanthrene	1.79 E+00	2.15 E-05	4.52 E-08	0		3.16 E-07	0	
Total for Pathway:					NR			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: TRESPASSER Receptor: HIGH END

Route of Exposure		Total Child Carcinogenic Risk	Total Child Hazard Index
Dermal Contact with Sediment		2.72 E-05	4.8 E-05
Dermal Contact with Surface Soil		3.71 E-07	5.4 E-04
Ingestion of Sediment		3.76 E-05	6.6 E-04
Ingestion of Surface Soil		8.37 E-07	7.5 E-03
Inhalation of Surface Soil		6.47 E-11	
Inhalation of Surface Soil Vapors			
	Total Risk:	6.60 E-05	8.7 E-03

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Dermal Contact with Sediment** **HIGH END**

Equations for Cancer Effects
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 5.68 E-07

Equations for Noncancer Effects
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 3.98 E-06

Description of Variables

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** *bioavailability*	Carcinogenic Effects LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Arsenic (inorganic)	3.60 E+00	1.00 E-03	2.05 E-09	1.50 E+00	3.07 E-09	1.43 E-08	3.00 E-04	4.77 E-05
Benzo(a)anthracene	7.30 E+02	1.00 E-02	4.15 E-06	7.30 E-01	3.03 E-06	2.90 E-05	NA	
Benzo(a)pyrene	3.80 E+02	1.00 E-02	2.16 E-06	7.30 E+00	1.58 E-05	1.51 E-05	NA	
Benzo(b)fluoranthene	1.80 E+03	1.00 E-02	1.02 E-05	7.30 E-01	7.47 E-06	7.16 E-05	NA	
Chrysene	8.20 E+02	1.00 E-02	4.66 E-06	NA		3.26 E-05	NA	
Dibenz(a,h)anthracene	7.00 E-01	1.00 E-02	3.98 E-09	7.30 E+00	2.90 E-08	2.78 E-08	NA	
Indeno(1,2,3-cd)pyrene	2.20 E+02	1.00 E-02	1.25 E-06	7.30 E-01	9.13 E-07	8.75 E-06	NA	
Lead (and compounds)	1.90 E+02	1.00 E-03	1.08 E-07	NA		7.56 E-07	NA	
Phenanthrene	7.00 E+01	1.00 E-02	3.98 E-07	NA		2.78 E-06	NA	
Total for Pathway:					2.72 E-05			2.72 E-05

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Dermal Contact with Surface Soil** **HIGH END**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 5.68 E-07

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 3.98 E-06

Description of Variables:

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	3.00 E-01	1.00 E-02	1.70 E-09	NA		1.19 E-08	NA	
Arsenic (inorganic)	4.10 E+01	1.00 E-03	2.33 E-08	1.50 E+00	3.50 E-08	1.63 E-07	3.00 E-04	5.44 E-04
Benzo(a)anthracene	5.30 E+00	1.00 E-02	3.01 E-08	7.30 E-01	2.20 E-08	2.11 E-07	NA	
Benzo(a)pyrene	3.90 E+00	1.00 E-02	2.22 E-08	7.30 E+00	1.62 E-07	1.55 E-07	NA	
Benzo(b)fluoranthene	1.40 E+01	1.00 E-02	7.96 E-08	7.30 E-01	5.81 E-08	5.57 E-07	NA	
Benzo(k)fluoranthene	1.90 E+00	NR	1.08 E-06	7.30 E-02	7.88 E-08	7.56 E-06	NA	
Dibenz(a,h)anthracene	2.40 E-01	1.00 E-02	1.36 E-09	7.30 E+00	9.96 E-09	9.55 E-09	NA	
Indeno(1,2,3-cd)pyrene	1.40 E+00	1.00 E-02	7.96 E-09	7.30 E-01	5.81 E-09	5.57 E-08	NA	
Phenanthrene	2.40 E+00	1.00 E-02	1.36 E-08	NA		9.55 E-08	NA	
Total for Pathway:					3.71 E-07			3.71 E-07

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Ingestion of Sediment** **HIGH END**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 7.83 E-09

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 5.48 E-08

Description of Variables:

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Arsenic (inorganic)	3.60 E+00	NR	2.82 E-08	1.50 E+00	4.23 E-08	1.97 E-07	3.00 E-04	6.58 E-04
Benzo(a)anthracene	7.30 E+02	NR	5.71 E-06	7.30 E-01	4.17 E-06	4.00 E-05	NA	
Benzo(a)pyrene	3.80 E+02	NR	2.97 E-06	7.30 E+00	2.17 E-05	2.08 E-05	NA	
Benzo(b)fluoranthene	1.80 E+03	NR	1.41 E-05	7.30 E-01	1.03 E-05	9.86 E-05	NA	
Chrysene	8.20 E+02	NR	6.42 E-06	7.30 E-03	4.69 E-08	4.49 E-05	NA	
Dibenz(a,h)anthracene	7.00 E-01	NR	5.48 E-09	7.30 E+00	4.00 E-08	3.84 E-08	NA	
Indeno(1,2,3-cd)pyrene	2.20 E+02	NR	1.72 E-06	7.30 E-01	1.26 E-06	1.21 E-05	NA	
Lead (and compounds)	1.90 E+02	NR	1.49 E-06	NA		1.04 E-05	NA	
Phenanthrene	7.00 E+01	NR	5.48 E-07	NA		3.84 E-06	NA	
Total for Pathway:					3.76 E-05			3.76 E-05

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Ingestion of Surface Soil** **HIGH END**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 7.83 E-09

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 5.48 E-08

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	3.00 E-01	NR	2.35 E-09	NA		1.64 E-08	NA	
Arsenic (inorganic)	4.10 E+01	NR	3.21 E-07	1.50 E+00	4.81 E-07	2.25 E-06	3.00 E-04	7.49 E-03
Benzo(a)anthracene	5.30 E+00	NR	4.15 E-08	7.30 E-01	3.03 E-08	2.90 E-07	NA	
Benzo(a)pyrene	3.90 E+00	NR	3.05 E-08	7.30 E+00	2.23 E-07	2.14 E-07	NA	
Benzo(b)fluoranthene	1.40 E+01	NR	1.10 E-07	7.30 E-01	8.00 E-08	7.67 E-07	NA	
Benzo(k)fluoranthene	1.90 E+00	NR	1.49 E-08	7.30 E-02	1.09 E-09	1.04 E-07	NA	
Dibenz(a,h)anthracene	2.40 E-01	NR	1.88 E-09	7.30 E+00	1.37 E-08	1.32 E-08	NA	
Indeno(1,2,3-cd)pyrene	1.40 E+00	NR	1.10 E-08	7.30 E-01	8.00 E-09	7.67 E-08	NA	
Phenanthrene	2.40 E+00	NR	1.88 E-08	NA		1.32 E-07	NA	
Total for Pathway:					8.37 E-07			8.37 E-07

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Inhalation of Surface Soil** **HIGH END**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 3.10 E-14

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 2.19 E-13

Description of Variables:

LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF:** **modifying factor**	Carcinogenic Effects LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	3.00 E-01	NR	9.00 E-15	0		6.60 E-14	0	
Arsenic (inorganic)	4.10 E+01	NR	1.27 E-12	5.00 E+01	6.36 E-11	8.98 E-12	0	
Benzo(a)anthracene	5.30 E+00	NR	1.64 E-13	6.10 E-01	1.00 E-13	1.16 E-12	0	
Benzo(a)pyrene	3.90 E+00	NR	1.21 E-13	6.10 E+00	7.37 E-13	8.54 E-13	0	
Benzo(b)fluoranthene	1.40 E+01	NR	4.34 E-13	6.10 E-01	2.65 E-13	3.07 E-12	0	
Benzo(k)fluoranthene	1.90 E+00	NR	5.90 E-14	6.10 E-02		4.16 E-13	0	
Dibenz(a,h)anthracene	2.40 E-01	NR	7.00 E-15	6.10 E+00	4.50 E-14	5.30 E-14	0	
Indeno(1,2,3-cd)pyrene	1.40 E+00	NR	4.30 E-14	6.10 E-01	2.60 E-14	3.07 E-13	0	
Phenanthrene	2.40 E+00	NR	7.40 E-14	0		5.26 E-13	0	
Total for Pathway:					6.47 E-11			6.47 E-11

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY AND CHEMICAL

TRESPASSER **Inhalation of Surface Soil Vapors** **HIGH END**

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 1.17 E-03

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 8.22 E-03

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/m3	MF:** *Inverse of VF*	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Acenaphthylene	3.00 E-01	2.25 E-04	7.93 E-08	0		5.55 E-07	0	
Phenanthrene	2.40 E+00	2.15 E-05	6.06 E-08	0		4.24 E-07	0	
Total for Pathway:					NR			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: ANGLER **Receptor: TYPICAL**

Route of Exposure		Total Adult Carcinogenic Risk	Total Adult Hazard Index
Ingestion of Fish		8.40 E-06	
	Total Risk:	8.40 E-06	NR

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

ANGLER — Ingestion of Fish — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 3.98 E-05

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 9.29 E-05

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/l	MF**	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Benzo(a)anthracene	4.30 E-02	NR	1.71 E-06	7.30 E-01	1.25 E-06	3.99 E-06	NA	
Benzo(a)pyrene	2.10 E-02	NR	8.36 E-07	7.30 E+00	6.10 E-06	1.95 E-06	NA	
Benzo(b)fluoranthene	3.60 E-02	NR	1.43 E-06	7.30 E-01	1.05 E-06	3.34 E-06	NA	
Total for Pathway:					8.40 E-06			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: ANGLER **Receptor: HIGH END**

Route of Exposure		Total Adult Carcinogenic Risk	Total Adult Hazard Index
Ingestion of Fish		3.87 E-05	
	Total Risk:	3.87 E-05	NR

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

ANGLER — Ingestion of Fish — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.84 E-04

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 4.29 E-04

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/l	MF**	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
Benzo(a)anthracene	4.30 E-02	NR	7.90 E-06	7.30 E-01	5.77 E-06	1.84 E-05	NA	
Benzo(a)pyrene	2.10 E-02	NR	3.86 E-06	7.30 E+00	2.82 E-05	9.00 E-06	NA	
Benzo(b)fluoranthene	3.60 E-02	NR	6.61 E-06	7.30 E-01	4.83 E-06	1.54 E-05	NA	
Total for Pathway:					3.87 E-05			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: INDUSTRIAL Receptor: TYPICAL

Route of Exposure		Total Adult Carcinogenic Risk	Total Adult Hazard Index
Dermal Contact with Surface Soil		1.24 E-06	3.9 E-04
Ingestion of Surface Soil		1.75 E-06	1.4 E-02
Inhalation of Surface Soil		4.97 E-11	
	Total Risk:	2.99 E-06	1.4 E-02

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Surface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.69 E-07

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 1.19 E-05

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/kg	MF** Dermal Absorption	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
2,3,7,8-TCDD	2.30 E-03	3.00 E-02	1.17 E-11	1.00 E+05	1.17 E-06	8.18 E-10	NA	
Arsenic (inorganic)	9.80 E+00	1.00 E-03	1.66 E-09	1.50 E+00	2.49 E-09	1.16 E-07	3.00 E-04	3.87 E-04
Benzo(a)pyrene	4.70 E+00	1.00 E-02	7.96 E-09	7.30 E+00	5.81 E-08	5.57 E-07	NA	
Benzo(b)fluoranthene	8.30 E+00	1.00 E-02	1.41 E-08	7.30 E-01	1.03 E-08	9.84 E-07	NA	
Benzo(g,h,i)perylene	3.00 E+00	1.00 E-02	5.08 E-09	NA		3.56 E-07	NA	
Phenanthrene	2.10 E+00	1.00 E-02	3.56 E-09	NA		2.49 E-07	NA	
Total for Pathway:					1.24 E-06			3.87 E-04

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Ingestion of Surface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 6.15 E-09

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 4.31 E-07

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
2,3,7,8-TCDD	2.30 E-03	NR	1.41 E-11	1.00 E+05	1.41 E-06	9.90 E-10	NA	
Arsenic (inorganic)	9.80 E+00	NR	6.03 E-08	1.50 E+00	9.04 E-08	4.22 E-06	3.00 E-04	1.41 E-02
Benzo(a)pyrene	4.70 E+00	NR	2.89 E-08	7.30 E+00	2.11 E-07	2.02 E-06	NA	
Benzo(b)fluoranthene	8.30 E+00	NR	5.10 E-08	7.30 E-01	3.73 E-08	3.57 E-06	NA	
Benzo(g,h,i)perylene	3.00 E+00	NR	1.85 E-08	NA		1.29 E-06	NA	
Phenanthrene	2.10 E+00	NR	1.29 E-08	NA		9.04 E-07	NA	
Total for Pathway:					1.75 E-06			1.41 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Surface Soil — TYPICAL

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 6.60 E-14

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 4.63 E-12

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
2,3,7,8-TCDD	2.30 E-03	NR	< 8 E-15	1.00 E+05	1.52 E-11	1.10 E-14	0	
Arsenic (inorganic)	9.80 E+00	NR	6.47 E-13	5.00 E+01	3.23 E-11	4.54 E-11	0	
Benzo(a)pyrene	4.70 E+00	NR	3.10 E-13	6.10 E+00	1.89 E-12	2.18 E-11	0	
Benzo(b)fluoranthene	8.30 E+00	NR	5.48 E-13	6.10 E-01	3.34 E-13	3.84 E-11	0	
Benzo(g,h,i)perylene	3.00 E+00	NR	1.98 E-13	0		1.39 E-11	0	
Phenanthrene	2.10 E+00	NR	1.39 E-13	0		9.72 E-12	0	
Total for Pathway:					4.97 E-11			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

TOTAL NONCARCINOGENIC AND CARCINOGENIC RISKS

Scenario: INDUSTRIAL **Receptor: HIGH END**

Route of Exposure		Total Adult Carcinogenic Risk	Total Adult Hazard Index
Dermal Contact with Surface Soil		2.83 E-06	1.5 E-03
Ingestion of Surface Soil		4.40 E-06	5.7 E-02
Inhalation of Surface Soil		8.69 E-11	
	Total Risk:	7.23 E-06	5.9 E-02

NR: Not Relevant

CARCINOGENIC AND NONCARCINOGENIC RISK
BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Dermal Contact with Surface Soil — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 3.32 E-07

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 2.32 E-05

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

			Carcinogenic Effects			Noncarcinogenic Effects		
Chemical	Conc. mg/kg	MF** Dermal Absorption	LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
2,3,7,8-TCDD	2.60 E-03	3.00 E-02	2.59 E-11	1.00 E+05	2.59 E-06	1.81 E-09	NA	
Arsenic (inorganic)	2.00 E+01	1.00 E-03	6.64 E-09	1.50 E+00	9.96 E-09	4.65 E-07	3.00 E-04	1.55 E-03
Benzo(a)pyrene	7.90 E+00	1.00 E-02	2.62 E-08	7.30 E+00	1.92 E-07	1.84 E-06	NA	
Benzo(b)fluoranthene	1.40 E+01	1.00 E-02	4.65 E-08	7.30 E-01	3.39 E-08	3.25 E-06	NA	
Benzo(g,h,i)perylene	5.00 E+00	1.00 E-02	1.66 E-08	NA		1.16 E-06	NA	
Phenanthrene	4.20 E+00	1.00 E-02	1.39 E-08	NA		9.76 E-07	NA	
Total for Pathway:					2.83 E-06			1.55 E-03

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Ingestion of Surface Soil — HIGH END

Equations for Cancer Effects:
LADI = Conc. x MF x HIFcancer
Risk = LADI x SF

HIFcancer: 1.23 E-08

Equations for Noncancer Effects:
CDI = Conc. x MF x HIFnoncancer
Hazard Quotient = CDI / RfD

HIFnoncancer: 8.61 E-07

Description of Variables:
LADI: Lifetime Average Daily Intake
CDI: Chronic Daily Intake
Conc.: Chemical Concentration
MF: Modifying Factor
HIFcancer: Human Intake Factor, cancer*
HIFnoncancer: Human Intake Factor, noncancer*
SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
2,3,7,8-TCDD	2.60 E-03	NR	3.20 E-11	1.00 E+05	3.20 E-06	2.24 E-09	NA	
Arsenic (inorganic)	2.00 E+01	NR	2.46 E-07	1.50 E+00	3.69 E-07	1.72 E-05	3.00 E-04	5.74 E-02
Benzo(a)pyrene	7.90 E+00	NR	9.72 E-08	7.30 E+00	7.09 E-07	6.80 E-06	NA	
Benzo(b)fluoranthene	1.40 E+01	NR	1.72 E-07	7.30 E-01	1.26 E-07	1.21 E-05	NA	
Benzo(g,h,i)perylene	5.00 E+00	NR	6.15 E-08	NA		4.31 E-06	NA	
Phenanthrene	4.20 E+00	NR	5.17 E-08	NA		3.62 E-06	NA	
Total for Pathway:					4.40 E-06			5.74 E-02

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

CARCINOGENIC AND NONCARCINOGENIC RISK BY SCENARIO, PATHWAY, AND CHEMICAL

INDUSTRIAL — Inhalation of Surface Soil — HIGH END

Equations for Cancer Effects: LADI = Conc. x MF x HIFcancer; Risk = LADI x SF

HIFcancer: 6.60 E-14

Equations for Noncancer Effects: CDI = Conc. x MF x HIFnoncancer; Hazard Quotient = CDI / RfD

HIFnoncancer: 4.63 E-12

Description of Variables:
- LADI: Lifetime Average Daily Intake
- CDI: Chronic Daily Intake
- Conc.: Chemical Concentration
- MF: Modifying Factor
- HIFcancer: Human Intake Factor, cancer*
- HIFnoncancer: Human Intake Factor, noncancer*
- SF: Cancer Slope Factor

Chemical	Conc. mg/kg	MF**	Carcinogenic Effects: LADI (mg/kg-day)	SF (mg/kg-day)-1	Cancer Risk	Noncarcinogenic Effects: CDI (mg/kg-day)	RfD (mg/kg-day)	Hazard Quotient
2,3,7,8-TCDD	2.60 E-03	NR	< 8 E-15	1.00 E+05	1.72 E-11	1.20 E-14	0	
Arsenic (inorganic)	2.00 E+01	NR	1.32 E-12	5.00 E+01	6.60 E-11	9.26 E-11	0	
Benzo(a)pyrene	7.90 E+00	NR	5.21 E-13	6.10 E+00	3.18 E-12	3.66 E-11	0	
Benzo(b)fluoranthene	1.40 E+01	NR	9.24 E-13	6.10 E-01	5.64 E-13	6.48 E-11	0	
Benzo(g,h,i)perylene	5.00 E+00	NR	3.30 E-13	0		2.31 E-11	0	
Phenanthrene	4.20 E+00	NR	2.77 E-13	0		1.94 E-11	0	
Total for Pathway:					8.69 E-11			NR

* Human intake factor includes all exposure parameters that are not chemical specific;
i.e., generically, contact rate x exposure frequency x exposure duration x 1/body weight x 1/averaging time.

** See text for units of modifying factor. NR = Not Relevant.
NA: Not Available

Part II:

Ecological Risk Assessment

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1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

Part II of this document constitutes a screening-level ecological risk assessment (ERA) for the Southern Wood Piedmont (SWP) facility (herein referred to as the "Site") located in Wilmington, North Carolina (Figure 1-1). This screening-level ERA was prepared to: (1) evaluate the potential adverse impacts to ecological resources posed by physical and chemical stressors at the Site; and, (2) provide the underpinning for a risk-based remedial action plan (if necessary) protective of local ecological resources. To that end, this screening-level ERA is organized into the following sections:

Section 1.0 - Introduction
Section 2.0 - Field and Laboratory Investigations and Methods
Section 3.0 - Site Characterization
Section 4.0 - Problem Formulation
Section 5.0 - Analysis
Section 6.0 - Ecological Risk Characterization
Section 7.0 - Summary and Conclusions
Section 8.0 - References

The results and conclusions of this screening-level ERA are based on the synthesis of data and information collected from previous historical sampling investigations, as well as from recent Site investigations conducted by Virogroup, during February of 1996. This report addresses the entire Site, including the drainage ditch, Greenfield Creek and tributaries, and portions of the Cape Fear River which border the Site to the northwest.

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Figure 1-1.
Site Location Map

2.0 FIELD AND LABORATORY INVESTIGATIONS AND METHODS

2.1 SUMMARY OF HISTORICAL OBSERVATIONS

Since 1985, various sampling investigations have been conducted at the Site. These investigations are summarized below in chronological order for each environmental media (e.g. surface water and sediment) and are applicable and relevant to this screening-level ERA. A discussion of historical sampling efforts for groundwater and soils is described in the Part I HHRA. The following sections illustrate the previous level of sampling efforts, and provide the rationale for recent sampling and analysis programs in support of this screening-level ERA.

2.1.1 Surface Water Sampling

Previous investigations have produced some information regarding the nature and extent of chemicals in surface waters that may be associated with the Site. Since 1985, surface water samples have been collected semi-annually from the Cape Fear River at four locations: the US Route 74 Bridge, at the old slip (upgradient from the Site), the mouth of Greenfield Creek and at the southeast tip of the NCSPA pier (downgradient from the Site). These samples have been tested for Semi-Volatile Organic Compounds (SVOCs) and inorganic chemicals (e.g. metals). In general, the results of the surface water sampling program have indicated that organic and inorganic chemicals are not consistently detected in the River (Virogroup, 1994). Infrequent detection of naphthalene (0.05 mg/l), chromium (0.011 - 0.046 mg/l), and copper (0.02 - 0.052 mg/l), were observed at one of the upgradient and downgradient River stations. The drainage ditch and Greenfield Creek were not included in this historical surface water sampling program.

In 1996, Virogroup, conducted the most comprehensive surface water sampling program to date. In this investigation, the four locations which had been regularly sampled since 1985 were re-sampled, in addition to one surface water sample collected from the drainage ditch, and four surface water samples collected from Greenfield Creek and its tributaries (Figure 2-1). All of the surface waters were analyzed for site-specific wood-preserving constituents (Table 2-1). Field and laboratory methods for the collection and analysis of surface water samples during this investigation are described in Sections 2.2.1 and 2.2.2, respectively. The results of these analyses are discussed in later sections of this report, and are provided in Part II, Appendix A.

2.1.2 Sediment Sampling

Historically, sediment chemistry has been well characterized at the Site. In 1985, NUS Corporation collected one sediment sample in the Cape Fear River adjacent to the north slip of the Site. The sample contained several SVOCs including isophorone, 2-chloronaphthalene, acenaphthalene, phenanthrene, anthracene, fluoranthene, benzo(j,k)fluorene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene. Metals detected in the samples were limited to lead and cyanide (NUS Corporation, 1986). Furthermore, a sediment sample collected from below Greenfield Lake Dam, (located upstream from the Site), contained similar concentrations of isophorone, 2-chloronaphthalene, fluoranthene, and pyrene. Lead and cyanide were also detected in the Greenfield Lake sample, ranging between 6-15 mg/kg, and 0.225 - 0.430 mg/kg for each metal, respectively.

In 1992, 11 additional sediment samples were collected from the drainage ditch and the north bank of Greenfield Creek. The results of these samples were summarized in a Phase II Groundwater Quality Assessment performed by Virogroup (1994). Samples were analyzed for Volatile Organic Compounds (VOCs), SVOCs, and inorganics. The calculated percent detection frequency for VOCs was as follows: dichloromethane (100%), xylenes (27-55%) toluene (36%), and ethyl benzene (9%). For SVOCs, particularly polycyclic aromatic hydrocarbons (PAHs), chemicals most frequently detected included: benzo(a)anthracene (73%), chrysene (73%), and fluoranthene (73%). Lowest detected PAHs were napthalene (18%) and dibenz(a,h)anthracene (18%); all other PAHs were detected at between 25-65% of the stations. Phenolic compounds were consistently non-detect. Chromium, copper, and lead were detected at all of the stations (100%), and arsenic was detected at only 45% of the stations.

In 1996, Virogroup further characterized the sediment chemistry of the Cape Fear River by sampling and analyzing surface sediments at 11 locations along the Cape Fear River (Figure 2-1). Virogroup also collected two additional sediment samples from a southern tributary to Greenfield Creek (Figure 2-1), to further characterize off-Site sediments. All of the sediments were analyzed for site-specific wood-preserving constituents (Table 2-1). Field and laboratory methods for the collection and analysis of sediment samples during this investigation are described in Sections 2.2.1 and 2.2.2, respectively.

In 1996, Virogroup also collected samples to specifically address the issue of bioavailability of sediment-associated chemicals for this screening-level ERA. The sediment investigation focused on parameters that are used to evaluate the bioavailability of chemicals in sediments from the biologically active zone. The results of these analyses are discussed in later sections of this report. The results of the historical and current sediment sampling and analyses are presented in Part II, Appendix B.

2.1.3 Biological Sampling

Historical information about the local and regional biology has been described during Site visits and communications with state and federal agencies concerning the status of Threatened and Endangered (T&E) species in the area. In 1993, Geraghty and Miller, Inc., performed a limited Site characterization and contacted the North Carolina Heritage Program for documentation on the occurrence of rare, threatened, and endangered species in the Wilmington area. State fishery biologists have reported that both the Cape Fear River and Northeast Cape Fear River support seasonal commercial fisheries, and reaches of the Cape Fear River have been characterized as being used as nurseries for species of commercially harvested blue crab, eel, and shrimp (NCDEHNR, 1995).

In March 1996, a ChemRisk ecologist performed a site reconnaissance, and conducted a comprehensive habitat characterization which focused on the drainage ditch, Greenfield Creek and associated tributaries, the Cape Fear River, and local riverine habitats. A limited survey of benthic macroinvertebrates in the ditch/Creek system was also conducted in order to qualitatively examine the composition of the local infaunal community. A summary of the site characterization approach is described in Section 2.2.3, and the results are presented in Section 4.4.

2.2 Summary of Recent Investigations

Surface water and sediment sampling used in this screening-level ERA were collected between the years of 1993 and 1996 as previously described in Section 2.1. Details concerning the procedure of sampling, handling, and analysis of Site media are provided in a workplan submitted by Virogroup to SWP in 1996. The following Sections briefly describe both the field and laboratory methods used by Virogroup, for sampling surface water and sediments.

2.2.1 Field Methodology

Sample locations were permanently located by placing survey stakes at a right angle to the shoreline. Two survey stakes were placed at each sample location for surveying purposes. All stations were approached from downstream, and surface water were samples collected directly into the appropriate containers.

Sediment samples consisting predominantly of sand were collected using a 6-inch by 6-inch stainless steel Ponar™ dredge sampler. The sediment samples consisting of muck were collected with a stainless steel hand auger or a PVC push tube, whichever provided the most undisturbed sediment sample. The sediment samples within the Cape Fear River were collected 50 feet from the stake closest to the shoreline consistent with the 1985 EPA sediment sample (NUS Corporation, 1986). The sediment samples in the south slip were collected near the bank and at the

center of the slip. Sediment samples were analyzed for the Site-specific wood-preserving constituent list (Table 2-1).

2.2.1.1 Surface Water Chemistry

The surface water samples collected for SVOC analysis were placed into 1-liter amber glass sample containers with Teflon™ coated lids and stored at 4°C. The holding time before extraction did not exceed 7 days and the holding time after extraction did not exceed 40 days. VOCs were placed into 40-milliliter VOA glass sample vials with Teflon™ lined septa and preserved with HCL to a pH≤2, and stored at 4°C. The holding time for VOC analysis did not exceed 14 days.

The surface water samples collected for metals were placed into 200 ml plastic sample containers and preserved with HNO_3. The samples were stored at 4°C. The holding time before analysis did not exceed six months.

2.2.1.2 Sediment Chemistry

Sediment samples were placed in 250-millimeter wide mouth glass sample containers with a Teflon™ coated lid. Sediment VOC samples were placed into 125-milliliter amber glass sample containers with a Teflon™ coated lid and sediment metal samples were placed into 250-milliliter plastic sample containers. All storage and holding requirements were similar to those described for surface waters.

To determine the bioavailability of the metals in the sediments, additional samples were collected for acid volatile sulfide and simultaneous extracted metals (AVS/SEM) analysis. AVS/SEM sediment samples were collected in the drainage ditch at former sediment sample location SS-7 and SS-8, along Greenfield Creek at former sediment sample locations SS-1, SS-9, and SS-11, and along the Cape Fear River at proposed sample locations at the Highway 74 bridge (SS-14), the T-head (SS-18), the old slip (SS-20), and the mouth of Greenfield Creek (SS-23).

2.2.2 Laboratory Methodology

Laboratory analyses were performed by an outside contractor, Savannah Laboratories and Environmental Services, Inc., in Savannah Georgia. For both sediments and surface water samples, SVOCs were analyzed by EPA approved Method 8270 and VOCs were analyzed by EPA Method 8240. Arsenic was analyzed by EPA Method 7060, and chromium and copper were analyzed by EPA Method 6010. Total Kjeldahl nitrogen was analyzed by EPA Method 351.2, nitrate + nitrite by EPA Method 353.1, total phosphorus by EPA Method 365.1, total organic carbon by EPA Method 415.1, chloride by EPA Method 325.1, pH by EPA Method 150.1, and AVS-SEM by EPA Method 68-03-3534/6010.

2.2.3 Site Characterization

As a first step in the screening-level ERA, a characterization of the Site environs was performed by a ChemRisk ecologist in March 1996. The Site characterization provides an understanding of the extent and quality of available habitats, and potential exposure pathways for ecological receptors that may or utilize the Site. The objective of the Site characterization task was to evaluate aspects of the Site that influence potential ecological exposure, and to characterize the marsh and aquatic habitats that exist at the Site and in the adjacent areas of the Cape Fear River. A photographic survey was performed as part of this effort to document ecological resources and to aid in the evaluation of habitat types. The results of the Site characterization are presented in Section 4.4. Two additional tasks completed during the Site visit included evaluating the physicochemical characteristics of Site surface waters, and sampling the sediments for qualitatively evaluating the benthic community. The procedures for these tasks are described below.

2.2.3.1 Surface Water Quality Measurements

Water quality measurements were made at a total of six locations (Figure 2-1) using a Horiba, multiparameter probe. Parameters included temperature, dissolved oxygen, conductivity, pH, and salinity. Measurements were made at two locations in the drainage ditch, three locations in Greenfield Creek, and at one location in the Cape Fear River. All sample areas were generally less than two feet deep, therefore, measurements were made at the water-sediment interface.

2.2.3.2 Benthic Invertebrate Assessment

At each of the surface water quality stations identified in Figure 2-1, benthic macroinvertebrate samples were collected using a three-inch diameter polyvinyl chloride (PVC) push corer. The corer was pushed into the sediments twice, to a depth of approximately four to six inches to adequately sample the biological active zone (i.e., about zero to six inches in depth). Samples were sieved through a 500 micron sieve, and the remaining material was then placed in 500 ml teflon jars and preserved with a 10 percent buffered formalin solution. Each of the samples were qualitatively examined by a ChemRisk ecologist. Notes were made in reference to the type of organisms identified. Samples were not sorted, or enumerated.

Table 2-1. Site-Specific Wood Preserving Constituents

Semi-Volatile	Volatile	Metal
Acenaphthene	Benzene	Arsenic
Acenaphthylene	Bromodichloromethane	Chromium
Anthracene	Bromomethane	Copper
Benzo(a)anthracene	Carbon Tetrachloride	
Benzo(a)pyrene	Chlorobenzene	
Benzo(b)fluoranthene	Chloroethane	
Benzo(k)fluoranthene	2-chloroethylvinylether	
Bis(2-chloroethyl)ether	Chloromethane	
Carbazole	Cis-1,3-dichloropropene	
4-chloro-3-methylphenol	Dibromochloromethane	
Chrysene	1,2-dibromomethane (Edb)	
2-chlorophenol	Dichlorodifluoromethane	
Dibenzo(a,h)anthracene	1,1-dichloroethane	
2,4-dimethylphenol	1,2-dichloroethane	
2,4-dinitrophenol	1,1-dichloroethene	
Fluoranthene	Dichloromethane	
Indeno(1,2,3-cd)pyrene	1,2-dichloropropane	
Naphthalene	Ethyl benzene	
p-Chloro-m-cresol	Fluorotrichloromethane	
Pentachlorophenol	M/P-Xylene	
Phenanthrene	Methyl-T-Butyl Ether (Mtbe)	
Phenol	O-Xylene	
Tetrachlorophenol	1,1,2,2-tetrachloroethane	
2,4,5-trichlorophenol	Toluene	
2,4,6-trichlorophenol	Trans-1,2-dichloroethene	
	1,1,1-trichloroethane	
	1,1,2-trichloroethane	
	Trichloroethene	
	Vinyl Chloride	

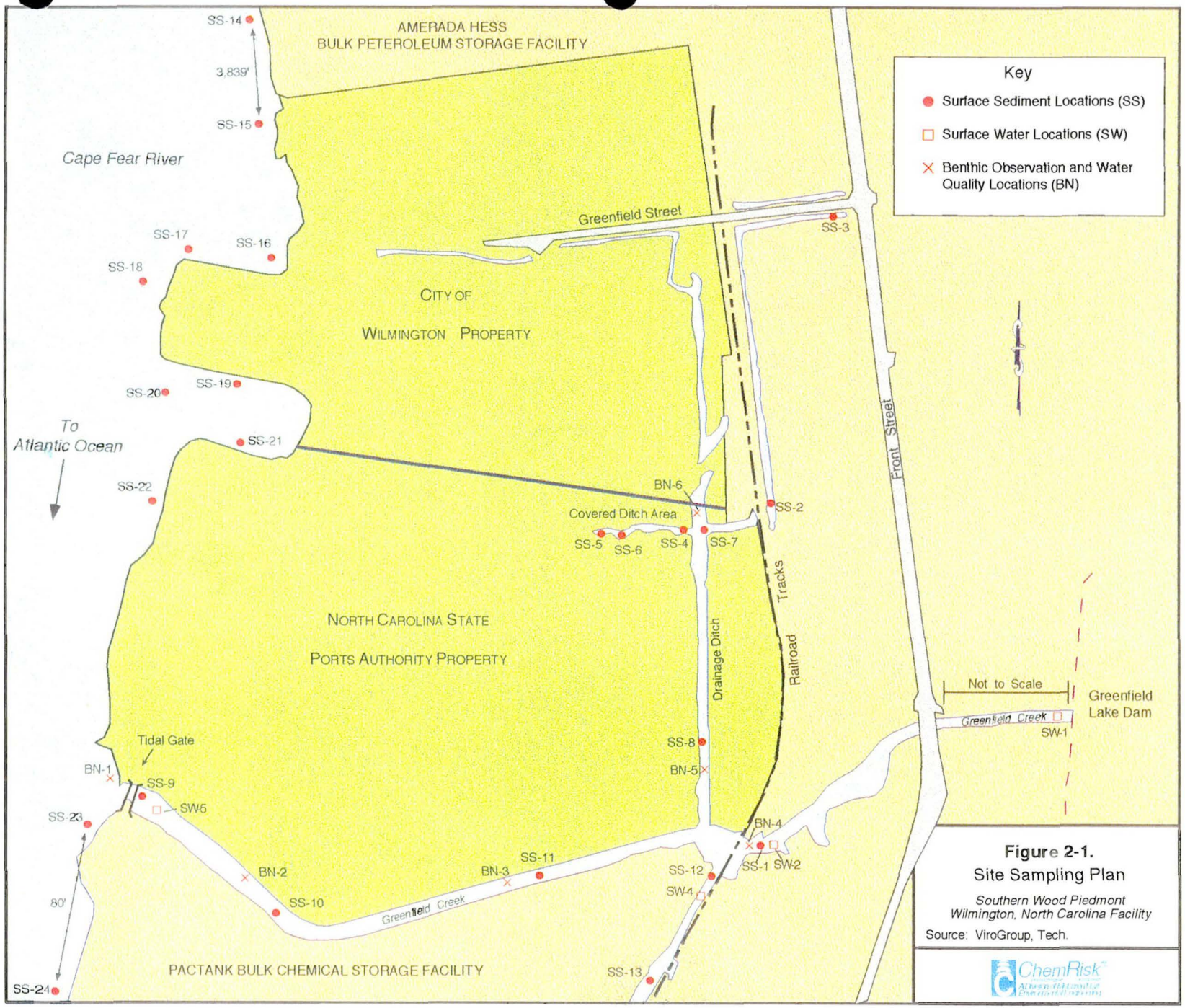

Figure 2-1.
Site Sampling Plan

Southern Wood Piedmont
Wilmington, North Carolina Facility

Source: ViroGroup, Tech.

3.0 SITE CHARACTERIZATION

3.1 REGIONAL SETTING

The Site (Figure 1-1) is located in the southwest corner of the City of Wilmington, along the Cape Fear River at approximately 2.5 miles north of the confluence with the Brunswick River and directly east of Eagle Island. The Site consists of approximately 52 acres of vacant land, of which 35 acres are owned by the City of Wilmington, and the remaining 17 acres are owned by the NCSPA (NUS Corporation, 1986). Most of the land south of the Site is undeveloped coastal prairie and wetland which drain into the Cape Fear River. The Cape Fear River estuary approximately represents the portion of the river which extends from Baldhead Island (near the River mouth) to points north of Castle Hayne in the Northeast Cape Fear River. Numerous tidal creeks and tributaries enter the estuary as the river flows southward, and provide extensive habitat for transient and resident species of vertebrate and invertebrate organisms that utilize the marsh throughout the year (Weinstein, 1979).

Land use immediately bordering the Site to the south is primarily undeveloped urban wetland and marsh. Greenfield Creek drains water from the wetland into the Cape Fear River. To the south of Greenfield Creek is an undeveloped portion of land owned by the NCSPA, and bulk chemical storage facilities. The Cape Fear River borders the Site to the west, with the remains of an old former slips area along the eastern shoal of the River. To the immediate north of the Site is a petroleum storage facility. Along the eastern border of the Site are parking areas, a recreational park, and a City of Wilmington wastewater treatment facility.

Beyond the immediate vicinity of the Site, developed land is present primarily to the northeast, east, and southeast of the Site. Although land use is variable, residential areas are the most prevalent in these areas. Greenfield Lake is located directly east of the Site, as are several schools, a stadium, and a drive-in theater. The NCSPA occupies the majority of the land to the south of the Site, with tank farms and petroleum facilities extending almost two miles downriver of the Site. To the west, Eagle Island splits the confluence of the Brunswick and Cape Fear River, and land use in this area is predominately classified as low relief tidal flats, with an extensive series of meandering creeks and channels cut throughout an extensive marsh. To the north, Sturgeon, Alligator, and Redmond Creeks provide the main drainage network from the tidal flats to the Brunswick River (and to a lesser extent) the Cape Fear River. To the south and past the

confluence of the two rivers, Jackeys, Mallory, and Little Mallory Creek drain a network of tidal flats to both rivers.

3.2 SITE SETTING

As mentioned previously, the Site is approximately 52 acres in size, with a series of aquatic systems that drain runoff from the Site to the Cape Fear River. For the purpose of this screening-level ERA, these aquatic systems can be separated into three areas; the drainage ditch, Greenfield Creek and associated tributary, and the Cape Fear River. Surface water runoff from the Site flows predominately to the south-southeast, where it is carried from shallow (perennial) road-side ditches to the drainage ditch. This ditch drains runoff from the majority of the Site to Greenfield Creek, located approximately 900 feet south of the property boundary. Sediments and surface waters in the drainage ditch have been sampled recently, as described in Section 2.0.

Greenfield Creek originates at a dam located approximately 700 feet upstream from the confluence of the drainage ditch. The creek is supplied in part by freshwater flow from Greenfield Lake; however, saltwater intrusion into this area may occur based on the low relief of the creek gradient to the Cape Fear River (NCDEHNR, 1995). The creek flows westward past a tributary located across from the confluence with the drainage ditch, and continues another 1800 feet through a wetland area past the Pactank Bulk Chemical Storage Facility, and into the surface waters of the Cape Fear River. Sediments and surface waters in Greenfield Creek have been sampled recently, as described in Section 2.0.

The Cape Fear River along the southern reaches is primarily estuarine, and significantly influenced by tide. Under normal tidal conditions, the reach of the River that borders the Site is primarily oligohaline (e.g., that portion of the River that has, on a mean high and low tide, a salinity range of 0.5 - 5.0 ppt). This classification is in accordance with the Venice System (NOAA, 1990), and based on earlier work by Weinstein et al. (1980), who found that the salinity taken along the river shoal at Spoil Island (three miles downstream of the Site) and Hechtic Creek (two miles downstream of the Site) averaged between 2.0 - 3.0 ppt under normal tidal conditions. The extent of saltwater intrusion has been documented at the river section north of Castle Hayne, approximately 15 nautical miles upstream from the Site (Giese et al., 1985). Sediments and surface waters in the Cape Fear River have been sampled at various times between 1985 and 1996, as described in Section 2.0.

4.0 PROBLEM FORMULATION

The problem formulation stage of a screening-level ERA involves characterization of both the ecosystem and stressors at a Site. This characterization has been developed through an evaluation of available historical data, reconnaissance surveys, biological and habitat surveys, and supporting information from fisheries reports or conversations with state and federal biologists. The results of the evaluation provide the foundation for the selection of key organisms that are representative of the balanced, indigenous community. Collectively, the efforts of the problem formulation stage assist in the overall development of the conceptual model for implementing the screening-level ERA.

4.1 STRESSOR CHARACTERIZATION

An estuary is an enclosed or partly enclosed coastal body of water that is connected with the open sea and within which seawater is diluted with freshwater drainage from the estuary watershed. The salinity and density gradients created by mixtures of seawater and freshwater in an estuary, as well as the harsh and dynamic environmental conditions produced by semi-diurnal tides, are responsible for the unique ecological attributes of estuaries that place significant physiological demands on biota. Estuaries are naturally characterized by large populations of relatively few species due to the relative small number of species that are tolerant of such dynamic environmental conditions (Levinton, 1982). A "typical" estuary normally supports large, fluctuating populations of phytoplankton, invertebrates, fishes, and fish-eating wildlife such as waterfowl and semi-aquatic mammals. However, at the SWP Site and in estuaries throughout the United States, urban development and industrialization have contributed to the physical and chemical stressors that are prevalent in most coastal environments.

4.1.1 Physical Stressors

In general, estuaries are typical of high stressed ecosystems in that they are comprised of numerous environmental factors which include: dissolved oxygen, salinity, temperature, organic enrichment, tidal exchange, chemical loadings, and other activities from multiple urban and industrial locations. Many of these natural and anthropogenic stresses may produce sharp environmental gradients that influence the physical distribution and zonation patterns of localized biological communities. The types of factors listed above are present in the Cape Fear River Estuary, however, there are some

physical alterations in the estuary that are not normally found in other systems, and these alterations must be considered prior to examining the exposure of the aquatic community to Site-related chemicals.

As described in Section 3.0, the characteristics of the Site hydrology include runoff of surface waters into the drainage ditch, which then flows into Greenfield Creek and ultimately into the Cape Fear River. Previous studies have consistently indicated that the ditch and Creek surface waters are subject to water level changes and intermittent flooding as a direct result of tidal exchange in the River (Virogroup, 1994; NCDEHNR, 1995). The reports have then indicated that the "flushing activity" observed in the Ditch and Creek may be a means of transporting Site chemicals into the Cape Fear River. Recent modifications to the aquatic system through the repair of a tidal gate at the mouth of Greenfield Creek have altered this scenario.

It was during the 1930s that the City of Wilmington installed a tidal gate at the mouth of Greenfield Creek to control stormwater runoff from a variety of sources including the Sunset Park Area, northern sections of the NCSPA property, and sections of Burnett Boulevard (pers. comm., 1996). Over the years the gate had periodically become worn with age, and at times did not function properly as a result of structural damage and clogging due to treefall, debris, and sediment. During the period of inoperation, tidal waters passed freely through the gate into Greenfield Creek and portions of the drainage ditch. These conditions favored not only the transport of Site- (and non-Site-) related chemicals into and out of the ditch and Creek, but also allowed the potential for the passage of fish and invertebrate communities from the Cape Fear River. Although habitat for aquatic communities appears to be limited in the ditch and Creek system (Section 4.4.1.1 and 4.4.2.1, respectively), the structure of the biological communities may at one time have resembled that of other estuarine creeks near the area (Weinstein et al., 1979).

Although the City of Wilmington did conduct major repair work on the tidal gate in the 1950s and 1980s, it was during the years of 1992 and 1993 that the NCSPA replaced the tidal gate and now currently maintains the gate on a regular basis (pers. comm., 1996). Observations made on the biological community in the drainage ditch, and Greenfield Creek and associated tributaries indicate that the benthic community is subsequently dominated by freshwater taxa (Section 4.4.1.2 and 4.4.2.2). The surface hydrology of the Site has changed (from that stated in previous reports) in that surface waters from the Site now flow towards the River, and extensive tidal flushing from the Cape Fear River is no longer observed up in the back channels of the drainage ditch and Greenfield Creek. The implications of a functional tidal gate has not only changed the biological community structure in the ditch and Creek, but has also effectively blocked the access of fish and macroinvertebrates from the Cape Fear River, thereby reducing the potential of exposure through direct contact and ingestion of ditch and Creek sediments. In the following sections of this screening-level ERA, the evaluation of potential exposure routes and selection of key organisms assumes the continued operational status of the tidal gate.

4.1.2 Chemical Stressors

For ecological risk assessments, EPA's *Risk Assessment Guidance for Superfund, Volume II Environmental Evaluation Manual - Interim Final* (1989) suggests that chemical-specific factors should be considered when evaluating the potential risks of chemicals at a Site. These factors include: physicochemical properties, bioaccumulation potential, known toxic effects, and exceedance of potential applicable, relevant, and appropriate requirements (ARARs), including available regulatory criteria and benchmarks. Consistent with EPA guidance, chemical stressors for this screening-level ERA were selected based on the results of historically collected data at the site.

The identification of chemical stressors involves two steps which collectively focus the risk evaluation on chemicals that pose a potential hazard to key ecological receptors. These steps, as portrayed in the following Sections of this report, describe the screening evaluation (Section 4.2) used to select the appropriate and relevant chemical stressors (Section 4.3) for further consideration in the screening-level ERA. Following the selection of chemical stressors, the characteristics, potential sources, and distribution of these chemicals are considered prior to characterizing the ecological habitat and biological communities at the Site.

4.2 Screening Evaluation of Available Chemical Data

Screening of chemicals for adverse ecological effects must consider two major components: (1) an evaluation of the potential toxicity of chemicals on aquatic communities; and (2) an assessment of the potential bioaccumulation of chemicals by biota, and the subsequent transfer through the food web. In the following sections, an initial screening evaluation of chemicals in various media is conducted to remove chemicals from further consideration that are not of toxicological concern, and/or do not accumulate in biological communities at the Site.

4.2.1 Surface Water

Surface water samples have been collected semi-annually since 1985 in four locations along the Cape Fear River, and in 1996, along the drainage ditch and Greenfield Creek. The results of these sampling efforts are presented in Part II, Appendix A. Each of the samples were analyzed for a site-specific suite of organic and inorganic chemicals (Table 2-1). With the exception of chromium and copper which were detected in samples collected in 1990, other chemicals have not been detected in surface water samples. In 1990, the concentration of chromium at the old slip was 11.0 ug/l, and at the mouth of Greenfield Creek (in the Cape Fear River) chromium was detected at 46.0 ug/l. Both of these values are below the saltwater screening-level criteria proposed by EPA (1995). At the Greenfield Creek/Cape Fear sampling station, chromium was two times the concentration of the water quality standard amended for tidal saltwaters by the State of North

Carolina (NCDEHNR, 1993). Also at the Greenfield Creek/Cape Fear station (in 1990), copper was detected at 52.0 ug/l; slightly above EPA (1995b) saltwater screening-level criteria, and above the saltwater water quality standards (NCDEHNR, 1993).

Given the preponderance of historical surface water sampling efforts in the River, and as a result of the more recent sampling activities in which surface waters at the Site were also not detected, the relatively low frequency of detect (<1%) of inorganic chemicals does not indicate that inorganics are of sufficient ecological concern in surface waters. On this basis, inorganic chemicals in surface waters are not addressed further in this report.

4.2.2 Sediment

For surface sediments, the screening analysis for chemicals is based on comparisons of Site surface sediment data to proposed regulatory sediment quality guidelines (SQG). These guidelines already take into account the physicochemical properties and toxic effects of chemicals; however, the proposed regulatory SQG do not take into account the potential bioaccumulation of chemicals in aquatic organisms and the consequences of chemical residues in organisms. Therefore, as an additional step in the screening process, a bioaccumulation screening was performed, as previously described in Section 2.2.1.2. The primary concern regarding bioaccumulation is that some chemicals that may be present in sediments at low concentrations and, therefore, do not in and of themselves exceed proposed SQG, may nonetheless accumulate to high concentrations in aquatic organisms. The concentrations of such chemicals may be biomagnified within the food web, particularly in higher organisms, such as predatory fish and crabs, which might ingest substantial quantities of contaminated prey. The concentrations of chemicals in aquatic organisms may cause adverse effects to the organism, as well as pose substantial risks to higher trophic level consumers (including humans) that feed on contaminated prey.

The sediment screening analysis for the screening-level ERA is presented in Table 4-1. Site data were tested for normality, and where non-normal, the 95 percent upper confidence limit (95% UCL) of the geometric mean was compared to available marine and estuarine SQG. Although a variety of SQGs have been offered by regulatory agencies for comparison with environmental data, there is no consensus on a universal benchmark or even, in most cases, an appropriate method for developing benchmarks. For this evaluation, benchmarks used to compare observed concentrations of chemicals in Site sediments were derived principally from studies by Long et al. (1995), MacDonald et al. (1994), Washington State Department of Ecology (WSDOE, 1991) and EPA Regional Guidance (1995a).

Most of the chemicals were screened out as a result of exceeding the Long et al. (1995) benchmarks, and for this reason the approach used by Long and coworkers bears discussion. Using a preponderance of evidence approach, Long et al. (1995) present two values, the Effects Range - Low (ER-L) and Effects Range - Median (ER-M), for a number of common environmental

contaminants in freshwater, marine, and estuarine sediments. The ER-L value was defined as the level at which adverse effects may begin or are predicted for sensitive life stages. The ER-M was defined as the concentration beyond which effects were frequently or always observed. Sediment concentrations observed between the ER-L and ER-M are those at which a marginal level of adverse effects may occur.

The ER-L and ER-M values derived by Long et al. (1995) draw upon a large number of data assembled in the Biological Effects Database for Sediments (BEDS) developed by MacDonald and co-workers (1994). This database includes an assemblage of marine and estuarine studies that have evaluated benthic community structure and sediment toxicity studies for a wide variety of species (e.g., polychaetes, oligochaetes, sea urchins, bivalves, crustaceans, several species of fish, etc.) throughout North America. The disparity of data sources used in BEDS reflect the inherent variability in many of the toxicological endpoints for both organismal and suborganismal effects, and accordingly, the conclusions reached are intended to be general guidelines rather than specific sediment quality criteria.

4.3 Selection of Chemicals of Potential Concern (COPC)

Chemicals for which the 95% UCL of the Site surface sediment data exceed the lowest available SQG, and/or those that are potentially bioaccumulative, were considered as COPC. Those chemicals that are not potentially bioaccumulative and, for which no available sediment quality guidelines exist, were not retained as COPC. Because there has not been any national attention given to deriving SQG for these chemicals, and because they are not considered bioaccumulative, it was assumed that their toxicological significance in sediments is relatively low.

Table 4-2 contains the final list of the COPC for the screening-level ERA. Twelve PAHs and four metals were retained as COPC, whereas volatile organics and one semi-volatile organic (carbazole) were, as a group not considered to be bioaccumulative, and subsequently removed from the COPC list. In the following sections, a discussion on the characteristics, potential sources, and distributions of selected COPCs are described.

4.3.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous environmental contaminants that have gained considerable attention in recent years. Until recently, the scientific community believed that PAHs in sediment did not pose significant chronic hazards to aquatic organisms, as PAHs are quickly metabolized and excreted upon uptake. Increased awareness of the potential ecological risks associated with PAHs has resulted from studies that link increased incidences of neoplasms in feral fish populations inhabiting industrialized waterways to PAHs in sediments (Black et al., 1980; Malins et al., 1987). Puget Sound, Chesapeake Bay, and the Great Lakes are examples of industrialized waterways that have severe PAH sediment contamination that has been correlated to

ecological effects, such as high tumor frequencies in fish populations (Black, 1983; Malins et al., 1987; Volgelbein et al., 1990; Baumann et al., 1991).

The primary ecological concern regarding PAHs is the toxicological effects exerted on aquatic organisms that are exposed to PAHs in water and/or sediment. Researchers have verified that PAHs are rapidly accumulated and metabolized upon uptake by many aquatic organisms, and have recently demonstrated that PAH metabolites may exert the toxic effects observed in fish. Some PAHs, such as benzo(a)pyrene, phenanthrene, and naphthalene, are rapidly metabolized to mutagenic, tumorigenic, genotoxic, or carcinogenic agents (Jerina et al., 1984; James, 1989; Varanasi et al., 1989; Stegeman and Lech, 1991).

The fact that PAHs are rapidly metabolized by aquatic organisms to a variety of potentially toxic agents makes it difficult to assess the ecological risks posed by these compounds in aquatic systems. Many environmental chemicals are resistant to metabolism and can be evaluated based on reported critical body burdens. Other chemicals (including some PAHs) are rapidly detoxified via metabolism and then excreted from the organism, making them non-toxic due to their short biological residence time. Because of these attributes, PAHs do not bioaccumulate substantially in most organisms and therefore the ecological risks posed by PAHs in sediments and biological tissue require careful consideration in addressing species-specific effects.

4.3.1.1 Characteristics of PAHs

Polycyclic aromatic hydrocarbons are compounds which contain two or more fused benzene rings. They are categorized as high molecular weight (HPAH) or low molecular weight PAH (LPAH) based on the number of benzene rings each compound contains. LPAHs are compounds with 2 or 3 rings, while compounds with 4 or more rings are classified as HPAHs (NOAA, 1994). Examples of HPAHs include: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene; and LPAHs include: fluoranthene, pyrene, benz(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

Once in an aquatic system, PAHs do not usually exist in the dissolved form because they are hydrophobic. PAHs are either removed from the water column via photodegradation, are taken up by aquatic organisms, or they rapidly become associated with particles and are deposited in bottom sediments (McElroy, 1985; McElroy et al., 1989). As a result of their hydrophobicity and strong affinity for organic matter, accumulation in sediments and bioaccumulation in fish and shellfish tend to be the primary removal pathways for PAHs in the environment (Herbes and Schwall, 1978). However, studies have shown that PAH bioaccumulation by aquatic organisms is positively correlated to physical/chemical properties of the PAH, such as molecular weight and octanol/water partition coefficients (McElroy et al., 1989) which may influence the bioavailability of PAHs to aquatic organisms. Based on the hydrophobic nature of PAHs and the tendency to

sorb to sediments, as a group, PAHs could be characterized as only moderately bioavailable, particularly in estuaries like the Cape Fear River Estuary which provide considerable amounts of organic carbon to the marine environment.

4.3.1.2 Potential Sources of PAHs

HPAHs and LPAHs found in the environment are the result of numerous natural and anthropogenic activities. Natural sources include: synthesis by bacteria, plants, and fungi and releases by marine seeps, forests, and grass fires. Anthropogenic inputs of PAHs to aquatic systems can be from combustion sources, wood treatment facilities, oil spills, activities associated with normal shipping operations, and land-based discharges associated with the use of fossil fuels in industrialized areas (McElroy, 1985; McElroy et al., 1989; Gunster et al., 1993; Crawford, 1994; Huntley et al., 1993, 1995). Petroleum products and their derivatives are commonly referred to as petrogenic PAH, and the products of various combustion processes are considered pyrogenic PAH. In industrialized sections of coastal estuaries, many of these anthropogenic sources are present, and contribute significantly to the overall distribution and pattern of PAHs and other chemicals throughout the aquatic environment.

4.3.1.3 Distribution of PAHs

It was recognized some time ago that the relative proportions of PAH compounds in different types of products vary in a consistent and recognizable manner and that it is possible to identify probable sources of observed environmental levels of PAHs from their characteristic compound mixture, or "fingerprint." In this Section of the report, comparison of PAH fingerprints from the individual stations sampled throughout the Site will be presented to examine the potential contribution of the Wilmington Site to the observed levels of PAHs seen in the drainage ditch, Greenfield Creek, and the Cape Fear River estuary. The following section is a subjective examination of the PAHs present in each sample through the use of graphical display of the data, to qualitatively determine underlying similarities or dissimilarities between groups of stations.

Appendix C to this document, (Part II) includes the analytical results for the 12 PAH compounds (and carbazole) analyzed for in this study, presented in the form of histograms showing the relative (percent-normalized) contribution of each compound to the total PAHs. The histograms were examined with reference to the known pattern of PAHs at the covered ditch area and with other sources including crude and refined oil products (Neff and Anderson, 1981). In examining the histograms it is necessary to bear in mind not only the pattern of individual compounds, but also the absolute concentrations of the PAH that are the basis for the histograms. Because each histogram is internally percent-normalized, small amounts of a compound can appear inappropriately large if few other compounds are present. In conducting the examination reported here, both the pattern of the PAHs and their absolute concentrations were considered.

Several consistent patterns emerge from this examination. The PAH distribution in the samples nearest the covered ditch area (SS-4, SS-5, SS-6, and SS-7) are characterized by a predominance of 2- and 3-ring PAHs, primarily acenaphthalene, anthracene, naphthalene, fluoranthene, and phenanthrene, overlain on a low-level background of 4-, 5-, and 6-ring compounds and carbazole. The presence of these PAHs are consistent with respect to the covered ditch, as the main probably point of entry (PPE) (NCDEHNR, 1995). Two- and 3-ring PAHs are often considered petrogenic and comprise the bulk of the PAHs in oil and petroleum products. Four-, 5-, and 6-ring PAHs are considered pyrogenic, (i.e., produced by combustion processes), and are present at very low levels, if at all, in oil and petroleum products.

In spite of their absence from petroleum sources, the presence of pyrogenic PAHs is evident in drainage ditch samples and in one of the upstream stations (SS-2) from the covered ditch. This is not unexpected because pyrogenic PAHs are widely distributed in the environment. There are numerous, geographically dispersed combustion sources, such as motor vehicles, boats, boilers, and power generating stations, that produce pyrogenic PAHs which are subsequently transported through the air and ultimately enter aquatic systems via wet and dry deposition processes (Eisler, 1987).

In most of the samples from Greenfield Creek, the PAH distribution is predominantly characterized by pyrogenic PAH, with some indication that these chemicals enter the system through outside sources. As an example, SS-12 and SS-13, located in the tributary adjacent to the west side of the railroad tracks, have profiles dominated by 4- and 5-ring PAHs. This small inlet to Greenfield Creek drains wetland and surface waters collected in road side ditches that border portions of the surrounding southeast property, before passing under the railroad tracks and ultimately into Greenfield creek. Moreover, during the Site visit, railroad ties were observed "sweating" a non-aqueous product along several lengths of the track, which can readily washed into nearby surface waters during rain events.

Perhaps the most compelling evidence that PAHs are, as a group, one of the most ubiquitous chemicals in the environment, is through an examination of the PAH distributions in the Cape Fear River. Station SS-14, located under Highway #74 and approximately 3,800 feet upriver from the Site is well represented by both pyrogenic and petrogenic PAHs. In fact, the PAH profile at SS-14 is remarkably similar to the percent contribution of PAHs averaged at the covered ditch, yet SS-14 is far enough upriver to be outside of the Site zone of influence. PAHs at SS-14 therefore represent background concentrations which may be present in the River and are within the range that would be expected for an industrialized estuary.

Table 4-3 illustrates the percent of PAHs at each location (as a fraction) relative to background concentrations observed at SS-14. Values greater than one indicate an exceedance of background concentrations and are in bold; values less than one are below background levels and are not in bold. As indicated in Table 4-3, PAHs in other areas of the River are generally well below

background concentrations. For those stations where PAHs exceeded background concentrations, exceedances were consistently within 1-3 times the concentration at SS-14. A pattern is evident concerning the clustering of exceedances in the old slip (SS-19 and SS-21). Several PAHs in this area were above background concentrations, however, most of the PAHs were pyrogenic, with the exception of carbazole that was detected at relatively high concentrations in this area, but was not detected at SS-14.

After examining the chemical characteristics, potential sources, and distribution of the variety of PAHs near the Site, it is reasonable to conclude that as widespread environmental contaminants, PAHs may enter the aquatic environment through a number of point and non-point sources, possibly contributing to toxicological effects on aquatic organisms. Expectedly, PAHs in aquatic environments are most likely to be present at elevated levels in industrialized waterways, where the level of anthropogenic activity and the subsequent loading of petrogenic and pyogenic PAH to the system is greatest. The nature and extent of PAHs observed in the ditch/Creek system and the Cape Fear River sediments suggest that other, possibly multiple, sources of these chemicals may contribute to the overall pattern of observed PAH levels.

4.3.2 Trace Metals

Sediments may act as a sink, at least temporarily, for metals in aquatic ecosystems (Campbell et al, 1988). Metals-enriched sediments may be recycled to the water column or through food chains. Metals involved in this process may adversely affect water quality and aquatic organisms (Schropp and Windom, 1988). The partitioning of trace metals in sediments is influenced by numerous physicochemical variables and the concentration and nature of ligands in the ambient water. In turn, the partitioning of the metals determines the bioavailability of the chemical to aquatic organisms (Campbell et al., 1988).

Some trace metals such as zinc, iron, manganese, and copper are essential micronutrients for aquatic organisms and are required to sustain metabolic processes. Other trace metals, such as cadmium, mercury, and lead, are not required and may be detrimental. All metals, however, including the essential micronutrients, may be toxic to aquatic organisms if present at sufficiently high exposure levels (Laws, 1981; Campbell et al., 1990).

Increased concentrations of trace metals in biota may act to lower the diversity and production of aquatic communities (Mackie et al., 1989; Guerrero and Kesten, 1993). Winner et al. (1980) reported that macroinvertebrate communities subjected to single toxicants at relatively constant concentrations may suffer impacts comparable to those subjected to multiple toxicants at higher and more variable concentrations. In other words, a continuous, low-level stress can achieve an impact similar to that of intermittent events of much greater intensity (Winner et al., 1980).

Trace metal concentrations are extremely variable in tissues of aquatic biota (Salanki et al., 1982; Guerrero and Kesten, 1993). Aquatic organisms ingest metals from both the water column and from food sources, resulting in an independent and additive effect. Once accumulated, metals react biochemically to ultimately produce toxic effects at higher trophic levels, such as behavior or reproduction. Subsequent alterations in population or community structure may be used to measure the impact of metals in aquatic ecosystems (Hare, 1992).

4.3.2.1 Characteristics of Metals

Numerous studies have demonstrated that the geochemistry and the physicochemical environment play a vital role in metal speciation and subsequent bioavailability (Chapman et al., 1980; Krantzberg and Stokes, 1988; Hare et al., 1989; Ankley et al., 1994; Krantzberg, 1994). Once ingested by an organism, trace metals may interact with specific metabolic processes, return to the environment, or become stored or immobilized thereby reducing the potential to exert toxicological effects (Campbell et al., 1988).

Bioavailability and toxicity to aquatic organisms may vary with the form of the metal (EPA, 1992c). Biological responses to metals are determined by the concentration of the metal species being assimilated by the organism. Trace metals tend to be present at higher concentrations in food particles than in water. However, trace metals adsorbed to particles tend to be less bioavailable than those dissolved in water. The toxicity of metals has been demonstrated at all levels of biological organization including the cell, tissue, individual, population, and community (Hare, 1992). In general, most metals do not bioaccumulate significantly; concentrations of most metals are often elevated in tissues of producers and primary consumers rather than in higher level organisms (Suedel et al., 1994).

The most relevant mechanism of toxicity concerns the chemical inactivation of enzymes. The divalent transition metals react readily with the amino, imino, and sulfhydryl groups of proteins and may displace essential elements. In addition, some trace metals may damage cells by forming chelates or precipitates with essential metabolites or by acting as antimetabolites (Forstner, 1990). Some trace metals may be present in a variety of dissolved species with varying toxicological significance. For instance, the divalent free copper cation and some inorganic copper complexes show potential for substantial toxicity, while the dissolved organic complexes generally exhibit significantly less toxicity. As a result, the same concentration of dissolved copper may exert different toxicological impacts in different ecosystems (EPA, 1992c).

Some trace metals (i.e., arsenic, methyl mercury, and inorganic mercury) exhibit potential for trophic transfer via uptake from food, but quantities are insufficient to result in biomagnification (Suedel et al., 1994). Mercury and arsenic transform rapidly to more toxic, organic forms in aquatic food chains, thus increasing the lipid solubility and modifying the rates of transfer across membranes, which ultimately affects the accumulation of these metals among aquatic organisms

(Bryan and Langston, 1992; Suedel et al., 1994). Other factors which may affect the biological availability of trace metals to organisms include temperature, salinity, hydrogen ion concentration, redox potential, complexation, methylation, and demethylation. In addition, bioaccumulation may also depend on sediment properties such as the presence and concentration of iron oxides, sulfides, and organic matter (Campbell et al., 1988).

4.3.2.2 Potential Sources of Metals

Trace metals occur as natural constituents of rocks, soils, sediments, and waters (Forstner, 1990). Metals may be introduced to aquatic systems as a result of numerous natural causes such as the weathering of localized soils and rocks (Laws, 1981). In addition to natural causes, a variety of anthropogenic activities have resulted in elevated concentrations of metals in many aquatic ecosystems (Laws, 1981; Schropp and Windom, 1988). High concentrations of trace metals are often found in waterbodies exposed to direct inputs from mines, smelters, and other industries involved in the processing or use of metals or substances that contain metal contaminants. For example, sediments containing copper, lead, and nickel are often associated with discharges from smelters, while metal-based and paint and dye manufacturing industries typically discharge lead, chromium, cadmium, and mercury (Forstner, 1990).

There also exists a variety of secondary sources which may supply metal contaminants to aquatic ecosystems. Sediments near sewer outfalls often contain elevated concentrations of trace metals as a result of urban runoff or wastewater discharges (Laws, 1981; Forstner, 1990). Some metals may also be transported in the atmosphere, creating the potential for contaminant deposition to waterbodies distant from local sources. Further, as contaminant reservoirs are created, acidic precipitation and flooding may enhance the mobility of some trace metals from soils to aquatic systems (Hare, 1992).

4.3.2.3 Distribution of Metals

Trace metals sampled for, and detected in Site sediments include arsenic, chromium, copper, and lead. With the exception of lead, samples for metals analysis were collected in three separate areas, including the drainage ditch, Greenfield Creek, and the Cape Fear River. Figure 4-1 illustrates the concentration and distribution of the Site metals relative to the ER-L (Long et al., 1995).

Metals in the drainage ditch were consistently below the reported ER-L (Long et al., 1995). Of the seven samples taken from this location, the highest concentration was reported for lead at a maximum of 290.0 ppm. Maximum reported concentrations for other trace metals in the drainage ditch include 5.2 ppm for arsenic, 14.0 ppm for chromium, and 48.0 ppm for copper. Mean concentrations for these inorganics in the drainage ditch were reported at 55.9, 2.1, 7.0, and 11.7 ppm for lead, arsenic, chromium, and copper, respectively. Concentrations for metals were highest at stations located in sections of the ditch upstream from the Site (SS-2 and SS-3).

In Greenfield Creek sediments, the highest reported concentrations were for copper at a maximum concentration of 16.0 ppm. The maximum concentrations of the other trace metals detected in Greenfield Creek were 4.7 ppm for arsenic, 5.5 ppm for chromium, and 14.0 ppm for lead. A total of six samples were taken from this location for copper, arsenic, and chromium, and four samples were taken for lead. Mean concentrations for these trace metals in Greenfield Creek sediments were 1.8, 1.8, 5.6, and 5.0 ppm for arsenic, chromium, copper, and lead, respectively. All metals in Greenfield Creek were consistently below the ER-L (Long et al., 1995).

With the exception of lead, arsenic, chromium, and copper were detected in the Cape Fear River at maximum concentrations of 11.0, 65.0, and 74.0 ppm, respectively, over all river stations. Sampling points in the River indicate that mean concentrations for these trace metals were 8.2 ppm for arsenic, 35.0 ppm for chromium, and 30.6 ppm for copper. There were only a few stations that had minor exceedances of arsenic and copper above the respective ER-L, and background concentrations were within the range of these exceedances.

The characteristics, potential sources, and distribution of metals near the Site are different from those identified for PAHs. Like PAHs, metals at sufficient concentrations may be toxic to aquatic organisms. However, sources of metals are largely due to natural weathering, processing/manufacturing industries, sewer outfalls, and, to a lesser extent, surface water runoff of soils in atmospheric depositional areas. The distribution of sediment metal concentrations in the ditch/Creek system were consistently below benchmarks, indicating that the covered ditch area was not a likely source. Similarly, metal concentrations in the Cape Fear River sediments (including background) are consistently above those observed in the ditch/Creek system.

4.4 Characterization of Ecological Habitat and Communities

The purpose of this section is to describe the extent and quality of habitats that exist on and adjacent to the Site. The habitat characterization supports the screening-level ERA process by developing an understanding of the relationship among habitats, associated organisms, and how both support the structure and function of the local ecosystem. Because the transport of Site-related chemicals is primarily through the ditch/creek system, the habitat characterization focuses on these areas to discern off-site exposure pathways, and sensitive habitats where exposure to chemicals may be of concern.

A visual survey of the area was conducted by foot and by boat on March 12 and 13, 1996. Habitat types on and adjacent to the Site were identified through field observations, and by reviewing earlier studies conducted at the Site. The physical characteristics of the shoreline and surrounding areas at each location was recorded, and a photographic record of the Site was documented during the survey. Baseline water quality parameters were measured and include: pH, conductivity, turbidity, dissolved oxygen, temperature, and salinity (Table 4-4). In addition, sediments were

qualitatively sampled at locations to examine the composition of the benthic community. These results are discussed in Sections 4.4.1, 4.4.2, and 4.4.3.

In addition to visual censusing, historical observations and data on the ecological characteristics of the Site and Cape Fear River were compiled and evaluated. The sources of information for the Site ecology included observations made during previously conducted risk assessments and site inspections. Of equal benefit were resource maps developed from previous sampling activities (Virogroup, 1994), photographs, and observations made during the habitat characterization performed by ChemRisk. In addition to these data, historical data collected from the Cape Fear River were comprised mostly of comprehensive studies conducted in the 1970s and 1980s by the Carolina Power and Light Company (CPLC) for compliance with permitting requirements for the Brunswick Steam Electric Plant (CPLC, 1979; 1985; 1986; 1987) were utilized. Other relevant information was obtained from the National Oceanic and Atmospheric Administration (NOAA) on the distribution and abundance of fishes and invertebrates in southeast estuaries (NOAA, 1991). Photographs sited in the following sections are presented in Part II, Appendix D.

4.4.1 Drainage Ditch and Tributaries (Photos 1-6)

4.4.1.1 Habitat Structure

There are several small inlets and depressions that form a small collection network supplying the drainage ditch flowing from the southeast corner of the Site (Figure 2-1). To the east of the Site, drainage ditches border both sides of Greenfield Street and are supplied by culverts which collect surface waters from off-site locations east of Front Street. These ditches were full of water (2-3 feet), and appear to provide the majority of water volume to the drainage ditch leaving the Site. The two ditches merge and flow to the south along the east side of the railroad tracks (adjacent to Optimist Park) before passing under a railroad trestle, and continuing south to Greenfield Creek.

At the point where the ditch turns south, other small tributaries merge to contribute additional runoff to the drainage ditch. A small shallow ditch borders the covered ditch area to the south, before entering the drainage ditch from the west. The ditch appears to collect water from wetlands bordering the southeast corner of the Site, and was observed to have very little volume. To the north, a small temporal ditch which borders Greenfield Street passes through dense vegetation, and collects at a culvert before entering the drainage ditch from the north. The drainage ditch flows south through an upland marsh for approximately 800 feet before entering Greenfield Creek.

Habitat within the drainage ditch is variable in both quality and abundance. The ditch flows slowly (<0.5 cfs), is generally shallow (1-2 feet), and has sediments which are dominated by high fractions of silt and clay. Leafy organics and small twigs were estimated to be as much as thirty to forty percent of the surface sediments. The ditch banks were gradually sloped and along the northern reach, exposed mudflats predominate (Photos 3 and 4).

Surface waters characteristic of the drainage ditch did not indicate stressful conditions for aquatic organisms (Table 4-4). Surface water temperature ranged from twelve to eighteen degrees Celsius, pH was mostly neutral (7.1 - 7.4), and dissolved oxygen (7.8 - 9.4 mg/L) was considered normal in support of aquatic life adapted to aerobic conditions. Salinity measurements indicated that surface waters in the ditch were generally fresh [< 0.02 parts per thousand].

4.4.1.2 Ecological Community

Aquatic life was observed in the ditch, and the use of the waterway by terrestrial species was also documented. Benthic organisms observed in ditch sediments were represented mainly by aquatic earthworms (Oligochaeta), scuds (Amphipoda), and midges (Chironomidae). No fish were observed at any time while surveying the ditch. Fiddler crabs (*Uca* spp.) have been observed in large numbers along low relief shoreline during spring and early summer months, and numerous crab borrows were observed during the Site visit around some fringe areas of the ditch. Turtles were observed basking in the sun along the ditch banks and were tentatively identified as the common Box Turtle (*Terrapene carolina*). Raccoon (*Procyon lotor*) tracks were common along the ditch banks where access to the surface waters was not impeded by heavy vegetation. Habitat in some of the area appears to be suitable for aquatic or semi-aquatic mammals (i.e., muskrats, mink etc.) but none of these animals were observed directly by sight or sign. Barnacle (Balanidae) calices were observed along the bottom of the inactive sewer line which crosses the ditch (Photo 6), indicating that during the time when river water passed through the tidal gate, water and flow conditions were sufficient for supporting brackish water communities.

Vegetation along the drainage ditch is characteristic of a lowland, transitional wetlands. Most of the drainage ditch flows along a low relief gradient through exposed areas dominated with grasses, shrub/sedge wetland, and hardwood stands contributing to some treefall. Submerged macrophytes were limited to duckweed (*Lemna* sp.) in the upper reaches. Emergent wetlands were dominated by sedge (*Scirpus* sp.), giant reedgrass (*Spartina* sp.), and black needlerush (*Juncus roemerianus*). Magnolia (*Magnolia sp.*) was often observed in more elevated soils throughout the wetland. Canopy species were dominated by bald cypress (*Taxodium distichum*), loblolly pine (*Pinus taeda*), oaks (*Quercus sp.*), maple (*Acer* sp.), and hickory (*Carya* sp.). Treefall in the ditch was predominately due to bald cypress, which was dominant in stands along the ditch banks (Photo 5).

Several families of birds were observed flying between thickets along the ditch fringe. Warblers (Parnlidae), chickadees (Paridae) and sparrows and finches (Fringillidae), were among the most dominant and conspicuous species, both along the ditch and throughout other areas of the Site. Crows (Corridae) were also often observed or heard. During the Site visit, a red tail hawk (*Buteo jamaicensis*) was observed encircling the wooded area near the Site access road.

4.4.2 Greenfield Creek and Tributaries (Photos 7-20)

4.4.2.1 Habitat Structure

Greenfield Creek originates at Greenfield lake dam (Figure 2-1), flows through a culvert under Front Street, and continues along the southern border of the Site to the Cape Fear River. At a distance of approximately 650 feet downstream from the dam, the Creek passes underneath a trestle that supports active railroad tracks. Along the west bank of these tracks, a small tributary enters the Creek through a small drainage swale further south. At approximately 50 feet downstream of the trestle, the drainage ditch enters the Greenfield Creek from the north (Photo 10). The Creek continues southwest along a low gradient, splitting the Site property to the north, and property leased by Pactank Bulk Chemical Storage Facility to the south. At this point, the Creek bends to the west, and widens slightly as it continues towards the Cape Fear River. Exposed shoreline is predominate along the lower reach of the Creek (Photo 20). At the mouth of the Creek is a tidal gate which allows surface waters to empty into the Cape Fear River, but under normal conditions does not allow a significant flow of exchange tidal waters into the Creek.

In the upper reaches of the creek, adjacent to the railroad trestle, is a small tributary which enters the creek from the south. Observations made on the tributary indicated the release of a cloudy, milky floc into Greenfield Creek; possibly a result of disturbed debris from a passing train. The Creek bottom consisted of stones and large cobble that were primarily covered with a tan fungus-like growth (Photos 19 and 20). The tributary was shallow (<6"), with small riffles and pools, and scattered debris in the form of treefall and scrub grass. Large stone rip rap supported the east bank adjacent to the railroad tracks, and wetland/woody vegetation was dominate along the west bank. Small unidentified minnows (<1") were observed, along with water striders (Gerridae) and duckweed (*Lemna* sp.) in pool areas.

Downstream from the trestle, Greenfield Creek has some of the characteristics of the drainage ditch. The Creek flows slowly (<1.0 cfs), is mostly shallow (1-2 feet), and has sediments consisting of high silt and clay fractions. However, unlike the ditch, sediments closer to the mouth of the Creek have higher fractions of sand and small cobble than do sediments further upstream. Leafy organics and small twigs were present, and estimated to be between ten to twenty percent of the surface sediments. On average, the Greenfield Creek banks were sloped at greater angles than in the drainage ditch, averaging about 2-3 feet of vertical relief. (Photos 13 and 14).

Surface water parameters measured in Greenfield Creek did not indicate stressful conditions for aquatic organisms, and were similar to those parameters observed for the drainage ditch (Table 4-4). Surface water temperature ranged from eleven to thirteen degrees celsius, pH was mostly neutral (6.8-8.0), and dissolved oxygen (8.8-10.23 mg/L) was relatively high. Each of these

parameters were within the expected regional range for supporting aquatic life. Salinity measurements indicated that surface waters in the drainage ditch were generally fresh (< 0.01ppth).

4.4.2.2 Ecological Community

Benthic organisms observed in Creek sediments were similar to those observed in the drainage ditch, and were represented mainly by aquatic earthworms, scuds, midges and damselflies (Zygoptera). Only a few small unidentified minnows (< 1") were observed in shallows upstream from the trestle. No other fish were seen, and habitat was limited in that bank overhang was virtually absent, there was no distinguishable riffle or pool areas, and the Creek substrate was not complex enough to afford suitable cover. Raccoon tracks were observed along the banks and in areas of low, wet soils. Fiddler crab burrows were observed throughout some of the lowland swamps in the upper reaches of the Creek (upstream from the trestle), but were not observed in areas closer to the tidal gate. Terrapin were observed along the banks of the Creek, mostly in the upstream reaches. Many of the birds identified along the drainage ditch were also commonly observed along Greenfield Creek with one exception; two great blue heron (*Ardea herodias*) were startled from the trees at approximately 800 feet downstream from the trestle. Both birds were believed to have been the same individuals that had been observed earlier along the shoreline of the Cape Fear River.

The terrestrial and semi-terrestrial vegetation along Greenfield Creek changes significantly from upstream areas of swamp wetland to downstream reaches characterized by steeper banks, and a greater abundance of canopy and understory species comprising thickets and woody snags along the creek edge (Photos 15 and 16). Bald cypress, occurs extensively in marginal zones along the south bank of the creek, and is common upstream from the railroad trestle (Photo 8). Further downstream, bald cypress is less apparent as the banks of the creek steepen. Species generally observed in downstream areas include: atlantic cedar (*Chamaecyparis thyoides*), longleaf pine (*Pinus palustris*), magnolia, oaks, maple, and hickory. Most of these species were abundant along the north bank of the creek, but were limited in some sections of the south bank due to development (Photo 20). Submergent vegetation (*Elodea* sp.) was observed in the Creek at approximately 600 feet upstream from the tidal gate.

4.4.3 Cape Fear River Estuary (Photos 21-36)

4.4.3.1 Habitat Structure

The Cape Fear River estuary is approximately that portion of the River which extends from Baldhead Island (near the River mouth) to points north of Castle Hayne in the Northeast Cape Fear River (a distance of about 15 nautical miles). Numerous tidal creeks and tributaries enter the estuary as the River flows southward, and provide extensive habitat for transient and resident species vertebrate and invertebrate organisms that utilize the marsh throughout the year (Weinstein,

1979). Eagle Island, which divides the lower reaches of the Brunswick River and the Cape Fear River, is directly west of the Site. A brief discussion of Eagle Island is provided in Section 4.4.4. To the north of Eagle Island, at approximately five nautical miles upriver and adjacent to the City of Wilmington, the Northeast Cape Fear River enters the Cape Fear River from the northwest (Photo 32).

Industrial uses within 2 nautical miles upriver and downriver of the Site are concentrated along the east bank of the Cape Fear River with comparatively little development or encroachment of anthropogenic activity along the west bank. To the south of the Site, the North Carolina State Ports Authority (NCSPA) occupies over one mile of river frontage in the form of a large terminal comprised of sheet piling and pier. Dredging operations were being conducted in this area during the Site visit. North of the NCSPA terminal is property leased by Pactank Bulk Chemical Storage Facility. The shoreline adjacent to this facility supports limited habitat for biota in the form of exposed tidal flats, and marsh grass (*Spartina* spp.), which is dominant along the intertidal zone (Photos 23 through 26).

4.4.3.2 Ecological Community

The Site is located north of the Pactank Facility, and has a shoreline that is characterized (going upriver) by exposed tidal flats to the north of the tidal gate (Photo 21), a former barge area with tidal flats and an abandoned pier (Photo 22), and at the northern extreme of the River's edge, a network of abandoned pilings (Photos 25, 27, and 28). Gill nets were observed parallel to the shore, possibly being used for monitoring shad (*Alosa* spp.) runs in the River. Habitat availability in this area is favorable for piscivorous birds, including herons (Ardeidae) and egrets (Ardeidae), all of which were observed wading in the former barge area. Marsh grass is abundant along the mudflats north of the tidal gate (Photo 23), but is limited along the Site boundary thereafter. Small sandpipers (Scolopacidae) were observed along the shoreline of the River during low tide, where small clumps of green filamentous algae were observed along the shoreline (Photo 26).

Increasing land use and development along the east bank of the River are characteristic of the shoreline further upriver from the Site. Hess Bulk Petroleum Storage Facility is located to the immediate north, and the shoreline along the east bank of the River adjacent to this facility is mostly marshgrass (*Spartina* spp.), and exposed pilings (Photo 29) and debris. Gulls (Laridae), and Heron (Ardeidae) were commonly observed perching on tied pilings in this area. Further north, the shoreline increases in cobble and scrub vegetation (Photo 30), and development of residential communities becomes evident (Photo 31) approaching the Highway #74 bridge. In this area, a considerable amount of old partially submerged pilings, rip/rap, and refuse, dominate the shoreline throughout Wilmington's city limits.

During the 1970s, the aquatic biological communities in the Cape Fear River were extensively studied by the Carolina Power and Light Company (CPLC), in support of permitting requirements

for the Brunswick Steam Electric Plant (CPLC, 1979). The plant is located near the mouth of the River, two miles north of Southport, NC. In the initial studies, shallow marsh habitats and the River fringe in these locations were determined to be critical areas for developing stages of fish and shellfish. Numerous species of aquatic fish and macroinvertebrates were observed during these initial investigations.

More recently, monitoring studies conducted by CPLC have further characterized aquatic communities along a temporal scale, and in select areas of the estuary that correspond to changes in the estuarine salinity gradient (CPLC, 1985; 1986; 1987). Near-field and far-field marsh stations corresponding to limnetic (0-0.5 ppt), oligohaline (0.5-5 ppt), mesohaline (5-18 ppt), and polyhaline (18-30 ppt) sections of the estuary were identified to account for species zonation patterns. As indicated in Table 4-6, the most abundant species collected in the estuary were spot *(Leiostomus xanthurus)*, grass shrimp *(Palaemonetes* spp.*)*, brown shrimp (*Penaeus aztecus*) bay anchovy (*Anchoa mitchilli*), atlantic menhaden (*Brevoortia tyrannus*), striped mullet (*Mugil cephalus*), croaker (*Micropogon undulatos*), blue crab (*Callinectes sapidus*), mummichog (*Fundulus heteroclitus*), pink shrimp *(Penaeus duorarum)*, southern flounder (*Paralichthys lethostigma*), atlantic silverside (*Menidia menidia*), and white shrimp (*Penaeus setiferus*). Table 4-5(a,b) also illustrate the difference of the two collection methods (trawl and seine) in the characterization of the organisms in the estuary. Although spot and grass shrimp are most commonly caught in either type of sampling gear, mullet, mummichog, and atlantic silversides, which are common in eastern United States coastal estuaries, were not commonly observed in great abundance in the trawls. However, they did collectively provide between 1-8% of the species caught in seines during each year of the study. In addition, several species collected in trawl samples were not collected in seines, including: croaker, blue crab, pink shrimp, southern flounder, and hogchoker *(Trinectes maculatus)*.

To more accurately determine the River species which may be present within the Site environs, data from the CPLC reports were summarized for two of the marsh stations (Alligator Creek and Mott's Bay) respectively positioned upriver and downriver of the Site. Alligator Creek is located approximately 2 miles north of the Site, and is characteristic of limnetic-oligohaline reaches. As shown in Table 4-6(a,b), the most commonly observed species in Alligator Creek included: spot (14-68%), croaker (4-36%), bay anchovy (16%), southern flounder (5-13%) and white shrimp (0-13%). Brown shrimp, pink shrimp, blue crab, and atlantic menhaden were generally less than 5% of the total species caught during the three-year period.

The dominant species patterns are similar at Mott's Bay, located approximately 5 miles south of the Site in oligohaline to mesohaline surface waters (CPLC, 1987). Similar to observations in Alligator Creek, species in Mott's Bay were dominated by spot, bay anchovy, and croaker. Brown and pink shrimp, which are limited in distribution to more saline waters, were observed at higher concentrations in this area. Brown shrimp ranged between 1-9% of the total annual catch, and pink shrimp averaged 2%. White shrimp, which was one of the most dominate species collected in

Alligator Creek was consistently less than 1% of the annual catch in Mott's Bay. Both the Cape Fear River and North Cape Fear River support seasonal commercial fisheries of these shrimp, as well as blue crab, and eel. (NCDEHNR, 1995).

NOAA (1991) has identified several other fish species which, although not collected in the CPLC studies, have been identified as either common or abundant in the Cape Fear River Estuary. These species include: pinfish (*Lagodon rhomboides*), American eel (*Anguilla rostrata*), blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), atlantic sturgeon (*Acipenser oxyrhynchus*), and ladyfish (*Elops saurus*). Each of these species and the general distribution of their life stages in the Cape Fear River Estuary is shown in Table 4-7.

4.4.4 Eagle Island (Photos 33-36)

4.4.4.1 Habitat Structure

As previously mentioned, Eagle Island, which is located directly across the river from the Site, splits the confluence of the Brunswick and Cape Fear River, and has a series of meandering creeks and channels cut throughout an extensive northern marsh system. The island is predominately undeveloped, although there is some activity attributed to ship repair and servicing companies, old abandoned wooden shipwrecks, boilers, and abandoned shacks across the River from Wilmington. The extent of this activity is as far south as the Highway #74 bridge, however, the majority of the island's river bank is pristine undeveloped habitat with extensive intertidal mud flats and productive *Spartina* beds along the River's edge.

4.4.4.2 Ecological Community

Observation made from the River indicate that the vegetation on Eagle Island (from shore to inland) follows a sharp gradient from *Spartina* dominated shorelines to sparse stands of bald cypress, pine, and understory brush concentrated around a small, elevated ridge (Photo 33-36). The *Spartina* dominated shoreline was observed to be both extensive, and favorable as fringe habitat for small fish and invertebrates. A snowy egret was observed feeding along the River's edge, wading between one of the many small, intermittent cuts in the islands shoreline (Photo 35). Two osprey (*Pandion haliaetus*) were observed gliding along the treeline of a small stand of bald cypress.

4.5 IDENTIFICATION OF KEY ECOLOGICAL RECEPTORS

Key ecological receptors are those organisms that may be exposed directly, or indirectly to COPC through direct contact with chemicals or through trophic transfer via ingestion of contaminated prey. Consistent with EPA guidance (1989; 1992b; 1994a), key organisms include: (a) resident organisms subject to the greatest exposure to contaminated sediments and water; (b) species considered to be essential to, or indicative of, the normal functioning of the existing habitat; and (c)

federal or state threatened or endangered species. Based on the habitat characterization and ecological community evaluation presented in Section 4.4, there are a number of candidate receptors that could be evaluated in this screening-level ERA. Each of these candidates is discussed below, along with the rationale for their selection as key receptors. Section 4.5.7 provides the life history summaries for the receptors selected in this screening-level ERA.

4.5.1 Plants

As primary producers, plants constitute the base of all food webs. They are ubiquitous and may under certain circumstances be among the first organisms potentially affected by on-site stressors (EPA, 1991). However, plants are not particularly useful receptors of interest for hydrophobic compounds like PAHs due to the fact that they are limited in their ability to transport substantial amounts of these compounds, thereby limiting their potential for uptake and exposure (EPA, 1991). Because of the low solubility of these compounds, dimethyl sulfozide (DMSO) is often used in this study as a carrier to dissolve the PAHs into solution. In general, many studies must either use a carrier such as DMSO to achieve aqueous concentrations high enough to elicit a response or are based on extrapolations which result in concentrations greater than the aqueous solubility. For example, Huang and coworkers (1993) examined photoinduced PAH toxicity to duck weed (*Lemna gibba*), a higher aquatic plant species which has been observed in Site surface waters. Duckweed was exposed for eight days to photomodified anthracene, benzo[a]pyrene, and phenanthrene. A LOEL for growth inhibition was observed at 0.2 ug/l for anthracene and 0.5 ug/l for phenanthrene. Exposure to benzo[a]pyrene at concentrations ranging from 4 to 8 ug/l resulted in only a modest inhibition of plant growth. As previously discussed in Section 4.3, the surface waters at the Site are consistently non-detect for a range of tested chemicals, including PAHs and would not likely effect aquatic plants.

While aquatic plants comprise a critical element of an ecological food web, the abundance of Site vegetation is limited more to wetland species of reeds, grasses, and sedges, located along the more riverine boundaries of the Site surface waters. For this reason, and because of the low uptake and lack of sensitivity to PAHs, plants were not selected as key receptors for this screening-level ERA.

4.5.2 Benthic Macroinvertebrates

Benthic communities include organisms which inhabit the substrate surface or burrow within sediments for food or shelter. The occurrence, density, and distribution of invertebrates has been suggested as indicative of the overall water quality of aquatic ecosystems (Plafkin et al., 1989; APHA, 1989). Furthermore, benthic macroinvertebrates function as strong indicators of extant environmental (local) conditions as many taxa have limited migration patterns and are excellent indicators of existing conditions due to the relatively short life cycle of larval stages (Plafkin et al., 1989). Natural factors may also influence the type and abundance of benthic species in that season, water temperature, dissolved oxygen, anaerobic sediments, organic loading to the system,

and chemical contamination are all important in structuring communities. The combined effect of these environmental factors may be sufficient in producing the cyclic patterns of infaunation and defaunation often associated within estuarine ecosystems.

The majority of species that comprise benthic macroinvertebrate communities are dynamic, consisting primarily of year-round mobile and immobile residents whose abundance, distribution, and structure can be indicative of a variety of natural and anthropogenic stresses. The benthic invertebrates observed in the drainage ditch and Greenfield Creek are dominated by freshwater taxa, including: aquatic earthworms, scuds, chironomids, damselflies and perhaps numerous other aquatic diptera. Fiddler crabs appear to be the primary species found along the borders of the creeks; however, these species are considered to be mostly terrestrial, borrowing in the riparian margins of the aquatic system and therefore are not directly exposed to aquatic sediment.

In the Cape Fear River, the benthic community adjacent to the Site is expected to be represented by different taxa but dominated by organisms typically associated with oligohaline reaches of southeastern estuaries. Previous studies on the benthic community structure have not been identified, but it is more than likely that the species typically found in the Estuary include representatives of oligochaetes, polychaetes, and amphipods. Blue crab, grass shrimp, and pennaid shrimp have been observed throughout much of the estuary as reported by the CPLC (1979; 1985; 1986; 1987). Although the specific benthic taxa between the predominately freshwater ditches and oligohaline reach of the Cape Fear River are different, each occupy similar trophic levels and are arguably similar in their functional biology, in that they are in direct contact with and ingest sediments throughout the Site. For the reasons described above, benthic macroinvertebrates were selected as key receptors of potential concern for this screening-level ERA, and representatives of these communities are described in Section 4.5.7.

4.5.3 Fish

Fish are conspicuous, easy to identify and can serve as primary indicators of environmental conditions within an aquatic ecosystem (APHA, 1989). Fish may take up chemicals that are dissolved in the water column; however, this is not the primary route of exposure for most species - particularly bottom feeders. Bottom feeding fish may take up chemicals via the ingestion of benthic invertebrates and the incidental ingestion of sediments during feeding. Predatory pelagic fish may ingest chemicals through feeding on smaller fish or other contaminated prey. Most of the fish species potentially present in the Cape Fear River occupy mid-trophic levels of the food web, and therefore consume lower trophic organisms; primarily benthic invertebrates. As such, the accumulation of chemicals in most fish are primarily through the ingestion of potentially contaminated prey.

Fish communities generally include a range of species that represent a variety of trophic levels with abundance and diversity of lower trophic levels influencing the ecological structure of higher

trophic levels. Because fish were not observed during the Site characterization, and in conversations with Site personnel, have not typically been observed in the drainage ditch and Greenfield Creek, the trophic structure of these areas appears to be truncated. With the tidal gate in operation, habitat conditions in the ditch and Creek have been altered to effectively exclude an established fish community from these areas. The result, is an incomplete exposure pathway for fish.

In the Cape Fear River, the spot appears to be the most predominant forage fish, comprising most of the annual biomass in the River (Table 4-5). It is readily apparent from the historical data that the spot are important to the normal functioning of the ecosystem, particularly along the *Spartina* habitat which not only borders the Site along the River's intertidal zone, but is also present in riverine locations north, west, and south of the Site. Although other forage fish species are certainly as equal in economic and ecological important, the spot is unequivocally the most widespread and dominant forage fish in the River and, thus, is an appropriate key receptor for this screening-level ERA.

4.5.4 Amphibians and Reptiles

Many kinds of amphibians (e.g., frogs and toads) and reptiles (e.g. alligators, turtles, snakes etc.) can typically be found near aquatic systems, where an abundance of low treefall, overhanging branches and slow muddy waters offer suitable habitat. Generally, amphibians are terrestrial as adults and move to aquatic habitats to breed. Most deposit their eggs in or near the water and the eggs hatch into free swimming and feeding larvae. Eventually these larvae metamorphose into their adult forms and move back into the terrestrial habitat where they continue to feed and grow. The diet of most amphibians would include adult and aquatic insects and invertebrates. Although amphibians may be exposed to sediment COPC through contact or ingestion of contaminated foods, the toxicological literature on the effects of COPC to this group of organisms is limited. Overall, Eisler (1987) has determined that amphibians appear to be generally insensitive and capable of metabolizing COPC similar to that demonstrated in mammals.

Certain reptiles may be exposed to COPC in the aquatic system, and those observed in the drainage ditch and Greenfield Creek were often spotted along the banks of these areas or when startled, submerged into nearby surface waters. Similar to that found in amphibians, the toxicological literature on the effects of COPCs to reptiles appears to be considerably vague. What little work that has been done has focused on PCBs, which found that reptiles are considerably insensitive to the toxic effects of these compounds (Olafsson et al., 1983; Bryan et al., 1987a,b). Of the few studies that have been conducted, the identification of the direct toxic response to PCBs has been compounded by exposure of the turtles to a multitude of other organic and inorganic contaminants. Turtles are generally not consumed by higher trophic organisms, and therefore even in the absence of adequate toxicological information, the food web transfer of COPC to higher trophic levels is

not expected to be a significant exposure route. For the reasons described above, both amphibians and reptiles have not been chosen as receptors of concern for this screening-level ERA.

4.5.5 Piscivorous Wildlife

4.5.5.1 Birds

Piscivorous birds (e.g., herons, egrets, and osprey) feed predominately on fish which may consist of well over 80% of their respective diets. Most piscivorous birds form colonies near fresh or brackish waters in marshes, swamps, coastal areas, and heavy stands of mangroves (Terres, 1980). There is only limited habitat available for most of these species within the Site environs, however, the overall abundance of suitable habitat is greatest along the shoreline of the Cape Fear River and Eagle Island. The slow-moving, shallow waters of the drainage ditch and Greenfield Creek are relatively poor habitat for sustaining a balanced, indigenous fish community, and furthermore, these systems are virtually inadequate as feeding areas for localized populations of piscivorous birds. Access to this area by fish is blocked to the east by the Greenfield Lake Dam and to the west by the tidal gate.

In the Cape Fear River, however, there is some potential for exposure to COPC by piscivorous birds. The overall importance of fish as a food source to larger consumer groups in the Cape Fear River is, in itself compelling evidence for selecting piscivorous birds as a key species for continued evaluation in this screening-level ERA. Because several species of herons and egrets have been observed at the Site, it is important to consider representative receptors of this group for risk analysis. Reptors, such as osprey or red tail hawk, were not chosen because their habitat and feeding preferences could not be conservatively assumed to be limited to fish species with a potentially high exposure to Site COPC (e.g. spot utilizing the *Spartina* dominated intertidal zone). Therefore, to characterize the potential for transfer of COPC through the food web, the great blue heron was selected as a representative species and included for further evaluation.

4.5.5.2 Mammals

Exposure to COPC by mammals through the food web at the Site would appear to be highly variable, more so than birds, due to the variability often observed in the feeding behavior of some common mammalian species. Mammals may be piscivorous, carnivorous, insectivorous, omnivorous, or herbivorous, and although the occurrence of mammals at the Site may include raccoon, river otter, mink, and weasel (among others), many of these species are sparsely distributed, and are not as apparent as the relatively larger populations of piscivorous birds at the Site. For the reasons described above, mammals have not been chosen as receptors of concern for this screening-level ERA.

4.5.6 Threatened, Endangered, and Rare Species

Within the United States Geological Survey (USGS) quadrat for the Wilmington area, the NCDEHNR's National Heritage Program (NHP) has identified 14 vertebrates, 6 invertebrates, and 14 vascular plants which are either threatened, endangered, rare, are of special concern, or are candidate species for listing. A list of these species has been provided in a memo sent by the NHP (Appendix E), following a request by ChemRisk to identify sensitive species in the proximity of the Site. None of the species in the NHP list were observed during the Site visit.

Historically, several rare species have been identified within about a mile of the Site, but have not been seen in recent years and several of these species have been presumed extant by the NHP (NCDEHNR, 1993, 1996). These species include: (1) the Carolina grasswort (*Lileopsis carolinensis*), which has been observed approximately 0.1 miles southeast of the Site; (2) the state endangered barell floater (*Anodonta couperiana*), a freshwater bivalve that has been observed near the northwest shores of Greenfield Lake; and (3) the state endangered magnificent ramshorn (*Planorbella magnifica*), a small gastropod which has been observed along the northwest shores of Greenfield Lake, and which is believed to be extinct. As indicated by the proximity of these three freshwater species to the Site (e.g. the Carolina grasswort, the barell floater, and the magnificent ramshorn snail), if present, these species exist in wetland areas characteristic of lentic habitat (lakes), which do not overlap with the predominately lotic habitat (streams) of the ditch and creek. The questionable presence of these species, and more importantly, the low potential exposure of these species to Site COPC precludes their selection as key organisms in this screening-level ERA.

In addition to these species, a rare skipper (*Problema bulenta*) and Duke's skipper (*Euphyes Dukes*) have also been identified as occurring within a one-mile radius of the Site. Also, the state and federal endangered short nose sturgeon (*Acipenser brevirostrum*), has been observed 0.5 miles to the northwest of the Site in the Cape Fear River. The short nose sturgeon, may be found in oligohaline reaches of rivers throughout the eastern United States (Lee, 1980). Van Den Avyle, (1984) has proposed that the greatest threat to this species is likely a result of being caught as by-catch (e.g. incidental catch) in commercial fisheries for the more common atlantic sturgeon and the american shad. This species was not considered for evaluation in this screening-level ERA for the following reasons: (1) habitat along the reach of the River is not critical for spawning or rearing purposes, and therefore exposure to Site COPC would be expected to be minimal; (2) the species is not representative of the balanced, indigenous food web of the estuary resulting in an incomplete exposure scenario for evaluating bioaccumulation; (3) there are numerous other residential and migratory species in the River which have more relevant commercial, recreational, and ecological value to the overall "health" of the ecosystem; and (4) there is an abundance of toxicological literature pertaining to the residential and migratory species described in (3). For these reasons, the shortnose sturgeon was not considered as a key species for evaluation in this screening-level ERA.

Another species that was not identified within one mile of the Site by the NHP, the threatened american alligator (*Alligator mississippiensis*), had been observed near the banks of Greenfield Creek during the sampling program conducted by Virogroup, in May of 1995. The american alligator has recovered in numbers following a decrease in the population during the late 1960s when the species was considered as federally endangered, and the previous restrictions which were responsible for the alligator's recovery were removed in some portions of the animal's range to allow for limited hunting (Hackney, 1992). Currently, the habitat or prey in the freshwater ditch and Creek do not appear to be favorable for supporting one, or for that matter, a population of american alligators. Most of these reptiles have been observed by the NHP primarily in the extensive network of small creeks and channels in the natural priority area northwest of the Site, and in locations further north. For this reason, and the rationale provided in Section 4.5.4. regarding reptiles, this species was not included as a key receptor in this screening-level ERA.

Finally, in addition to the occurrence or rare, threatened, and endangered species in vicinity of Site, the NCDEHNR (1993) has identified one natural priority area in the Brunswick River - Cape Fear River estuary located two to three miles northwest of the Site. This area is recognized as an extensive tidal freshwater marsh which provides favorable habitat for fish and other species that may occur in this area. The area is well outside of the zone of influence from Site PPE, and because of the predominately localized urban surroundings in this area (e.g. City of Wilmington, ship repair facilities, boat ramps, and associated highway and roads), the marsh was not considered for further evaluation in this screening-level ERA.

4.5.7 Summary and Life History of Key Receptors

4.5.7.1. Benthic Macroinvertebrates (Oligochaeta, Polychaeta, Decapoda, Amphipoda, Insecta)

As defined by Odum (1971), benthic macroinvertebrates include infaunal organisms which dig into the substrate, or construct tubes or burrows or epifaunal organisms which attach to hard substrate and move freely about. Some of the major groups of benthic invertebrates that have been observed, or are known to occur at the Site are described below.

The aquatic representatives of the class oligochaeta are morphometrically and functionally similar to their terrestrial counterparts. Aquatic earthworms are small, elongate and cylindrical in shape, and like terrestrial earthworms, utilize aquatic sediments for food and shelter. Oligochaetes are hermaphroditic and cross-fertilization usually takes place between two individuals (Pennak, 1978). Taxonomic delineation within these organisms is difficult, often requiring tissue sectioning for some genus-species level identification. The most frequently occurring representatives of this class occur in the Naididae, Tubificidae and Enchytraeidae (Pennak, 1978).

Polychaete annelids are typically found buried in sediments or moving about the bottom in search of food or space. Adult polychaetes are able to regenerate lost segments by either serial budding or

sexual metamorphosis (Pennak, 1978). Sexes are separate in most polychaetes, and gametes are usually released freely into the water column. Larvae occur in the plankton throughout the year, increasing in size and decreasing in buoyancy. As mature larvae settle to the bottom, they develop setae and metamorphosis into adult forms. Most polychaetes are deposit feeders which ingest detritus and algae, as well as other invertebrates (Pennak, 1978). These organisms represent an abundant food source for many species of fish.

Decapods are perhaps the most well recognized groups of benthic organisms in the estuarine environment and include many commercially and recreationally important species (e.g. crab, shrimp, and lobster). Decapods make up almost one third of the known species of crustaceans (Barnes, 1980). Many of these species are scavengers and omnivores, crawling about the surface of the bottom sediment for decaying plant and animal matter. As these species grow, the hard, chitinous, carapace surrounding the organism is lost through molting, leaving the organism "soft" and potentially vulnerable to predation during a brief period in the molting cycle. Although habitats vary with species, there is generally some overlap between species. Blue crabs prefer soft bottom substrates, and can excavate small burrows in the sediment for shelter. Lobsters utilize soft substrates in much the same way, but can also be found near hard substrates and structure where small crevices provide shelter. Shrimp can be found grazing along the bottom of soft substrate, and are also common among submergent vegetation.

Most amphipods are found in the marine environment, however there are about 800 species of freshwater amphipods worldwide. The majority of these species can be found in unpolluted lakes, ponds, streams, and are usually associated with substrate. Most amphipiods are extremely pollution sensitive, and the presence of these organics in the ditch/creek system may suggest that despite the current levels of chemicals detected in sediments, the presence of benthic taxa like the amphipoda indicate that this community is largely unaffected. Species of amphipods are typically between 5-20 mm long and are shrimp-like in structure. Often referred to as "scuds" these organisms are usually more active at night, and can be found crawling around stones, pebbles, and sand in search of food. Amphipods generally feed on plant and decaying animal matter (detritus), and can best be described as scavengers.

One of the largest orders of the aquatic insects are Diptera which include the flies, mosquitoes, and the midges. The adults are never aquatic, but the majority of the larvae within the group are, and typically inhabit freshwater environments. Many of the Dipteran families have immature stages that occur in freshwater streams, rivers, ponds, and lakes. Female Dipterans typically deposit eggs just below the surface of the water on vegetation, debris, or in the case of blackflies, on the surface of rocks (Pennak, 1978). Larvae creep about the substrate and feed on a variety of plant and animal matter which include periphyton, minute organisms, and debris. Representatives of one family of the Diptera, the Chironomidae or midges, can withstand low oxygen concentrations. It is common to see them among some of the tubificid oligochaetes that are associated with organic enrichment. The majority of chironomids often increase as one moves further from the sewage-

fungus zone. Chironomids thrive in anaerobic conditions and can even tolerate fairly high concentrations of salt, sulphur, and ammonia. Like some of the oligochaetes, these organism find an abundance of food in the rich organic mud. They are typically herbivorous, feeding on a variety of algae, higher aquatic plants, and organics. Chironomids live in tubes which they construct from detritus, algae, or small grains of sand cemented together by mucus that they secrete (Pennak, 1978).

Another order of insect that may be common at the Site are the Odonata, which include the dragonflies and damselflies. Adults are usually found in great abundance around marshes, ponds, rivers and lakes (Pennak, 1978). In the adults, the bodies are elongate, and the head supports large compound eyes. The wings are intricately veined, colorful, and at rest are usually left horizontally outward (dragonflies) or folded upward (damselflies). The nymphal stages of these organisms are usually associated with unpolluted ponds, marshes, streams, and in lake shallows. Odonate nymphs are carnivorous, and can be identified by their modified mouthparts used for feeding on a variety of organisms including other aquatic insects, annelids, and other small invertebrates. Most of the Odonate genera in the United States are represented by only a few major species (Pennak, 1978).

4.5.7.2 Spot

Spot are widespread throughout the Southeast and are a prized catch for many fisherman in addition to wildlife species. Spot are small, demersal fish, usually measuring six to ten inches in length. Spot are an estuary dependent fish. Adults migrate off-shore in the fall and spawning occurs from November through March. Larvae migration to the shore occurs shortly afterward (Lawler et al., 1988).

During larvae or early juvenile stages spot feed almost exclusively on zooplankton (Currin et al., 1984). After reaching 15 to 30 mm, spot switch to a mostly benthic mode of feeding, consuming both infauna and epifauna. However, spot are opportunistic feeders and will consume the most abundant and readily available resources (Currin et al., 1984). Juvenile spot actively utilize tidal rivulets, entering marsh areas with the incoming tide to obtain a substantial portion of their diet. Studies on the Cape Fear River estuary indicated that spot obtained more food in the marsh rivulet compared to the main creek as well as had more food in their guts at night, indicating a diel feeding pattern (Hodson et al., 1981).

4.5.7.3 Great Blue Heron

The great blue heron is the largest North American member of the Ardeidae family and is widely distributed in both saltwater and freshwater environments throughout the North American continent. Great blue herons forage in a variety of freshwater and marine areas, including lakes, rivers, brackish marshes, lagoons, mangrove swamps, coastal wetlands, tidal flats, sandbars

(Palmer, 1962). The principal determinant of foraging habitat quality is the availability of small fish in shallow areas (USFWS, 1985; Spendelow and Patton, 1988). In most cases, the water depth in foraging areas is less than 50 cm (Bent, 1926; Meyerriecks, 1960s; Bayer, 1978) and the substrate is firm (Palmer, 1962). Small fish (up to 30 cm) are the preferred prey of great blue herons, although they also consume amphibians, reptiles, crustaceans, insects, birds, carrion, and mammals (Bent, 1926; Kirkpatrick, 1940; Alexander, 1977; Hoffman, 1978; Peifer, 1979). Olsen and Johnson (1971) reported observing stilts (*Himantopus mexicanus*) being consumed by great blue herons, indicating that relatively large prey may also be taken on occasion. The great blue heron primarily feeds during the day, although nocturnal foraging is common in tidal habitats (Bayer, 1978). Adult great blue herons tend to feed solitarily and to actively defend feeding territories. However, occasional flock feeding may occur in areas of high prey density, where food resources cannot effectively be defended (USFWS, 1985).

Great blue herons are monogamous and colonial, and nest in dense colonies called heronries. Preferred nesting habitats are isolated (USFWS, 1985),with stands of tall trees with open canopies (Bent, 1926). Heron nests are often conspicuous, commonly placed from 5 to 15 m above ground (Burleigh, 1958; Cottrille, and Cottrille, 1958; Vermeer, 1969; McAloney, 1973). On occasion, great blue herons will nest on the ground, on rock ledges, or on sea cliffs (Palmer, 1962). Nests generally consist of a platform of sticks lined with finer material, over 1 m in diameter (Palmer, 1962; Dunning, 1994). Nests are often used for more than one year and the size of the nest is expanded with each use (Palmer, 1962).

Mean clutch size ranges from three to six eggs, with three or four eggs in most clutches (Pratt, 1972; Dunning, 1994). Clutch sizes increasing with latitude (Pratt, 1972). Incubation begins as soon as the first egg is laid (Dunning, 1994). One brood per pair is raised per year unless a clutch is destroyed, in which case a replacement clutch may be laid. The replacement clutch usually has fewer eggs than the initial clutch (Palmer, 1962; Pratt and Winkler; 1985). Incubation and feeding are shared by both parents (Palmer, 1962; Hancock and Kushlan, 1984). The incubation period is 25 to 29 days (Bent, 1926; Pratt, 1970) and fledging occurs approximately two months after hatching.

Natural survivorship of nestlings is primarily limited by starvation and predation. In a study of 243 nests in a coastal California colony, 65 percent of chicks fledged, 20 percent starved, 7 percent were taken by predators, and 7 percent were lost to other causes (Pratt and Winkler, 1985). Pratt (1970) observed nestling mortality of 30 and 45 percent for two different years of observation. Henny and Bethers (Henny and Bethers, 1971) reported 78 percent of nests observed were successful and Pratt (1970) reported 76-82 percent of nests observed were successful. Estimates of the number of young fledged each year by breeding pairs range from 0.85 to 3.1 (Henny and Bethers, 1971; Pratt, 1972; Alexander, 1977; Quinney, 1982; Pratt and Winkler, 1985). Based on banding studies, about one-third of fledglings survive more than one year, although survivorship is likely better in protected wildlife refuges (Bayer, 1981). Researchers also report than about one-

third to one-fifth of birds two years old and older are lost each year (Owen, 1959; Henny, 1972; Bayer, 1981).

4.6 CONCEPTUAL SITE MODEL

As described by EPA (1992b), the major focus of the conceptual site model (CSM) is to develop a series of working hypotheses regarding how stressor might affect ecological resources of the natural environment (NRC, 1986). The CSM focuses on the selection of potential receptors and the associated exposure pathways and provides the foundation for characterizing ecological risk. Collectively, each of the preceding sections have addressed the preliminary analysis of the ecosystem, specific habitats, identification of key organisms, stressor characteristics, and potential ecological effects to organisms, for further evaluation in the risk characterization.

A summary of the conceptual model for the Site is shown in Figure 4-2, which illustrates a simplified structure of the Cape Fear River and ditch/Creek food webs, along with the representation of major trophic levels by key selected receptors. In summary, the aquatic food web of the drainage ditch and Greenfield Creek are similar, in that physical barriers (e.g. Greenfield Lake dam and Greenfield Creek tidal gate) have created conditions that support only a limited trophic structure. Therefore, the selection of key receptors for this system is limited to benthic organisms which are in direct contact with, and ingest sediments. Contrary to this system, and as discussed in Section 4.4.3, the Cape Fear River is comprised of numerous species of benthic macroinvertebrates, fish, and wildlife species that constitute an interactive and complex food web. In recognition of the complex nature of the Cape Fear River food web, the key selected receptors were chosen as those species which represent, to the extent possible, trophic levels that are most likely exposed to COPC.

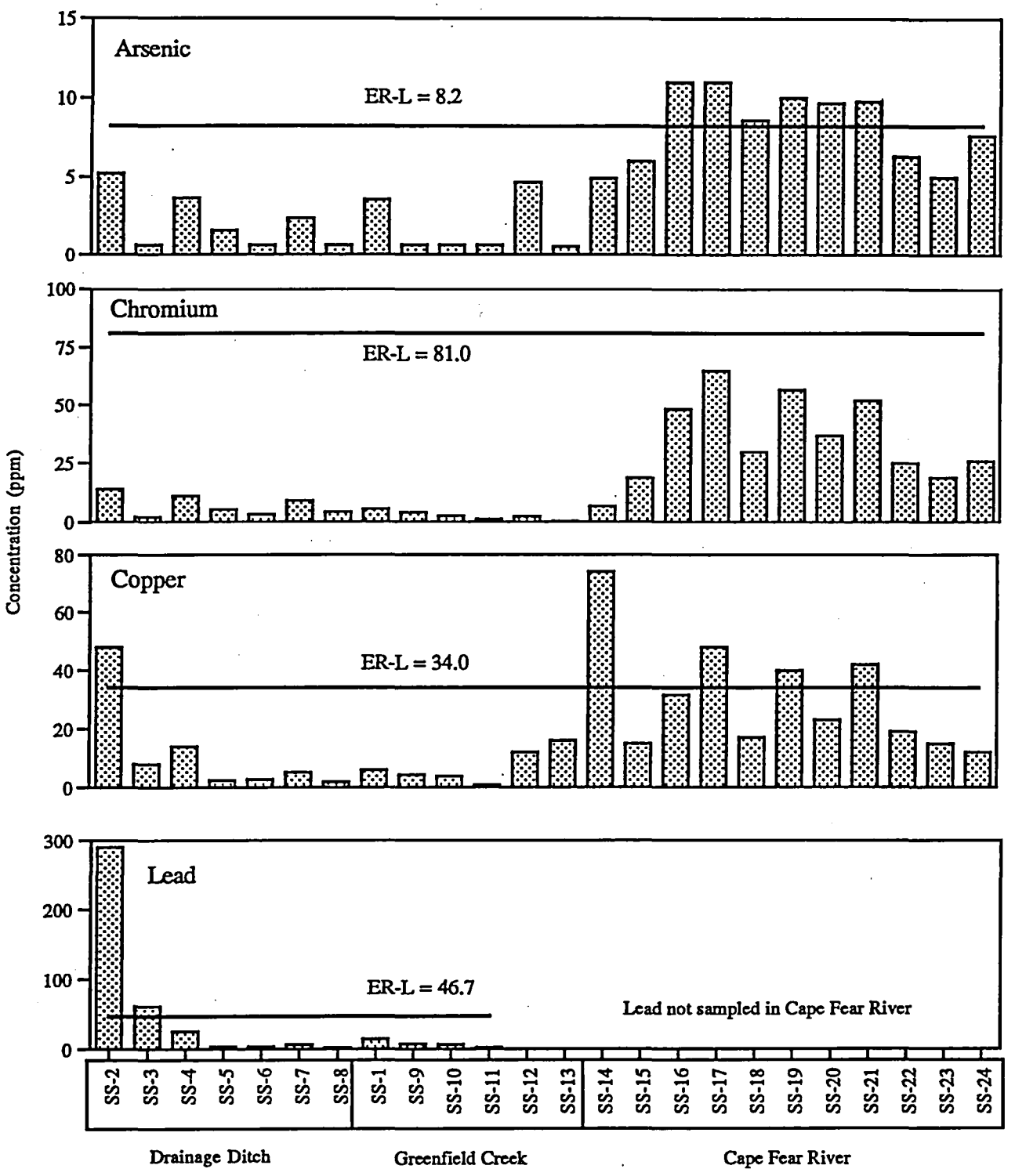

Figure 4-1. Distribution of metals relative to the ER-L (Long et al., 1995) in the drainage ditch, Greenfield Creek, and the Cape Fear River.

Figure 4-2. Summary of Conceptual Model Results Illustrating Trophic Level, Aquatic Food Webs, and Selected Key Receptors

TROPHIC LEVEL	CAPE FEAR RIVER AQUATIC FOOD WEB	DITCH/CREEK AQUATIC FOOD WEB	SELECTED KEY RECEPTOR(S)
TERTIARY CONSUMER	Piscivorous birds and mammals	Not Present	Great Blue Heron *(Ardea herodias)*
SECONDARY CONSUMER	Omnivorous fish Exposure point for piscivorous birds and mammals	Not Present	Spot *(Leiostomus xanthurus)*
PRIMARY CONSUMER	Benthic macroinvertebrates Exposure point for omnivorous fish, and predatory invertebrates	Benthic macroinvertebrates Exposure point for omnivorous fish, and predatory invertebrates	Benthic macroinvertebrates (Oligochaeta, Polychaeta, Insecta etc.)

SOURCE: SEDIMENT PAH and METALS

Table 4-1. Sediment Screening Analysis for Compounds of Potential Concern (COPC)

		Proposed Marine Sediment Quality Guidelines						95% UCL on the Mean			Screening Evaluation									
	Log	NOAA, 1995[a]		WSDOE, 1991[d]		EPA, 1995[g]		Drainage	Greenfield	Cape Fear	95% UCL Below Minimum Criteria			Not Bioaccumulative (or Kow <3.5)			No Sediment	CPC?		
Parameter	Kow	ER-L[b]	ER-M[c]	SQC[e]	MCL[f]	SSV[h]	Other	Ditch	Creek	Estuary	DD	GC	CF	DD	GC	CF	Criteria	DD	GC	CF
ORGANICS - Semivolatiles																				
Acenaphthene	3.98	16	500	160	570	330		2.47E+06	1.92E+07	47,974	-	-	-	-	-	-	-	YES	YES	YES
Anthracene	4.45	85	1,100	2,200	12,000	330		1.71E+09	8.94E+07	1.57E+06	-	-	-	-	-	-	-	YES	YES	YES
Benzo(a)anthracene	5.60	261	1,600	1,100	2,700	330		149,886	2.06E+12	75,601	-	-	-	-	-	-	-	YES	YES	YES
Benzo(a)pyrene	6.06	430	1,600	990	2,100	330		19,199	3.54E+13	8,316	-	-	-	-	-	-	-	YES	YES	YES
Benzo(b)fluoranthene	6.06							444	4.00E+15	62,439	-	-	-	-	-	-	Y	YES	YES	YES
Benzo(k)fluoranthene	6.06						490[ij]	130,261	1,806	1,601	-	-	-	-	-	-	-	YES	YES	YES
Carbazole								2.08E+07	ND	11,295	-	-	-	Y	Y	Y	Y	NO	NO	NO
Chrysene	5.61	384	2,800	1,100	4,600	330		61,951	3.69E+12	82,974	-	-	-	-	-	-	-	YES	YES	YES
Dibenz(a,h)anthracene	6.84	63	260	120	330	330		3,964	826	ND	-	-	-	-	-	-	-	YES	YES	YES
Fluoranthene	4.90	600	5,100	1,600	12,000	330		4.20E+08	4.28E+13	606,603	-	-	-	-	-	-	-	YES	YES	YES
Indeno(1,2,3-cd)pyrene	6.51			340	880			2,974	2.51E+14	ND	-	-	-	-	-	-	-	YES	YES	NO
Naphthalene	3.37	160	2,100	990	1,700	330		3.31E+06	ND	4,426	-	-	-	Y	Y	Y	-	YES	NO	YES
Phenanthrene	4.45	240	1,500	1,000	4,800	330		8.95E+09	7.32E+08	1.45E+06	-	-	-	-	-	-	-	YES	YES	YES
ORGANICS - Volatiles																				
Dichloromethane	1.30							45	74	2.5	-	-	-	Y	Y	Y	Y	NO	NO	NO
1,2-Dichloropropane	2.00							ND	ND	14	-	-	-	Y	Y	Y	Y	NO	NO	NO
Ethylbenzene	3.15							6770	ND	139	-	-	-	Y	Y	Y	Y	NO	NO	NO
m/p-xylene	3.26							822	24	66	-	-	-	Y	Y	Y	Y	NO	NO	NO
o-xylene	3.26							696	23	46	-	-	-	Y	Y	Y	Y	NO	NO	NO
Toluene	2.73							41	7.4	2.5	-	-	-	Y	Y	Y	Y	NO	NO	NO
INORGANICS - Metals																				
Arsenic		8.2	70	57	93	7.2		8.0	13	9.5[k]	-	-	-	-	-	-	-	YES	YES	YES
Chromium		81	370	260	270	52		17	13	45.8[k]	Y	Y	Y	-	-	-	-	YES	YES	YES
Copper		34	270	390	390	19		82	54	47	-	-	-	-	-	-	-	YES	YES	YES
Lead		47	218	450	530	30		6714	293	NA	-	-	-	-	-	-	-	YES	YES	YES

a. National Oceanic Atmospheric Administration (NOAA) values for marine and estuarine sediments reported in Long et al. (1995)
b. Effect range-low
c. Effect range-median
d. Washington State Department of Ecology
e. Sediment Quality Criteria
f. Minimum cleanup levels developed for Puget Sound
g. Environmental Protection Agency (EPA) Supplemental Guidance to RAGs: Region 4 bulletins
h. Sediment Screening Values
i. Minimum reported screening guidelines for a chemical
j. Benthic Apparent Effects Threshold (AET) reported in CASWRCB, 1990
k. Data normally dist. 95th UCL of data not log transformed
ND = Non Detect

Table 4-2. Chemicals of Potential Concern (COPC) for Ecological Risk Assessment

ORGANICS Polycyclic Aromatic Hydrocarbons	INORGANICS Metals
Acenaphthene	Arsenic
Anthracene	Chromium
Benzo(a)anthracene	Copper
Benzo(a)pyrene	Lead
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Fluoranthene	
Indeno(1,2,3-cd)pyrene	
Naphthalene	
Phenanthrene	

Table 4-3. Ratio of PAH Concentrations in Cape Fear River Stations Relative to Background

PARAMETERS	CFE SS-14 (a) (Background)	CFE SS-15	CFE SS-16	CFE SS-17	CFE SS-18	CFE SS-19	CFE SS-20	CFE SS-21	CFE SS-22	CFE SS-23	CFE SS-24
SEMIVOLATILES											
Acenaphthene	24000	0.01	0.01	0.01	0.05	0.01	0.01	0.46	0.01	0.01	0.01
Anthracene	13000	0.01	0.01	0.01	0.17	**1.54**	0.01	**3.08**	0.14	**1.31**	0.01
Benzo(a)anthracene	6400	0.22	0.03	0.20	0.27	**1.88**	0.03	**2.03**	0.03	0.03	0.03
Benzo(a)pyrene	6300	0.21	0.03	0.03	0.03	0.94	0.03	0.03	0.03	0.03	0.03
Benzo(b)fluoranthene	6600	0.27	0.12	0.24	0.02	**1.67**	0.02	**1.67**	0.02	0.02	0.02
Benzo(k)fluoranthene	160		**5.50**			**34.38**					
Carbazole	160					**29.38**		**93.75**			
Chrysene	5700	0.21	0.21	0.25	0.28	**2.63**	0.03	**3.16**	0.03	0.03	0.03
Dibenz(a,h)anthracene	160										
Fluoranthene	22000	0.05	0.14	0.21	0.34	**2.73**	0.12	**2.45**	0.13	**2.50**	0.01
Indeno(1,2,3-cd)pyrene	160										
Naphthalene	20000	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Phenanthrene	40000	0.00	0.00	0.00	0.00	0.48	0.00	0.78	0.00	0.00	0.00

CFE = Cape Fear Estuary

a. Concentrations at SS-14 are in µg/kg dry weight

Table 4-4. Water Quality Characterizations

Sample Reference	Sample Location	Temperature (Degrees °C)	pH	Conductivity (µmho/cm)	Dissolved Oxygen (mg/L)	Salinity (ppth) (a)
Cape Fear River	BN-1	10.4	7.9	1.14	7.80	0.041
Greenfield Creek	BN-2	11.5	7.7	0.3	8.80	0.01
	BN-3	12.5	6.8	0.25	9.90	0.00
	BN-5	12.3	8.0	0.20	10.23	0.00
Drainage Ditch	BN-4	12.9	7.4	0.23	9.43	0.00
	BN-6	18.1	7.1	0.51	7.84	0.02

a. ppth = parts per thousand

Table 4-5a. Total Catch and Percent Total of the Ten Most Abundant Species Collected in Bottom Trawls from the Cape Fear River Estuary (Carolina Power and Light, 1985; 1986; 1987)

Species	1985 Catch	Percent of Total	1986 Catch	Percent of Total	1987 Catch	Percent of Total
Spot	57,607	37%	48,833	49%	47,919	52%
Grass shrimp	54,624	35%	25,382	25%	12,637	14%
Brown shrimp	11,624	7%	6,415	6%	2,529	3%
Bay anchovy	10,915	7%	6,724	7%	4,933	5%
Atlantic menhaden	7,460	5%	581	1%	5,337	6%
Croaker	2,886	2%	3,514	3%	5,540	6%
Blue crab	1,932	1%	1,199	1%	1,193	1%
Pink shrimp	1,754	1%	750	1%	0	0%
Southern flounder	1,177	1%	1,272	1%	1,842	2%
Hogchoker	944	1%	0	0%	0	0%
White shrimp	0	0%	2,122	2%	4,937	5%
Mummichog	0	0%	0	0%	968	1%
Other:	5,797	4%	3,803	4%	4,116	4%
Total:	156,720		100,595		91,951	

Table 4-5b. Total Catch and Percent Total of the Ten Most Abundant Species Collected in Beach Seines from the Cape Fear River Estuary (Carolina Power and Light, 1985; 1986; 1987)

Species	1985 Catch	Percent of Total	1986 Catch	Percent of Total	1987 Catch	Percent of Total
Grass shrimp	35,023	48%	56,388	65%	33,941	43%
Spot	11,270	15%	10,580	12%	22,536	28%
Atlantic menhaden	6,212	8%	1,249	1%	8,640	11%
Mullet	5,724	8%	3,727	4%	2,156	3%
Mummichog	3,183	4%	3,869	4%	4,184	5%
Brown shrimp	3,130	4%	2,209	3%	610	1%
Atlantic silverside	3,011	4%	3,733	4%	777	1%
Bay anchovy	2,904	4%	1,003	1%	1,731	2%
White shrimp	0	0%	791	1%	1,862	2%
Other:	2,633	4%	3,388	4%	2,840	4%
Total:	73,090		86,937		79,277	

Table 4-6a. Annual Catch-per-unit-effort (CPUE) in an Oligohaline Reach of the Cape Fear River: Alligator Creek (Carolina Power and Light, 1985; 1986; 1987)

Species	1985 CPUE *	Percent of Total	1986 CPUE *	Percent of Total	1987 CPUE *	Percent of Total
Spot	183	68%	155	43%	39	14%
Croaker	11	4%	59	16%	97	36%
Bay anchovy	44	16%	56	16%	44	16%
Southern flounder	14	5%	34	9%	36	13%
White shrimp	0	0%	33	9%	36	13%
Brown shrimp	5	2%	12	3%	1	0%
Blue crab	3	1%	7	2%	5	2%
Pink shrimp	1	0%	2	1%	1	0%
Atlantic menhaden	7	3%	1	0%	14	5%
Total:	268		359		273	

Note: * - CPUE is based on trawl samples only.

Table 4-6b. Annual Catch-per-unit-effort (CPUE) in an Oligo-Mesohaline Reach of the Cape Fear River: Mott's Bay (Carolina Power and Light, 1985; 1986; 1987)

Species	1985 CPUE *	Percent of Total	1986 CPUE *	Percent of Total	1987 CPUE *	Percent of Total
Spot	187	37%	126	43%	221	50%
Bay anchovy	135	27%	87	29%	63	14%
Croaker	40	8%	31	10%	45	10%
Brown shrimp	24	5%	28	9%	3	1%
Pink shrimp	8	2%	6	2%	7	2%
Atlantic silverside	8	2%	6	2%	2	0%
Blue crab	5	1%	4	1%	2	0%
Mullet	69	14%	4	1%	10	2%
Atlantic menhaden	28	6%	1	0%	83	19%
Southern flounder	1	0%	1	0%	4	1%
White shrimp	0	0%	1	0%	1	0%
Mummichog	1	0%	1	0%	1	0%
Total:	506		296		442	

Note: * - CPUE is based on a combination of trawl and seine samples

Table 4-7. Distribution of Other Potential Fish Species in the Cape Fear River Estuary (NOAA, 1991)

		Estuarine Salinity Zone		
Species	Life Stage	Tidal Fresh	Mixing Zone	Seawater
Pinfish	Adult		X	X
	Spawning Adult			
	Juvenile	¦	X	X
	Larvae			¦
	Eggs			
American eel	Adult	¦	¦	¦
	Spawning Adult			
	Juvenile	¦	¦	X
	Larvae	¦	¦	¦
	Eggs			
Blueback herring	Adult	X	¦	¦
	Spawning Adult	X		
	Juvenile	¦	¦	¦
	Larvae	¦	¦	
	Eggs	¦		
American Shad	Adult	¦	¦	¦
	Spawning Adult	¦		
	Juvenile	¦	¦	¦
	Larvae	¦	¦	
	Eggs	¦		
Atlantic Sturgeon	Adult	¦	¦	¦
	Spawning Adult	¦		
	Juvenile	¦	¦	¦
	Larvae	¦	¦	
	Eggs	¦		
Ladyfish	Adult	¦	¦	¦
	Spawning Adult			
	Juvenile	¦	¦	¦
	Larvae	¦	¦	¦
	Eggs			

Notes: X - Abundant
¦ - Common

5.0 ANALYSIS

5.1 EXPOSURE ASSESSMENT

The exposure assessment integrates information on ecological receptors and COPC, in order to quantify potential exposure to Site-related chemicals. The Site-specific exposure assessment focuses on the pathways of exposure that are most likely to affect each of the key receptor groups. In the following Section, potential exposure pathways for key organisms are identified and evaluated according to published guidance (EPA, 1989; 1992a,b; 1994a).

For aquatic organisms, uptake of chemicals can occur from exposure to contaminated water, sediment, and food sources. The contributions of chemicals from each of these media vary between species, and are dependent on the life history, and feeding ecology of an organism, as well as the physicochemical properties of both the environmental media and the COPC. A complete ecological exposure pathway should include the following elements:

- a source and mechanism of chemical release to the environment;
- an environmental transport medium (e.g., water, sediment, biota); and
- an ecological exposure route at the contact point (e.g., ingestion, dermal contact).

The characteristics, sources, and distribution of chemical release to the Site have been previously discussed in this report (Section 4.3). In Section 4.2.1, it was concluded that the combination of extensive sampling and minimal frequency and concentration of detected chemicals, was sufficient to exclude surface waters as a potential exposure pathway. To that end, the analysis phase of this screening-level ERA will address the potential exposure routes for key receptors through sediment and ingestion of biota. In the following sections, the primary potential exposure pathways will be addressed following an evaluation of the bioavailability of COPCs in Site sediments. Bioavailability at the Site is addressed through an evaluation of site-specific factors that influence the available fraction of COPC to key receptors (Section 5.1.1 and 5.1.2). Secondly, the exposure pathways for key benthic invertebrates is considered through the direct contact and ingestion of sediments (Section 5.1.3). Finally, for fish and piscivorous wildlife, an evaluation of the exposure to COPC through bioaccumulation of COPC is presented in Section 5.1.4.

5.1.1 Bioavailability of PAHs

In the last several years, the U.S. EPA (Zarba, 1989; EPA, 1988, 1991), has evaluated the applicability of the equilibrium partitioning (EqP) approach as a means of developing national sediment quality criteria (SQC). In 1992, the Science Advisory Board (SAB) Sediment Quality Subcommittee approved the EqP method as being scientifically sound. EPA has recommended that users of the EqP approach determine the appropriate use of this and other criteria development methods within the context and needs of their own programs.

The EqP approach is based on the theory that a contaminant in a sediment matrix can exist in two states: either adsorbed onto the sediment (more precisely the organic carbon associated with the sediment), or dissolved in the pore, or interstitial, water. According to the theory, only the dissolved fraction of the contaminant is bioavailable and therefore toxicity is related not to the total chemical concentration, but only to the dissolved fraction. Concentrations of non-polar organic compounds, such as PAHs, in adsorbed and dissolved phases are in equilibrium and can be related by the contaminant-specific organic carbon partitioning coefficient (K_{oc}). In the following section, the development of a site-specific sediment quality criteria (ssSQC) for the drainage ditch, Greenfield Creek, and Cape Fear River is described.

5.1.1.1 Development of Site Specific Sediment Quality Criteria (ssSQC)

In developing a sediment quality criterion using EqP, the partitioning coefficient is used to calculate a bulk sediment concentration of a contaminant that results in a pore water concentration of the contaminant that does not exceed an appropriately chosen water quality criterion. The equation is expressed as:

$$ssSQC = WQC \times k_{oc} \times f_{oc}, \qquad (1)$$

where:

ssSQC = the site-specific sediment quality criterion expressed as a bulk sediment concentration;

WQC = the appropriate water quality criterion;

k_{oc} = the chemical-specific octanol-water partitioning coefficient; and

f_{oc} = the organic carbon fraction of the sediment, expressed as a decimal.

Because k_{oc} is difficult to measure directly and not available for many environmental contaminants it is usually calculated from the empirically determined octanol-water partitioning coefficient (k_{ow}), via the regression (EPA, 1988):

$$Log_{10} (K_{oc}) = 0.00028 + 0.983 \times Log_{10} (K_{ow})$$

Despite some of the limitations concerning the combination of the EqP approach with a criterion more applicable to the water column (Iannuzzi et al., 1995), use of the EqP method to evaluate bioavailability of PAHs in Site sediments can provide a relative measure of the conditions in these sediments, and would certainly represent a "worst case" assessment, because the concentration of a contaminant in overlying water would always be less than, or at the very least, equal to the EqP-predicted concentration in the porewater. Table 5-1 shows the parameters used for the calculation of ssSQC for the drainage ditch, Greenfield Creek, and the Cape Fear River. Koc's for each of the PAHs were derived from Kow's reported in the literature. For freshwater (drainage ditch and Greenfield Creek) and saltwater (Cape Fear River) water quality standards, two sources of information were used: (1) acute and chronic screening values for use at hazardous waste sites (EPA, 1995b); and (2) interim sediment criteria guidelines proposed by EPA (1988).

5.1.1.2. Comparison of ssSQCs with Observed Contaminant Levels

Table 5-2 lists the EqP-derived ssSQC and sediment concentrations for acenaphthalene, benzo(a)anthracene, benzo(a)pyrene, fluoranthene, naphthalene, and phenanthrene for individual stations in the drainage ditch, Greenfield Creek, and the Cape Fear River respectively. The concentration of TOC encountered in each water body was reported in the tables as the 95th UCL on the mean, similar to that procedure used in screening chemicals for identification of COPC (Section 4.2). Other PAHs detected at the Site were not included due to the lack of water quality standards, criteria, or published screening values. For the six PAHs shown in Table 5-2, exceedances of the applicable criteria are indicated by an asterisk.

Most of the PAH concentrations were well below the calculated ssSQCs at all stations and although some exceedances were apparent, these were judged to be relatively unsubstantial when the distribution and magnitude of the exceedances were examined in greater detail. In the drainage ditch, there were only five occurrences of concentrations that exceeded ssSQCs, and three of these exceedances were at SS-7; a result of elevated concentrations of acenaphthalene, naphthalene, and phenanthrene. The results suggest that at SS-7, one or more of these three PAHs are probably, at some level, bioavailable and therefore, potentially toxic to aquatic organisms.

An entirely different pattern emerges for one of the stations in Greenfield Creek. When compared to organic-adjusted benchmarks, concentrations of benzo(a)anthracene, benzo(a)pyrene, and fluoranthene most commonly exceeded ssSQC at SS-10. The results are notable in that the pattern

of potentially bioavailable PAHs has shifted from those representative of expected petrogenic sources in the drainage ditch, to predominately pyrogenic forms of PAH in Greenfield Creek. Overall, the disparity of the pattern of exceedances between these two areas is not consistent with the hypothesis that the buried Site ditch is the sole source of bioavailable PAHs throughout the system, and points toward other, possibly multiple sources.

Fewer saltwater screening values are available for developing ssSQC in the Cape Fear River, and as a result, the comparison of potentially bioavailable PAHs observed in the drainage ditch and Greenfield Creek to those observed in the River, are more difficult to interpret. Regardless, a few notable observations can be made with respect to acenaphthene, fluoranthene, and naphthalene, for which there are saltwater screening values (Table 5-2). There are two obvious patterns of PAHs which have exceeded ssSQC. First, fluoranthene appears to be one of the more bioavailable PAHs in that ssSQCs developed for this PAH were most frequently exceeded. Fluoranthene was not determined to be bioavailable in the drainage ditch, and with the exception of SS-10 in Greenfield Creek, was not bioavailable at any of the other freshwater stations. Also evident is the presence of bioavailable fractions of acenaphthene, fluroanthene, and naphthalene at the Cape Fear River background station (SS-14).

5.1.2 Bioavailability of Trace Metals

The EPA (1994b) has also described an approach for estimating the concentration of bioavailable metals in sediments based on equilibrium partitioning (EqP) theory. The approach is premised on the observation that many metal ions form sulfides and organic complexes that make them unavailable to biota and hence are non-toxic. As described by EPA (1994), by measuring the concentration of AVS and SEM in sediments, and deriving an AVS/SEM ratio, a prediction can be made as to the availability and, thus, toxicity of selected metals at a site. If the ratio of SEM to AVS is smaller than unity, then all of the extractable metals for which the method is applicable (Cu, Pb, Zn, Ni, Cd) should be present in the sediment only as insoluble sulfides, and therefore, should be unavailable and non-toxic to aquatic organisms.

Table 5-3 presents an analysis of AVS and SEM concentrations in nine sediment samples collected in the drainage ditch (n = 2); Greenfield Creek (n = 3); and the Cape Fear River (n = 4) at the Site. It is notable that the AVS/SEM ratio is near, or below one at eight of the nine sites, indicating that little or no metal toxicity should be expected, even without consideration of other complexing (e.g. Organic carbon) agents. It is also notable that for all of the stations that exceed a ratio greater than one, zinc is the primary metal for driving the ratio above unity, and in the Cape Fear River at the reference station (SS-14), the potential for bioavailability is considerably higher than at other stations.

As noted by EPA (1994b), the five metals included in this analysis have differing binding affinities for AVS, with Cu having the highest affinity and Ni the lowest. At equilibrium, Cu will

preferentially bind to AVS, displacing all other metals. If the available AVS in not completely saturated by Cu, then the remaining metals will bind in the order Pb, Cd, Zi, Ni. This means that even at the station with the highest metal concentrations, all of the Cu, and most of the other metals would be present only as insoluble sulfides. The remaining metals would not be present as sulfides, but still could be bound by organic complexing agents.

All five of these metals complex readily with organic carbon, and concentrations of TOC at the Site are reported at levels between 4.0 and 10.0%. An example of the affinity for metals to bind to organic carbon can be demonstrated for Cu, where the sediment/water partitioning coefficient at pH 7 (approximate pH at the Site) is 2.7×10^6 L/kg OC, or about 1.8×10^5 L/kg sediment, compared to 163 L/kg sediment in sea sand (EPA, 1994b). This means that for a given concentration of Cu in bulk sediment, the free Cu concentration in pore water would be about 1000 times lower for sediment similar to the Site sediment, as compared to sand. Therefore, it would be expected that the high organic carbon concentrations detected in sediments at the Site would provide substantial immobilization capacity for heavy metals above and beyond the binding due to AVS, particularly with those stations that are at or slightly above unity. It is more than likely that the combined effects of AVS- and TOC-binding of metals in surface sediments at the Site would greatly reduce the bioavailability of metals from sediments. In regards to these observations, it has been shown that the exposure of benthic invertebrates to metals at the Site is expected to be very limited, as a result of low metal concentrations which are neither toxic, or as demonstrated here, bioavailable.

5.1.3 Summary of Chemical Bioavailability

At this point in the screening-level ERA there is considerable information that has been presented to suggest that trace metals, if at all detected, are not only present at very low concentrations in Site sediments, but are also consistently below levels that would be of concern based on available sediment quality benchmarks (Section 4.3.2). Furthermore, and as demonstrated by the preceding section, the concentrations of trace metals at the Site would not be considered significantly bioavailable (AVS/SEM $\leq$ 1.6), even in the absence of other chelating agents such as TOC. As a result of these findings for metals, the remainder of this screening-level ERA will focus explicitly on the exposure, effects, and potential risk of PAHs on the key ecological receptors selected in Section 4.5.

5.1.4 Direct Contact/Ingestion

5.1.4.1 Benthic Macroinvertebrates

For benthic macroinvertebrates, the primary exposure pathway has been shown to be primarily through direct contact and ingestion of sediments. Benthic macroinvertebrates can be described as belonging to two functionally different groups: infaunal invertebrates (e.g., amphipods, polychaetes, copepods, bivalves, etc.) which are organisms that dig into the substrate, or construct

tubes or burrows; and epifaunal macroinvertebrates (e.g., crabs, lobsters, shrimp) which are organisms that live freely on the sediment surface, and are either attached or mobile. Although fish are likely to have some contact and incidental ingestion of sediments while feeding, this exposure route is likely to be minimal compared to the accumulation of xenobiotics through contaminated foods.

Once ingested, metabolism of PAHs occurs primarily in the digestive tract of annelida, the hepatopancreas of crustacea and arthropods, and the digestive glands of mollusks (Buhler and Williams, 1989). Metabolism occurs at different rates in various species depending on many of the same factors that affect uptake (i.e., environmental conditions, lifestage of organism, sex, and phylogenetic scale etc.). For example, PAHs are metabolized slower, if at all, in species lower on the phylogenetic scale relative to higher organisms and within the invertebrate group there are clear differences in metabolic capability. Studies have shown that the first stage of PAH metabolism occurs very slowly or not at all in the more primitive invertebrates, such as protozoa, cnidaria, and mollusks and rapidly in phylogenetically higher invertebrates, such as arthropods, echinoderms, and annelids (James, 1989).

One of the factors that affects the fate of PAHs in invertebrates that are in direct contact with sediments is molecular weight. Generally, LPAHs are readily excreted by skin and mucous, while HPAHs are too large to be excreted in this manner and must be metabolized to more polar compounds prior to excretion. In a study by Varanasi et al. (1985), amphipods exposed to Puget Sound sediment contained only trace amounts of 2-ring aromatic hydrocarbons, and higher concentrations of 3-, 4-, and 5-ring aromatic hydrocarbons. HPAHs, such as 5-ring aromatic hydrocarbons, may be absorbed by aquatic organisms to a lesser extent than LPAHs due to their large molecular size (which physically impede direct absorption) and strong affinity for binding to organic carbon in sediments.

There appears to be general agreement within the scientific literature that although crabs directly contact and ingest sediment, they are not likely to bioaccumulate sediment PAHs. Based on a study in which blue crabs were exposed to sediments contaminated with phenanthrene and fluoranthene, O'Connor and Squibb (1989) reported that blue crabs take up PAHs from sediments, but do not accumulate them. Hale (1988), also reported that PAHs may be accumulated in the hepatopanicreas of the crab where they are sequestered. Lee et al. (1976) found that blue crabs also absorb PAHs from water and food and that the major site of metabolism is the hepatopancreas (which is functionally similar to the vertebrate liver). Regardless, the fact that PAHs are not accumulated to a great extent is due to the metabolic capability of blue crabs. Compared to other aquatic species, the blue crab metabolizes PAHs at a fairly moderate rate and the mechanism of metabolism is via the cytochrome P-450 system (Elskus and Stegeman, 1989; McElroy and Sisson, 1989).

5.1.5 Bioaccumulation

5.1.5.1 Spot

In the environment, particularly in aquatic ecosystems, food ingestion is considered by many to be the most important exposure route to chemicals, particularly for persistent chlorinated organic compounds (e.g., PCBs, pesticides, etc.). In contrast, much of the literature pertaining to PAHs has suggested that these chemicals do not bioaccumulate or persist in most species of fish. PAHs that cannot be readily excreted by fish or other aquatic organisms may undergo rapid biotransformation to make them more excretable. The basic physiological and biochemical mechanisms of this process are fairly well understood, and are described briefly below.

The majority of recent findings suggest that metabolic activity involving the mixed-function oxidase (MFO) system in fish is highly developed. In general, once PAHs are ingested through contaminated food, they are readily metabolized to more polar compounds that can be excreted more readily than untransformed xenobiotics (i.e., parent compound). PAHs generally undergo oxidative metabolism during phase I reactions through a mixed-function oxidase (MFO) system. MFO systems are groups of cellular enzymes that function as a unit to oxidize xenobiotics during detoxification (and toxification) reactions. Cytochrome P-450, a heme protein that is concentrated in the endoplasmic reticulum of hepatic tissues, is believed to be the predominant MFO enzyme responsible for PAH metabolism (Stegeman and Lech, 1991). Metabolism of PAHs occurs primarily in the livers of teleost fish and elasmobranchs (Buhler and Williams, 1989).

A study on the accumulation of B(a)P and fluoranthene by the freshwater midge (*Chironomus riparius*) and the food chain transfer of these chemicals to the bluegill (*Lepomis macrochirus*) indicated that although *C. riparius* rapidly accumulated the PAH, tissue levels in *L. macrochirus* were generally low; this was attributed to low uptake and metabolism (Clements, 1994). Similar patterns between invertebrates and fish have been seen in other studies as well.

5.1.5.2 Great Blue Heron

The extent of exposure potential for wildlife organisms is based not only upon the functional biology of the selected receptor, but the bioavailability of PAH as well. As indicated in earlier Sections (5.1.2, 5.1.3, and 5.1.4) the factors controlling the bioavailability of sediment PAH and the ability of organisms that contact, or ingest sediment PAH to metabolize and assimilate these chemicals, reduces the potential exposure to higher trophic level organisms. However, as a conservative estimate for this screening-level ERA, and in the absence of site-specific tissue data, estimated concentrations of PAH from sediment through the food chain were used to demonstrate the low potential for exposure and risks to piscivorous birds.

Although documentation on the feeding habits of avian species at the Site are not available, estimates of exposure can be evaluated based on dietary intake. Given that great blue herons were sited at or near the Site, it can be assumed that at least a portion of the diet of each of these species originates from the waterways near the Site. Because the drainage ditch and Greenfield Creek were not considered suitable foraging grounds for great blue heron, these areas were excluded from the risk evaluation. However, to remain conservative, the exposure point concentrations at all stations in the Cape Fear River were used to estimate sediment concentrations of PAH in benthic invertebrates, fish, and finally, in great blue heron. The calculations used to estimate hypothetical risks to piscivorous wildlife at the Site are described in Section 6.1.3.

5.2 ECOLOGICAL EFFECTS ASSESSMENT

The objective of the effects assessment is to compare toxicological criteria or literature values from studies which have examined the level of PAH in aquatic organisms to demonstrated effects. The primary assessment endpoints being evaluated for the Site are the lethal and sublethal effects of sediment-associated PAH to benthic invertebrates from ingestion and direct exposure to PAH in sediment. Furthermore, and to remain conservative in addressing the potential for bioaccumulation in higher trophic species, the spot and the great blue heron were evaluated using a relationship of sediment of hepatic lesions in the spot, and an estimated no effect ingestion rate for the great blue heron. As stated above, the ecological effects assessment consists of the following elements: (a) a summary of ecotoxicity information from the literature, including results of field and laboratory studies; and (b) the identification of ecotoxicological criteria for sediments and key organisms.

5.2.1 Identification and Evaluation of Ecotoxicological Effects of PAHs on Key Receptors

One of the most critical components of the screening-level ERA is the evaluation of pertinent ecotoxicological literature to assess the sensitivity of various species and various toxicological endpoints to the chemical stressor of interest. To provide a sufficiently conservative estimate of the potential for ecological risks at the Site, it is important to account for several taxonomic groups between and among trophic levels that may be sensitive to the chemicals of interest. It is important to account for the highly sensitive endpoints that have biological or ecological significance at the subpopulation, community, or system-wide level. The following sections provide a brief overview of the scientific literature as it pertains to the ecotoxicological effects of PAHs in key receptors, or species with similar functional characteristics.

5.2.1.1 PAH Toxicity to Benthic Macroinvertebrates

Several researchers have noted that high concentrations of PAHs in sediment may cause effects in infaunal invertebrates (Fries and Lee, 1984; Plesha et al., 1988). The most comprehensive database on infaunal invertebrate toxicity currently available is presented by MacDonald (1994).

This database was compiled for the purpose of developing Florida sediment quality guidelines that are protective of ecological health, and includes both laboratory and field data from different marine/estuarine waterways around North America. The Florida database contains results from a wide variety of study methods and approaches. Data were included from three types of studies, including equilibrium partitioning modeling, laboratory spiked-sediment bioassays, and field investigations of sediment toxicity and benthic community composition (MacDonald, 1994). Studies from many different geographic locations around North America, including Washington, California, Virginia, British Columbia, Mississippi, and Nova Scotia, are included in the database. At the present time, the database is being used by NOAA to calculate sediment guidelines.

BEDS includes a comprehensive assemblage of marine and estuarine studies that have evaluated benthic community structure and sediment toxicity studies for a wide variety of species (e.g., polychaetes, oligochaetes, sea urchins, bivalves, crustaceans, several species of fish, etc.) throughout North America. Numerous endpoints are included in the database, such as community level responses (e.g., taxa richness, abundance, density, diversity richness and evenness); organismal responses (e.g., mortality, growth, respiration, and several types of behavior); and suborganismal responses (changes in MFO, and abnormal chromosomes). Although the BEDS database is primarily comprised of estuarine organisms and their response to chemicals, the absence of an equally comprehensive freshwater database does not preclude the use of BEDS in assessing freshwater communities like those found in the drainage ditch and Greenfield Creek.

The PAH sediment toxicity values reported in the scientific literature for benthic infaunal invertebrates (i.e., amphipods, copepods, and nematodes) vary substantially for each PAH. For example, the acenaphthene concentrations shown to cause lethal or sublethal effects in infaunal invertebrates range from 12.5 to 39,557 ppb in sediment (MacDonald, 1993). The lack of agreement on toxicity values is most likely explained by a myriad of factors including site-specific variables such as organic carbon content of the sediment, other chemical exposures, magnitude of photo-induced toxicity, and variability within species, as well as differences in study design (e.g. methods of evaluation and endpoint of interest). Several examples of factors that may cause large differences in toxicity between sites are: 1) warm water species may be more sensitive to PAH toxicity than cold water species; 2) some of the waterways studied may contain contaminants that have synergistic or antagonistic effects on PAH toxicity; 3) physical factors, such as sediment organic carbon content, render PAHs more or less bioavailable at different sites; 4) warmer temperatures may increase biological uptake of chemicals, and thus increase exposure causing an increase in toxicity. The large ranges of concentrations associated with toxic effects are likely explained by one or more of these factors.

5.2.1.2 PAH Toxicity to Spot

Fish have probably been the most widely studied organisms throughout many of the industrialized harbors of both freshwater and marine environments. Several studies have hypothesized that a

relationship exists between sediment concentrations of PAHs and the development of abnormal tissue lesions in fish tissue. Hargis et al. (1989) and Vogelbein et al. (1990), have reported that mummichogs (*Fundulus heteroclitus*) collected in the Elizabeth River, Virginia, had external (e.g. fin rot, ulcerations, cataracts) and internal (e.g. hepatic) lesions in the presence of elevated sediment PAH concentrations. (2200mg total PAH/kg dry sediment) Comparables, mummichogs collected from two reference locations of low to moderate PAH concentrations (3-61mg total PAH/kg dry sediment) did not have hepatic lesions (Vogelbein et al., 1990). In addition, Roberts et al. (1989), who used sediments from the Elizabeth River, measured acute toxicity in the spot at exposure concentrations of 21,200 - 33,000 mg total PAH/kg dry sediment, whereas control sediments that showed no effect to this species were measured at 2 - 4 mg total PAH/kg dry sediment. Additional work conducted in the Elizabeth River by Hargis and Zwerner (1988) documented several types of microscopic lesions in spot, croaker (*Micropogonias undulatus*), weakfish (*Cynoscion regalis*), hogchoker (*Trinectes maculatus*), and oyster toadfish (*Opeanus tau*) when compared to similar species from a relatively less contaminated river. Although several of the studies listed above have identified a correlation between Elizabeth River sediments and lesions in several species of fish (including spot), two important considerations are that: (1) the total PAH concentrations observed in these studies are one or two orders of magnitude greater than the total PAH concentrations observed at Cape Fear River Stations (e.g. SS-14, SS-19, and SS-21) and, (2) as reported by Roberts et al. (1989), exposure of fish to sediment PAH in the Elizabeth River studies does not account for the other potential toxic substances including polar aromatics, heterocyclical, and heavy metal compounds all of which were not measured.

Several other field observations have been reported from both freshwater and estuarine river systems which have attributing the occurrence of lesions in fish to exposure of sediment PAH. Baumann and Harshbarger (1985) attributed frequencies of liver neoplasia in brown bullheads (*Ictalurus nebulosus*) to sediment PAH concentrations (80 mg total PAH/kg dry sediment) in the Black River, Ohio. Neoplasm incidence in brown bullhead collected along several rivers in the Great Lakes Basin have been correlated with PAH concentrations in sediments (Baumann et al., 1991). In two studies designed to evaluate the relationship between sediments and toxicity in bottom-dwelling fish collected in Puget Sound, Washington, Malins et al., (1984; 1988) reported a positive correlation between sediment PAH concentration, tissue disease, and liver neoplasia in English sole (*Parophrys vetulus*) and sculpin (*Leptocottus armatus*).

However, although many field studies have reported tissue lesions and neoplasia in fish collected from sites with high concentrations of sediment PAHs, some investigators have cautioned against inferring a causal relationship between PAH concentrations in sediments and tissues with disease (Malins et al., 1984; 1987; 1988; Myers et al., 1992). Numerous other factors that include the nutritional state and age of the organism, natural toxicants in foodstuffs, synergistic/antagonistic interactions of xenobiotics, and potential toxicity of unidentified compounds cannot be ignored in defining (with some degree of certainty) a cause-and-effect relationship. Such a relationship

cannot be inferred however, without considering laboratory studies which recognize and control external variables to reproduce environmentally relevant exposure conditions (Malins et al., 1988).

A comprehensive database for fish is currently not available, however, there has been considerable ecotoxicological information on PAHs in fish, predominately in the form of histopathological data. In these data, endpoints address sediment and some tissue levels which may be associated with detrimental effects in fish, mostly in the form of hepatic lesions. These data were compiled and are presented in Section 6.1.2. Some of the data indicate one or more of the following: location of the study, sediment PAH concentration, fish species, tissue level, effect, and endpoint. The data were examined and the Lowest Observable Apparent Effects Level (LOAEL) for the development of hepatic lesions was used as a benchmark for evaluating potential risks to the spot.

5.2.1.3 PAH Toxicity to the Great Blue Heron

Much of the information on the toxicity of chemicals to birds and other wildlife has focused on organochlorines (e.g., PCDD, PCDF, and non-ortho PCBs) and various pesticides prevalent in a variety of environmental media (e.g., surface waters, sediments, biota). The literature on the toxicity of PAH to aquatic birds is generally poorly represented, and contributions to the understanding of PAH effects to avian species appear to be limited to only a few studies. For example, Patton and Dieter (1980) fed 400 and 4000 ppm of a mixture of aromatic hydrocarbons to mallard ducks for seven months, and found no significant effects were seen at either concentration, although at 4000 ppm the authors noted increased liver weights due to liver hypertrophy.

Two other studies examined the effects of PAHs on avian eggs. In 1981, Hoffman and Gay measured embryotoxicity in mallard eggs following the application of a synthetic petroleum mixture to the surface of the shells. Concentrations of 7,12-dimethylbenz(a)anthracene, chrysene, and benzo(a)pyrene, resulted in varying mortality to eggs, however dimethylbenz(a)anthracene appeared was the most toxic in the time tested contributing to approximately 90% mortality within 18 days (Hoffman and Gay, 1981). A more recent study has examined the profiles of PAHs following the injection of a 16 PAH mixture into the eggs of chicks and common eiders (Naf et al., 1992). Using a total dose of 200 ppb the authors found that over 94% of the injected PAH was metabolized, including a large PAH (coronene) which was not readily accumulated.

As it appears, the paucity of literature pertaining to PAH in avian species (and other higher organisms) does not reflect an uninterested scientific community, but rather, the ability of lower organisms (prey species) to effectively manage PAH in their systems. Unless experimentally induced, the exposure of higher trophic level species to PAHs appears to be minimal, as a result of the prey species ability to photolyze, metabolize, and/or excrete PAHs from their systems. The result is reduced exposure (and toxicity) to higher trophic organisms including piscivorous wildlife.

For great blue herons, potential exposure to PAH was evaluated based on dietary intake, assuming that 100 percent of the diet originates from the Cape Fear River. Although wildlife species may be exposed to PAH through incidental contact with sediment or water, the majority of chemical uptake is through the ingestion of contaminated prey items. Therefore, uptake of PAH is dependent on the amount of contaminated prey consumed, and the concentration of the PAH in the prey item. As discussed by EPA (1993), a large portion of the diet of the great blue heron is comprised of small fish (i.e., less than 20 cm in length). In the Cape Fear River, juvenile and adult Spot are one of the most abundant and productive forage fishes in areas where the great blue heron are commonly observed feeding. Consequently, spot were selected as the representative prey species for this evaluation, and estimated tissue concentrations were derived using the methods described in Section 6.1.3.

Table 5-1. List of Parameters Used to Derive Site-specific Sediment Quality Criteria

	Log Kow	Source	Log Koc	Koc l/kg	Fresh Chronic WQC	Source	Salt Chronic WQC	Source
Acenaphthene	3.98	EPA, 1982	3.913	8,177	17.0	EPA, 1995	9.7	EPA, 1995
Anthracene	4.45	EPA, 1982	4.375	23,694	na		na	
Benzo(a)anthracene	5.60	EPA, 1982	5.505	319,948	3.0	EPA, 1988	na	
Benzo(a)pyrene	6.06	EPA, 1982	5.957	906,275	1.2	EPA, 1988	na	
Benzo(b)fluoranthene	6.06	EPA, 1982	5.957	906,275	na		na	
Benzo(k)fluoranthene	6.06	EPA, 1982	5.957	906,275	na		na	
Chrysene	5.61	EPA, 1982	5.515	327,273	na		na	
Dibenz(a,h)anthracene	6.84	EPA, 1982	6.724	5,296,634	na		na	
Fluoranthene	4.90	EPA, 1982	4.817	65,612	39.8	EPA, 1995	1.6	EPA, 1995
Indeno(1,2,3-cd)pyrene	6.51	EPA, 1982	6.400	2,509,632	na		na	
Naphthalene	3.37	EPA, 1982	3.313	2,056	62.0	EPA, 1995	23.5	EPA, 1995
Phenanthrene	4.45	EPA, 1982	4.375	23,694	6.4	EPA, 1988	na	

Note: na = not available

Table 5-2. Calculation of Site-specific Sediment Quality Criteria (ssSQC) for Selected PAHs

			Acenaphthene		Benzo(a)anthracene		Benzo(a)pyrene		Fluoranthene		Naphthalene		Phenanthrene	
Location	Station	TOC	ssSQC	Conc.	ssSQC	Conc.	ssSQC	Conc.	ssSQC	Conc.	ssSQC	Conc.	ssSQC	Conc.
Drainage Ditch	SS-2	4.87	6,770		46,744	540	52,963		127,172	870	6,207		7,385	560
Drainage Ditch	SS-3	"	6,770		46,744		52,963		127,172		6,207		7,385	
Drainage Ditch	SS-4	"	6,770	590	46,744	1,100	52,963	2,000	127,172	1,800	6,207		7,385	
Drainage Ditch	SS-5	"	6,770	4,400	46,744	5,800	52,963	3,100	127,172	38,000	6,207	1,800	7,385	42,000 *
Drainage Ditch	SS-6	"	6,770	2,900	46,744	7,400	52,963	1,900	127,172	52,000	6,207		7,385	36,000 *
Drainage Ditch	SS-7	"	6,770	44,000 *	46,744	3,200	52,963	640	127,172	26,000	6,207	44,000 *	7,385	55,000 *
Drainage Ditch	SS-8	"	6,770	1,000	46,744		52,963		127,172		6,207		7,385	
Greenfield Creek	SS-1	9.77	13,582	510	93,777	1,100	106,252	420	255,128	3,800	12,453		14,815	1,500
Greenfield Creek	SS-9	"	13,582	32,000 *	93,777	26,000	106,252	9,000	255,128	130,000	12,453		14,815	70,000 *
Greenfield Creek	SS-10	"	13,582		93,777	730,000 *	106,252	660,000 *	255,128	1,300,000 *	12,453		14,815	
Greenfield Creek	SS-11	"	13,582		93,777		106,252		255,128		12,453		14,815	
Greenfield Creek	SS-12	"	13,582	1,850	93,777	1,650	106,252	860	255,128	6,400	12,453		14,815	
Greenfield Creek	SS-13	"	13,582		93,777	2,300	106,252		255,128	10,000	12,453		14,815	
Cape Fear River	SS-14	6.66	5,283	24,000 *	0	6,400	0	6,300	6,992	22,000 *	3,218	20,000 *	0	40,000
Cape Fear River	SS-15	"	5,283		0	1,400	0	1,300	6,992	1,100	3,218		0	
Cape Fear River	SS-16	"	5,283		0		0		6,992	3,100	3,218		0	
Cape Fear River	SS-17	"	5,283		0	1,300	0		6,992	4,700	3,218		0	
Cape Fear River	SS-18	"	5,283	1,100	0	1,700	0		6,992	7,500 *	3,218		0	
Cape Fear River	SS-19	"	5,283		0	12,000	0	5,900	6,992	60,000 *	3,218		0	19,000
Cape Fear River	SS-20	"	5,283		0		0		6,992	2,600	3,218		0	
Cape Fear River	SS-21	"	5,283	11,000 *	0	13,000	0		6,992	54,000 *	3,218		0	31,000
Cape Fear River	SS-22	"	5,283		0		0		6,992	2,900	3,218		0	
Cape Fear River	SS-23	"	5,283		0		0		6,992	55,000 *	3,218		0	
Cape Fear River	SS-24	"	5,283		0		0		6,992		3,218		0	

Note: * = observed concentrations in sediment exceeds ssSQC benchmark

Table 5-3. Results of Acid Volatile Sulfide and Simultaneously Extractable Metals (AVS/SEM) Analyses (Concentrations are in µmoles/gram)

Location	Station	AVS	Cadmium	Copper	Nickel	Lead	Zinc	SEM	SEM:AVS
Drainage Ditch	SS-7	0.59	0.001	0.043	0.009	0.095	0.497	0.646	1.094
Drainage Ditch	SS-8	12	0.002	0.126	0.020	0.205	1.071	1.424	0.119
Greenfield Creek	SS-1	1.2	0.004	0.150	0.021	0.471	1.109	1.754	1.462
Greenfield Creek	SS-9	0.38	0.001	0.013	0.009	0.034	0.145	0.201	0.528
Greenfield Creek	SS-11	0.41	0.001	0.037	0.009	0.036	0.184	0.265	0.647
Cape Fear Estuary	SS-14	0.47	0.010	0.005	0.119	0.869	10.707	11.709	24.913
Cape Fear Estuary	SS-18	0.6	0.001	0.059	0.022	0.062	0.841	0.985	1.642
Cape Fear Estuary	SS-20	1.2	0.002	0.055	0.020	0.048	0.535	0.660	0.550
Cape Fear Estuary	SS-23	0.91	0.001	0.043	0.009	0.046	0.497	0.595	0.654

6.0 ECOLOGICAL RISK CHARACTERIZATION

In this screening-level ERA, the ecological risk characterization is limited to a quantitative evaluation of the relative potential risks of PAH to key organisms at the Site. As described earlier, the primary assessment endpoints being evaluated for the Site are: (1) lethality and sublethality of sediment-associated benthic invertebrates (primary consumers) from direct exposure to PAH in sediment; (2) the relationship between sediment PAH concentration and the prevalence of hepatic lesions in the spot (secondary consumers); and (3) the estimated dietary intake of PAH to great blue heron (tertiary consumers).

6.1 CALCULATION OF ECOTOXICOLOGICAL (HAZARD) QUOTIENTS

6.1.1 Benthic Macroinvertebrates

For benthic macroinvertebrates, direct exposure to sediments at the Site was evaluated using ecotoxicological or hazard quotients (HQs). Hazard quotients are calculated by taking the ratio of the exposure point concentration over that of an ecotoxicological effects concentration (benchmark).

The HQ equation is then:

HQ=EPC/EEC

where:

HQ	=	Hazard Quotient
EPC	=	Exposure Point Concentration
EEC	=	Ecotoxicological Effects Concentration

For this direct exposure, HQs were calculated as the ratio of the 95% UCL of the mean surface sediment concentration at the Site to the lowest reported sediment benchmark reported for individual PAHs in the BEDS database (MacDonald, 1994). The lowest available sediment benchmark reported in the BEDS database is the No Observable Effects Level, or NOEL. Table 6-1 illustrates the hazard quotients developed for the benthic macroinvertebrate community. In

general, an HQ that is greater than one suggests that potential hazards to benthic invertebrates may exist at the Site (EPA, 1989, 1994a). Potential hazards to benthic invertebrates are presented in Section 6.2.

6.1.2 Spot

For the spot, literature values of total sediment PAHs compared to recorded incidences of hepatic lesions and neoplasms in studies were used to derive an EEC for comparing Site PAH concentrations. This procedure follows the rationale provided by Malins (1988), who found a highly significant correlation ($P \leq 0.0001$) between concentrations of sediment associated PAH and the prevalence of hepatic neoplasms in fish. Using Malins (1988) approach, Table 6-2 represents the distribution of the effects data from several studies which have reported sediment PAH concentrations and examined the occurrence of hepatic lesions for several common estuarine species. These studies have been previously discussed in Section 5.2.1.2. The EEC was calculated as the 10th percentile of the effects data, consistent with the approach used by Long et al., (1995), and MacDonald et al., (1994), in calculating benchmarks for benthic macroinvertebrates. The EECs were compared to total PAH derived at each of the Cape Fear River Stations, and the subsequent HQs are presented in Table 6-3. Consistent with EPA guidance (1989, 1994a), the HQ is defined as the concentration of the PAH in the key organism divided by the relevant ecotoxicological effects concentration. HQs greater than one suggests a potential for risks to the fish.

6.1.3 Great Blue Heron

In order to develop hazard quotients for estimating potential risks to great blue herons from consumption of potentially contaminated fish, it was necessary to estimate the concentration of PAH present in spot. In the absence of Site-specific biological data, concentrations of PAH in aquatic organisms were estimated by the following simplified equation:

$$Cf = Cf_s + Cf_w$$

where:

Cf	=	Estimated concentration (mg/kg-wet wt) of a chemical in spot
Cf_s	=	Estimated concentration (mg/kg-wet wt) in spot resulting from indirect uptake from feeding on contaminated organisms
Cf_w	=	Estimated concentration (mg/kg-wet wt) in spot resulting from direct uptake from the water column (dissolved fraction)

This relationship was used to calculate estimated body burdens of PAH in spot based on sediment and surface water data collected at the Site.

The first portion of the equation addresses uptake of PAH through consumption of contaminated food items. For the purpose of this assessment, spot were assumed to feed entirely on benthic invertebrates (i.e., polycheates and oligocheates). This is a conservative assumption, given the variability in the diets of forage fish, and the fact that benthic invertebrates have the highest exposure to sediment-associated chemicals. The accumulation of chemicals by benthic invertebrates is a function of the organic carbon content of the sediment and the lipid content of the organism as follows:

$$Cb = (Cs/f_{oc}) \times BSAF \times fL$$

where:

Cb	=	Concentration of COPC in prey (i.e., benthic invertebrates) (mg/kg-wet wt)
Cs	=	Concentration in sediment (mg/kg)
f_{oc}	=	Organic carbon content of sediments at the Site (reported as fraction)
BSAF	=	Biota Sediment Accumulation Factor (mg/kg-oc/mg/kg-lipid)
fL	=	Conversion factor to convert lipid-normalized body burden to a wet weight concentration (mg/kg-lipid/mg/kg-wet wt)

Consistent with the equilibrium partitioning theory (EPA, 1993), BSAFs were assumed to approximate unity (1.0) for all PAH. Table 6-4 summarizes the calculation of PAH concentrations in benthic invertebrates based on measured concentrations of chemicals in surface sediments from the Cape Fear River.

Based on the concentrations of PAH in benthic invertebrates presented in Table 6-4, it is possible to derive an estimate of the concentration in spot due to uptake from food (Cf_s). This is a function of the consumption rate of the spot and the concentration of the chemical in the prey item (Cb), as described in the following equation:

$$Cf = (Cb \times IR \times AF \times FI)/(GR + ER + MT)$$

where:

Cf	=	Concentration of PAH in spot due to ingestion of contaminated prey (mg/kg-wet wt)
Cb	=	Concentration of PAH in prey (i.e., benthic invertebrates) (mg/kg-wet wt)
IR	=	Ingestion rate of spot (kg/kg-day)
AF	=	Absorption fraction of PAH (unitless)
FI	=	Fraction of spot diet comprised of prey
GR	=	Growth rate of spot (1/day)

ER	=	Excretion rate of spot (1/day)
MT	=	Metabolic rate (1/day)

Values used for each of the parameters listed above, as well as estimated concentrations of PAH in spot resulting from this exposure pathway are presented in Table 6-5.

In addition to uptake from contaminated food items, it is also necessary to consider direct uptake from the water column. Water samples collected from the Cape Fear River, however, verify that concentrations of PAH in all samples collected between 1985 and 1996 are non-detect (See Section 4.2.2). Therefore, uptake of PAH by spot from the water column was not evaluated.

Using the total concentrations estimated for spot, dietary intakes of PAH were calculated for great blue heron using the exposure parameters described in the following equation:

$$DI = Cf \times IR \times AF \times FS \times FF \times 1/BW$$

where;

DI	=	Daily intake (mg/kg-d)
Cf	=	Concentration in fish (mg/kg)
IR	=	Ingestion rate (kg/d)
AF	=	Absorption fraction (unitless)
FS	=	Fraction of diet from the Site (unitless)
FF	=	Fraction of diet consisting of fish (unitless)
BW	=	Body weight (kg)

Values used for each of the exposure parameters listed above are presented in Table 6-6. To be conservative, the diet of great blue herons was assumed to consist entirely of fish. In addition, the absorption fraction of all chemicals and the fraction of the diet obtained from the site were assumed to be 100 percent.

For PAHs little information is available which describes the potential effects to avian species from the consumption of contaminated food items. In fact, only one relevant study could be located in the literature which tested the toxicity of PAHs in avian species. Patton and Dieter (1980) fed 400 and 4000 ppm of a mixture of aromatic hydrocarbons to mallard ducks for seven months. No significant effects were seen at either concentration, although at 4000 ppm the authors noted increased liver weights from liver hypertrophy. Although the liver hypertrophy was associated with increased physiological demand and not the PAHs themselves, as a conservative measure the 400 ppm dose level was used to calculate the toxicity reference value (TRV).

The concentration administered by Patton and Dieter (400 ppm) was converted to a daily dose of 103.4 mg/kgBW-d assuming a mallard body weight of 1.16 kg (Nelson and Martin, 1953) and an ingestion rate of 0.3 kg/d (Nagy, 1987). The dose shown not to cause adverse effects in the mallard (103.4 mg/kgBW-d) was then converted to a TRV for great blue heron using the following equation as described in Opresko et al. (1994):

$$TRV = D_b x \left(\frac{BW_b}{BW_a}\right)^{1/3}$$

where:

D_b	=	Daily dose producing a given effect in the test organism (mg/kgBW-d)
BW_b	=	Body weight of the test organism (kg)
BW_a	=	Body weight of the receptor of concern (kg)

For great blue heron, this resulted in a TRV of 82.5 mg/kgBW-d. This value was used in the ecological risk characterization as a benchmark for comparing estimated dietary intakes. Hypothetical risks to great blue heron are described in Section 6.4.

The resulting HQs are based on a inherent benchmark of unity, where values less than one indicate no adverse effects to ecological receptors, and values greater than one indicate the potential for adverse effects. HQs greater than one imply that chronic effects to individuals and populations is possible; however, the extent of effects at the population level cannot be accurately determined without direct measure of these populations in the field, and without proper consideration of the factors which regulate bioavailability of these chemicals in the field.

6.2 Potential Hazards to Benthic Macroinvertebrates

With the exception of naphthalene and dibenz(a,h)anthracene at some of the locations (Table 6-1), all detected concentrations of each PAH exceeded the FDEP benchmark (i.e., the HQ was greater than one). This suggests that PAHs may be causing adverse effects to benthic invertebrates that utilize the sediments. For example, predicted hazards to benthic organisms by four PAHs; acenaphthene, anthracene, naphthalene, and phenanthrene account for approximately 90% of the total hazard in the drainage ditch, and 80% of the total hazard in the Cape Fear River. In Greenfield Creek, the total hazard by this same group of PAHs is less than 15%. Hazards in Greenfield Creek are driven by four different PAHs, benzo(a)anthracene, benzo(a)pyrene, chrysene, and fluoranthene which as a group account for over 85% of the total hazard in the Creek. The total hazard index for each area as shown in Table 6-1 is as follows, in increasing order: the Cape Fear River ($\Sigma HQ = 887$), the drainage ditch ($\Sigma HQ = 1{,}815$), and Greenfield Creek ($\Sigma HQ = 8{,}763$).

The results of the risk characterization for benthic macroinvertebrates demonstrate that the potential hazards from exposure to sediment PAH at the Site are driven by several individual PAHs which differ between systems. The greatest potential hazards appear to be posed by four PAHs: benzo(a)anthracene, benzo(a)pyrene, chrysene, and fluoranthene, which occur at elevated levels in Greenfield Creek. A group, each of these PAHs are approximately seven times the total hazard observed in the drainage ditch, and over eight times the total hazard observed in the Cape Fear River.

6.3 Potential Hazards to Spot

The risks estimates for spot vary between each of the stations, as illustrated by the range of calculated hazard quotients (Table 6-3). Four locations in the River present the greatest potential for risk to spot, with HQs ranging between 11.4 and 28.3. These stations include: the reference location (SS-14); the old slip area (SS-19 and SS-21); and the northern shoreline of the Pactank Bulk Chemical Storage Facility (SS-23). The majority of the remaining stations have hazard quotients at or just below 1.0 and in fact, it is these stations are located near *Spartina* sp, which provides more suitable habitat for spot.

The results of the risk characterization for spot demonstrate discrete, isolated locations along the Cape Fear River where there is a potential risk of exposure to total sediment PAH. Background concentrations of PAH in the River are at levels which were observed in locations adjacent to the Site, suggesting that risks to fish may occur at other River locations subject to different PAH sources. These findings are not uncommon in other industrialized estuaries, where the risks from PAH may be widespread, and not a result of a specific point source.

As with benthic macroinvertebrates, the HQs derived for spot do not account for site-specific physicochemical parameters that control the bioavailability of PAHs to these organisms. Furthermore, the studies that are used to derive the benchmarks have numerous other chemicals in the sediments besides PAH (e.g. PCBs, trace metals, pesticides, and PCDD and PCDF) which may contribute to the overall toxicity of the reported benchmark value. The results, therefore, are conservatively used to predict only the potential for risks from sediment PAHs.

6.4 Potential Hazards to Great Blue Heron

Estimates of individual PAH dietary intake developed for the great blue heron were compared to toxicity reference values to derive a hazard quotient (HQ). The HQ calculated for great blue herons for each of the COPC are presented in Table 6-6. For all of the PAH, the HQs were well below 1.0, even under the conservative assumptions used in the risk assessment.

The results of this assessment clearly indicate that exposure of great blue herons to COPC in Cape Fear River sediments does not pose an adverse health risk to either individuals or the populations

of great blue herons living near the Cape Fear River. In addition, the conservative nature of the risk calculations ensure that other species at the Site are also likely to be adequately protected. Great blue herons, as tertiary consumers in the aquatic food web are expected to be exposed to PAH at the Site as a result of their high consumption of fish. However, as demonstrated in this study, PAH concentrations observed in Site sediments do not accumulate to levels in fish which would result in any apparent effects to the great blue heron.

It is reasonable to assume that species at similar trophic levels, but with different life histories from that of the great blue heron are even less exposed, and should not be adversely affected by PAH concentrations in sediment or biota. In fact, the lower potential for exposure, coupled with an increasing ability of higher trophic level organisms (like the great blue heron) to effectively metabolize the concentrations of PAH through their MFO systems, dictates that the ecological health of these populations are likely to be protected from PAH effects. As a final note, the disposition of PAHs in the food chain appear to represent the antithesis of behavior exhibited by other hydrophobic compounds (e.g. PCBs, PCDD, and PCDFs) in that PAHs do not appear to be biomagnified through the food web, resulting in lower concentrations at progressively higher trophic levels (Broman, 1990).

6.5 Identification of Uncertainties

Within any step of the ecological risk assessment process, assumptions must be made based on professional judgement in the absence of concise scientific data. There are several uncertainties associated with this screening-level ERA, many of which can substantially affect the overall interpretation of ecological risk at the Site. Some of the assumptions are supported by considerable scientific evidence, while others have less scientific support. Every assumption introduces some degree of uncertainty into the risk assessment process. Conservative assumptions are made throughout the risk assessment to ensure that the ecological receptors are sufficiently protected. Therefore, when all of the assumptions are combined, it is much more likely that risks are overestimated rather than underestimated. This approach is consistent with EPA guidance (1992, 1994a), and was used throughout this report.

6.5.1 Selection of Ecological COPC

The selection of COPC for the ecological risk assessment accurately designated PAHs as COPC based on their exceedance of the SQGs. In addition to these exceedances, PAHs were also considered for their bioaccumulation potential in aquatic organism based on reported log K_{ow}'s, of greater than 3.5. The selection of PAHs based on bioaccumulation potential is overly conservative since scientific studies have repeatedly found that these chemicals do not generally bioaccumulate in tissues of higher trophic level organisms. Regardless, as a conservative measure, this issue was specifically addressed and evaluated throughout sections of this screening-level ERA. Through empirical calculations, the results support literature findings in that PAH concentrations modeled

for the spot were typically expected to be below 1.0 ppb, resulting in extremely low risk to the great blue heron.

The COPC selection process also conservatively selected trace metals, which are potentially bioaccumulative in aquatic organisms. However, the paucity of data regarding the bioaccumulative potential for many of the trace metals at the Site, and the lack of a screening method which accounts for bioavailability (similar to that for PAHs), made it necessary to assume that each may be bioaccumulated to some degree in key organisms. The overall result of the COPC screening was, therefore, a conservative list of ecological COPC that included trace metals at concentrations which may pose little or no threat to ecological receptors at the Site. This is further supported by the fact that frequency of detection was not accounted for in the COPC screen and, therefore, many of the metals that were infrequently detected above SQG at the Site were included in the list of ecological COPC.

6.5.2 Selection of Key Receptors

An extensive habitat characterization of the surrounding Site environs identified numerous potential invertebrate and vertebrate species which could exist on the Site. Although it is recognized that a large number of species may utilize available habitat at the Site, the spot and great blue heron were selected as key, representative species. Although there is some uncertainty whether the predicted effects in spot and great blue heron will forecast potential effects in other species, the conservative nature of the risk assessment indicates that the species selected are likely to overstate potential risks. Specifically, the ecological receptors selected for evaluation are expected to have the highest exposure to PAH compared to all other wildlife species. In both cases, it was conservatively assumed that 100 percent of the food consumed was benthic invertebrates (for spot) and spot (for the great blue heron), collected from the Cape Fear River at locations specifically sampled near the Site.

It is uncertain whether predicted effects in the species studied will forecast potential effects to other species, populations, or communities in this ecosystem. The spot and great blue heron were chosen for this study because of their high potential for exposure in habitats adjacent to the Site. The results of this screening-level ERA indicate that there are isolated potential risks for spot, and no adverse individual species effects for the great blue heron. However, there is some uncertainty involved in using individual species effects to predict effects for the entire ecosystem. Regardless, the species studied are common to the Wilmington, North Carolina region and thus, should serve as good indicators of potential effects from exposure to the selected chemicals.

6.5.3 Exposure Assessment

Physicochemical parameters that influence the results of the exposure assessment include the data analysis of concentrations of PAH and trace metals in sediments, the lack of specific water quality criteria or standards for each PAH in deriving ssSQC, the organic carbon content of the sediments, and the binding capabilities of acid volatile sulfides to sediment metal concentrations. As a result, the bioavailability of sediment PAH by key organisms is likely understated in the exposure assessment, because the absence of water quality standards for many of the individual PAH were not available. As a conservative measure, the direct contact and ingestion of Site sediment PAH by benthic macroinvertebrates were evaluated on non-normalized bulk sediment concentrations that correlate with benthic effects in the literature. By ensuring that the exposure assessment is conservative, the effects assessment and risk characterization will be inherently conservative as well.

For metals, AVS/SEM analyses were used to illustrate that sulfides in Site sediments were more than likely to be adequate in reducing bioavailability to aquatic species. The bioavailability of metals in sediments also include several assumptions concerning the numerous geochemical and biological factors that influence availability. Abiotic factors may include: oxidation and reduction, precipitation and dissolution, adsorption and desorption to binding agents. Many of these factors cannot be measured pragmatically in sampling programs; however, an attempt to measure the physicochemical factors (e.g. AVS and TOC) that regulate the availability of metals significantly reduces the uncertainty in the assessment of bioavailability.

Additionally, this screening-level ERA assumed that the 95% UCL of the mean of measured environmental concentrations of the PAHs represents the tissue concentrations to which aquatic biota and subsequently, piscivorous wildlife may be exposed. The diet of the great blue heron was assumed to be restricted to one species which may or may not be present at the Site, and their feeding range was assumed to be limited to those locations where sediments were collected (e.g. adjacent to the Site and along the east bank of the River). In actuality, these exposure assumptions are very conservative. Although the site-specific feeding behavior of the great blue heron are uncertain, it is unlikely that these birds would only feed from along the shoreline near the Site. It is far more likely that the great blue heron feeds over a much larger territory encompassing many other creeks, channels, and portions of the Cape Fear River where more extensive habitat (e.g. Eagle Island) is accessible, abundant, and reasonably undisturbed by anthropogenic activity. Similarly, spot are likely to forage along riverine edges where *Spatina* sp. is abundant and offers good foraging cover. Much of this habitat is east of the Site, along the intertidal zone of Eagle Island. Thus, the exposure assumptions applied in this analysis are likely to overestimate the potential for ecological risks to the spot and great blue heron.

6.5.4 Ecological Effects Assessment

The primary uncertainties associated with an ecological effects assessment in this screening-level ERA is the selection of assessment endpoints for consideration, evaluation of the most sensitive effects (i.e., stressor-response) of individual chemicals or chemical groups, and the selection of effects-based concentrations of PAH that will be protective of aquatic organisms. The assessment endpoints considered in this screening-level ERA were direct toxicity of PAH in sediments to benthic organisms that may disrupt or alter benthic communities, and indirect effects of PAH that may be bioaccumulated by secondary (e.g. spot) and tertiary (e.g. great blue heron) consumers at the Site.

For benthic macroinvertebrates, the most comprehensive database on infaunal invertebrate toxicity currently available is presented by MacDonald (1994). Although this database contains: (1) results from different geographic locations, (2) a wide variety of study methods and approaches, and (3) data from several types of studies (e.g. equilibrium partitioning modelling, laboratory spiked-sediment bioassays, and field investigations of sediment toxicity and benthic community composition), it is by far the most comprehensive and widely accepted means for evaluating toxicity to benthic communities. Perhaps the most conservative aspect of using the database in this screening-level ERA is that many of the studies which have reported effects using co-occurrence data. Drawing conclusions from co-occurrence data is a conservative measure in assessing effects particularly from sediments which may have, in addition to PAHs, numerous other chemicals present.

In addressing the uncertainties associated with bioaccumulation in higher trophic level organisms, a review of the literature indicates that the most common endpoint associated with fish exposure to PAH is reportedly tissue lesions and neoplasia. The primary uncertainty associated with observed neoplasms in fish is in the inference of a causal relationship between PAH concentrations in sediments and tissues with disease. Numerous other factors that include the nutritional state and age of the organism, natural toxicants in foodstuffs, synergistic/antagonistic interactions of xenobiotics, and potential toxicity of unidentified compounds cannot be ignored in defining (with some degree of certainty) a cause-and-effect relationship. To remain conservative, and to remain consistent with the approach used in the benthic effects assessment, the identification of studies that were used to evaluate effects of PAH on fish (and for the great blue heron) were based on the most reasonable and applicable benchmark.

6.5.5 Summary of Risk Characterization

To evaluate the sediment toxicity to benthic organisms, the lowest reported SQG for PAH were directly compared to the 95 percent UCL of the surface sediment data. An HQ was calculated for each PAH, if possible, and a total HQ was calculated by summing all individual PAH HQs. An obvious uncertainty in this approach is the absence of reported SQG for a number of PAH. For

this reason, the risk characterization does not take into account some chemicals that may be directly toxic to benthic organisms.

The toxicity quotient method estimates the potential risk to a species by comparing the estimated exposure point concentration with an ecotoxicological benchmark concentration. Uncertainties associated with exposure point concentrations have been previously addressed in Section 6.5.3. Many uncertainties may also accompany the use of ecotoxicological benchmarks. First, toxicological data exist for only a limited number of species, chemicals, and effects, so that it is often necessary to extrapolate to the species or ecological receptor selected for evaluation. In addition, variability in test methods and test species increases the uncertainty associated with the test results. Despite the limitations and uncertainties in the available data, the calculated benchmarks (e.g. the NOEL for benthic organisms, the EEC for spot, and the TRV for higher trophic level organisms) most likely overestimates the potential risk to a species because the benchmarks selected were the most sensitive toxicological endpoints observed for either the indicator species or an appropriate surrogate species.

One of the most difficult uncertainties associated with using the ecotoxicological quotient method in a risk assessment is the assumption that the risks from various chemicals in a mixture are additive. Although this is not likely the case, addressing the relative risk potential of chemicals in a mixture is difficult, and repeated attempts to develop an approach, or strategy, for evaluating mixtures have made little progress in the scientific community. As a result, addressing the potentially synergistic effects of chemical mixtures is beyond the scope of this screening-level ERA.

Table 6-1. Calculated Hazard Quotients for Benthic Invertebrates

Parameter	FDEP, 1994(a) NOEL(b)	FDEP, 1994(a) PEL(c)	Drainage Ditch (mg/kg) 95th UCL(d)	Drainage Ditch (mg/kg) Hazard Quotient	Drainage Ditch (mg/kg) % HI	Greenfield Creek (mg/kg) 95th UCL(d)	Greenfield Creek (mg/kg) Hazard Quotient	Greenfield Creek (mg/kg) % HI	Cape Fear Estuary (mg/kg) 95th UCL(d)	Cape Fear Estuary (mg/kg) Hazard Quotient	Cape Fear Estuary (mg/kg) % HI
ORGANICS - Semivolatiles											
Acenaphthene	22	250	44,000	**2,000**	56	32,000	**1,455**	8.3	24,000	**1,091**	49
Anthracene	85	740	45,000	**528**	15	49,000	**574**	3.3	40,000	**469**	21
Benzo(a)anthracene	160	1,300	7,400	**46**	1.3	730,000	**4,563**	26	13,000	**81**	3.6
Benzo(a)pyrene	230	1,700	3,100	**13**	0.37	660,000	**2,870**	16	6,300	**27**	1.2
Benzo(b)fluoranthene			444			1,800,000			11,000		
Benzo(k)fluoranthene			4,900			1,500			1,600		
Carbazole			18,000			160			11,300		
Chrysene	220	1,700	5,500	**25**	0.69	920,000	**4,182**	24	18,000	**82**	3.7
Dibenz(a,h)anthracene	31	320	3,700	**119**	3.3	826	**27**	0.15	160	**5**	0.23
Fluoranthene	380	3,200	52,000	**137**	3.8	1,300,000	**3,421**	19	60,000	**158**	7.1
Indeno(1,2,3-cd)pyrene			2,000			680,000			160		
Naphthalene	130	1,100	44,000	**338**	9.4	160	**1**	0.0070	4,400	**34**	1.5
Phenanthrene	140	1,200	55,000	**393**	11	70,000	**500**	2.8	40,000	**286**	13
			Hazard Index	3,600			17,592			2,233	

a. Florida Department of Environmental Protection

b. No Observed Effect Level

c. Permissible Effect Level

d. Minimum of either the 95th upper confidence limit on arithmetic mean of log transformed data or the maximum detected concentration

Table 6-2. Distribution of Ecotoxicological Literature Pertaining to Observed Incidences of Lesions or Neoplasia from the Exposure of PAH in Fish

Location	Total Sediment PAH (µg/kg)	Effect	Species	Common Name	Endpoint	Reference
Elizabeth River, VA	3,900,000	*	*Fundulus heteroclitus*	mummichog	Integument lesions	Hargis et al., 1989
Elizabeth River, NJ	2,200,000	*	*Fundulus heteroclitus*	mummichog	Hepatic lesion	Vogelbein et al., 1990
Elizabeth River, NJ	1,990,000	*	*Leiostomus xanthurus*	spot	Integument lesions, mortality	Hargis et al., 1984
Eagle Harbor, WA	120,000	*	*Parophrys vetulus*	english sole	Hepatic neoplasms	Malins et al., 1985
Elizabeth River, NJ	61,000	NE	*Fundulus heteroclitus*	mummichog	Hepatic lesion	Vogelbein et al., 1990
Puget Sound, WA	33,000	*	*Parophrys vetulus*	english sole	Hepatic neoplasms	Malins et al., 1985b
Eagle Harbor, WA	16,000	*	*Parophrys vetulus*	english sole	Hepatic neoplasms	Malins et al., 1985
Puget Sound, WA	7,800	*	*Parophrys vetulus*	english sole	Hepatic neoplasms	Malins et al., 1985b
Berkeley Bay, CA	4,600	NE	*Platichthys stellatus*	starry flounder	Hepatic AHH activity	Spies et al., 1988
Elizabeth River, NJ	3,000	NE	*Fundulus heteroclitus*	mummichog	Hepatic lesion	Vogelbein et al., 1990
Eagle Harbor, WA	2,800	*	*Parophrys vetulus*	english sole	Hepatic neoplasms	Malins et al., 1985
San Pablo Bay, CA	2,600	NE	*Platichthys stellatus*	starry flounder	Hepatic AHH activity	Spies et al., 1988
Presidents Point, WA	1,100	NE	*Parophrys vetulus*	english sole	Hepatic neoplasms	Malins et al., 1985
Elizabeth River, NJ	376	NE	*Leiostomus xanthurus*	spot	Integument lesions	Hargis et al., 1984

Notes:
* indicates effect at concentration in sediment
NE - No Effect

Table 6-3. Calculated Hazard Quotients for Fish

Cape Fear River Station	Total PAH (ug/kg)	Ecotoxicological Effects Conc. (EEC) * (ug/kg)	Hazard Quotient (ug/kg)
SS-14	144,000	6,300	22.9
SS-15	6,800	6,300	1.1
SS-16	5,960	6,300	0.9
SS-17	9,000	6,300	1.4
SS-18	14,100	6,300	2.2
SS-19	148,400	6,300	23.6
SS-20	2,600	6,300	0.4
SS-21	178,000	6,300	28.3
SS-22	4,700	6,300	0.7
SS-23	72,000	6,300	11.4
SS-24	0	6,300	0.0

* EEC was developed using the 10th percentile of the distribution of effects data in

Table 6-4. Concentrations in Benthic Invertebrates (Cb)

Chemical	Cs Cape Fear River Sediment Conc. (mg/kg)	foc Fraction Org. Carbon (unitless)	BSAF Biota-Sediment Accumlation Factor [(mg/kg-L) / (mg/kg-oc)]	fL (wet) Lipid/wet wt. Conversion Factor [kg-L/kg (wet)]	Cb Invertebrate Concentration [mg/kg (wet)]
Acenaphthene	24.00	0.066	1.0	0.01	3.64
Anthracene	40	0.066	1.0	0.01	6.06
Benzo(a)anthracene	13.00	0.066	1.0	0.01	1.97
Benzo(a)pyrene	6.30	0.066	1.0	0.01	0.95
Benzo(b)fluoranthene	11.00	0.066	1.0	0.01	1.67
Benzo(k)fluoranthene	1.60	0.066	1.0	0.01	0.24
Chrysene	18.00	0.066	1.0	0.01	2.73
Dibenzo(a,h)anthracene	ND	0.066	1.0	0.01	ND
Fluoranthene	60	0.066	1.0	0.01	9.09
Indeno(1,2,3-c,d)pyrene	ND	0.066	1.0	0.01	ND
Naphthalene	4.4	0.066	1.0	0.01	0.67
Phenanthrene	40	0.066	1.0	0.01	6.06
Arsenic	0.010	0.066	1.0	0.01	0.0015
Chromium	0.046	0.066	1.0	0.01	0.0070
Copper	0.0473	0.066	1.0	0.01	0.0072
Lead	ND	0.066	1.0	0.01	ND

Cb = Cs/focxBSAFxfL
ND = Non-dect
NA = Not available

Table 6-5. Estimated Concentrations of PAH in Spot

Chemical	Cb Invertebrate Concentration [mg/kg (wet)]	IR (a) Ingestion Rate (Kg/Kg-day)	AF Absorption Fraction (unitless)	FI Fraction Diet Invert. (unitless)	BW (a) Body Weight (kg)	GR Growth Rate (1/day)	ER Excretion Rate (1/day)	MT Metabolism Rate (1/day)	Cf Spot Concentration (mg/kg)
Acenaphthene	3.64	0.084	1	1	0.136	0.00018	0.021	0.95	0.31
Anthracene	6.06	0.084	1	1	0.136	0.00018	0.021	0.95	0.52
Benzo(a)anthracene	1.97	0.084	1	1	0.136	0.00018	0.021	0.95	0.17
Benzo(a)pyrene	0.95	0.084	1	1	0.136	0.00018	0.021	0.95	0.083
Benzo(b)fluoranthene	1.67	0.084	1	1	0.136	0.00018	0.021	0.95	0.14
Benzo(k)fluoranthene	0.24	0.084	1	1	0.136	0.00018	0.021	0.95	0.021
Chrysene	2.73	0.084	1	1	0.136	0.00018	0.021	0.95	0.24
Dibenzo(a,h)anthracene	ND	0.084	1	1	0.136	0.00018	0.021	0.95	-
Fluoranthene	9.09	0.084	1	1	0.136	0.00018	0.021	0.95	0.79
Indeno(1,2,3-c,d)pyrene	ND	0.084	1	1	0.136	0.00018	0.021	0.95	-
Naphthalene	0.67	0.084	1	1	0.136	0.00018	0.021	0.95	0.058
Phenanthrene	6.06	0.084	1	1	0.136	0.00018	0.021	0.95	0.52
Arsenic	0.0015	0.084	1	1	0.136	0.00018	0.021	0.0	0.00601
Chromium	0.0070	0.084	1	1	0.136	0.00018	0.021	0.0	0.02764
Copper	0.0072	0.084	1	1	0.136	0.00018	0.021	0.0	0.02842
Lead	ND	0.084	1	1	0.136	0.00018	0.021	0.0	-

Cf=(Cb x IR x AF x FI)/ (GR+ER+MT)

$GR=0.01*(BW)^2$

ER=0.25*IR

NA = Not available

Table 6-6. Calculation of Daily Intake of PAH by Great Blue Herons

Chemical	Cf 95th UCL Fish Conc. (mg/kg)	IR Ingestion Rate (kg/d)	AF Absorption Fraction (unitless)	FS Fraction Diet from Site (unitless)	FF Fraction Diet Fish (unitless)	BW Body Weight (kg)	DI Daily Intake (mg/kg-d)	TRV Toxicity Reference Value (mg/kg-d)	HQ Hazard Quotient
Acenaphthene	0.31	0.4	1	1	1	2.3	0.05470	82.5	6.6E-04
Anthracene	0.52	0.4	1	1	1	2.3	0.09116	82.5	1.1E-03
Benzo(a)anthracene	0.17	0.4	1	1	1	2.3	0.02963	82.5	3.6E-04
Benzo(a)pyrene	0.08	0.4	1	1	1	2.3	0.01436	82.5	1.7E-04
Benzo(b)fluoranthene	0.14	0.4	1	1	1	2.3	0.02507	82.5	3.0E-04
Benzo(k)fluoranthene	0.02	0.4	1	1	1	2.3	0.00365	82.5	4.4E-05
Carbazole	0.15	0.4	1	1	1	2.3	0.02575	82.5	3.1E-04
Chrysene	0.24	0.4	1	1	1	2.3	0.04102	82.5	5.0E-04
Dibenzo(a,h)anthracene	-	0.4	1	1	1	2.3	-	82.5	-
Fluoranthene	0.79	0.4	1	1	1	2.3	0.13675	82.5	1.7E-03
Indeno(1,2,3-c,d)pyrene	-	0.4	1	1	1	2.3	-	82.5	-
Naphthalene	0.06	0.4	1	1	1	2.3	0.01003	82.5	1.2E-04
Phenanthrene	0.52	0.4	1	1	1	2.3	0.09116	82.5	1.1E-03

DI = Cf x IR x AF x FS x FF x 1/BW
HQ = DI/TRV
NA = Not available

7.0 SUMMARY AND CONCLUSIONS

The variety of data analyses and interpretations presented in this report collectively provide a clear and consistent picture of the distribution, potential exposure, and potential toxicity of observed levels of PAH and to a lesser extent, trace metals, to aquatic organisms. As illustrated in this report, extensive sampling of surface water, and sediment have been conducted at the SWP Wilmington Site since 1985. The data generated from these sampling investigations have provided a database of information from which an assessment of chemicals in various environmental media can be evaluated. In addition to these sampling efforts, numerous estuarine studies conducted throughout the Cape Fear River and neighboring estuaries over the years have produced substantial observations characterizing the local habitat, species, populations, and communities that occur in the area. It is clear from the available information that:

- Concentrations of organic compounds and metals in surface waters were consistently non-detect, or, in the only few instances where concentrations of these chemicals were detected, were generally below AWQC.

- Metal concentrations in sediments of the drainage ditch and Greenfield Creek system are generally below levels that would be of concern based on available sediment quality benchmarks. Cape Fear River sediments have slightly higher concentrations of metals above benchmarks; however, AVS/SEM results indicate that most locations have sufficient chelating properties (including TOC) to reduce the bioavailability of these metals to aquatic organisms. This may not be the case at the reference location in the Cape Fear River (SS-14), where background concentrations of SEM zinc and lead appear to be bioavailable to some aquatic organisms.

- Elevated levels of PAHs are ubiquitous throughout the Site, and are dominated by several petrogenic and pyrogenic PAHs which do not consistently suggest the Site as the sole source. Perhaps the most convincing observation regarding the potential for multiple sources of PAHs is governed by the type and pattern of PAH contamination in the area. If the Site were the principal PAH source of these contaminants, it would be reasonable to expect the highest levels in sediments closest to the covered ditch, and then to see a pattern of decreasing concentrations with increasing distance from the Site. In fact, the observed compositions and concentrations are quite different. PAH in background sediments of the

Cape Fear River further support the conclusion that ? Sources of these compounds in an urban setting have resulted in their ubiquity.

The sampling efforts conducted at the Site have sufficiently characterized the nature and extent of chemicals in various environmental media. By examining and evaluating the historical data, ChemRisk has reduced the number of Site chemicals to those of ecological concern (COPCs), namely, PAHs. An evaluation of the ecology and potential pathways of exposure at the Site have provided a focused analysis of the most likely receptors that would be affected by PAH. It is clear from this information that:

- Although several rare species have been identified within approximately one mile of the Site, these species (which do not appear to be present) are primarily plants that are limited to terrestrial/wetland habitat and are not considered to be affected by PAH or metals in sediments of the aquatic habitat surrounding the Site. Threatened, endangered, or rare fish species (if present) would not have access to the freshwater ditch and creek, but could be exposed to Cape Fear River sediments. Reptiles, including the american alligator which was observed near Greenfield Creek, are expected to be relatively insensitive to PAHs, and are therefore not likely to be exposed directly or indirectly through the ingestion of contaminated prey. To that end, the selection of a representative Site taxa is critical in effectively evaluating whether communities at the Site are at potential risk from PAH exposure. For this Site, the selection of benthic invertebrates, the spot, and the great blue heron are the most appropriate and relevant species for evaluating risk.

- The exposure of indigenous, commercially, and recreationally important fish and invertebrate communities of the Cape Fear River to PAHs in the drainage ditch and Greenfield Creek is limited, due to the presence of the Greenfield Creek tidal gate that acts as a physical barrier to the surface waters of the Cape Fear River. Observations made in the ditch and creek indicate that surface waters in these areas are predominately freshwater, and support only a limited benthic community, and virtually no fishery. The result is that this area is not a viable pathway for wildlife species, and in it's current state does not pose an ecological threat to resident or migratory biota of the Cape Fear River.

- Extensive study in the scientific literature have indicated that sediment PAH do not bioaccumulate in, and are not toxic to higher trophic level biota. In support of these findings, the risk characterization of area wildlife to Cape Fear River PAH concentrations provides substantial evidence that these chemicals are not likely to impact communities indirectly exposed to PAH through the consumption of contaminated prey. However, risks associated with the direct contact and ingestion of sediments by benthic invertebrates, and to a lesser extent, the locally abundant spot, have been shown to present a potential hazard to these species at some riverine locations. These risks have been conservatively identified

based on hazard quotients that do not incorporate the use of physicochemical factors that control bioavailability (e.g. AVS and TOC).

Based on the results of this screening-level ERA, it is apparent that PAHs present in the drainage ditch and Greenfield Creek sediments do not pose a substantial risk to the ecological resources (e.g. commercial and recreational fish, wildlife) of the Cape Fear River Estuary because these resources do not have access to these areas, and therefore have limited exposure via pathways of direct contact, ingestion of sediment, or consumption of contaminated prey. Potential risks in the ditch/Creek sediments appear to be currently confined to benthic macroinvertebrates. However, despite the elevated HQ's derived for benthic organisms, observations made on the community composition indicate that they are still well represented by taxa that are suited for freshwater habitats having shallow surface waters, low flow, and silt/sand substrate.

Similarly, potential risks from PAH exposure in the Cape Fear River are also predominately attributed to direct contact and ingestion by benthic organisms. Hazard Quotients for the Cape Fear River are not of the magnitude observed in the ditch/creek system, and there have been no studies which have examined the composition or structure of the Cape Fear River benthic community from which to draw conclusions. Potential hazards of PAH exposure for the spot appear to be limited to only a few locations in the study area (e.g the old slip, and the north shoreline near Pactank Bulk Chemical Storage Facility) which are of limited size relative to the overall habitat range of this species. Finally, as indicated by background concentrations of PAH in the Cape Fear River, the potential hazard of PAH exposure to these fish is more than likely not restricted to sediments or areas adjacent to the Site.

8.0 REFERENCES

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Appendix A

Historical and Recent Surface Water Sampling Results

HISTORICAL SURFACE WATER SAMPLE PARAMETER SUMMARY TABLE
SEMI–VOLATILES AND METALS
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	U.S. HIGHWAY #74 BRIDGE																											
	12/05		6/06		1/07		7/07		1/08		6/08		1/09		6/09		1/00		7/00		12/01		6/02		1/03		7/03	
SEMI–VOLATILES	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*
Acenaphthene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Acenaphthylene	NA	--	NA	--	NA	--	NA	--	NA	--	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Anthracene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Pyrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(b,k)Fluoranthene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Carbazole	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2–Chlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Chrysene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Dibenzo(a,h)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4–Dimethylphenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4–Dinitrophenol	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.05	ND	0.05	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Fluoranthene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Indeno(1,2,3–cd)pyrene	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Naphthalene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
p–chloro–m–cresol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Pentachlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Phenanthrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Phenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Tetrachlorophenols	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.050	ND	0.050	ND	0.050
Trichlorophenols	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
METALS																												
Arsenic	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Chromium	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Copper	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.025	ND	--	ND	0.025	ND	0.025	ND	0.025

NOTE: R* = Laboratory Result
DL* = Detection Limit
ND = Below Laboratory Detection Limit
NA = Not Analyzed
All units in mg/l

HISTORICAL SURFACE WATER SAMPLE PARAMETER SUMMARY TABLE
SEMI-VOLATILES AND METALS
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	OLD SLIP																											
	12/85		6/86		1/87		7/87		1/88		6/88		1/89		6/89		1/90		7/90		12/91		6/92		1/93		7/93	
SEMI-VOLATILES	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*
Acenaphthene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Acenaphthylene	NA	--	NA	--	NA	--	NA	--	NA	--	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Anthracene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Pyrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(b,k)Fluoranthene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Carbazole	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2-Chlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Chrysene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Dibenzo(a,h)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4-Dimethylphenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4-Dinitrophenol	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.05	ND	0.05	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Fluoranthene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Indeno(1,2,3-cd)pyrene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Naphthalene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
p-chloro-m-cresol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Pentachlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Phenanthrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Phenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Tetrachlorophenols	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.050	ND	0.050	ND	0.050
Trichlorophenols	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
METALS																												
Arsenic	ND	0.01	NA	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Chromium	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	0.011	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Copper	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	0.02	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.025	ND	--	ND	0.025	ND	0.025	ND	0.025

NOTE: R* = Laboratory Result
DL* = Detection Limit
ND = Below Laboratory Detection Limit
NA = Not Analyzed
All units in mg/l

HISTORICAL SURFACE WATER SAMPLE PARAMETER SUMMARY TABLE
SEMI-VOLATILES AND METALS
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	GREENFIELD CREEK																													
	12/85		6/86		1/87		7/87		1/88		6/88		1/89		6/89		7/89		1/90		7/90		12/91		6/92		1/93		7/93	
SEMI-VOLATILES	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*
Acenaphthene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Acenaphthylene	NA	--	NA	--	NA	--	NA	--	NA	--	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Anthracene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Pyrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(b,k)Fluoranthene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Carbazole	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2-Chlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Chrysene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Dibenzo(a,h)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4-Dimethylphenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4-Dinitrophenol	ND	0.05	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.05	ND	0.05	ND	0.050	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Fluoranthene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Indeno(1,2,3-cd)pyrene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Naphthalene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	0.050	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
p-chloro-m-cresol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Pentachlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.050	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Phenanthrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Phenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Tetrachlorophenols	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.050	ND	0.050	ND	0.050
Trichlorophenols	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
METALS																														
Arsenic	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Chromium	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	0.046	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Copper	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	0.052	0.025	ND	--	ND	0.025	ND	0.025	ND	0.025

NOTE: R* = Laboratory Result
DL* = Detection Limit
ND = Below Laboratory Detection Limit
NA = Not Analyzed
All units in mg/l

HISTORICAL SURFACE WATER SAMPLE PARAMETER SUMMARY TABLE
SEMI-VOLATILES AND METALS
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	STATE PORTS AUTHORITY																											
	12/85		6/86		1/87		7/87		1/88		6/88		1/89		6/89		1/90		7/90		12/91		6/92		1/93		7/93	
SEMI-VOLATILES	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*
Acenaphthene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Acenaphthylene	NA	--	NA	--	NA	--	NA	--	NA	--	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Anthracene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(a)Pyrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Benzo(b,k)Fluoranthene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Carbazole	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2-Chlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Chrysene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Dibenzo(a,h)Anthracene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4-Dimethylphenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
2,4-Dinitrophenol	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.05	ND	0.05	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Fluoranthene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Indeno(1,2,3-cd)pyrene	ND	0.01	ND	0.03	ND	0.03	ND	0.03	ND	0.03	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Naphthalene	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
p-chloro-m-cresol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Pentachlorophenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.050	ND	0.05	ND	0.050	ND	0.050	ND	0.050	ND	0.050	ND	0.050
Phenanthrene	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Phenol	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
Tetrachlorophenols	ND	0.01	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.050	ND	0.050	ND	0.050
Trichlorophenols	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	0.010
METALS																												
Arsenic	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Chromium	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.010	ND	--	ND	0.010	ND	0.010	ND	0.010
Copper	ND	0.01	ND	0.05	ND	0.05	ND	0.05	ND	0.05	ND	0.01	ND	0.010	ND	0.010	ND	0.010	ND	0.025	ND	--	ND	0.025	ND	0.025	ND	0.025

NOTE: R* = Laboratory Result
DL* = Detection Limit
ND = Below Laboratory Detection Limit
NA = Not Analyzed
All units in mg/l

SL SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S6-80296
Received: 17 JAN 96
Reported: 05 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80296-1	State Port Authority C/F River # 76 (# 13480)	01-15-96
80296-2	SWP Old Slip C/F River # 78 (# 13482)	01-15-96
80296-3	US 74 Hwy New Bridge C/F River # 79 (# 13483)	01-15-96

PARAMETER	80296-1	80296-2	80296-3
K001 (Method 8270)			
2-Chlorophenol, mg/l	ND	ND	ND
Phenol, mg/l	ND	ND	ND
2,4-Dimethylphenol, mg/l	ND	ND	ND
Trichlorophenols, mg/l	ND	ND	ND
p-Chloro-m-cresol, mg/l	ND	ND	ND
Tetrachlorophenols, mg/l	ND	ND	ND
2,4-Dinitrophenol, mg/l	ND	ND	ND
Pentachlorophenol, mg/l	ND	ND	ND
Naphthalene, mg/l	ND	ND	ND
Acenaphthene, mg/l	ND	ND	ND
Acenaphthylene, mg/l	ND	ND	ND
Phenanthrene, mg/l	ND	ND	ND
Anthracene, mg/l	ND	ND	ND
Fluoranthene, mg/l	ND	ND	ND
Chrysene, mg/l	ND	ND	ND
Benzo(a)Anthracene, mg/l	ND	ND	ND
Benzo(b,k)fluoranthene, mg/l	ND	ND	ND
Benzo(a)pyrene, mg/l	ND	ND	ND
Indeno(1,2,3-cd)pyrene, mg/l	ND	ND	ND
Dibenzo(a,h)anthracene, mg/l	ND	ND	ND
Carbazole, mg/l	ND	ND	ND
Dilution factor	1.0	1.0	1.0
Arsenic (6010), mg/l	ND	ND	ND

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Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80296-1	State Port Authority C/F River # 76 (# 13480)	01-15-96
80296-2	SWP Old Slip C/F River # 78 (# 13482)	01-15-96
80296-3	US 74 Hwy New Bridge C/F River # 79 (# 13483)	01-15-96

PARAMETER	80296-1	80296-2	80296-3
Chromium (6010), mg/l	ND	ND	ND
Copper (6010), mg/l	ND	ND	ND

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Received: 17 JAN 96
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Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80296-4	Greenfield Creek C/F River # 77 (# 13481)	01-15-96

PARAMETER	80296-4
Arsenic (6010), mg/l	ND
Chromium (6010), mg/l	ND
Copper (6010), mg/l	ND

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Received: 17 JAN 96
Reported: 05 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80296-5	Method Blank
80296-6	Detection Limits
80296-7	Accuracy (mean % recovery)
80296-8	Precision (% RPD)
80296-9	Analyst Initials

PARAMETER	80296-5	80296-6	80296-7	80296-8	80296-9
KO01 (Method 8270)					
2-Chlorophenol, mg/l	ND	0.010	64 %	8 %	LH
Phenol, mg/l	ND	0.010	66 %	2 %	LH
2,4-Dimethylphenol, mg/l	ND	0.010	66 %	4 %	LH
Trichlorophenols, mg/l	ND	0.010	62 %	5 %	LH
p-Chloro-m-cresol, mg/l	ND	0.010	72 %	6 %	LH
Tetrachlorophenols, mg/l	ND	0.050	42 %	7 %	LH
2,4-Dinitrophenol, mg/l	ND	0.050	87 %	21 %	LH
Pentachlorophenol, mg/l	ND	0.050	58 %	3 %	LH
Naphthalene, mg/l	ND	0.010	52 %	2 %	LH
Acenaphthene, mg/l	ND	0.010	60 %	7 %	LH
Acenaphthylene, mg/l	ND	0.010	62 %	8 %	LH
Phenanthrene, mg/l	ND	0.010	62 %	2 %	LH
Anthracene, mg/l	ND	0.010	64 %	2 %	LH
Fluoranthene, mg/l	ND	0.010	64 %	5 %	LH
Chrysene, mg/l	ND	0.010	69 %	3 %	LH
Benzo(a)Anthracene, mg/l	ND	0.010	66 %	4 %	LH
Benzo(b,k)fluoranthene, mg/l	ND	0.010	61 %	4 %	LH
Benzo(a)pyrene, mg/l	ND	0.010	61 %	3 %	LH
Indeno(1,2,3-cd)pyrene, mg/l	ND	0.010	60 %	8 %	LH
Dibenzo(a,h)anthracene, mg/l	ND	0.010	58 %	12 %	LH
Carbazole, mg/l	ND	0.010	62 %	5 %	LH
Dilution factor	1.0	1.0	---	---	LH

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Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80296-5	Method Blank
80296-6	Detection Limits
80296-7	Accuracy (mean % recovery)
80296-8	Precision (% RPD)
80296-9	Analyst Initials

PARAMETER	80296-5	80296-6	80296-7	80296-8	80296-9
Arsenic (6010), mg/l	ND	0.010	86 %	5.8 %	DM
Chromium (6010), mg/l	ND	0.010	93 %	6.5 %	DM
Copper (6010), mg/l	ND	0.025	88 %	5.6 %	DM

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Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80296-10	EPA Method Numbers
80296-11	Dates Extracted
80296-12	Dates Analyzed

PARAMETER	80296-10	80296-11	80296-12
KO01 (Method 8270)			
2-Chlorophenol	8270	01.18.96	01.19.96
Phenol	8270	01.18.96	01.19.96
2,4-Dimethylphenol	8270	01.18.96	01.19.96
Trichlorophenols	8270	01.18.96	01.19.96
p-Chloro-m-cresol	8270	01.18.96	01.19.96
Tetrachlorophenols	8270	01.18.96	01.19.96
2,4-Dinitrophenol	8270	01.18.96	01.19.96
Pentachlorophenol	8270	01.18.96	01.19.96
Naphthalene	8270	01.18.96	01.19.96
Acenaphthene	8270	01.18.96	01.19.96
Acenaphthylene	8270	01.18.96	01.19.96
Phenanthrene	8270	01.18.96	01.19.96
Anthracene	8270	01.18.96	01.19.96
Fluoranthene	8270	01.18.96	01.19.96
Chrysene	8270	01.18.96	01.19.96
Benzo(a)Anthracene	8270	01.18.96	01.19.96
Benzo(b,k)fluoranthene	8270	01.18.96	01.19.96
Benzo(a)pyrene	8270	01.18.96	01.19.96
Indeno(1,2,3-cd)pyrene	8270	01.18.96	01.19.96
Dibenzo(a,h)anthracene	8270	01.18.96	01.19.96
Carbazole	8270	01.18.96	01.19.96
Dilution factor	8270	01.18.96	01.19.96
Arsenic (6010)	6010	---	01.19.96

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CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80296-10	EPA Method Numbers
80296-11	Dates Extracted
80296-12	Dates Analyzed

PARAMETER	80296-10	80296-11	80296-12
Chromium (6010)	6010	---	01.19.96
Copper (6010)	6010	---	01.19.96

Methods: EPA SW-846
ND = Not Detected

J. W. Andrews, Ph. D., Project Manager

Final Page Of Report

SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

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LOG NO: S6-80422
Received: 24 JAN 96
Reported: 02 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80422-1	Greenfield Creek Cape Fear River # 80 (# 13514)	01-22-96

PARAMETER	80422-1
K001 (Method 8270)	
2-Chlorophenol, mg/l	ND
Phenol, mg/l	ND
2,4-Dimethylphenol, mg/l	ND
Trichlorophenols, mg/l	ND
p-Chloro-m-cresol, mg/l	ND
Tetrachlorophenols, mg/l	ND
2,4-Dinitrophenol, mg/l	ND
Pentachlorophenol, mg/l	ND
Naphthalene, mg/l	ND
Acenaphthene, mg/l	ND
Acenaphthylene, mg/l	ND
Phenanthrene, mg/l	ND
Anthracene, mg/l	ND
Fluoranthene, mg/l	ND
Chrysene, mg/l	ND
Benzo(a)Anthracene, mg/l	ND
Benzo(b,k)fluoranthene, mg/l	ND
Benzo(a)pyrene, mg/l	ND
Indeno(1,2,3-cd)pyrene, mg/l	ND
Dibenzo(a,h)anthracene, mg/l	ND
Carbazole, mg/l	ND
Dilution factor	1

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LOG NO: S6-80422
Received: 24 JAN 96
Reported: 02 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
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Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80422-2	Method Blank
80422-3	Detection Limits
80422-4	Accuracy (mean % recovery)
80422-5	Precision (% RPD)
80422-6	Analyst Initials

PARAMETER	80422-2	80422-3	80422-4	80422-5	80422-6
KOO1 (Method 8270)					
2-Chlorophenol, mg/l	ND	0.010	82 %	4 %	CJR
Phenol, mg/l	ND	0.010	87 %	2 %	CJR
2,4-Dimethylphenol, mg/l	ND	0.010	90 %	1 %	CJR
Trichlorophenols, mg/l	ND	0.010	88 %	0 %	CJR
p-Chloro-m-cresol, mg/l	ND	0.010	90 %	2 %	CJR
Tetrachlorophenols, mg/l	ND	0.050	60 %	2 %	CJR
2,4-Dinitrophenol, mg/l	ND	0.050	135 %	7 %	CJR
Pentachlorophenol, mg/l	ND	0.050	90 %	3 %	CJR
Naphthalene, mg/l	ND	0.010	72 %	4 %	CJR
Acenaphthene, mg/l	ND	0.010	87 %	2 %	CJR
Acenaphthylene, mg/l	ND	0.010	87 %	2 %	CJR
Phenanthrene, mg/l	ND	0.010	93 %	4 %	CJR
Anthracene, mg/l	ND	0.010	94 %	3 %	CJR
Fluoranthene, mg/l	ND	0.010	83 %	7 %	CJR
Chrysene, mg/l	ND	0.010	105 %	10 %	CJR
Benzo(a)Anthracene, mg/l	ND	0.010	99 %	2 %	CJR
Benzo(b,k)fluoranthene, mg/l	ND	0.010	90 %	5 %	CJR
Benzo(a)pyrene, mg/l	ND	0.010	88 %	1 %	CJR
Indeno(1,2,3-cd)pyrene, mg/l	ND	0.010	94 %	5 %	CJR
Dibenzo(a,h)anthracene, mg/l	ND	0.010	92 %	3 %	CJR
Carbazole, mg/l	ND	0.010	78 %	4 %	CJR
Dilution factor	1	1	---	---	---

SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

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LOG NO: S6-80422
Received: 24 JAN 96
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Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80422-7	EPA Method Numbers
80422-8	Dates Extracted
80422-9	Dates Analyzed

PARAMETER	80422-7	80422-8	80422-9
KOO1 (Method 8270)			
2-Chlorophenol	8270	01.25.96	1.29/30.96
Phenol	8270	01.25.96	1.29/30.96
2,4-Dimethylphenol	8270	01.25.96	1.29/30.96
Trichlorophenols	8270	01.25.96	1.29/30.96
p-Chloro-m-cresol	8270	01.25.96	1.29/30.96
Tetrachlorophenols	8270	01.25.96	1.29/30.96
2,4-Dinitrophenol	8270	01.25.96	1.29/30.96
Pentachlorophenol	8270	01.25.96	1.29/30.96
Naphthalene	8270	01.25.96	1.29/30.96
Acenaphthene	8270	01.25.96	1.29/30.96
Acenaphthylene	8270	01.25.96	1.29/30.96
Phenanthrene	8270	01.25.96	1.29/30.96
Anthracene	8270	01.25.96	1.29/30.96
Fluoranthene	8270	01.25.96	1.29/30.96
Chrysene	8270	01.25.96	1.29/30.96
Benzo(a)Anthracene	8270	01.25.96	1.29/30.96
Benzo(b,k)fluoranthene	8270	01.25.96	1.29/30.96
Benzo(a)pyrene	8270	01.25.96	1.29/30.96
Indeno(1,2,3-cd)pyrene	8270	01.25.96	1.29/30.96
Dibenzo(a,h)anthracene	8270	01.25.96	1.29/30.96
Carbazole	8270	01.25.96	1.29/30.96

Methods: EPA SW-846
ND = Not Detected

J. W. Andrews, Ph. D., Project Manager

SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

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LOG NO: S6-80961
Received: 17 FEB 96
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Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-21	SW5 (#13616)	02-15-96
80961-22	SW4 (#13617)	02-15-96
80961-23	SW4-Dup (#13618)	02-15-96
80961-24	SW3 (#13619)	02-15-96
80961-25	SW2 (#13620)	02-15-96

PARAMETER	80961-21	80961-22	80961-23	80961-24	80961-25
Semivolatile Organics (8270)					
bis(2-Chloroethyl)ether, mg/l	ND	ND	ND	ND	ND
Naphthalene, mg/l	ND	ND	ND	ND	ND
Acenaphthylene, mg/l	ND	ND	ND	ND	ND
Acenaphthene, mg/l	ND	ND	ND	ND	ND
Phenanthrene, mg/l	ND	ND	ND	ND	ND
Anthracene, mg/l	ND	ND	ND	ND	ND
Fluoranthene, mg/l	ND	ND	ND	ND	ND
Chrysene, mg/l	ND	ND	ND	ND	ND
Benzo(a)anthracene, mg/l	ND	ND	ND	ND	ND
Benzo(b)fluoranthene, mg/l	ND	ND	ND	ND	ND
Benzo(k)fluoranthene, mg/l	ND	ND	ND	ND	ND
Benzo(a)pyrene, mg/l	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene, mg/l	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene, mg/l	ND	ND	ND	ND	ND
2-Chlorophenol, mg/l	ND	ND	ND	ND	ND
Phenol, mg/l	ND	ND	ND	ND	ND
2,4-Dimethylphenol, mg/l	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol, mg/l	ND	ND	ND	ND	ND
4-Chloro-3-methylphenol, mg/l	ND	ND	ND	ND	ND

SL SAVANNAH LABORATORIES
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Reported: 29 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-21	SW5 (#13616)	02-15-96
80961-22	SW4 (#13617)	02-15-96
80961-23	SW4-Dup (#13618)	02-15-96
80961-24	SW3 (#13619)	02-15-96
80961-25	SW2 (#13620)	02-15-96

PARAMETER	80961-21	80961-22	80961-23	80961-24	80961-25
2,4-Dinitrophenol, mg/l	ND	ND	ND	ND	ND
Pentachlorophenol, mg/l	ND	ND	ND	ND	ND
2,4,5-Trichlorophenol, mg/l	ND	ND	ND	ND	ND
Carbazole, mg/l	ND	ND	ND	ND	ND
Tetrachlorophenols, mg/l	ND	ND	ND	ND	ND
Dilution factor	1.0	1.0	1.0	1.0	1.0

SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

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LOG NO: S6-80961
Received: 17 FEB 96
Reported: 29 FEB 96

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Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-21	SW5 (#13616)	02-15-96
80961-22	SW4 (#13617)	02-15-96
80961-23	SW4-Dup (#13618)	02-15-96
80961-24	SW3 (#13619)	02-15-96
80961-25	SW2 (#13620)	02-15-96

PARAMETER	80961-21	80961-22	80961-23	80961-24	80961-25
Volatiles by GC/MS (8240)					
Chloromethane, mg/l	ND	ND	ND	ND	ND
Bromomethane, mg/l	ND	ND	ND	ND	ND
Vinyl chloride, mg/l	ND	ND	ND	ND	ND
Chloroethane, mg/l	ND	ND	ND	ND	ND
Methylene chloride (Dichloromethane), mg/l	ND	ND	ND	ND	ND
1,1-Dichloroethene, mg/l	ND	ND	ND	ND	ND
1,1-Dichloroethane, mg/l	ND	ND	ND	ND	ND
trans-1,2-Dichloroethylene, mg/l	ND	ND	ND	ND	ND
1,2-Dichloroethane, mg/l	ND	ND	ND	ND	ND
1,1,1-Trichloroethane, mg/l	ND	ND	ND	ND	ND
Carbon tetrachloride, mg/l	ND	ND	ND	ND	ND
Bromodichloromethane, mg/l	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane, mg/l	ND	ND	ND	ND	ND
1,2-Dichloropropane, mg/l	ND	ND	ND	ND	ND
Trichloroethene, mg/l	ND	ND	ND	ND	ND
Dibromochloromethane, mg/l	ND	ND	ND	ND	ND
1,1,2-Trichloroethane, mg/l	ND	ND	ND	ND	ND
Benzene, mg/l	ND	ND	ND	ND	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-21	SW5 (#13616)	02-15-96
80961-22	SW4 (#13617)	02-15-96
80961-23	SW4-Dup (#13618)	02-15-96
80961-24	SW3 (#13619)	02-15-96
80961-25	SW2 (#13620)	02-15-96

PARAMETER	80961-21	80961-22	80961-23	80961-24	80961-25
cis-1,3-Dichloropropene, mg/l	ND	ND	ND	ND	ND
2-Chloroethylvinyl ether, mg/l	ND	ND	ND	ND	ND
Toluene, mg/l	ND	ND	ND	ND	ND
Chlorobenzene, mg/l	ND	ND	ND	ND	ND
Ethylbenzene, mg/l	ND	ND	ND	ND	ND
1,2-Dibromoethane (EDB) , mg/l	ND	ND	ND	ND	ND
Methyl tert-butyl ether (MTBE), mg/l	ND	ND	ND	ND	ND
m&p-Xylene, mg/l	ND	ND	ND	ND	ND
o-Xylene, mg/l	ND	ND	ND	ND	ND
Trichlorofluoromethane, mg/l	ND	ND	ND	ND	ND
Dichlorodifluoromethane, mg/l	ND	ND	ND	ND	ND
Arsenic (6010), mg/l	ND	ND	ND	ND	ND
Chromium (6010), mg/l	ND	ND	ND	ND	ND
Copper (6010), mg/l	ND	ND	ND	ND	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-26	SW1 (#13621)	02-15-96
80961-27	Drum (#13622)	02-15-96
80961-28	Equipment Blank-CF	02-15-96

PARAMETER	80961-26	80961-27	80961-28
Semivolatile Organics (8270)			
bis(2-Chloroethyl)ether, mg/l	ND	ND	ND
Naphthalene, mg/l	ND	1.5	ND
Acenaphthylene, mg/l	ND	ND	ND
Acenaphthene, mg/l	ND	1.0	ND
Phenanthrene, mg/l	ND	2.2	ND
Anthracene, mg/l	ND	0.33	ND
Fluoranthene, mg/l	ND	1.4	ND
Chrysene, mg/l	ND	0.22	ND
Benzo(a)anthracene, mg/l	ND	0.24	ND
Benzo(b)fluoranthene, mg/l	ND	ND	ND
Benzo(k)fluoranthene, mg/l	ND	ND	ND
Benzo(a)pyrene, mg/l	ND	ND	ND
Indeno(1,2,3-cd)pyrene, mg/l	ND	ND	ND
Dibenzo(a,h)anthracene, mg/l	ND	ND	ND
2-Chlorophenol, mg/l	ND	ND	ND
Phenol, mg/l	ND	ND	ND
2,4-Dimethylphenol, mg/l	ND	ND	ND
2,4,6-Trichlorophenol, mg/l	ND	ND	ND
4-Chloro-3-methylphenol, mg/l	ND	ND	ND
2,4-Dinitrophenol, mg/l	ND	ND	ND
Pentachlorophenol, mg/l	ND	ND	ND
2,4,5-Trichlorophenol, mg/l	ND	ND	ND
Carbazole, mg/l	ND	ND	ND
Tetrachlorophenols, mg/l	ND	ND	ND
Dilution factor	1.0	20	1.0

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-26	SW1 (#13621)	02-15-96
80961-27	Drum (#13622)	02-15-96
80961-28	Equipment Blank-CF	02-15-96

PARAMETER	80961-26	80961-27	80961-28
Volatiles by GC/MS (8240)			
Chloromethane, mg/l	ND	ND	ND
Bromomethane, mg/l	ND	ND	ND
Vinyl chloride, mg/l	ND	ND	ND
Chloroethane, mg/l	ND	ND	ND
Methylene chloride (Dichloromethane), mg/l	ND	ND	ND
1,1-Dichloroethene, mg/l	ND	ND	ND
1,1-Dichloroethane, mg/l	ND	ND	ND
trans-1,2-Dichloroethylene, mg/l	ND	ND	ND
1,2-Dichloroethane, mg/l	ND	ND	ND
1,1,1-Trichloroethane, mg/l	ND	ND	ND
Carbon tetrachloride, mg/l	ND	ND	ND
Bromodichloromethane, mg/l	ND	ND	ND
1,1,2,2-Tetrachloroethane, mg/l	ND	ND	ND
1,2-Dichloropropane, mg/l	ND	ND	ND
Trichloroethene, mg/l	ND	ND	ND
Dibromochloromethane, mg/l	ND	ND	ND
1,1,2-Trichloroethane, mg/l	ND	ND	ND
Benzene, mg/l	ND	ND	ND
cis-1,3-Dichloropropene, mg/l	ND	ND	ND
2-Chloroethylvinyl ether, mg/l	ND	ND	ND
Toluene, mg/l	ND	ND	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80961-26	SW1 (#13621)	02-15-96
80961-27	Drum (#13622)	02-15-96
80961-28	Equipment Blank-CF	02-15-96

PARAMETER	80961-26	80961-27	80961-28
Chlorobenzene, mg/l	ND	ND	ND
Ethylbenzene, mg/l	ND	ND	ND
1,2-Dibromoethane (EDB) , mg/l	ND	ND	ND
Methyl tert-butyl ether (MTBE), mg/l	ND	ND	ND
m&p-Xylene, mg/l	ND	ND	ND
o-Xylene, mg/l	ND	ND	ND
Trichlorofluoromethane, mg/l	ND	ND	ND
Dichlorodifluoromethane, mg/l	ND	ND	ND
Arsenic (6010), mg/l	ND	0.11	ND
Chromium (6010), mg/l	ND	0.14	ND
Copper (6010), mg/l	ND	0.35	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES
80961-29	Trip Blank

PARAMETER	80961-29
Volatiles by GC/MS (8240)	
Chloromethane, mg/l	ND
Bromomethane, mg/l	ND
Vinyl chloride, mg/l	ND
Chloroethane, mg/l	ND
Methylene chloride (Dichloromethane), mg/l	ND
1,1-Dichloroethene, mg/l	ND
1,1-Dichloroethane, mg/l	ND
trans-1,2-Dichloroethylene, mg/l	ND
1,2-Dichloroethane, mg/l	ND
1,1,1-Trichloroethane, mg/l	ND
Carbon tetrachloride, mg/l	ND
Bromodichloromethane, mg/l	ND
1,1,2,2-Tetrachloroethane, mg/l	ND
1,2-Dichloropropane, mg/l	ND
Trichloroethene, mg/l	ND
Dibromochloromethane, mg/l	ND
1,1,2-Trichloroethane, mg/l	ND
Benzene, mg/l	ND
cis-1,3-Dichloropropene, mg/l	ND
2-Chloroethylvinyl ether, mg/l	ND
Toluene, mg/l	ND
Chlorobenzene, mg/l	ND
Ethylbenzene, mg/l	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES
80961-29	Trip Blank

PARAMETER	80961-29
1,2-Dibromoethane (EDB) , mg/l	ND
Methyl tert-butyl ether (MTBE), mg/l	ND
m&p-Xylene, mg/l	ND
o-Xylene, mg/l	ND
Trichlorofluoromethane, mg/l	ND
Dichlorodifluoromethane, mg/l	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80961-30	Method Blank
80961-31	Detection Limits
80961-32	Accuracy (mean % recovery)
80961-33	Precision (% RPD)
80961-34	Analyst Initials

PARAMETER	80961-30	80961-31	80961-32	80961-33	80961-34
Semivolatile Organics (8270)					
bis(2-Chloroethyl)ether, mg/l	ND	0.010	---	---	LB
Naphthalene, mg/l	ND	0.010	66 %	2 %	LB
Acenaphthylene, mg/l	ND	0.010	66 %	4 %	LB
Acenaphthene, mg/l	ND	0.010	66 %	3 %	LB
Phenanthrene, mg/l	ND	0.010	68 %	4 %	LB
Anthracene, mg/l	ND	0.010	68 %	6 %	LB
Fluoranthene, mg/l	ND	0.010	80 %	5 %	LB
Chrysene, mg/l	ND	0.010	73 %	3 %	LB
Benzo(a)anthracene, mg/l	ND	0.010	76 %	4 %	LB
Benzo(b)fluoranthene, mg/l	ND	0.010	84 %	2 %	LB
Benzo(k)fluoranthene, mg/l	ND	0.010	82 %	5 %	LB
Benzo(a)pyrene, mg/l	ND	0.010	74 %	4 %	LB
Indeno(1,2,3-cd)pyrene, mg/l	ND	0.010	56 %	4 %	LB
Dibenzo(a,h)anthracene, mg/l	ND	0.010	58 %	3 %	LB
2-Chlorophenol, mg/l	ND	0.010	72 %	3 %	LB
Phenol, mg/l	ND	0.010	66 %	2 %	LB
2,4-Dimethylphenol, mg/l	ND	0.010	68 %	1 %	LB
2,4,6-Trichlorophenol, mg/l	ND	0.010	80 %	2 %	LB
4-Chloro-3-methylphenol, mg/l	ND	0.010	76 %	6 %	LB
2,4-Dinitrophenol, mg/l	ND	0.050	58 %	16 %	LB
Pentachlorophenol, mg/l	ND	0.050	54 %	9 %	LB
2,4,5-Trichlorophenol, mg/l	ND	0.010	---	---	LB
Carbazole, mg/l	ND	0.010	56 %	2 %	LB
Tetrachlorophenols, mg/l	ND	0.050	69 %	3 %	LB

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80961-30	Method Blank
80961-31	Detection Limits
80961-32	Accuracy (mean % recovery)
80961-33	Precision (% RPD)
80961-34	Analyst Initials

PARAMETER	80961-30	80961-31	80961-32	80961-33	80961-34
Volatiles by GC/MS (8240)					
Chloromethane, mg/l	ND	0.010	---	---	CD
Bromomethane, mg/l	ND	0.010	---	---	CD
Vinyl chloride, mg/l	ND	0.010	---	---	CD
Chloroethane, mg/l	ND	0.010	---	---	CD
Methylene chloride (Dichloromethane), mg/l	ND	0.0050	---	---	CD
1,1-Dichloroethene, mg/l	ND	0.0050	96 %	4 %	CD
1,1-Dichloroethane, mg/l	ND	0.0050	---	---	CD
trans-1,2-Dichloroethylene, mg/l	ND	0.0050	---	---	CD
1,2-Dichloroethane, mg/l	ND	0.0050	---	---	CD
1,1,1-Trichloroethane, mg/l	ND	0.0050	---	---	CD
Carbon tetrachloride, mg/l	ND	0.0050	---	---	CD
Bromodichloromethane, mg/l	ND	0.0050	---	---	CD
1,1,2,2-Tetrachloroethane, mg/l	ND	0.0050	---	---	CD
1,2-Dichloropropane, mg/l	ND	0.0050	---	---	CD
Trichloroethene, mg/l	ND	0.0050	88 %	0 %	CD
Dibromochloromethane, mg/l	ND	0.0050	---	---	CD
1,1,2-Trichloroethane, mg/l	ND	0.0050	---	---	CD
Benzene, mg/l	ND	0.0050	89 %	2 %	CD

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80961-30	Method Blank
80961-31	Detection Limits
80961-32	Accuracy (mean % recovery)
80961-33	Precision (% RPD)
80961-34	Analyst Initials

PARAMETER	80961-30	80961-31	80961-32	80961-33	80961-34
cis-1,3-Dichloropropene, mg/l	ND	0.0050	---	---	CD
2-Chloroethylvinyl ether, mg/l	ND	0.050	---	---	CD
Toluene, mg/l	ND	0.0050	91 %	2 %	CD
Chlorobenzene, mg/l	ND	0.0050	92 %	0 %	CD
Ethylbenzene, mg/l	ND	0.0050	---	---	CD
1,2-Dibromoethane (EDB) , mg/l	ND	0.0050	---	---	CD
Methyl tert-butyl ether (MTBE), mg/l	ND	0.010	---	---	CD
m&p-Xylene, mg/l	ND	0.0050	---	---	CD
o-Xylene, mg/l	ND	0.0050	---	---	CD
Trichlorofluoromethane, mg/l	ND	0.0050	---	---	CD
Dichlorodifluoromethane, mg/l	ND	0.0050	---	---	CD
Arsenic (6010), mg/l	ND	0.010	88 %	2.3 %	RR
Chromium (6010), mg/l	ND	0.010	100 %	3.0 %	RR
Copper (6010), mg/l	ND	0.025	98 %	3.1 %	RR

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80961-35	EPA Method Numbers
80961-36	Dates Extracted
80961-37	Dates Analyzed

PARAMETER	80961-35	80961-36	80961-37
Semivolatile Organics (8270)			
bis(2-Chloroethyl)ether	8270	02.20.96	2.22/23.96
Naphthalene	8270	02.20.96	2.22/23.96
Acenaphthylene	8270	02.20.96	2.22/23.96
Acenaphthene	8270	02.20.96	2.22/23.96
Phenanthrene	8270	02.20.96	2.22/23.96
Anthracene	8270	02.20.96	2.22/23.96
Fluoranthene	8270	02.20.96	2.22/23.96
Chrysene	8270	02.20.96	2.22/23.96
Benzo(a)anthracene	8270	02.20.96	2.22/23.96
Benzo(b)fluoranthene	8270	02.20.96	2.22/23.96
Benzo(k)fluoranthene	8270	02.20.96	2.22/23.96
Benzo(a)pyrene	8270	02.20.96	2.22/23.96
Indeno(1,2,3-cd)pyrene	8270	02.20.96	2.22/23.96
Dibenzo(a,h)anthracene	8270	02.20.96	2.22/23.96
2-Chlorophenol	8270	02.20.96	2.22/23.96
Phenol	8270	02.20.96	2.22/23.96
2,4-Dimethylphenol	8270	02.20.96	2.22/23.96
2,4,6-Trichlorophenol	8270	02.20.96	2.22/23.96
4-Chloro-3-methylphenol	8270	02.20.96	2.22/23.96
2,4-Dinitrophenol	8270	02.20.96	2.22/23.96
Pentachlorophenol	8270	02.20.96	2.22/23.96
2,4,5-Trichlorophenol	8270	02.20.96	2.22/23.96
Carbazole	8270	02.20.96	2.22/23.96
Tetrachlorophenols	8270	02.20.96	2.22/23.96

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80961-35	EPA Method Numbers
80961-36	Dates Extracted
80961-37	Dates Analyzed

PARAMETER	80961-35	80961-36	80961-37
Volatiles by GC/MS (8240)			
Chloromethane	8240	---	02.22.96
Bromomethane	8240	---	02.22.96
Vinyl chloride	8240	---	02.22.96
Chloroethane	8240	---	02.22.96
Methylene chloride (Dichloromethane)	8240	---	02.22.96
1,1-Dichloroethene	8240	---	02.22.96
1,1-Dichloroethane	8240	---	02.22.96
trans-1,2-Dichloroethylene	8240	---	02.22.96
1,2-Dichloroethane	8240	---	02.22.96
1,1,1-Trichloroethane	8240	---	02.22.96
Carbon tetrachloride	8240	---	02.22.96
Bromodichloromethane	8240	---	02.22.96
1,1,2,2-Tetrachloroethane	8240	---	02.22.96
1,2-Dichloropropane	8240	---	02.22.96
Trichloroethene	8240	---	02.22.96
Dibromochloromethane	8240	---	02.22.96
1,1,2-Trichloroethane	8240	---	02.22.96
Benzene	8240	---	02.22.96
cis-1,3-Dichloropropene	8240	---	02.22.96
2-Chloroethylvinyl ether	8240	---	02.22.96
Toluene	8240	---	02.22.96

SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S6-80961
Received: 17 FEB 96
Reported: 29 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80961-35	EPA Method Numbers
80961-36	Dates Extracted
80961-37	Dates Analyzed

PARAMETER	80961-35	80961-36	80961-37
Chlorobenzene	8240	---	02.22.96
Ethylbenzene	8240	---	02.22.96
1,2-Dibromoethane (EDB)	8240	---	02.22.96
Methyl tert-butyl ether (MTBE)	8240	---	02.22.96
m&p-Xylene	8240	---	02.22.96
o-Xylene	8240	---	02.22.96
Trichlorofluoromethane	8240	---	02.22.96
Dichlorodifluoromethane	8240	---	02.22.96
Arsenic (6010)	6010	---	02.26.96
Chromium (6010)	6010	---	02.26.96
Copper (6010)	6010	---	02.26.96

Methods: EPA SW-846
ND = Not Detected

J. W. Andrews, Ph. D., Project Manager

Final Page Of Report

Appendix B

Historical and Recent Surface Sediment Sampling Results

HISTORICAL SOIL SAMPLE PARAMETER SUMMARY TABLE
VOLATILES
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	SS-1		SS-2		SS-3		SS-4		SS-5		SS-6		SS-7		SS-8		SS-9		SS-10		SS-11	
VOLATILES	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*
Benzene	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Bromodichloroethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Bromomethane	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.001
Carbon Tetrachloride	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.005
Chlorobenzene	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Chloroethane	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.001
2-Chloroethylvinyl Ether	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.005
Chloroform	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Chloromethane	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.001
Cis-1,3-Dichloropropene	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.005
Dibromochloromethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
1,2-Dibromomethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.005	ND	0.001	ND	0.005	ND	0.001	ND	0.001
Dichlorodifluoromethane	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005
1,1-Dichloroethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.005
1,2-Dichloroethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
1,1-Dichloroethene	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Dichloromethane	0.024	0.001	0.0064	0.001	0.015	0.001	0.017	0.001	0.012	0.001	0.014	0.001	0.059	0.001	0.007	0.001	0.020	0.001	0.008	0.001	0.0068	0.001
1,2-Dichloropropane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Ethyl Benzene	ND	0.001	ND	0.001	ND	0.02	ND	0.001	ND	0.001	ND	0.001	0.15	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Fluorotrichloromethane	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.006	ND	0.006	ND	0.005	ND	0.001
M/P-Xylene	0.0025	0.001	ND	0.001	ND	0.02	0.001	0.001	0.0011	0.001	0.0014	0.001	0.084	0.001	ND	0.001	0.0071	0.001	ND	0.001	ND	0.005
Methyl-T-Butyl Ether (Mtbe)	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.001
o-Xylene	0.0011	0.001	ND	0.001	ND	0.02	ND	0.001	ND	0.001	ND	0.001	0.069	0.001	ND	0.001	0.0075	0.001	ND	0.001	ND	0.005
1,1,2,2-Tetrachloroethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Toluene	0.0024	0.001	ND	0.001	ND	0.001	ND	0.001	0.0013	0.001	0.0034	0.001	0.016	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Trans-1,2-Dichloroethylene	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
1,1,1-Trichloroethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
1,1,2-Trichloroethane	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Trichloroethene	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001	ND	0.001
Vinyl Chloride	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.005	ND	0.006	ND	0.005

NOTE: DL = Laboratory Detection Limit

All units in mg/kg dw

HISTORICAL SOIL SAMPLE PARAMETER SUMMARY TABLE
SEMI-VOLATILES
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	SS-1		SS-2		SS-3		SS-4		SS-5		SS-6		SS-7		SS-8		SS-9		SS-10		SS-11	
SEMI-VOLATILES	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*	RESULT	DL*
Acenaphthene	0.51	0.33	ND	0.33	ND	0.33	0.59	0.33	4.4	0.33	2.9	0.33	44.0	0.33	1.0	0.33	32.0	0.33	ND	0.33	ND	0.33
Anthracene	ND	0.33	ND	0.33	ND	0.33	ND	0.33	45.0	0.33	36.0	0.33	10.0	0.33	ND	0.33	49.0	0.33	ND	0.33	ND	0.33
Benzo(a)Anthracene	1.1	0.33	0.54	0.33	ND	0.33	1.1	0.33	5.6	0.33	7.4	0.33	3.2	0.33	ND	0.33	26.0	0.33	730.0	0.33	ND	0.33
Benzo(a)Pyrene	0.42	0.33	ND	0.33	ND	0.33	2.0	0.33	3.1	0.33	1.9	0.33	0.64	0.33	ND	0.33	9.0	0.33	660.0	0.33	ND	0.33
Benzo(b)Fluoranthene	ND	0.33	0.75	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	15.0	0.33	1600.0	0.33	ND	0.33
Benzo(k)Fluoranthene	1.5	0.33	ND	0.33	ND	0.33	4.9	0.33	3.60	0.33	3.6	0.33	1.2	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
Bis(2-Chloroethyl)Ether	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
Carbazole	ND	0.33	ND	0.33	ND	0.33	ND	0.33	18.0	0.33	4.4	0.33	17.0	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
4-Chloro-3-Methylphenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
2-Chlorophenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
Chrysene	1.1	0.33	0.53	0.33	ND	0.33	1.6	0.33	4.5	0.33	5.5	0.33	1.90	0.33	ND	0.33	22.0	0.33	920.0	0.33	ND	0.33
Dibenzo(a,h)Anthracene	ND	0.33	ND	0.33	ND	0.33	3.7	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	0.94	0.33	ND	0.33	ND	0.33
2,4-Dimethylphenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
2,4-Dinitrophenol	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60
Fluoranthene	3.6	0.33	0.87	0.33	ND	0.33	1.6	0.33	38.0	0.33	62.0	0.33	26.0	0.33	ND	0.33	130.0	0.33	1300.0	0.33	ND	0.33
Indeno(1,2,3-cd)Pyrene	ND	0.33	ND	0.33	ND	0.33	2.0	0.33	0.67	0.33	0.72	0.33	ND	0.33	ND	0.33	3.4	0.33	660.0	0.33	ND	0.33
Naphthalene	ND	0.33	ND	0.33	ND	0.33	ND	0.33	1.6	0.33	ND	0.33	44.0	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
Pentachlorophenol	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60	ND	1.60
Phenanthrene	1.5	0.33	0.56	0.33	ND	0.33	ND	0.33	42.0	0.33	36.0	0.33	55.0	0.33	ND	0.33	70.0	0.33	ND	0.33	ND	0.33
Phenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
Tetrachlorophenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
2,4,5-Trichlorophenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33
2,4,6-Trichlorophenol	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33	ND	0.33

NOTE: DL = Laboratory Detection Limit

All units in mg/kg dw

HISTORICAL SOIL SAMPLE PARAMETER SUMMARY TABLE
METALS
SOUTHERN WOOD PIEDMONT FACILITY
WILMINGTON, NORTH CAROLINA

	SS-1		SS-2		SS-3		SS-4		SS-5		SS-6		SS-7		SS-8		SS-9		SS-10		SS-11	
METALS	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*	R*	DL*
Arsenic	3.5	1.2	5.2	1.2	ND	1.2	3.6	1.2	1.5	1.2	ND	1.2	2.3	1.2	ND	1.2	ND	1.2	ND	1.2	ND	1.2
Chromium	5.5	0.75	14.0	0.75	2.1	0.75	11.0	0.75	5.2	0.75	3.1	0.75	9.2	0.75	4.2	0.75	4.1	0.75	2.6	0.75	1.3	0.75
Copper	6.1	0.75	46.0	0.75	8.0	0.75	14.0	0.75	2.4	0.75	2.8	0.75	5.1	0.75	1.9	0.75	4.4	0.75	3.9	0.75	1.0	0.75
Lead	14.0	5.0	290.0	5.0	61.0	5.0	25.0	5.0	3.4	1.2	3.1	1.1	6.3	5.0	2.3	1.2	6.9	5.0	6.2	5.0	1.9	5.0

NOTE: All units in mg/kg dw
R = Laboratory Analytical Result
DL = Laboratory Detection Limit

SL SAVANNAH LABORATORIES & ENVIRONMENTAL SERVICES, INC.

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Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80961-1	SS14 (#13623)	02-15-96
80961-2	SS18 (#13628)	02-15-96
80961-3	SS20 (#13630)	02-15-96
80961-4	SS23 (#13633)	02-15-96

PARAMETER	80961-1	80961-2	80961-3	80961-4
Semivolatile Organics (8270)				
Naphthalene, mg/kg dw	20	ND	ND	ND
bis(2-Chloroethyl)ether, mg/kg dw	ND	ND	ND	ND
Acenaphthylene, mg/kg dw	ND	ND	ND	ND
Acenaphthene, mg/kg dw	24	1.1	ND	ND
Phenanthrene, mg/kg dw	40	ND	ND	ND
Anthracene, mg/kg dw	13	2.2	ND	17
Fluoranthene, mg/kg dw	22	7.5	2.6	55
Chrysene, mg/kg dw	5.7	1.6	ND	ND
Benzo(a)anthracene, mg/kg dw	6.4	1.7	ND	ND
Benzo(b)fluoranthene, mg/kg dw	6.6	ND	ND	ND
Benzo(k)fluoranthene, mg/kg dw	ND	ND	ND	ND
Benzo(a)pyrene, mg/kg dw	6.3	ND	ND	ND
Indeno(1,2,3-cd)pyrene, mg/kg dw	ND	ND	ND	ND
Dibenzo(a,h)anthracene, mg/kg dw	ND	ND	ND	ND
2-Chlorophenol, mg/kg dw	ND	ND	ND	ND
Phenol, mg/kg dw	ND	ND	ND	ND
2,4-Dimethylphenol, mg/kg dw	ND	ND	ND	ND
2,4,6-Trichlorophenol, mg/kg dw	ND	ND	ND	ND
4-Chloro-3-methylphenol, mg/kg dw	ND	ND	ND	ND
2,4-Dinitrophenol, mg/kg dw	ND	ND	ND	ND
Pentachlorophenol, mg/kg dw	ND	ND	ND	ND
2,4,5-Trichlorophenol, mg/kg dw	ND	ND	ND	ND
Carbazole, mg/kg dw	ND	ND	ND	ND
Tetrachlorophenols, mg/kg dw	ND	ND	ND	ND
Dilution factor	10	1.0	1.0	10

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80961-3	SS20 (#13630)	02-15-96
80961-4	SS23 (#13633)	02-15-96

PARAMETER	80961-1	80961-2	80961-3	80961-4
Volatiles by GC/MS (8240)				
Chloromethane, mg/kg dw	ND	ND	ND	ND
Bromomethane, mg/kg dw	ND	ND	ND	ND
Vinyl chloride, mg/kg dw	ND	ND	ND	ND
Chloroethane, mg/kg dw	ND	ND	ND	ND
Methylene chloride (Dichloromethane), mg/kg dw	ND	ND	ND	ND
1,1-Dichloroethene, mg/kg dw	ND	ND	ND	ND
1,1-Dichloroethane, mg/kg dw	ND	ND	ND	ND
trans-1,2-Dichloroethylene, mg/kg dw	ND	ND	ND	ND
1,2-Dichloroethane, mg/kg dw	ND	ND	ND	ND
1,1,1-Trichloroethane, mg/kg dw	ND	ND	ND	ND
Carbon tetrachloride, mg/kg dw	ND	ND	ND	ND
Bromodichloromethane, mg/kg dw	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane, mg/kg dw	ND	ND	ND	ND
1,2-Dichloropropane, mg/kg dw	ND	ND	ND	ND
Trichloroethene, mg/kg dw	ND	ND	ND	ND
Dibromochloromethane, mg/kg dw	ND	ND	ND	ND
1,1,2-Trichloroethane, mg/kg dw	ND	ND	ND	ND
Benzene, mg/kg dw	ND	ND	ND	ND
cis-1,3-Dichloropropene, mg/kg dw	ND	ND	ND	ND
2-Chloroethylvinyl ether, mg/kg dw	ND	ND	ND	ND

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80961-1	SS14 (#13623)	02-15-96
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80961-3	SS20 (#13630)	02-15-96
80961-4	SS23 (#13633)	02-15-96

PARAMETER	80961-1	80961-2	80961-3	80961-4
Toluene, mg/kg dw	ND	ND	ND	ND
Chlorobenzene, mg/kg dw	ND	ND	ND	ND
Ethylbenzene, mg/kg dw	0.54	ND	ND	ND
1,2-Dibromoethane (EDB) , mg/kg dw	ND	ND	ND	ND
Methyl tert-butyl ether (MTBE), mg/kg dw	ND	ND	ND	ND
m&p-Xylene, mg/kg dw	0.30	ND	ND	ND
o-Xylene, mg/kg dw	0.22	ND	ND	ND
Trichlorofluoromethane, mg/kg dw	ND	ND	ND	ND
Dichlorodifluoromethane, mg/kg dw	ND	ND	ND	ND
Arsenic (6010), mg/kg dw	4.9	8.6	9.7	5.0
Chromium (6010), mg/kg dw	6.8	30	37	19
Copper (6010), mg/kg dw	74	17	23	15
Total Organic Carbon (415.1), mg/kg dw	9200	49000	73000	27000
AVS Extractable Metals				
Cadmium (6010), mg/kg dw	0.96	0.29	0.54	ND
Copper (6010), mg/kg dw	ND	7.0	7.9	1.9
Nickel (6010), mg/kg dw	6.0	2.4	2.6	ND
Zinc (6010), mg/kg dw	610	100	81	54
Lead (6010), mg/kg dw	160	24	23	16
Acid Volatile Sulfide, mg/kg dw	ND	53	ND	ND
Percent Solids (160.3), %	67	31	25	34

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& ENVIRONMENTAL SERVICES, INC.

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LOG NO: S6-80961
Received: 17 FEB 96
Reported: 29 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80961-5	SS15 (#13624)	02-15-96
80961-6	SS16 (#13625)	02-15-96
80961-7	SS16-Dup (#13626)	02-15-96
80961-8	SS17 (#13627)	02-15-96
80961-9	SS19 (#13629)	02-15-96

PARAMETER	80961-5	80961-6	80961-7	80961-8	80961-9
Semivolatile Organics (8270)					
Naphthalene, mg/kg dw	ND	ND	ND	ND	ND
bis(2-Chloroethyl)ether, mg/kg dw	ND	ND	ND	ND	ND
Acenaphthylene, mg/kg dw	ND	ND	ND	ND	ND
Acenaphthene, mg/kg dw	ND	ND	ND	ND	ND
Phenanthrene, mg/kg dw	ND	ND	ND	ND	19
Anthracene, mg/kg dw	ND	ND	ND	ND	20
Fluoranthene, mg/kg dw	1.1	3.0	3.2	4.7	60
Chrysene, mg/kg dw	1.2	1.2	1.2	1.4	15
Benzo(a)anthracene, mg/kg dw	1.4	ND	ND	1.3	12
Benzo(b)fluoranthene, mg/kg dw	1.8	ND	1.4	1.6	11
Benzo(k)fluoranthene, mg/kg dw	ND	1.6	ND	ND	5.5
Benzo(a)pyrene, mg/kg dw	1.3	ND	ND	ND	5.9
Indeno(1,2,3-cd)pyrene, mg/kg dw	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene, mg/kg dw	ND	ND	ND	ND	ND
2-Chlorophenol, mg/kg dw	ND	ND	ND	ND	ND
Phenol, mg/kg dw	ND	ND	ND	ND	ND
2,4-Dimethylphenol, mg/kg dw	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol, mg/kg dw	ND	ND	ND	ND	ND
4-Chloro-3-methylphenol, mg/kg dw	ND	ND	ND	ND	ND

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80961-8	SS17 (#13627)	02-15-96
80961-9	SS19 (#13629)	02-15-96

PARAMETER	80961-5	80961-6	80961-7	80961-8	80961-9
2,4-Dinitrophenol, mg/kg dw	ND	ND	ND	ND	ND
Pentachlorophenol, mg/kg dw	ND	ND	ND	ND	ND
2,4,5-Trichlorophenol, mg/kg dw	ND	ND	ND	ND	ND
Carbazole, mg/kg dw	ND	ND	ND	ND	4.7
Tetrachlorophenols, mg/kg dw	ND	ND	ND	ND	ND
Dilution factor	1.0	1.0	1.0	1.0	4.0

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80961-8	SS17 (#13627)	02-15-96
80961-9	SS19 (#13629)	02-15-96

PARAMETER	80961-5	80961-6	80961-7	80961-8	80961-9
Volatiles by GC/MS (8240)					
Chloromethane, mg/kg dw	ND	ND	ND	ND	ND
Bromomethane, mg/kg dw	ND	ND	ND	ND	ND
Vinyl chloride, mg/kg dw	ND	ND	ND	ND	ND
Chloroethane, mg/kg dw	ND	ND	ND	ND	ND
Methylene chloride (Dichloromethane), mg/kg dw	ND	ND	ND	ND	ND
1,1-Dichloroethene, mg/kg dw	ND	ND	ND	ND	ND
1,1-Dichloroethane, mg/kg dw	ND	ND	ND	ND	ND
trans-1,2-Dichloroethylene, mg/kg dw	ND	ND	ND	ND	ND
1,2-Dichloroethane, mg/kg dw	ND	ND	ND	ND	ND
1,1,1-Trichloroethane, mg/kg dw	ND	ND	ND	ND	ND
Carbon tetrachloride, mg/kg dw	ND	ND	ND	ND	ND
Bromodichloromethane, mg/kg dw	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane, mg/kg dw	ND	ND	ND	ND	ND
1,2-Dichloropropane, mg/kg dw	0.065	ND	ND	ND	ND
Trichloroethene, mg/kg dw	ND	ND	ND	ND	ND
Dibromochloromethane, mg/kg dw	ND	ND	ND	ND	ND
1,1,2-Trichloroethane, mg/kg dw	ND	ND	ND	ND	ND
Benzene, mg/kg dw	ND	ND	ND	ND	ND

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80961-8	SS17 (#13627)	02-15-96
80961-9	SS19 (#13629)	02-15-96

PARAMETER	80961-5	80961-6	80961-7	80961-8	80961-9
cis-1,3-Dichloropropene, mg/kg dw	ND	ND	ND	ND	ND
2-Chloroethylvinyl ether, mg/kg dw	ND	ND	ND	ND	ND
Toluene, mg/kg dw	ND	ND	ND	ND	ND
Chlorobenzene, mg/kg dw	ND	ND	ND	ND	ND
Ethylbenzene, mg/kg dw	ND	ND	ND	ND	ND
1,2-Dibromoethane (EDB) , mg/kg dw	ND	ND	ND	ND	ND
Methyl tert-butyl ether (MTBE), mg/kg dw	ND	ND	ND	ND	ND
m&p-Xylene, mg/kg dw	ND	ND	ND	ND	ND
o-Xylene, mg/kg dw	ND	ND	ND	ND	ND
Trichlorofluoromethane, mg/kg dw	ND	ND	ND	ND	ND
Dichlorodifluoromethane, mg/kg dw	ND	ND	ND	ND	ND
Arsenic (6010), mg/kg dw	6.0	10	12	11	10
Chromium (6010), mg/kg dw	19	49	47	65	57
Copper (6010), mg/kg dw	15	32	31	48	40
Percent Solids (160.3), %	51	29	29	29	29

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80961-10	SS21 (#13631)	02-15-96
80961-11	SS22 (#13632)	02-15-96
80961-12	SS24 (#13634)	02-15-96

PARAMETER	80961-10	80961-11	80961-12
Semivolatile Organics (8270)			
Naphthalene, mg/kg dw	ND	ND	ND
bis(2-Chloroethyl)ether, mg/kg dw	ND	ND	ND
Acenaphthylene, mg/kg dw	ND	ND	ND
Acenaphthene, mg/kg dw	11	ND	ND
Phenanthrene, mg/kg dw	31	ND	ND
Anthracene, mg/kg dw	40	1.8	ND
Fluoranthene, mg/kg dw	54	2.9	ND
Chrysene, mg/kg dw	18	ND	ND
Benzo(a)anthracene, mg/kg dw	13	ND	ND
Benzo(b)fluoranthene, mg/kg dw	11	ND	ND
Benzo(k)fluoranthene, mg/kg dw	ND	ND	ND
Benzo(a)pyrene, mg/kg dw	ND	ND	ND
Indeno(1,2,3-cd)pyrene, mg/kg dw	ND	ND	ND
Dibenzo(a,h)anthracene, mg/kg dw	ND	ND	ND
2-Chlorophenol, mg/kg dw	ND	ND	ND
Phenol, mg/kg dw	ND	ND	ND
2,4-Dimethylphenol, mg/kg dw	ND	ND	ND
2,4,6-Trichlorophenol, mg/kg dw	ND	ND	ND
4-Chloro-3-methylphenol, mg/kg dw	ND	ND	ND
2,4-Dinitrophenol, mg/kg dw	ND	ND	ND
Pentachlorophenol, mg/kg dw	ND	ND	ND
2,4,5-Trichlorophenol, mg/kg dw	ND	ND	ND
Carbazole, mg/kg dw	15	ND	ND
Tetrachlorophenols, mg/kg dw	ND	ND	ND
Dilution factor	10	1.0	1.0

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80961-11	SS22 (#13632)	02-15-96
80961-12	SS24 (#13634)	02-15-96

PARAMETER	80961-10	80961-11	80961-12
Volatiles by GC/MS (8240)			
Chloromethane, mg/kg dw	ND	ND	ND
Bromomethane, mg/kg dw	ND	ND	ND
Vinyl chloride, mg/kg dw	ND	ND	ND
Chloroethane, mg/kg dw	ND	ND	ND
Methylene chloride (Dichloromethane), mg/kg dw	ND	ND	ND
1,1-Dichloroethene, mg/kg dw	ND	ND	ND
1,1-Dichloroethane, mg/kg dw	ND	ND	ND
trans-1,2-Dichloroethylene, mg/kg dw	ND	ND	ND
1,2-Dichloroethane, mg/kg dw	ND	ND	ND
1,1,1-Trichloroethane, mg/kg dw	ND	ND	ND
Carbon tetrachloride, mg/kg dw	ND	ND	ND
Bromodichloromethane, mg/kg dw	ND	ND	ND
1,1,2,2-Tetrachloroethane, mg/kg dw	ND	ND	ND
1,2-Dichloropropane, mg/kg dw	ND	ND	ND
Trichloroethene, mg/kg dw	ND	ND	ND
Dibromochloromethane, mg/kg dw	ND	ND	ND
1,1,2-Trichloroethane, mg/kg dw	ND	ND	ND
Benzene, mg/kg dw	ND	ND	ND
cis-1,3-Dichloropropene, mg/kg dw	ND	ND	ND
2-Chloroethylvinyl ether, mg/kg dw	ND	ND	ND
Toluene, mg/kg dw	ND	ND	ND

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80961-12	SS24 (#13634)	02-15-96

PARAMETER	80961-10	80961-11	80961-12
Chlorobenzene, mg/kg dw	ND	ND	ND
Ethylbenzene, mg/kg dw	ND	ND	ND
1,2-Dibromoethane (EDB) , mg/kg dw	ND	ND	ND
Methyl tert-butyl ether (MTBE), mg/kg dw	ND	ND	ND
m&p-Xylene, mg/kg dw	ND	ND	ND
o-Xylene, mg/kg dw	ND	ND	ND
Trichlorofluoromethane, mg/kg dw	ND	ND	ND
Dichlorodifluoromethane, mg/kg dw	ND	ND	ND
Arsenic (6010), mg/kg dw	9.8	6.3	7.6
Chromium (6010), mg/kg dw	52	25	26
Copper (6010), mg/kg dw	42	19	12
Percent Solids (160.3), %	32	26	29

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80961-13	Method Blank
80961-14	Detection Limits
80961-15	Accuracy (mean % recovery)
80961-16	Precision (% RPD)
80961-17	Analyst Initials

PARAMETER	80961-13	80961-14	80961-15	80961-16	80961-17
Semivolatile Organics (8270)					
Naphthalene, mg/kg dw	ND	0.33	72 %	4 %	RALS
bis(2-Chloroethyl)ether, mg/kg dw	ND	0.33	---	---	RALS
Acenaphthylene, mg/kg dw	ND	0.33	76 %	8 %	RALS
Acenaphthene, mg/kg dw	ND	0.33	76 %	8 %	RALS
Phenanthrene, mg/kg dw	ND	0.33	79 %	8 %	RALS
Anthracene, mg/kg dw	ND	0.33	79 %	8 %	RALS
Fluoranthene, mg/kg dw	ND	0.33	79 %	8 %	RALS
Chrysene, mg/kg dw	ND	0.33	67 %	9 %	RALS
Benzo(a)anthracene, mg/kg dw	ND	0.33	64 %	9 %	RALS
Benzo(b)fluoranthene, mg/kg dw	ND	0.33	79 %	8 %	RALS
Benzo(k)fluoranthene, mg/kg dw	ND	0.33	90 %	10 %	RALS
Benzo(a)pyrene, mg/kg dw	ND	0.33	79 %	8 %	RALS
Indeno(1,2,3-cd)pyrene, mg/kg dw	ND	0.33	64 %	9 %	RALS
Dibenzo(a,h)anthracene, mg/kg dw	ND	0.33	66 %	4 %	RALS
2-Chlorophenol, mg/kg dw	ND	0.33	66 %	4 %	RALS
Phenol, mg/kg dw	ND	0.33	66 %	14 %	RALS
2,4-Dimethylphenol, mg/kg dw	ND	0.33	67 %	9 %	RALS
2,4,6-Trichlorophenol, mg/kg dw	ND	0.33	73 %	8 %	RALS
4-Chloro-3-methylphenol, mg/kg dw	ND	0.33	73 %	16 %	RALS

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80961-14	Detection Limits
80961-15	Accuracy (mean % recovery)
80961-16	Precision (% RPD)
80961-17	Analyst Initials

PARAMETER	80961-13	80961-14	80961-15	80961-16	80961-17
2,4-Dinitrophenol, mg/kg dw	ND	1.7	40 %	37 %	RALS
Pentachlorophenol, mg/kg dw	ND	1.7	70 %	8 %	RALS
2,4,5-Trichlorophenol, mg/kg dw	ND	0.33	---	---	RALS
Carbazole, mg/kg dw	ND	0.33	70 %	12 %	RALS
Tetrachlorophenols, mg/kg dw	ND	1.7	70 %	17 %	RALS
Dilution factor	1.0	1.0	---	---	---

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80961-13	Method Blank
80961-14	Detection Limits
80961-15	Accuracy (mean % recovery)
80961-16	Precision (% RPD)
80961-17	Analyst Initials

PARAMETER	80961-13	80961-14	80961-15	80961-16	80961-17
Volatiles by GC/MS (8240)					
Chloromethane, mg/kg dw	ND	0.010	---	---	CD
Bromomethane, mg/kg dw	ND	0.010	---	---	CD
Vinyl chloride, mg/kg dw	ND	0.010	---	---	CD
Chloroethane, mg/kg dw	ND	0.010	---	---	CD
Methylene chloride (Dichloromethane), mg/kg dw	ND	0.0050	---	---	CD
1,1-Dichloroethene, mg/kg dw	ND	0.0050	112 %	0 %	CD
1,1-Dichloroethane, mg/kg dw	ND	0.0050	---	---	CD
trans-1,2-Dichloroethylene, mg/kg dw	ND	0.0050	---	---	CD
1,2-Dichloroethane, mg/kg dw	ND	0.0050	---	---	CD
1,1,1-Trichloroethane, mg/kg dw	ND	0.0050	---	---	CD
Carbon tetrachloride, mg/kg dw	ND	0.0050	---	---	CD
Bromodichloromethane, mg/kg dw	ND	0.0050	---	---	CD
1,1,2,2-Tetrachloroethane, mg/kg dw	ND	0.0050	---	---	CD
1,2-Dichloropropane, mg/kg dw	ND	0.0050	---	---	CD
Trichloroethene, mg/kg dw	ND	0.0050	103 %	6 %	CD
Dibromochloromethane, mg/kg dw	ND	0.0050	---	---	CD
1,1,2-Trichloroethane, mg/kg dw	ND	0.0050	---	---	CD
Benzene, mg/kg dw	ND	0.0050	112 %	4 %	CD

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80961-13	Method Blank
80961-14	Detection Limits
80961-15	Accuracy (mean % recovery)
80961-16	Precision (% RPD)
80961-17	Analyst Initials

PARAMETER	80961-13	80961-14	80961-15	80961-16	80961-17
cis-1,3-Dichloropropene, mg/kg dw	ND	0.0050	---	---	CD
2-Chloroethylvinyl ether, mg/kg dw	ND	0.050	---	---	CD
Toluene, mg/kg dw	ND	0.0050	105 %	2 %	CD
Chlorobenzene, mg/kg dw	ND	0.0050	107 %	2 %	CD
Ethylbenzene, mg/kg dw	ND	0.0050	---	---	CD
1,2-Dibromoethane (EDB) , mg/kg dw	ND	0.0050	---	---	CD
Methyl tert-butyl ether (MTBE), mg/kg dw	ND	0.010	---	---	CD
m&p-Xylene, mg/kg dw	ND	0.0050	---	---	CD
o-Xylene, mg/kg dw	ND	0.0050	---	---	CD
Trichlorofluoromethane, mg/kg dw	ND	0.0050	---	---	CD
Dichlorodifluoromethane, mg/kg dw	ND	0.0050	---	---	CD
Arsenic (6010), mg/kg dw	ND	1.0	94 %	3.2 %	DM
Chromium (6010), mg/kg dw	ND	1.0	93 %	0 %	DM
Copper (6010), mg/kg dw	ND	2.5	94 %	2.1 %	DM
Total Organic Carbon (415.1), mg/kg dw	ND	100	116 %	1.7 %	TH

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80961-13	Method Blank
80961-14	Detection Limits
80961-15	Accuracy (mean % recovery)
80961-16	Precision (% RPD)
80961-17	Analyst Initials

PARAMETER	80961-13	80961-14	80961-15	80961-16	80961-17
AVS Extractable Metals					
Cadmium (6010), mg/kg dw	ND	0.072	109 %	0 %	JM
Copper (6010), mg/kg dw	ND	0.36	113 %	0 %	JM
Nickel (6010), mg/kg dw	ND	0.58	112 %	0.90 %	JM
Zinc (6010), mg/kg dw	ND	0.29	111 %	0 %	JM
Lead (6010), mg/kg dw	ND	0.72	106 %	0.94 %	JM
Acid Volatile Sulfide, mg/kg dw	ND	10	104 %	17 %	AW

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80961-18	EPA Method Numbers
80961-19	Dates Extracted
80961-20	Dates Analyzed

PARAMETER	80961-18	80961-19	80961-20
Semivolatile Organics (8270)			
Naphthalene	8270	02.21.96	2.26/28.96
bis(2-Chloroethyl)ether	8270	02.21.96	2.26/28.96
Acenaphthylene	8270	02.21.96	2.26/28.96
Acenaphthene	8270	02.21.96	2.26/28.96
Phenanthrene	8270	02.21.96	2.26/28.96
Anthracene	8270	02.21.96	2.26/28.96
Fluoranthene	8270	02.21.96	2.26/28.96
Chrysene	8270	02.21.96	2.26/28.96
Benzo(a)anthracene	8270	02.21.96	2.26/28.96
Benzo(b)fluoranthene	8270	02.21.96	2.26/28.96
Benzo(k)fluoranthene	8270	02.21.96	2.26/28.96
Benzo(a)pyrene	8270	02.21.96	2.26/28.96
Indeno(1,2,3-cd)pyrene	8270	02.21.96	2.26/28.96
Dibenzo(a,h)anthracene	8270	02.21.96	2.26/28.96
2-Chlorophenol	8270	02.21.96	2.26/28.96
Phenol	8270	02.21.96	2.26/28.96
2,4-Dimethylphenol	8270	02.21.96	2.26/28.96
2,4,6-Trichlorophenol	8270	02.21.96	2.26/28.96
4-Chloro-3-methylphenol	8270	02.21.96	2.26/28.96
2,4-Dinitrophenol	8270	02.21.96	2.26/28.96
Pentachlorophenol	8270	02.21.96	2.26/28.96
2,4,5-Trichlorophenol	8270	02.21.96	2.26/28.96
Carbazole	8270	08.21.96	2.26/28.96
Tetrachlorophenols	8270	08.21.96	2.26/28.96

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LOG NO: S6-80961
Received: 17 FEB 96
Reported: 29 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80961-18	EPA Method Numbers
80961-19	Dates Extracted
80961-20	Dates Analyzed

PARAMETER	80961-18	80961-19	80961-20
Volatiles by GC/MS (8240)			
Chloromethane	8240	---	02.24.96
Bromomethane	8240	---	02.24.96
Vinyl chloride	8240	---	02.24.96
Chloroethane	8240	---	02.24.96
Methylene chloride (Dichloromethane)	8240	---	02.24.96
1,1-Dichloroethene	8240	---	02.24.96
1,1-Dichloroethane	8240	---	02.24.96
trans-1,2-Dichloroethylene	8240	---	02.24.96
1,2-Dichloroethane	8240	---	02.24.96
1,1,1-Trichloroethane	8240	---	02.24.96
Carbon tetrachloride	8240	---	02.24.96
Bromodichloromethane	8240	---	02.24.96
1,1,2,2-Tetrachloroethane	8240	---	02.24.96
1,2-Dichloropropane	8240	---	02.24.96
Trichloroethene	8240	---	02.24.96
Dibromochloromethane	8240	---	02.24.96
1,1,2-Trichloroethane	8240	---	02.24.96
Benzene	8240	---	02.24.96
cis-1,3-Dichloropropene	8240	---	02.24.96
2-Chloroethylvinyl ether	8240	---	02.24.96
Toluene	8240	---	02.24.96

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80961-18	EPA Method Numbers
80961-19	Dates Extracted
80961-20	Dates Analyzed

PARAMETER	80961-18	80961-19	80961-20
Chlorobenzene	8240	---	02.24.96
Ethylbenzene	8240	---	02.24.96
1,2-Dibromoethane (EDB)	8240	---	02.24.96
Methyl tert-butyl ether (MTBE)	8240	---	02.24.96
m&p-Xylene	8240	---	02.24.96
o-Xylene	8240	---	02.24.96
Trichlorofluoromethane	8240	---	02.24.96
Dichlorodifluoromethane	8240	---	02.24.96
Arsenic (6010)	6010	---	02.27.96
Chromium (6010)	6010	---	02.27.96
Copper (6010)	6010	---	02.27.96
Total Organic Carbon (415.1)	9060	---	02.22.96
AVS Extractable Metals			
Cadmium (6010)	6010	02.22.96	02.23.96
Copper (6010)	6010	02.22.96	02.23.96
Nickel (6010)	6010	02.22.96	02.23.96
Zinc (6010)	6010	02.22.96	02.23.96
Lead (6010)	6010	02.22.96	02.23.96
Acid Volatile Sulfide	68-03-3534	---	02.29.96

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Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80935-13	SS-9 (0-3") (# 13608)	02-15-96
80935-14	SS-11 (0-6") (# 13609)	02-15-96
80935-15	SS-8 (0-6") (# 13610)	02-15-96
80935-16	SS-7 (0-6") (# 13611)	02-15-96
80935-17	SS-1 (0-6") (# 13612)	02-15-96

PARAMETER	80935-13	80935-14	80935-15	80935-16	80935-17
AVS Extractable Metals					
Cadmium (6010), mg/kg dw	ND	ND	0.31	0.18	0.97
Copper (6010), mg/kg dw	0:58	1.7	10	3.0	21
Nickel (6010), mg/kg dw	ND	ND	1.5	ND	2.8
Zinc (6010), mg/kg dw	6.7	8.9	89	36	160
Lead (6010), mg/kg dw	5.0	5.6	54	22	220
Acid Volatile Sulfide, mg/kg dw	ND	ND	370	ND	ND
Total Organic Carbon (415.1), mg/kg dw	3000	4600	41000	25000	99000
Percent Solids (160.3), %	80	78	46	52	26

October 1990
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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80935-18	SS-12 (0-6") (# 13613)	02-15-96
80935-19	SS-12 DUP (0-6") (# 13614)	02-15-96
80935-20	SS-13 (0-6") (# 13615)	02-15-96

PARAMETER	80935-18	80935-19	80935-20
Semivolatile Organics (8270)			
bis(2-Chloroethyl)ether, mg/kg dw	ND	ND	ND
Naphthalene, mg/kg dw	ND	ND	ND
Acenaphthylene, mg/kg dw	ND	ND	ND
Acenaphthene, mg/kg dw	1.8	1.9	ND
Phenanthrene, mg/kg dw	ND	ND	ND
Anthracene, mg/kg dw	1.1	ND	ND
Fluoranthene, mg/kg dw	6.8	6.0	10
Chrysene, mg/kg dw	2.4	1.6	3.0
Benzo(a)anthracene, mg/kg dw	1.9	1.4	2.3
Benzo(b)fluoranthene, mg/kg dw	2.0	1.5	2.2
Benzo(k)fluoranthene, mg/kg dw	ND	ND	ND
Benzo(a)pyrene, mg/kg dw	0.99	0.73	ND
Indeno(1,2,3-cd)pyrene, mg/kg dw	ND	ND	ND
Dibenzo(a,h)anthracene, mg/kg dw	ND	ND	ND
2-Chlorophenol, mg/kg dw	ND	ND	ND
Phenol, mg/kg dw	ND	ND	ND
2,4-Dimethylphenol, mg/kg dw	ND	ND	ND
2,4,6-Trichlorophenol, mg/kg dw	ND	ND	ND
4-Chloro-3-methylphenol, mg/kg dw	ND	ND	ND
2,4-Dinitrophenol, mg/kg dw	ND	ND	ND
Pentachlorophenol, mg/kg dw	ND	ND	ND
2,4,5-Trichlorophenol, mg/kg dw	ND	ND	ND
Carbazole, mg/kg dw	ND	ND	ND
Tetrachlorophenols, mg/kg dw	ND	ND	ND
Dilution factor	1.0	1.0	1.0

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80935-18	SS-12 (0-6") (# 13613)	02-15-96
80935-19	SS-12 DUP (0-6") (# 13614)	02-15-96
80935-20	SS-13 (0-6") (# 13615)	02-15-96

PARAMETER	80935-18	80935-19	80935-20
Volatiles by GC/MS (8240)			
Chloromethane, mg/kg dw	ND	ND	ND
Bromomethane, mg/kg dw	ND	ND	ND
Vinyl chloride, mg/kg dw	ND	ND	ND
Chloroethane, mg/kg dw	ND	ND	ND
Methylene chloride (Dichloromethane), mg/kg dw	ND	ND	ND
1,1-Dichloroethene, mg/kg dw	ND	ND	ND
1,1-Dichloroethane, mg/kg dw	ND	ND	ND
trans-1,2-Dichloroethylene, mg/kg dw	ND	ND	ND
1,2-Dichloroethane, mg/kg dw	ND	ND	ND
1,1,1-Trichloroethane, mg/kg dw	ND	ND	ND
Carbon tetrachloride, mg/kg dw	ND	ND	ND
Bromodichloromethane, mg/kg dw	ND	ND	ND
1,1,2,2-Tetrachloroethane, mg/kg dw	ND	ND	ND
1,2-Dichloropropane, mg/kg dw	ND	ND	ND
Trichloroethene, mg/kg dw	ND	ND	ND
Dibromochloromethane, mg/kg dw	ND	ND	ND
1,1,2-Trichloroethane, mg/kg dw	ND	ND	ND
Benzene, mg/kg dw	ND	ND	ND
cis-1,3-Dichloropropene, mg/kg dw	ND	ND	ND
2-Chloroethylvinyl ether, mg/kg dw	ND	ND	ND
Toluene, mg/kg dw	ND	ND	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
80935-18	SS-12 (0-6") (# 13613)	02-15-96
80935-19	SS-12 DUP (0-6") (# 13614)	02-15-96
80935-20	SS-13 (0-6") (# 13615)	02-15-96

PARAMETER	80935-18	80935-19	80935-20
Chlorobenzene, mg/kg dw	ND	ND	ND
Ethylbenzene, mg/kg dw	ND	ND	ND
1,2-Dibromomethane, mg/kg dw	ND	ND	ND
Trichlorofluoromethane, mg/kg dw	ND	ND	ND
Methyl tert-butyl ether (MTBE), mg/kg dw	ND	ND	ND
Dichlorodifluoromethane, mg/kg dw	ND	ND	ND
m&p-Xylene, mg/kg dw	ND	ND	ND
o-Xylene, mg/kg dw	ND	ND	ND
Arsenic (6010), mg/kg dw	4.4	4.9	ND
Chromium (6010), mg/kg dw	2.4	2.4	ND
Copper (6010), mg/kg dw	11	13	16
Percent Solids (160.3), %	51	49	25

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80935-21	Method Blank
80935-22	Detection Limits
80935-23	Accuracy (mean % recovery)
80935-24	Precision (% RPD)
80935-25	Analyst Initials

PARAMETER	80935-21	80935-22	80935-23	80935-24	80935-25
Semivolatile Organics (8270)					
bis(2-Chloroethyl)ether, mg/kg dw	ND	0.33	---	---	CB
Naphthalene, mg/kg dw	ND	0.33	74 %	4 %	CB
Acenaphthylene, mg/kg dw	ND	0.33	73 %	0 %	CB
Acenaphthene, mg/kg dw	ND	0.33	72 %	0 %	CB
Phenanthrene, mg/kg dw	ND	0.33	74 %	4 %	CB
Anthracene, mg/kg dw	ND	0.33	76 %	0 %	CB
Fluoranthene, mg/kg dw	ND	0.33	91 %	0 %	CB
Chrysene, mg/kg dw	ND	0.33	82 %	0 %	CB
Benzo(a)anthracene, mg/kg dw	ND	0.33	82 %	0 %	CB
Benzo(b)fluoranthene, mg/kg dw	ND	0.33	88 %	0 %	CB
Benzo(k)fluoranthene, mg/kg dw	ND	0.33	80 %	4 %	CB
Benzo(a)pyrene, mg/kg dw	ND	0.33	82 %	0 %	CB
Indeno(1,2,3-cd)pyrene, mg/kg dw	ND	0.33	66 %	4 %	CB
Dibenzo(a,h)anthracene, mg/kg dw	ND	0.33	66 %	4 %	CB
2-Chlorophenol, mg/kg dw	ND	0.33	76 %	8 %	CB
Phenol, mg/kg dw	ND	0.33	68 %	4 %	CB
2,4-Dimethylphenol, mg/kg dw	ND	0.33	73 %	8 %	CB
2,4,6-Trichlorophenol, mg/kg dw	ND	0.33	90 %	3 %	CB
4-Chloro-3-methylphenol, mg/kg dw	ND	0.33	86 %	3 %	CB

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80935-21	Method Blank
80935-22	Detection Limits
80935-23	Accuracy (mean % recovery)
80935-24	Precision (% RPD)
80935-25	Analyst Initials

PARAMETER	80935-21	80935-22	80935-23	80935-24	80935-25
2,4-Dinitrophenol, mg/kg dw	ND	1.7	39 %	15 %	CB
Pentachlorophenol, mg/kg dw	ND	1.7	46 %	6 %	CB
2,4,5-Trichlorophenol, mg/kg dw	ND	0.33	---	---	CB
Carbazole, mg/kg dw	ND	0.33	64 %	0 %	CB
Tetrachlorophenols, mg/kg dw	ND	1.7	79 %	0 %	CB
Dilution factor	1.0	1.0	---	---	---

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80935-21	Method Blank
80935-22	Detection Limits
80935-23	Accuracy (mean % recovery)
80935-24	Precision (% RPD)
80935-25	Analyst Initials

PARAMETER	80935-21	80935-22	80935-23	80935-24	80935-25
Volatiles by GC/MS (8240)					
Chloromethane, mg/kg dw	ND	0.010	---	---	CD
Bromomethane, mg/kg dw	ND	0.010	---	---	CD
Vinyl chloride, mg/kg dw	ND	0.010	---	---	CD
Chloroethane, mg/kg dw	ND	0.010	---	---	CD
Methylene chloride (Dichloromethane), mg/kg dw	ND	0.0050	---	---	CD
1,1-Dichloroethene, mg/kg dw	ND	0.0050	107 %	2 %	CD
1,1-Dichloroethane, mg/kg dw	ND	0.0050	---	---	CD
trans-1,2-Dichloroethylene, mg/kg dw	ND	0.0050	---	---	CD
1,2-Dichloroethane, mg/kg dw	ND	0.0050	---	---	CD
1,1,1-Trichloroethane, mg/kg dw	ND	0.0050	---	---	CD
Carbon tetrachloride, mg/kg dw	ND	0.0050	---	---	CD
Bromodichloromethane, mg/kg dw	ND	0.0050	---	---	CD
1,1,2,2-Tetrachloroethane, mg/kg dw	ND	0.0050	---	---	CD
1,2-Dichloropropane, mg/kg dw	ND	0.0050	---	---	CD
Trichloroethene, mg/kg dw	ND	0.0050	105 %	6 %	CD
Dibromochloromethane, mg/kg dw	ND	0.0050	---	---	CD
1,1,2-Trichloroethane, mg/kg dw	ND	0.0050	---	---	CD
Benzene, mg/kg dw	ND	0.0050	98 %	0 %	CD

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80935-21	Method Blank
80935-22	Detection Limits
80935-23	Accuracy (mean % recovery)
80935-24	Precision (% RPD)
80935-25	Analyst Initials

PARAMETER	80935-21	80935-22	80935-23	80935-24	80935-25
cis-1,3-Dichloropropene, mg/kg dw	ND	0.0050	---	---	CD
2-Chloroethylvinyl ether, mg/kg dw	ND	0.050	---	---	CD
Toluene, mg/kg dw	ND	0.0050	94 %	4 %	CD
Chlorobenzene, mg/kg dw	ND	0.0050	101 %	6 %	CD
Ethylbenzene, mg/kg dw	ND	0.0050	---	---	CD
1,2-Dibromomethane, mg/kg dw	ND	0.0050	---	---	CD
Trichlorofluoromethane, mg/kg dw	ND	0.0050	---	---	CD
Methyl tert-butyl ether (MTBE), mg/kg dw	ND	0.050	---	---	CD
Dichlorodifluoromethane, mg/kg dw	ND	0.0050	---	---	CD
m&p-Xylene, mg/kg dw	ND	0.0050	---	---	CD
o-Xylene, mg/kg dw	ND	0.0050	---	---	CD
Arsenic (6010), mg/kg dw	ND	1.0	88 %	1.1 %	DM
Chromium (6010), mg/kg dw	ND	1.0	100 %	1.0 %	DM
Copper (6010), mg/kg dw	ND	2.5	98 %	1.0 %	DM
Total Organic Carbon (415.1), mg/kg dw	ND	100	117 %	1.7 %	TH
Total Kjeldahl Nitrogen-N, mg/kg dw	ND	25	87 %	2.3 %	MM
Nitrate + Nitrite-N, mg/kg dw	ND	5.0	100 %	2.0 %	MM
Total Phosphorus (365.4), mg/kg dw	ND	25	98 %	2.0 %	TH
pH (9045), units	---	---	100 %	0 %	SJR
Chloride, mg/kg dw	ND	20	102 %	2.0 %	MM

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80935-21	Method Blank
80935-22	Detection Limits
80935-23	Accuracy (mean % recovery)
80935-24	Precision (% RPD)
80935-25	Analyst Initials

PARAMETER	80935-21	80935-22	80935-23	80935-24	80935-25
AVS Extractable Metals					
Cadmium (6010), mg/kg dw	ND	0.072	109 %	0 %	JM
Copper (6010), mg/kg dw	ND	0.36	113 %	0 %	JM
Nickel (6010), mg/kg dw	ND	0.58	112 %	0.90 %	JM
Zinc (6010), mg/kg dw	ND	0.29	111 %	0 %	JM
Lead (6010), mg/kg dw	ND	0.72	106 %	0.94 %	JM
Acid Volatile Sulfide, mg/kg dw	ND	10	104 %	17 %	AW

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80935-26	EPA Method Numbers
80935-27	Dates Extracted
80935-28	Dates Analyzed

PARAMETER	80935-26	80935-27	80935-28
Semivolatile Organics (8270)			
bis(2-Chloroethyl)ether	8270	02.19.96	02.21.96
Naphthalene	8270	02.19.96	02.21.96
Acenaphthylene	8270	02.19.96	02.21.96
Acenaphthene	8270	02.19.96	02.21.96
Phenanthrene	8270	02.19.96	02.21.96
Anthracene	8270	02.19.96	02.21.96
Fluoranthene	8270	02.19.96	02.21.96
Chrysene	8270	02.19.96	02.21.96
Benzo(a)anthracene	8270	02.19.96	02.21.96
Benzo(b)fluoranthene	8270	02.19.96	02.21.96
Benzo(k)fluoranthene	8270	02.19.96	02.21.96
Benzo(a)pyrene	8270	02.19.96	02.21.96
Indeno(1,2,3-cd)pyrene	8270	02.19.96	02.21.96
Dibenzo(a,h)anthracene	8270	02.19.96	02.21.96
2-Chlorophenol	8270	02.19.96	02.21.96
Phenol	8270	02.19.96	02.21.96
2,4-Dimethylphenol	8270	02.19.96	02.21.96
2,4,6-Trichlorophenol	8270	02.19.96	02.21.96
4-Chloro-3-methylphenol	8270	02.19.96	02.21.96
2,4-Dinitrophenol	8270	02.19.96	02.21.96
Pentachlorophenol	8270	02.19.96	02.21.96
2,4,5-Trichlorophenol	8270	02.19.96	02.21.96
Carbazole	8270	02.19.96	02.21.96
Tetrachlorophenols	8270	02.19.96	02.21.96

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Reported: 29 FEB 96

Ms. Sandra Watson
Southern Wood Piedmont (WI)
P.O. Box 5477
Spartanburg, SC 29304

CC: Greg Kuntz-ETE

Project: Wilmington, NC 12-53020.00
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
80935-26	EPA Method Numbers
80935-27	Dates Extracted
80935-28	Dates Analyzed

PARAMETER	80935-26	80935-27	80935-28
Volatiles by GC/MS (8240)			
Chloromethane	8240	---	02.20.96
Bromomethane	8240	---	02.20.96
Vinyl chloride	8240	---	02.20.96
Chloroethane	8240	---	02.20.96
Methylene chloride (Dichloromethane)	8240	---	02.20.96
1,1-Dichloroethene	8240	---	02.20.96
1,1-Dichloroethane	8240	---	02.20.96
trans-1,2-Dichloroethylene	8240	---	02.20.96
1,2-Dichloroethane	8240	---	02.20.96
1,1,1-Trichloroethane	8240	---	02.20.96
Carbon tetrachloride	8240	---	02.20.96
Bromodichloromethane	8240	---	02.20.96
1,1,2,2-Tetrachloroethane	8240	---	02.20.96
1,2-Dichloropropane	8240	---	02.20.96
Trichloroethene	8240	---	02.20.96
Dibromochloromethane	8240	---	02.20.96
1,1,2-Trichloroethane	8240	---	02.20.96
Benzene	8240	---	02.20.96
cis-1,3-Dichloropropene	8240	---	02.20.96
2-Chloroethylvinyl ether	8240	---	02.20.96
Toluene	8240	---	02.20.96

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80935-26	EPA Method Numbers
80935-27	Dates Extracted
80935-28	Dates Analyzed

PARAMETER	80935-26	80935-27	80935-28
Chlorobenzene	8240	---	02.20.96
Ethylbenzene	8240	---	02.20.96
1,2-Dibromomethane	8240	---	02.20.96
Trichlorofluoromethane	8240	---	02.20.96
Methyl tert-butyl ether (MTBE)	8240	---	02.20.96
Dichlorodifluoromethane	8240	---	02.20.96
m&p-Xylene	8240	---	02.20.96
o-Xylene	8240	---	02.20.96
Arsenic (6010)	6010	---	02.21.96
Chromium (6010)	6010	---	02.22.96
Copper (6010)	6010	---	02.21.96
Total Organic Carbon (415.1)	9060	---	02.20.96
Total Kjeldahl Nitrogen-N	3-202	---	02.23.96
Nitrate + Nitrite-N	EPACE3-183	02.21.96	02.23.96
Total Phosphorus (365.4)	365.4	---	02.27.96
pH (9045)	9045	02.27.96	02.27.96
Chloride	9251	02.21.96	02.23.96
AVS Extractable Metals			
Cadmium (6010)	6010	02.22.96	02.23.96
Copper (6010)	6010	02.22.96	02.23.96
Nickel (6010)	6010	02.22.96	02.23.96
Zinc (6010)	6010	02.22.96	02.23.96
Lead (6010)	6010	02.22.96	02.23.96
Acid Volatile Sulfide	68-03-3534	---	02.29.96

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80935-29	Equipment Blank-LF	02-15-96
80935-30	Equipment Blank-SS	02-15-96

PARAMETER	80935-29	80935-30
Semivolatile Organics (8270)		
bis(2-Chloroethyl)ether, mg/l	ND	ND
Naphthalene, mg/l	ND	ND
Acenaphthylene, mg/l	ND	ND
Acenaphthene, mg/l	ND	ND
Phenanthrene, mg/l	ND	ND
Anthracene, mg/l	ND	ND
Fluoranthene, mg/l	ND	ND
Chrysene, mg/l	ND	ND
Benzo(a)anthracene, mg/l	ND	ND
Benzo(b)fluoranthene, mg/l	ND	ND
Benzo(k)fluoranthene, mg/l	ND	ND
Benzo(a)pyrene, mg/l	ND	ND
Indeno(1,2,3-cd)pyrene, mg/l	ND	ND
Dibenzo(a,h)anthracene, mg/l	ND	ND
2-Chlorophenol, mg/l	ND	ND
Phenol, mg/l	ND	ND
2,4-Dimethylphenol, mg/l	ND	ND
2,4,6-Trichlorophenol, mg/l	ND	ND
4-Chloro-3-methylphenol, mg/l	ND	ND
2,4-Dinitrophenol, mg/l	ND	ND
Pentachlorophenol, mg/l	ND	ND
2,4,5-Trichlorophenol, mg/l	ND	ND
Carbazole, mg/l	ND	ND
Tetrachlorophenols, mg/l	ND	ND
Dilution factor	1.0	1.0

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80935-29	Equipment Blank-LF	02-15-96
80935-30	Equipment Blank-SS	02-15-96

PARAMETER	80935-29	80935-30
Volatiles by GC/MS (8240)		
Chloromethane, mg/l	ND	ND
Bromomethane, mg/l	ND	ND
Vinyl chloride, mg/l	ND	ND
Chloroethane, mg/l	ND	ND
Methylene chloride (Dichloromethane), mg/l	ND	ND
1,1-Dichloroethene, mg/l	ND	ND
1,1-Dichloroethane, mg/l	ND	ND
trans-1,2-Dichloroethylene, mg/l	ND	ND
1,2-Dichloroethane, mg/l	ND	ND
1,1,1-Trichloroethane, mg/l	ND	ND
Carbon tetrachloride, mg/l	ND	ND
Bromodichloromethane, mg/l	ND	ND
1,1,2,2-Tetrachloroethane, mg/l	ND	ND
1,2-Dichloropropane, mg/l	ND	ND
Trichloroethene, mg/l	ND	ND
Dibromochloromethane, mg/l	ND	ND
1,1,2-Trichloroethane, mg/l	ND	ND
Benzene, mg/l	ND	ND
cis-1,3-Dichloropropene, mg/l	ND	ND
2-Chloroethylvinyl ether, mg/l	ND	ND
Toluene, mg/l	ND	ND
Chlorobenzene, mg/l	ND	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
80935-29	Equipment Blank-LF	02-15-96
80935-30	Equipment Blank-SS	02-15-96

PARAMETER	80935-29	80935-30
Ethylbenzene, mg/l	ND	ND
1,2-Dibromomethane, mg/l	ND	ND
Trichlorofluoromethane, mg/l	ND	ND
Methyl tert-butyl ether (MTBE), mg/l	ND	ND
Dichlorodifluoromethane, mg/l	ND	ND
m&p-Xylene, mg/l	ND	ND
o-Xylene, mg/l	ND	ND
Arsenic (6010), mg/l	ND	ND
Chromium (6010), mg/l	ND	ND
Copper (6010), mg/l	ND	ND

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80935-31	Method Blank
80935-32	Detection Limits
80935-33	Accuracy (mean % recovery)
80935-34	Precision (% RPD)
80935-35	Analyst Initials

PARAMETER	80935-31	80935-32	80935-33	80935-34	80935-35
Semivolatile Organics (8270)					
bis(2-Chloroethyl)ether, mg/l	ND	0.010	---	---	LB
Naphthalene, mg/l	ND	0.010	62 %	2 %	LB
Acenaphthylene, mg/l	ND	0.010	76 %	1 %	LB
Acenaphthene, mg/l	ND	0.010	76 %	1 %	LB
Phenanthrene, mg/l	ND	0.010	78 %	0 %	LB
Anthracene, mg/l	ND	0.010	78 %	1 %	LB
Fluoranthene, mg/l	ND	0.010	79 %	0 %	LB
Chrysene, mg/l	ND	0.010	78 %	1 %	LB
Benzo(a)anthracene, mg/l	ND	0.010	88 %	0 %	LB
Benzo(b)fluoranthene, mg/l	ND	0.010	73 %	3 %	LB
Benzo(k)fluoranthene, mg/l	ND	0.010	78 %	0 %	LB
Benzo(a)pyrene, mg/l	ND	0.010	76 %	1 %	LB
Indeno(1,2,3-cd)pyrene, mg/l	ND	0.010	77 %	0 %	LB
Dibenzo(a,h)anthracene, mg/l	ND	0.010	74 %	0 %	LB
2-Chlorophenol, mg/l	ND	0.010	72 %	0 %	LB
Phenol, mg/l	ND	0.010	66 %	0 %	LB
2,4-Dimethylphenol, mg/l	ND	0.010	75 %	3 %	LB
2,4,6-Trichlorophenol, mg/l	ND	0.010	74 %	1 %	LB
4-Chloro-3-methylphenol, mg/l	ND	0.010	72 %	0 %	LB

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80935-31	Method Blank
80935-32	Detection Limits
80935-33	Accuracy (mean % recovery)
80935-34	Precision (% RPD)
80935-35	Analyst Initials

PARAMETER	80935-31	80935-32	80935-33	80935-34	80935-35
2,4-Dinitrophenol, mg/l	ND	0.050	105 %	10 %	LB
Pentachlorophenol, mg/l	ND	0.050	77 %	0 %	LB
2,4,5-Trichlorophenol, mg/l	ND	0.010	---	---	LB
Carbazole, mg/l	ND	0.010	84 %	1 %	LB
Tetrachlorophenols, mg/l	ND	0.050	74 %	0 %	LB
Dilution factor	1.0	1.0	---	---	---

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REPORT OF RESULTS

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80935-31	Method Blank
80935-32	Detection Limits
80935-33	Accuracy (mean % recovery)
80935-34	Precision (% RPD)
80935-35	Analyst Initials

PARAMETER	80935-31	80935-32	80935-33	80935-34	80935-35
Volatiles by GC/MS (8240)					
Chloromethane, mg/l	ND	0.010	---	---	CD
Bromomethane, mg/l	ND	0.010	---	---	CD
Vinyl chloride, mg/l	ND	0.010	---	---	CD
Chloroethane, mg/l	ND	0.010	---	---	CD
Methylene chloride (Dichloromethane), mg/l	ND	0.0050	---	---	CD
1,1-Dichloroethene, mg/l	ND	0.0050	110 %	4 %	CD
1,1-Dichloroethane, mg/l	ND	0.0050	---	---	CD
trans-1,2-Dichloroethylene, mg/l	ND	0.0050	---	---	CD
1,2-Dichloroethane, mg/l	ND	0.0050	---	---	CD
1,1,1-Trichloroethane, mg/l	ND	0.0050	---	---	CD
Carbon tetrachloride, mg/l	ND	0.0050	---	---	CD
Bromodichloromethane, mg/l	ND	0.0050	---	---	CD
1,1,2,2-Tetrachloroethane, mg/l	ND	0.0050	---	---	CD
1,2-Dichloropropane, mg/l	ND	0.0050	---	---	CD
Trichloroethene, mg/l	ND	0.0050	104 %	0 %	CD
Dibromochloromethane, mg/l	ND	0.0050	---	---	CD
1,1,2-Trichloroethane, mg/l	ND	0.0050	---	---	CD
Benzene, mg/l	ND	0.0050	99 %	2 %	CD

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80935-31	Method Blank
80935-32	Detection Limits
80935-33	Accuracy (mean % recovery)
80935-34	Precision (% RPD)
80935-35	Analyst Initials

PARAMETER	80935-31	80935-32	80935-33	80935-34	80935-35
cis-1,3-Dichloropropene, mg/l	ND	0.0050	---	---	CD
2-Chloroethylvinyl ether, mg/l	ND	0.050	---	---	CD
Toluene, mg/l	ND	0.0050	100 %	0 %	CD
Chlorobenzene, mg/l	ND	0.0050	101 %	2 %	CD
Ethylbenzene, mg/l	ND	0.0050	---	---	CD
1,2-Dibromomethane, mg/l	ND	0.0050	---	---	CD
Trichlorofluoromethane, mg/l	ND	0.0050	---	---	CD
Methyl tert-butyl ether (MTBE), mg/l	ND	0.050	---	---	CD
Dichlorodifluoromethane, mg/l	ND	0.0050	---	---	CD
m&p-Xylene, mg/l	ND	0.0050	---	---	CD
o-Xylene, mg/l	ND	0.0050	---	---	CD
Arsenic (6010), mg/l	ND	0.010	95 %	4.2 %	DM
Chromium (6010), mg/l	ND	0.010	100 %	4.0 %	DM
Copper (6010), mg/l	ND	0.025	100 %	5.0 %	DM

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REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80935-36	EPA Method Numbers
80935-37	Dates Extracted
80935-38	Dates Analyzed

PARAMETER	80935-36	80935-37	80935-38
Semivolatile Organics (8270)			
bis(2-Chloroethyl)ether	8270	02.19.96	02.22.96
Naphthalene	8270	02.19.96	02.22.96
Acenaphthylene	8270	02.19.96	02.22.96
Acenaphthene	8270	02.19.96	02.22.96
Phenanthrene	8270	02.19.96	02.22.96
Anthracene	8270	02.19.96	02.22.96
Fluoranthene	8270	02.19.96	02.22.96
Chrysene	8270	02.19.96	02.22.96
Benzo(a)anthracene	8270	02.19.96	02.22.96
Benzo(b)fluoranthene	8270	02.19.96	02.22.96
Benzo(k)fluoranthene	8270	02.19.96	02.22.96
Benzo(a)pyrene	8270	02.19.96	02.22.96
Indeno(1,2,3-cd)pyrene	8270	02.19.96	02.22.96
Dibenzo(a,h)anthracene	8270	02.19.96	02.22.96
2-Chlorophenol	8270	02.19.96	02.22.96
Phenol	8270	02.19.96	02.22.96
2,4-Dimethylphenol	8270	02.19.96	02.22.96
2,4,6-Trichlorophenol	8270	02.19.96	02.22.96
4-Chloro-3-methylphenol	8270	02.19.96	02.22.96
2,4-Dinitrophenol	8270	02.19.96	02.22.96
Pentachlorophenol	8270	02.19.96	02.22.96
2,4,5-Trichlorophenol	8270	02.19.96	02.22.96
Carbazole	8270	02.19.96	02.22.96
Tetrachlorophenols	8270	02.19.96	02.22.96

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80935-36	EPA Method Numbers
80935-37	Dates Extracted
80935-38	Dates Analyzed

PARAMETER	80935-36	80935-37	80935-38
Volatiles by GC/MS (8240)			
Chloromethane	8240	---	02.19.96
Bromomethane	8240	---	02.19.96
Vinyl chloride	8240	---	02.19.96
Chloroethane	8240	---	02.19.96
Methylene chloride (Dichloromethane)	8240	---	02.19.96
1,1-Dichloroethene	8240	---	02.19.96
1,1-Dichloroethane	8240	---	02.19.96
trans-1,2-Dichloroethylene	8240	---	02.19.96
1,2-Dichloroethane	8240	---	02.19.96
1,1,1-Trichloroethane	8240	---	02.19.96
Carbon tetrachloride	8240	---	02.19.96
Bromodichloromethane	8240	---	02.19.96
1,1,2,2-Tetrachloroethane	8240	---	02.19.96
1,2-Dichloropropane	8240	---	02.19.96
Trichloroethene	8240	---	02.19.96
Dibromochloromethane	8240	---	02.19.96
1,1,2-Trichloroethane	8240	---	02.19.96
Benzene	8240	---	02.19.96
cis-1,3-Dichloropropene	8240	---	02.19.96
2-Chloroethylvinyl ether	8240	---	02.19.96
Toluene	8240	---	02.19.96

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
80935-36	EPA Method Numbers
80935-37	Dates Extracted
80935-38	Dates Analyzed

PARAMETER	80935-36	80935-37	80935-38
Chlorobenzene	8240	---	02.19.96
Ethylbenzene	8240	---	02.19.96
1,2-Dibromomethane	8240	---	02.19.96
Trichlorofluoromethane	8240	---	02.19.96
Methyl tert-butyl ether (MTBE)	8240	---	02.19.96
Dichlorodifluoromethane	8240	---	02.19.96
m&p-Xylene	8240	---	02.19.96
o-Xylene	8240	---	02.19.96
Arsenic (6010)	6010	---	02.21.96
Chromium (6010)	6010	---	02.21.96
Copper (6010)	6010	---	02.21.96

Methods: EPA SW-846
ND = Not Detected

J. W. Andrews, Ph. D., Project Manager

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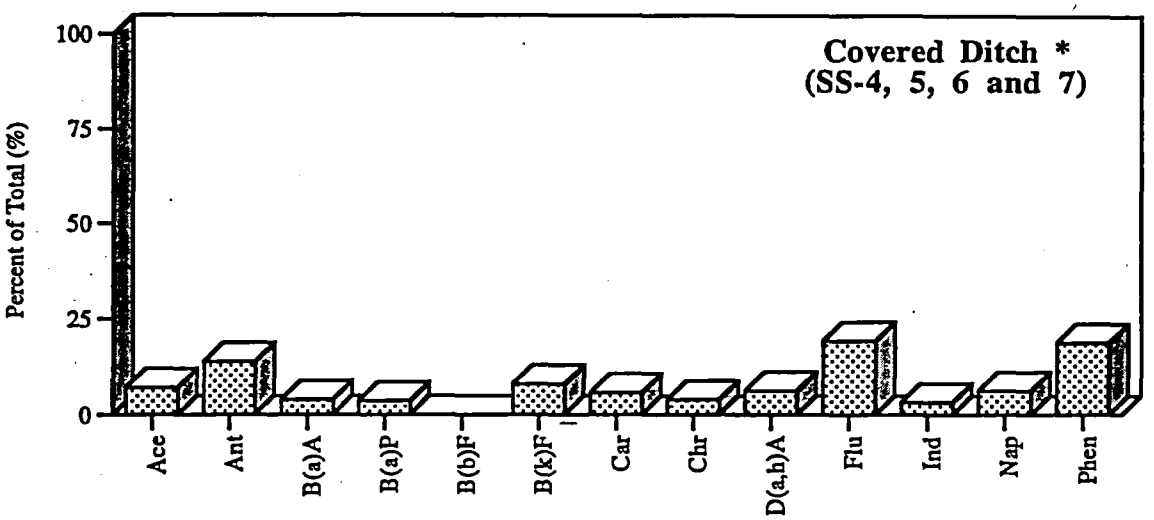
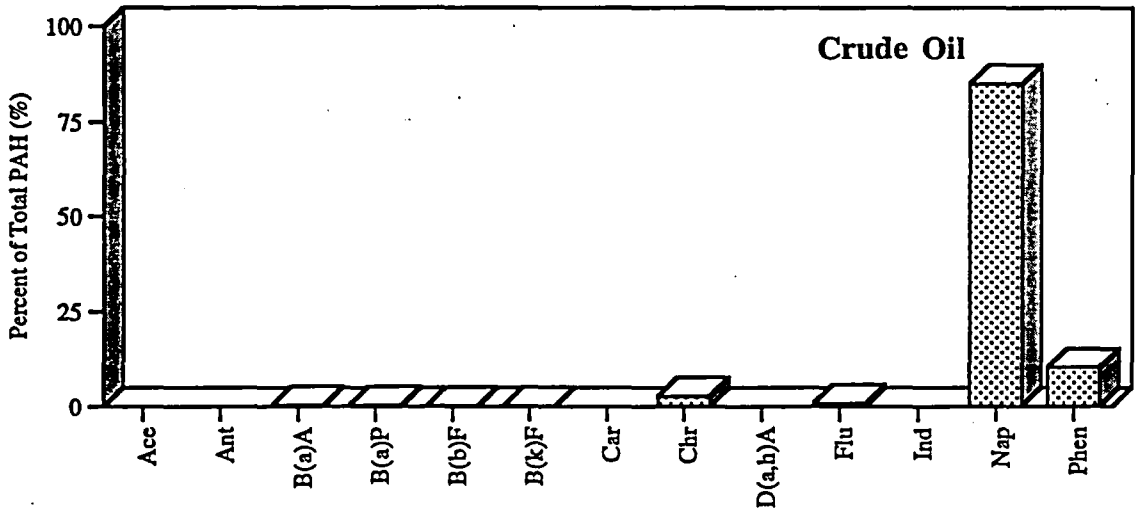
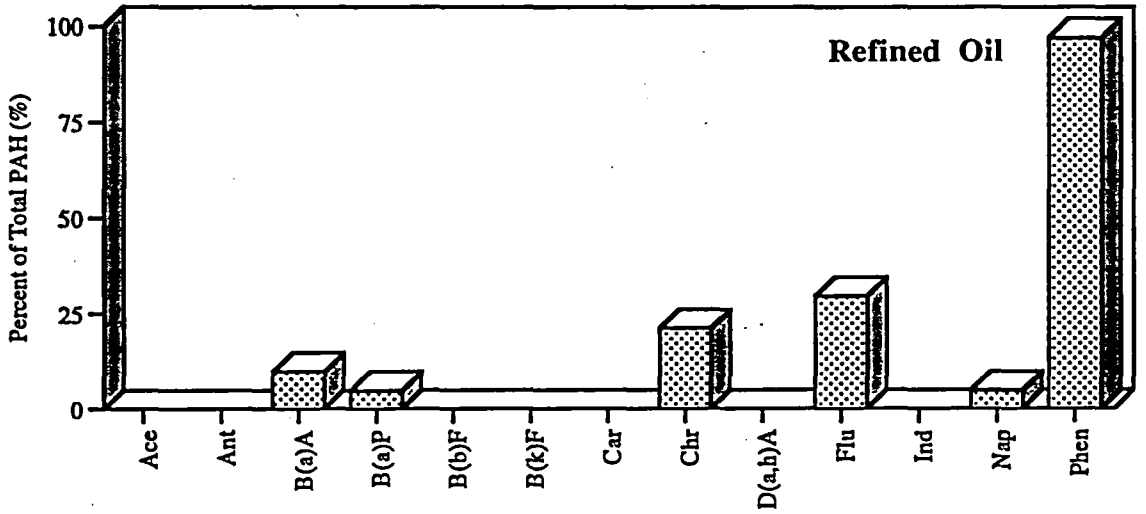
Appendix C

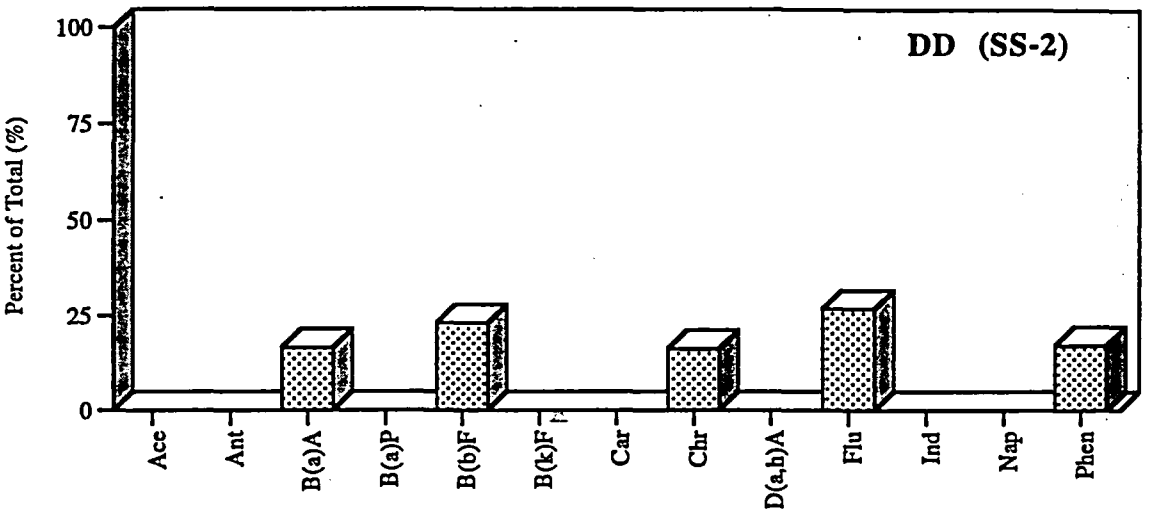
Sediment Profile Histograms

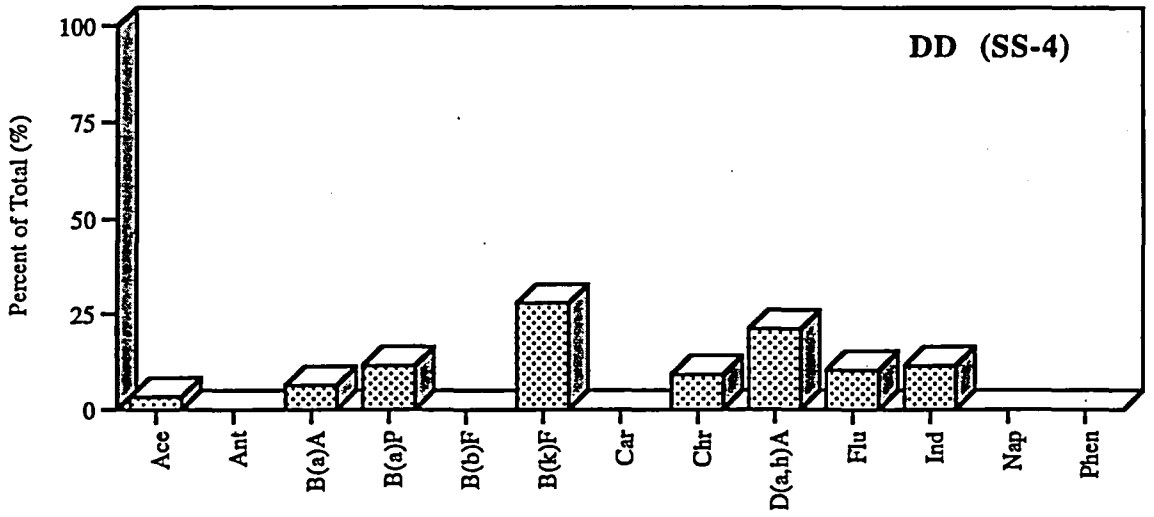






* Values in graph correspond to the percent of the average PAH conc. at the four stations nearest to the covered ditch area.


DD (SS-2)
Percent of Total (%)
100
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


DD (SS-4)
Percent of Total (%)
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75
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25
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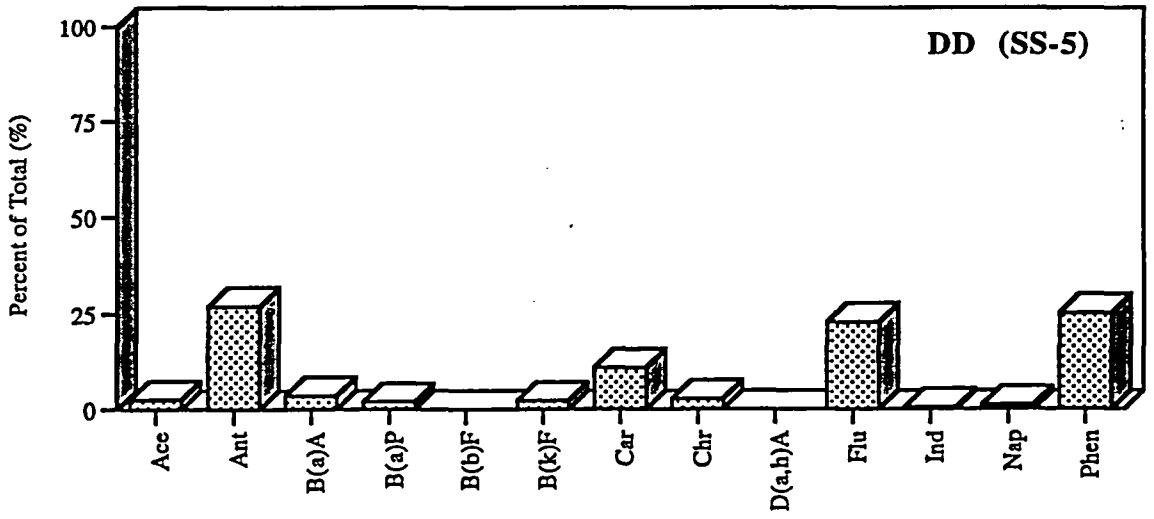
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


DD (SS-5)
Percent of Total (%)
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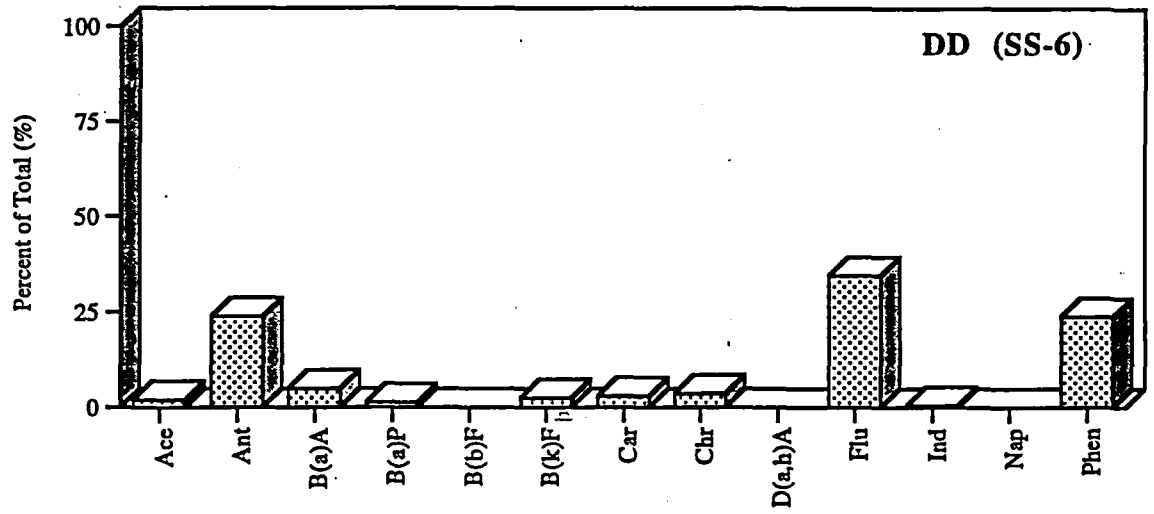
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


DD (SS-6)
Percent of Total (%)
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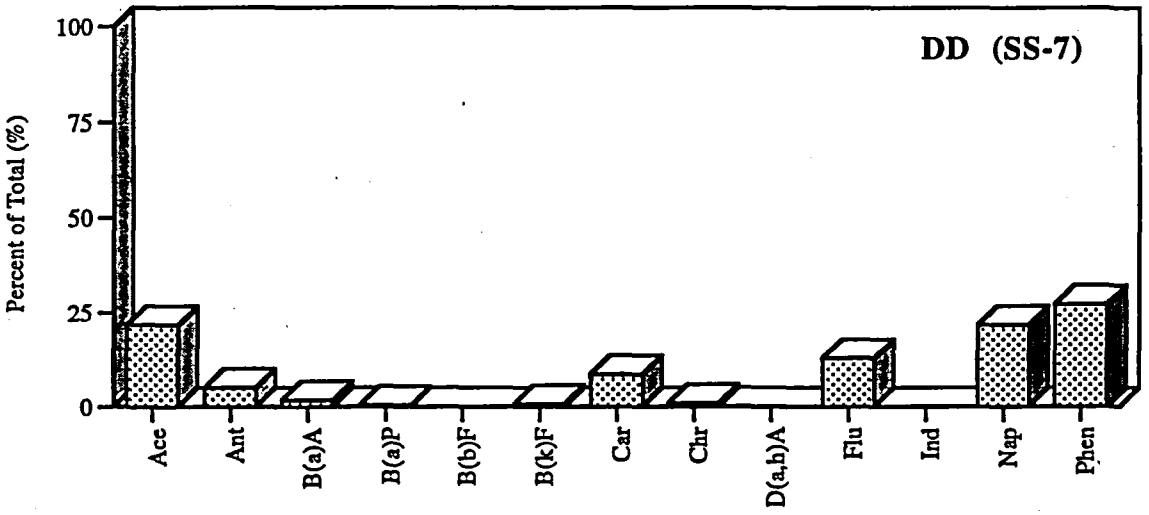
75
50
25
0
Acc
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


DD (SS-7)
Percent of Total (%)
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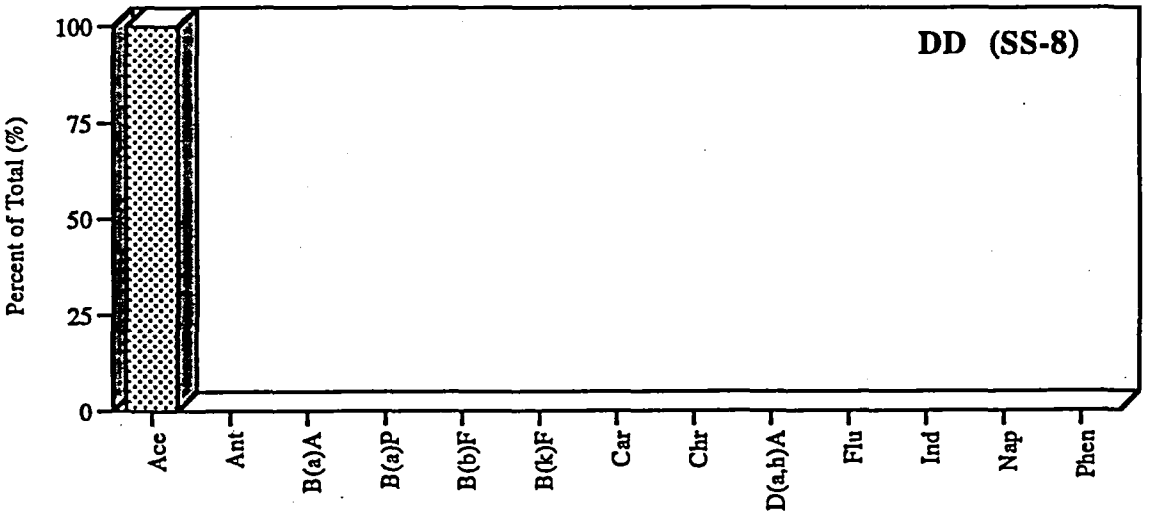
75
50
25
0
Acc
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


DD (SS-8)
Percent of Total (%)
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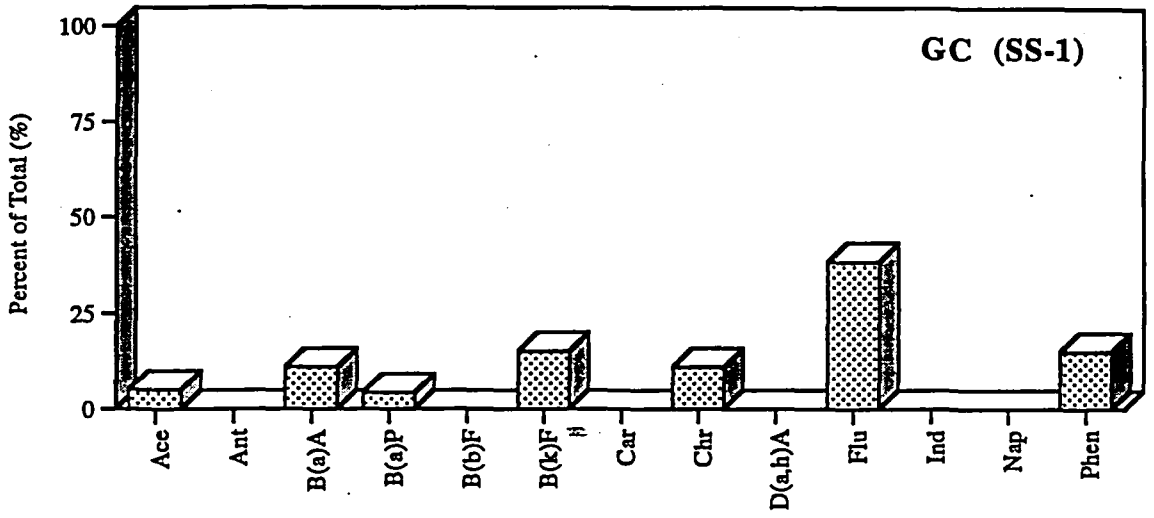
75
50
25
0
Acc
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


GC (SS-1)
Percent of Total (%)
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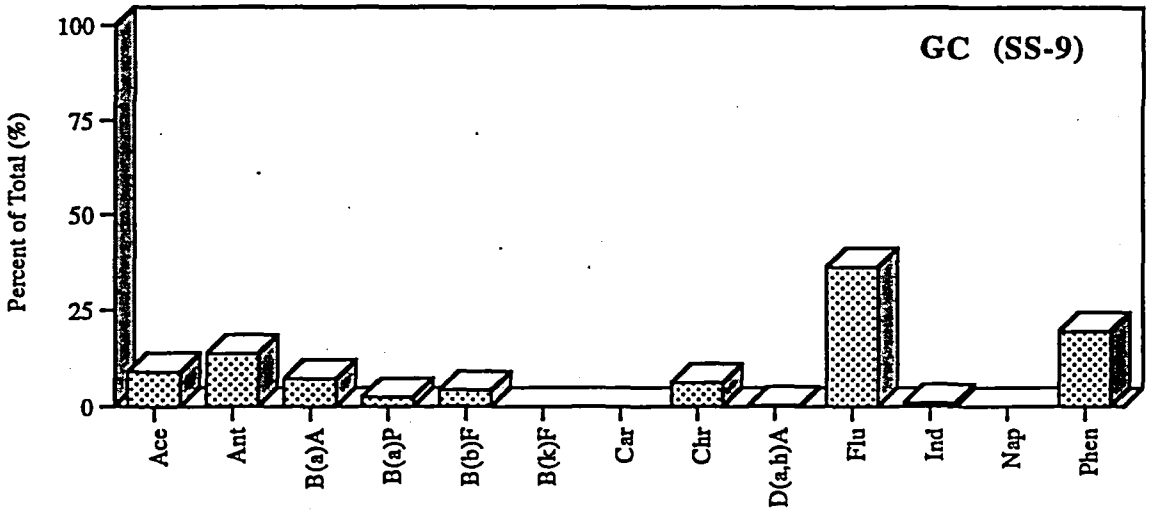
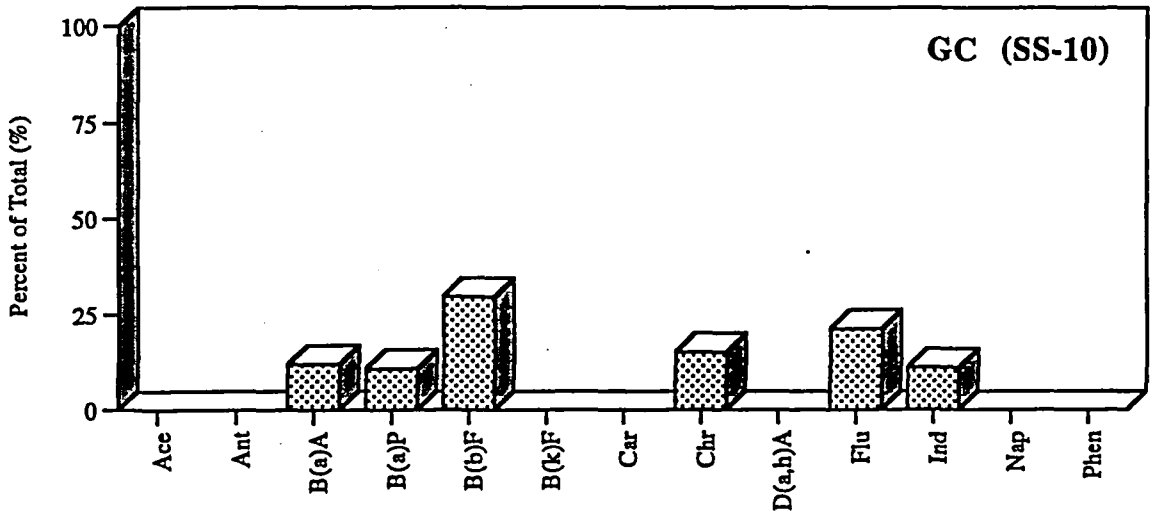
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


GC (SS-9)
Percent of Total (%)
100
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


GC (SS-10)
Percent of Total (%)
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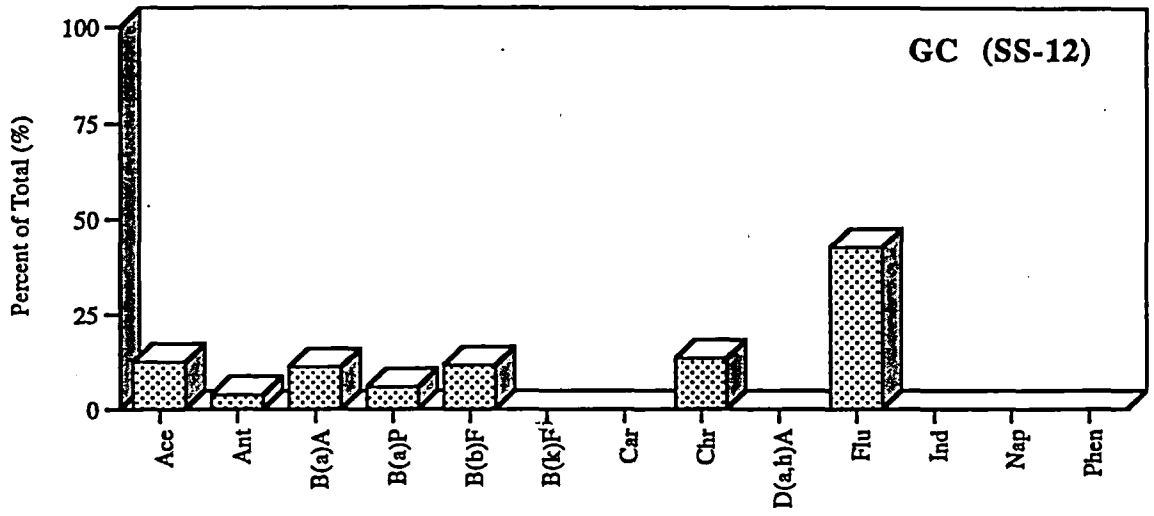
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


GC (SS-12)
Percent of Total (%)
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25
0
Ace
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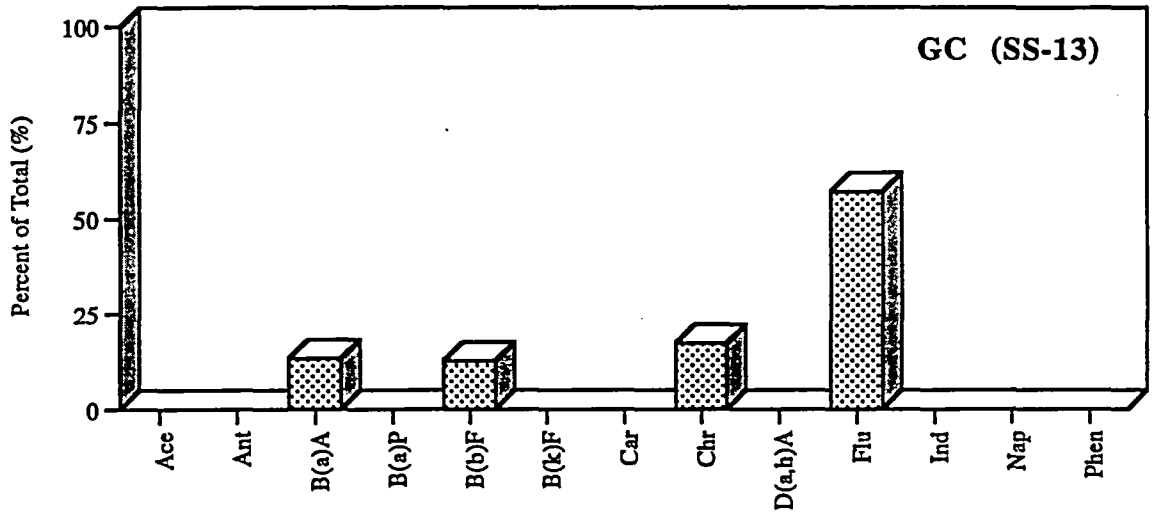
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


GC (SS-13)
Percent of Total (%)
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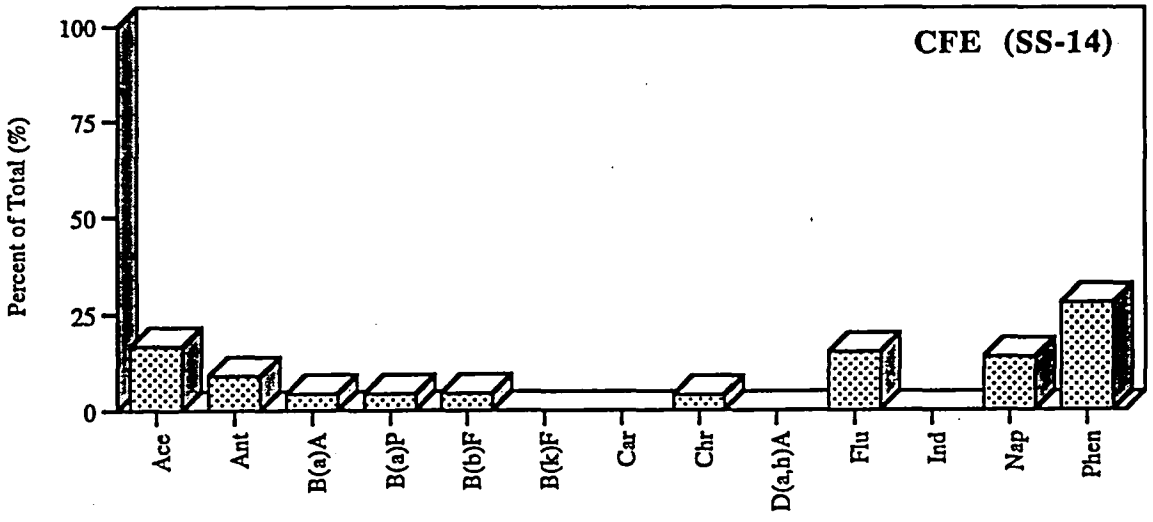
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-14)
Percent of Total (%)
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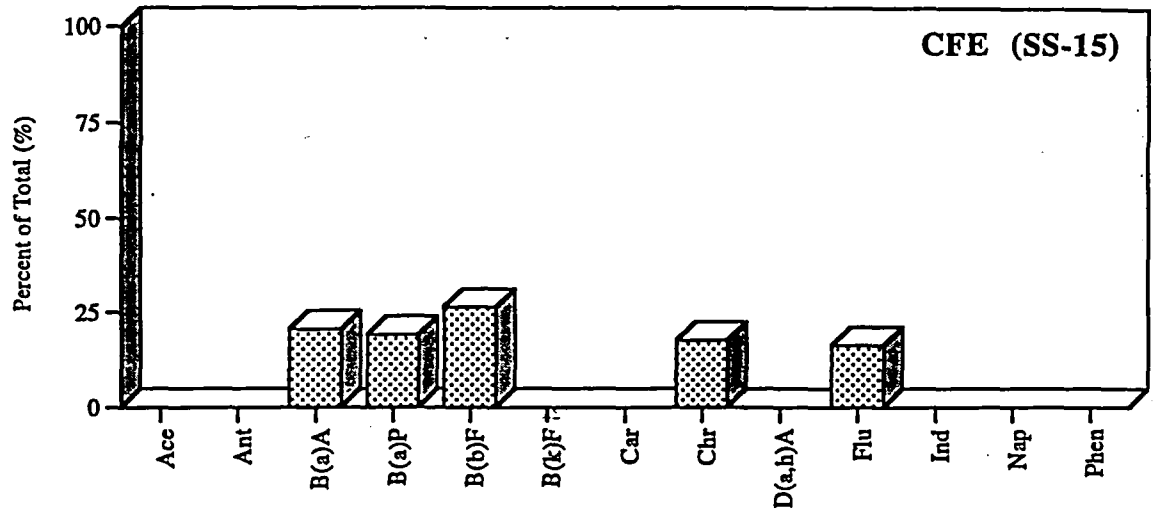
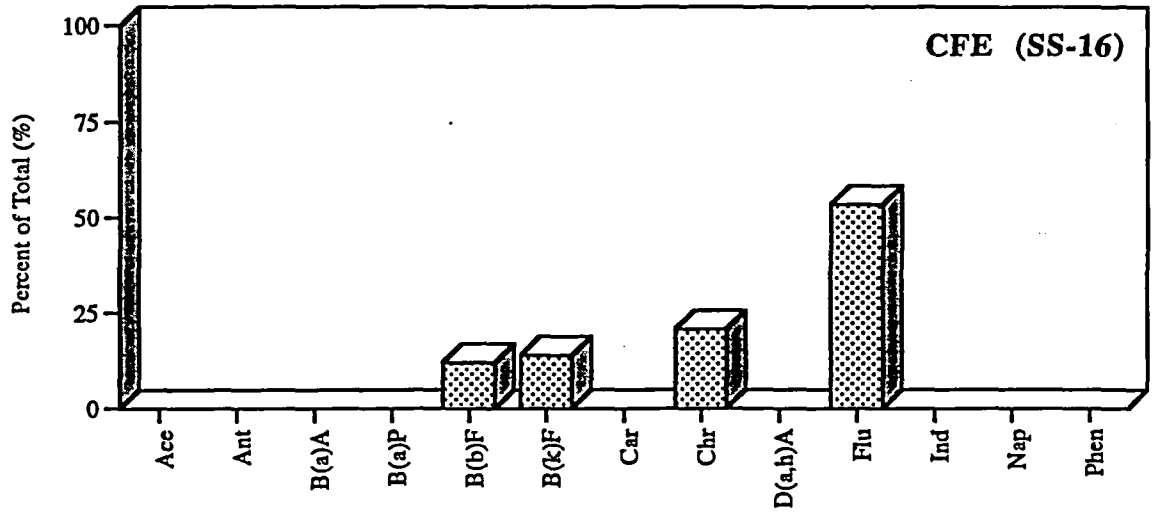
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-15)
Percent of Total (%)
100
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-16)
Percent of Total (%)
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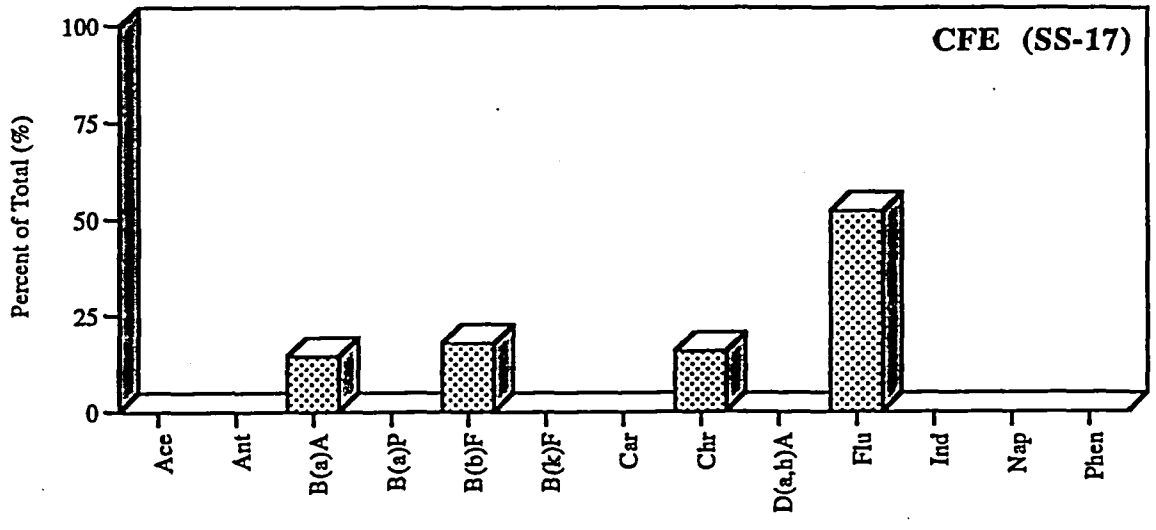
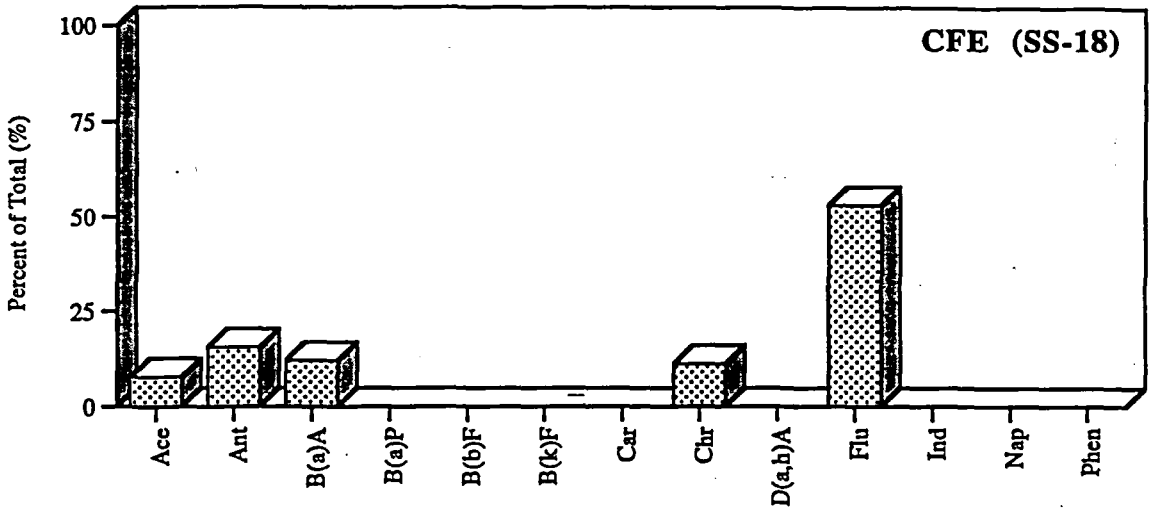
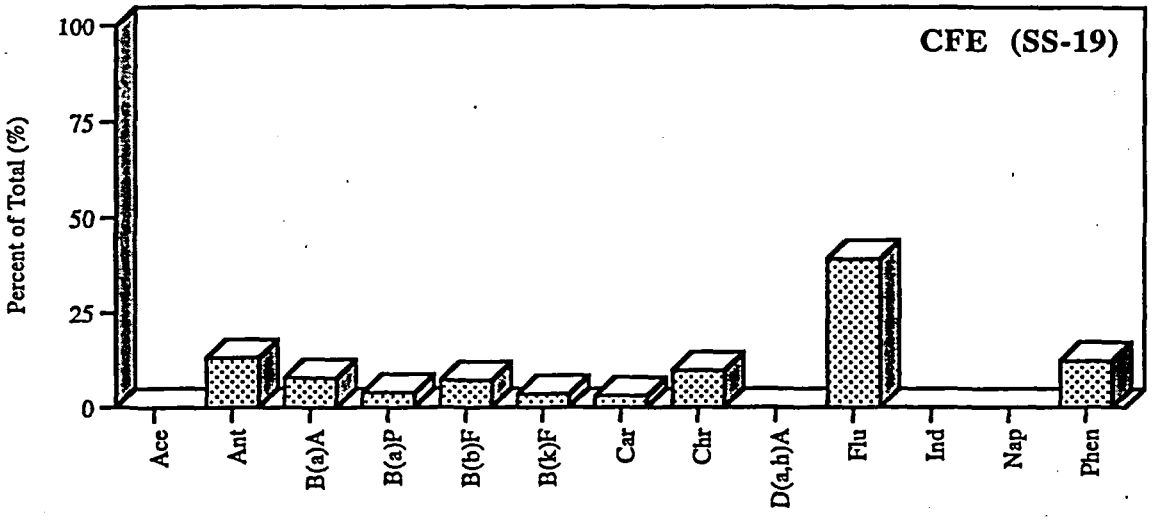
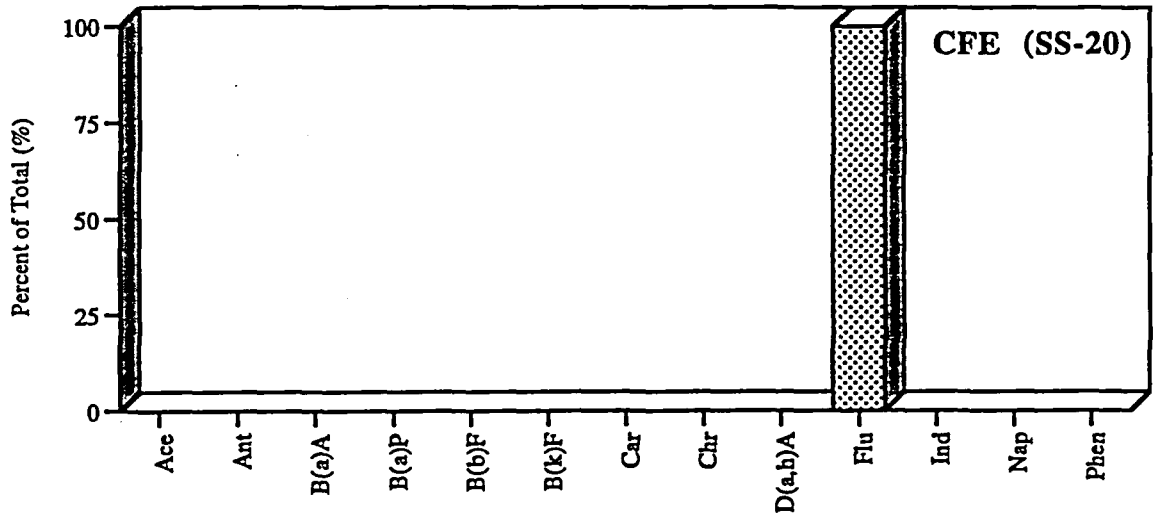
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-17)
Percent of Total (%)
100
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-18)
Percent of Total (%)
100
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-19)
Percent of Total (%)
100
75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen


CFE (SS-20)
Percent of Total (%)
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75
50
25
0
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen

Percent of Total (%)
0
25
50
75
100
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen
CFE (SS-21)

Percent of Total (%)
0
25
50
75
100
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen
CFE (SS-22)

Percent of Total (%)
0
25
50
75
100
Ace
Ant
B(a)A
B(a)P
B(b)F
B(k)F
Car
Chr
D(a,h)A
Flu
Ind
Nap
Phen
CFE (SS-23)

Appendix D

Photodocumentation for Characterizing Ecological Habitat

Photograph 1. Drainage Ditch: Adjacent to covered ditch area, view across ditch to the west; railroad tressle in the background, small creek entering ditch from the east.

Photograph 2. Drainage Ditch: View looking downstream at covered ditch area

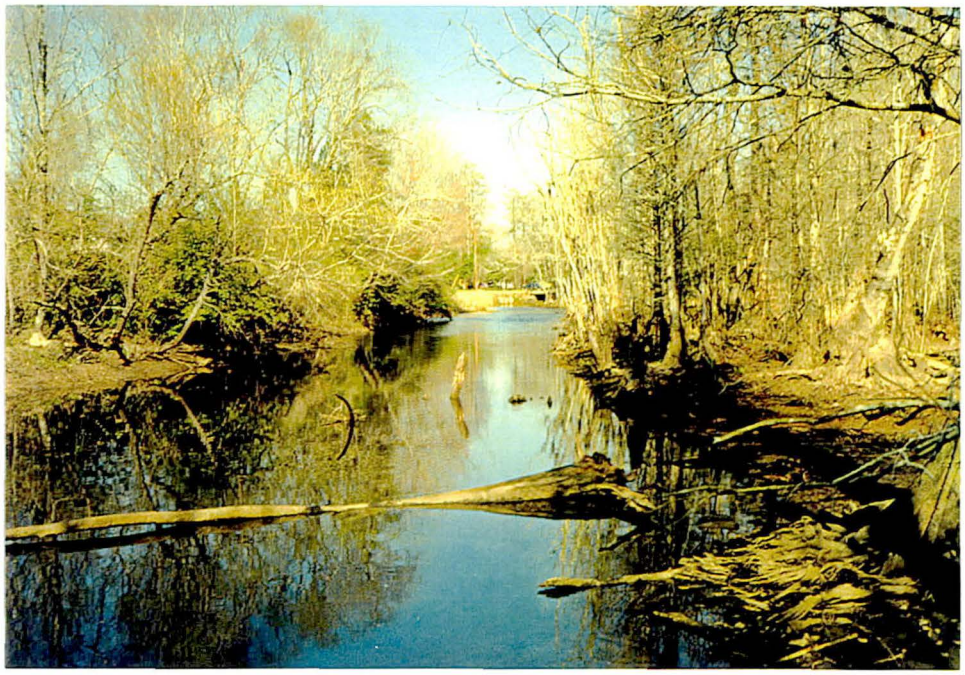
Photograph 3. Drainage Ditch: Adjacent to covered ditch area along westbank. View is downstream, sewer pipe can be seen traversing ditch in the background.

Photograph 4. Drainage Ditch: Adjacent to covered ditch, view upstream. Staff gauge in foreground, small Magnolia stand to right of picture.

Photograph 5. Drainge Ditch: View north approximately 100 feet upstream from ditch confluence with Greenfield Creek. Pipe crossing creek is sewer line from City of Wilmington wastewater treatment facility.

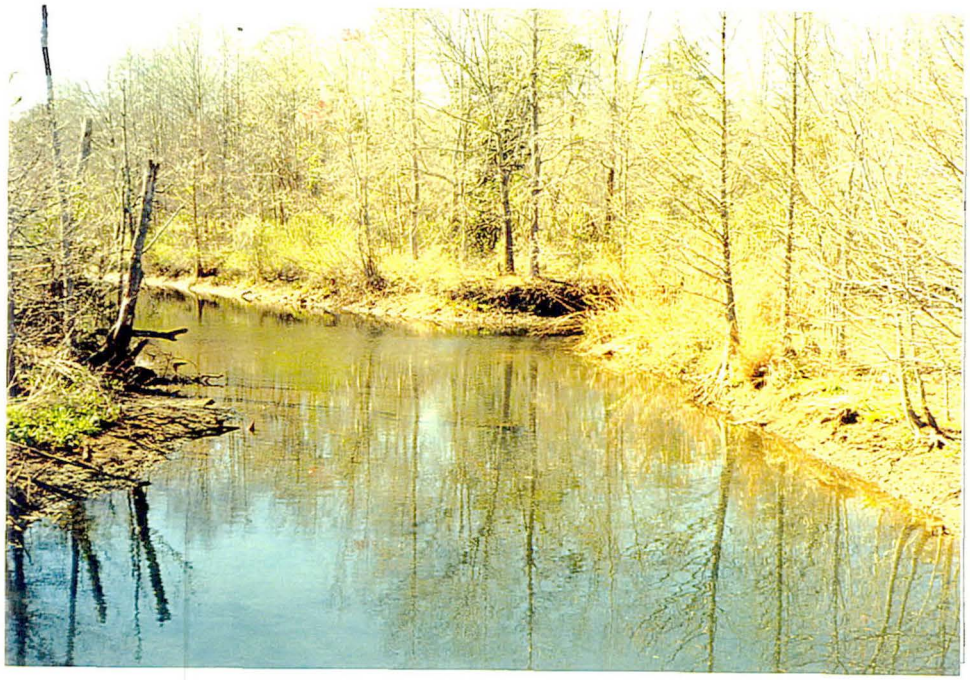
Photograph 6. Drainage Ditch: Close up of sewer line showing barnicalices along lower edge of pipe.

Photograph 7. Greenfield Creek: Upstream of railroad tressle along southbank of creek, view to the west.



Photograph 8. Greenfield Creek: View upstream from tressle approximately 600 feet downstream from Front street (in background).

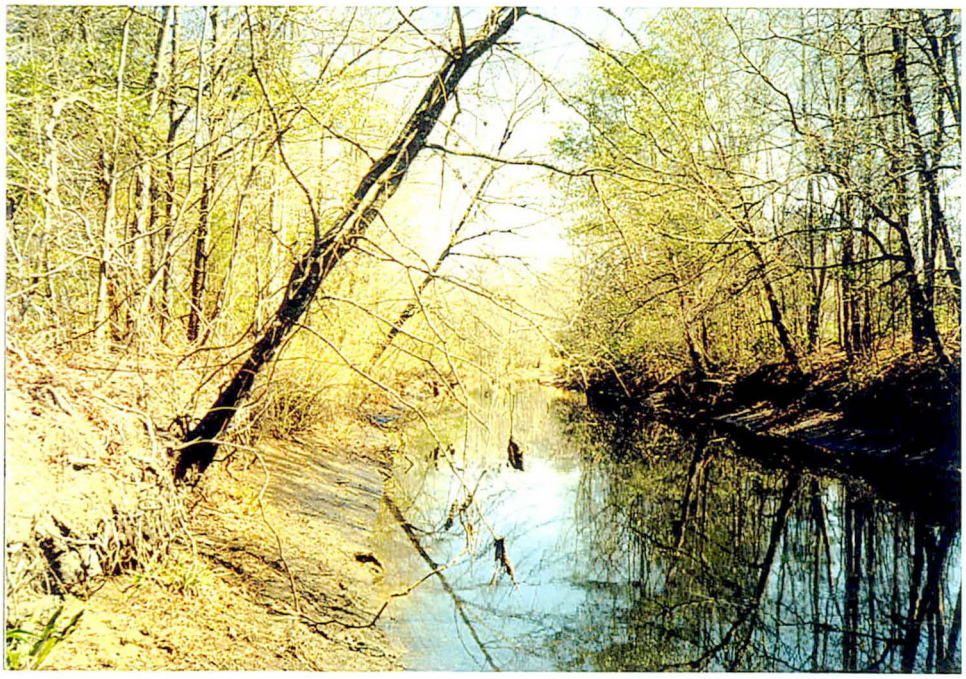
Photograph 9. Greenfield Creek: View upstream from railroad tressle crossing creek near southeast corner of SWP property. Photo taken at the confluence of the Drainage Ditch with the creek.



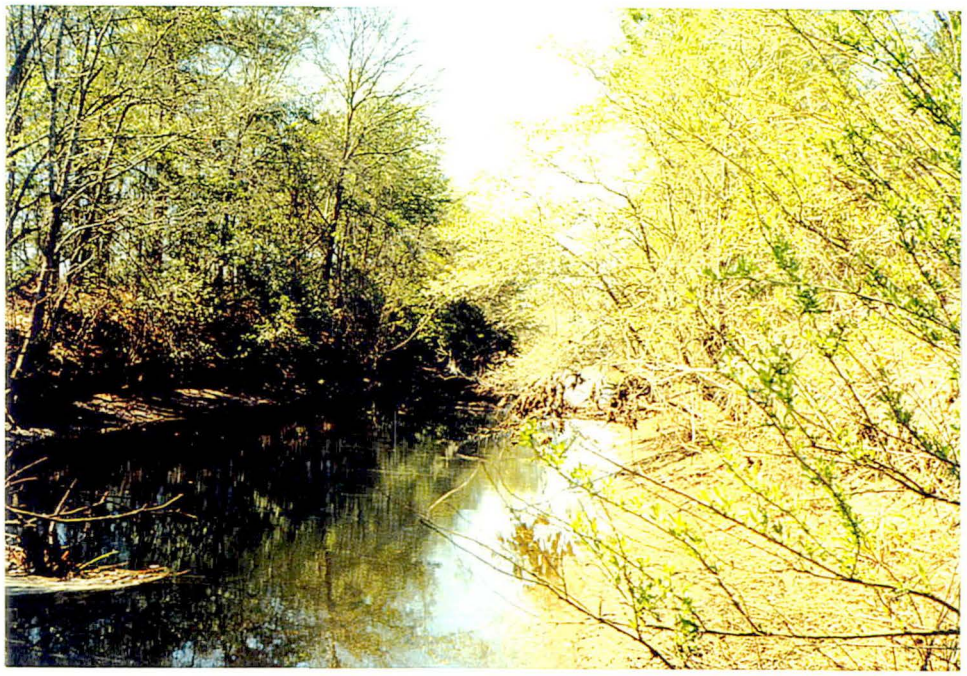
Photograph 10. Greenfield Creek: Photo taken from railroad tressle looking downstream. Confluence of Drainage Ditch is shown to the right.

Photograph 11. Tributary into Greenfield Creek: Tributary is located in southeast corner of site, bordering railroad tracks. Photo taken upstream south of creek from railroad tressle.

Photograph 12. Tributary into Greenfield Creek: View facing downstream. Rip rap from railroad tracks is to the right of the photo.



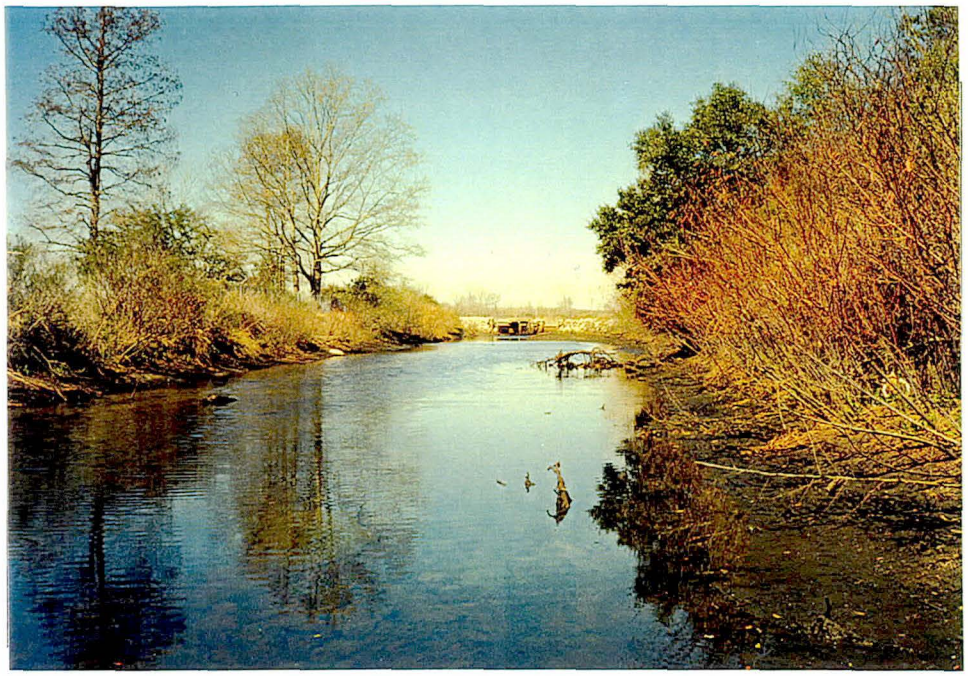
Photograph 13. Greenfield Creek: Northbank of creek looking upstream (East), approximately 600 feet downstream from railroad tressle.



Photograph 14. Greenfield Creek: Northbank of creek looking downstream (West), approximately 600 feet downstream from railroad tressle.

Photograph 15. Greenfield Creek: East view of creek looking upstream. Approximately 100 feet upstream from creek bend, on northbank.

Photograph 16. Greenfield Creek: West view towards bend along northbank. Pactank Chemical Storage Co. is shown in background.



Photograph 17. Greenfield Creek: Northbank of creek adjacent to Site. View is downstream approximately 600 feet from tidal gate.

Photograph 18. Greenfield Creek: Northbank of creek, upstream view, approximately 200 feet from bend.

Photograph 19. Greenfield Creek: West view from tidal gate.
Foreground: Cape Fear River. Background: Eagle Island.

Photograph 20. Greenfield Creek: Eastview (upstream) from tidal gate.
To the left in photo, SWP Site; to the right in photo, Pactank Chemical Storage Co.

Photograph 21. Cape Fear River: View is to the east towards Pactank Chemical Storage Co. located immediately south of the Site.

Photograph 22. Cape Fear River: View of former barge/slip area bordering the Site.

Photograph 23. Cape Fear River: View of eastbank transition zone (bordering Site) between mudflats and marsh grass (Spartina sp.)

Photograph 24. Cape Fear River: View of tidal gate to Greenfield Creek from exposed mudflats along eastbank of the river.

Photograph 25. Cape Fear River: Eastbank of river adjacent to Site - Upriver view of pilings.

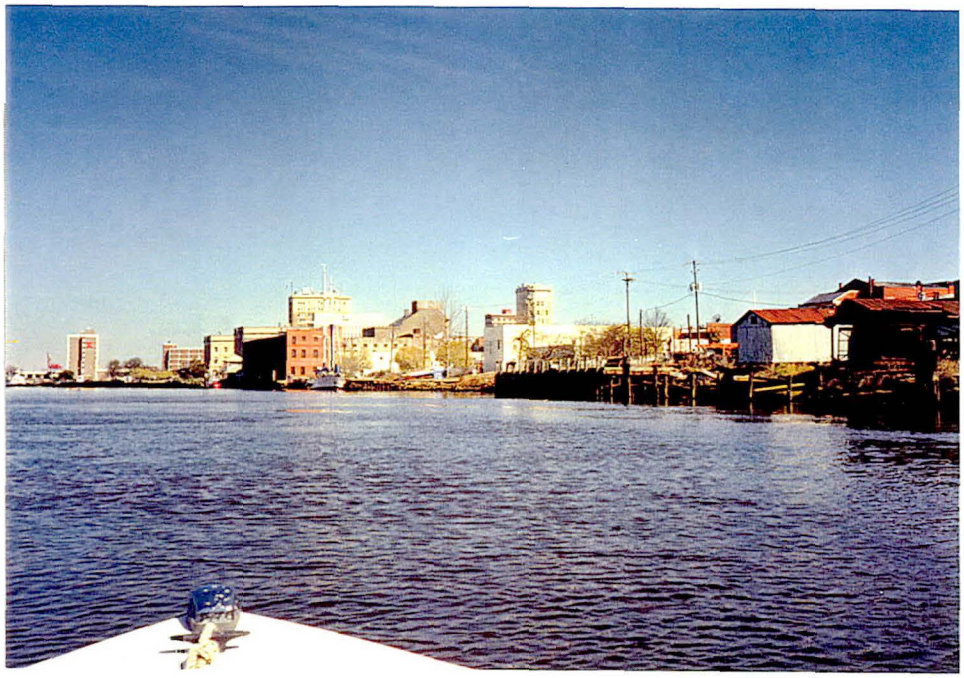
Photograph 26. Cape Fear River: Eastbank of river adjacent to Site - Downriver view of exposed mudflats

Photograph 27. Cape Fear River: Eastbank of river adjacent to Site - Downriver view.

Photograph 28. Cape Fear River: Eastbank of river adjacent to Site - Upriver view.

Photograph 29. Cape Fear River: View to the east showing Hess Bulk Petroleum facility.

Photograph 30. Cape Fear River: Eastbank of river at northern extreme of Hess property.



Photograph 31. Cape Fear River: View of eastbank just south of Wilmington.

Photograph 32. Cape Fear River: View to the north of Cape Fear River confluence with Northeast Cape Fear River

Photograph 33. Eagle Island: View looking north up the Cape Fear River. NC Ports Authority to the right.

Photograph 34. Eagle Island: Close up of shoreline along eastbank of island.

Photograph 35. Eagle Island: Shoreline view of Eagle Island; snowy egret feeding along (Spartina sp.) fringe

Photograph 36. Eagle Island: Shoreline view of island. Dredge spoil pipe from river operations shown in photo.

Appendix E

Threatened Endangered and Rare Species Recorded in Wilmington Area

State of North Carolina
Department of Environment, Health, and Natural Resources
512 North Salisbury Street • Raleigh, North Carolina 27604

James B. Hunt, Jr., Governor

Jonathan B. Howes, Secretary

RECEIVED
APR 2 1993
G & M RALEIGH

April 20, 1993

Mr. Adam Ayers
Geraghty & Miller, Inc.
CrossPointe II
2840 Plaza Place, Suite 350
Raleigh, NC 27612

SUBJECT: Rare, Threatened, and Endangered Species -- Wilmington

Dear Mr. Ayers:

The North Carolina Natural Heritage Program has numerous records of rare, threatened, and endangered species in the Wilmington area. Enclosed please find a list of such species, as well as significant natural communities, that are known to occur in the area depicted on the Wilmington USGS topo map.

Northwest of the site, there is an identified priority natural area called Brunswick River - Cape Fear River Marshes. This site is significant for its extensive Tidal Freshwater Marshes. These are important in their own right, and they also provide habitat for fish and other animal species.

We have several records of rare species within about a mile of the site. Some of these have not been seen in recent years. Field surveys would be necessary to determine what species are still extant in the area. Any rare species still surviving in the vicinity presumably could be impacted by the site, since they are all aquatic or wetland species.

Three rare plant species have been reported from the area: cypress knee sedge (Carex decomposita), a state Significantly Rare and federal Candidate (3C) species; Carolina grasswort (Liliaeopsis carolinensis), a state Threatened and federal Candidate (3C) species; and Carolina bishopweed (Ptiliumnium sp. 1), a state Candidate species. Rare animal species reported from the area include American alligator (Alligator mississippiensis), a state and federal Threatened species; shortnose sturgeon (Acipenser brevirostrum), a state and federal Endangered species of fish; least killifish (Heterandria formosa), a state Special Concern species of fish; barrel floater (Anodonta couperiana), a state

P.O. Box 27687, Raleigh, North Carolina 27611-7687 Telephone 919-733-4984 Fax # 919-733-0513

An Equal Opportunity Affirmative Action Employer

Endangered freshwater bivalve; Greenfield ramshorn snail (Helisoma eucosmium), believed to be extinct; and magnificent rams-horn (Planorbella magnifica), a state Endangered and federal Candidate freshwater snail.

Please contact me at 919-733-7701 or at the address given below if you have any questions or require further information.

Sincerely,

Ann W. Kelly

Ann W. Kelly
Natural Heritage Program
Division of Parks and Recreation

/awk

Enclosures

NATURAL HERITAGE ELEMENTS AND SPECIES STATUS CODES

The attached output from the N.C. Natural Heritage Program database is a listing of the elements (rare species, geologic features, natural communities, and special animal habitats) known to occur in your geographic area of interest. The information on this printout is compiled from a variety of sources, including field surveys, museums and herbaria, literature, and personal communications. The database is dynamic, with new records being added and old records being revised as we receive new information. The enclosed list cannot be considered a definitive record of natural heritage elements, and it should not be considered a substitute for field surveys. When this information is used in any document, we request that the printout date be given and that the Natural Heritage Program be credited.

This cover sheet explains the four columns of status codes that are given on the right-hand side of the printout.

STATE PROTECTION

CODE	STATUS	CODE	STATUS
E	Endangered	SR	Significantly Rare
T	Threatened	V	Vulnerable
SC	Special Concern	UNK	Undetermined
C	Candidate	EX	Extirpated
P_	Proposed (E, T, or C)		

Plant statuses are determined by the Plant Conservation Program (N.C. Dept. of Agriculture) and the Natural Heritage Program (N.C. Dept. of Environment, Health, and Natural Resources). E, T, and SC species are protected by state law (the Plant Protection and Conservation Act, 1979); C and SR designations indicate rarity and the need for population monitoring and conservation action, as determined by the Plant Conservation and Natural Heritage Programs.

Animal statuses that indicate state protection (E, T, and SC) are published in "Endangered Wildlife of North Carolina", March 16, 1992, N.C. Nongame and Endangered Wildlife Program. The Significantly Rare, Undetermined, Vulnerable and Extirpated statuses are (for the most part) Natural Heritage Program designations. They indicate rarity and the need for population monitoring and conservation action.

FEDERAL PROTECTION

The current federal status is listed in "Endangered and Threatened Wildlife and Plants, July 15, 1991 (50 CFR 17.11 & 17.12, Department of the Interior). Definitions are taken from the Endangered Species Act of 1973, as amended through the 100th Congress (1988), and the Federal Register, Part VIII, November 21, 1991 (50 CFR 17, Department of the Interior).

CODE	STATUS	DEFINITION
E	Endangered	A taxon which "is in danger of extinction throughout all or a significant portion of its range"
T	Threatened	A taxon "which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range"
P_	Proposed	A taxon which has been proposed for official listing as endangered or threatened
L_	Listed	A taxon which has been officially listed as endangered or threatened
C1	Category 1 ("Candidate 1")	A taxon which is under consideration, and for which there is sufficient information to support listing

USES Quad: Wilmington

N[illegible] NATURAL HERITAGE PROGRAM AND PLANT CONSERVATION PROGRAM ELEMENT LIST

SCIENTIFIC AND COMMON NAME	STATE PROT.	FED. PROT.	STATE RANK	GLOBAL RANK
*** Vertebrates				
Acipenser brevirostrum Shortnose sturgeon	E	LE	S1	G3
Alligator mississippiensis American alligator	T	T/SA	S3	G5
Heterandria formosa Least killifish	SC		S1	G5
Himantopus mexicanus Black-necked stilt	SR		S2B	G5
Micrurus fulvius Eastern coral snake	SR		S1	G5
Ophisaurus mimicus Mimic glass lizard	SC		S2	G3
Picoides borealis Red-cockaded woodpecker	E	LE	S2	G2
Rana capito capito Carolina gopher frog	SC	C2	S2	G4T?
Tadarida brasiliensis Brazilian free-tailed bat	SC		SUB,S2N	G5
*** Invertebrates				
Anodonta couperiana Barrel floater	E		S1	G3G4
Helisoma eucosmium Greenfield ramshorn snail	EX	C2	SX	GH
Planorbella magnifica Magnificent rams-horn	E	C2	S1	G1
Problema bulenta Rare skipper	SR	C2	S1?	G2G3
*** Vascular plants				
Carex decomposita Cypress knee sedge	SR	3C	SH	G3G4
Crinum americanum Swamp-lily	C		S1	G5
Cyperus lecontei Leconte's flatsedge	SR		S1	G4?
Dionaea muscipula Venus flytrap	C-SC	3C	S3	G3
Eleocharis melanocarpa Blackfruit spikerush	C		S1?	G4
Lilaeopsis carolinensis Carolina grasswort	T	3C	S2	G3
Litsea aestivalis Pondspice	C	C2	S2	G3G4
[illegible]tanthera nivea Snowy orchid	T		S2	G5

N.C. NATURAL HERITAGE PROGRAM AND PLANT CONSERVATION PROGRAM ELEMENT LIST

SCIENTIFIC AND COMMON NAME	STATE PROT.	FED. PROT.	STATE RANK	GLOBAL RANK
Ptilimnium costatum Ribbed bishop's-weed	C		S1	G5
Ptilimnium sp 1 Carolina bishopweed	C		S1	G2?
Rhynchospora oligantha Feather-bristle beakrush	C		S2	G5
Rhynchospora pleiantha Coastal beakrush	C		S1	G3

25 Records Processed

State of North Carolina
Department of Environment,
Health and Natural Resources
Division of Parks & Recreation

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
Dr. Philip K. McKnelly, Director

DEHNR

Mr. Todd Abel
ChemRisk
Stroudwater Crossing
1685 Congress Street
Portland, ME 04102

April 19, 1996

SUBJECT: Rare Species, High Quality Natural Communities, and Significant Natural Areas in the Proposed Project Area Adjacent to Optimist Park, New Hanover County, North Carolina

Dear Mr. Abel:

The North Carolina Natural Heritage Program does not have records of known rare species, high quality natural communities, or significant natural areas occurring at the proposed project site adjacent to Optimist Park. To our knowledge, this project site has not been systematically inventoried and we cannot definitively state that rare species or significant natural areas do not occur there.

We do however, have record of several rare species occurring within a 1-mile radius of the project site. These species are: shortnose sturgeon (Acipenser brevirostrum), Federal and State Endangered species; barrel floater (Anodonta couperiana), State Endangered species; magnificent rams-horn (Planorbella magnifica), State Endangered and Federal Species of Concern (former C2 Candidate species); Carolina grasswort (Lileopsis carolinensis), a State Threatened species; a rare skipper (Problema bulenta), significantly rare in North Carolina and a Federal Species of Concern (former C2 Candidate species); and Duke's skipper (Euphyes dukesi) and Greenfield ramshorn snail (Helisoma eucosmium), both significantly rare in the state.

Enclosed is a list of rare species known to occur in New Hanover County. If suitable habitat for any of these species occurs in the project area, then those species may be present at the project site. If it is necessary to be certain that this site does not contain rare species, a field survey would need to be conducted.

Please contact me at the address below or call me at (919) 733-7701 if you have any questions or need further information.

Sincerely,

Inge Smith

Inge Smith
Information Specialist
Natural Heritage Program

P.O. Box 27687, Raleigh, North Carolina 27611-7687 Telephone 919-733-4181 FAX 919-715-3085
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END

SCIENTIFIC AND COMMON NAME	STATE PROT.	FED. PROT.	STATE RANK	GLOBAL RANK
New Hanover				
Vertebrates				
ACIPENSER BREVIROSTRUM SHORTNOSE STURGEON	E	LE	S1	G3
ALLIGATOR MISSISSIPPIENSIS AMERICAN ALLIGATOR	T	T(S/A)	S3	G5
CARETTA CARETTA LOGGERHEAD TURTLE	T	LT	S2B,S2	G3
CHARADRIUS MELODUS PIPING PLOVER	T	LT	S2B,S2	G3
CHELONIA MYDAS GREEN TURTLE	T	LT	S1B,SZ	G3
COLUMBINA PASSERINA COMMON GROUND-DOVE	SR	-	SHB,SZ	G5
CONDYLURA CRISTATA POP 1 STAR-NOSED MOLE - EASTERN NC POPULATION	SC	-	S2	G5T2Q
COTURNICOPS NOVEBORACENSIS YELLOW RAIL	SR	-	S2N	G4
CROTALUS ADAMANTEUS EASTERN DIAMONDBACK RATTLESNAKE	SR	-	S1	G5
EGRETTA CAERULEA LITTLE BLUE HERON	SC	-	S3B,S3	G5
EGRETTA THULA SNOWY EGRET	SC	-	S3B,S3	G5
EGRETTA TRICOLOR TRICOLORED HERON	SC	-	S3B,S3	G5
ELEOTRIS PISONIS SPINYCHEEK SLEEPER	SR	-	S2	G5
EVORTHODUS LYRICUS LYRE GOBY	SR	-	S2	GU
HETERANDRIA FORMOSA LEAST KILLIFISH	SC	-	S1	G5
HETERODON SIMUS SOUTHERN HOGNOSE SNAKE	SR	C2	S3	G4G5
HYPSOBLENNIUS IONTHAS FRECKLED BLENNY	SR	-	S2	GU
LANIUS LUDOVICIANUS LUDOVICIANUS LOGGERHEAD SHRIKE	SC	3C	S3B,S3	G5T5
LUCANIA GOODEI BLUEFIN KILLIFISH	SC	-	S1	G5
MICRURUS FULVIUS EASTERN CORAL SNAKE	SR	-	S1	G5
MYOTIS AUSTRORIPARIUS SOUTHEASTERN MYOTIS	SC	C2	S2?	G4
OPHISAURUS MIMICUS MIMIC GLASS LIZARD	SC	C2	S2	G3
PASSERINA CIRIS CIRIS EASTERN PAINTED BUNTING	SR	C2	S3B,SZ	G5TU
PELECANUS OCCIDENTALIS BROWN PELICAN	SC	-	S3B,S4	G4
PICOIDES BOREALIS RED-COCKADED WOODPECKER	E	LE	S2	G3

SCIENTIFIC AND COMMON NAME	STATE PROT.	FED. PROT.	STATE RANK	GLOBAL RANK
ASTRAGALUS MICHAUXII SANDHILLS MILKVETCH	C	C2	S3	G3
BACOPA INNOMINATA A WATER-HYSSOP	C	-	SH	G5
CAREX CHAPMANII CHAPMAN'S SEDGE	WL	C2	S3	G3
CAREX DECOMPOSITA CYPRESS KNEE SEDGE	SR	-	S1	G4
CAREX VERRUCOSA WARTY SEDGE	SR	-	S1	G3G4
CRINUM AMERICANUM SWAMP-LILY	C	-	SH	G5
CYPERUS LECONTEI LECONTE'S FLATSEDGE	SR	-	S1	G4?
CYPERUS TETRAGONUS FOUR-ANGLED FLATSEDGE	SR	-	S2	G4?
DIONAEA MUSCIPULA VENUS FLYTRAP	C-SC	C2	S3	G3
ELEOCHARIS ROBBINSII ROBBINS'S SPIKERUSH	C	-	S2	G4G5
ERYTHRINA HERBACEA CORALBEAN	SR	-	S1	G5
EUPATORIUM LEPTOPHYLLUM LIMESINK DOG-FENNEL	C	-	S1	G4G5
GELSEMIUM RANKINII SWAMP JESSAMINE	SR	-	S2	G5
HELENIUM PINNATIFIDUM DISSECTED SNEEZEWEED	SR	-	S2	G4
HELIANTHEMUM GEORGIANUM GEORGIA SUNROSE	C	-	S1	G4
HIBISCUS ACULEATUS COMFORTROOT	C	-	S1	G4G5
HYPERICUM ADPRESSUM** BOG ST. JOHN'S-WORT	C	C2	SH	G2G3
LACHNOCAULON BEYRICHIANUM SOUTHERN BOGBUTTON	SR	-	S2S3	G2G3
LILAEOPSIS CAROLINENSIS CAROLINA GRASSWORT	T	3C	S3	G3
LITSEA AESTIVALIS PONDSPICE	C	C2	S2	G3
LOPHIOLA AUREA GOLDEN CREST	E	-	S1	G4
LUDWIGIA ALATA WINGED SEEDBOX	SR	-	S2	G3G4
LUDWIGIA LANCEOLATA LANCELEAF SEEDBOX	C	-	S1	G3
LUDWIGIA LINIFOLIA FLAXLEAF SEEDBOX	SR	-	S2	G4
LUDWIGIA SUFFRUTICOSA SHRUBBY SEEDBOX	SR	-	S2	G5
PANICUM TENERUM SOUTHEASTERN PANIC GRASS	SR	-	S2	G4
PELTANDRA SAGITTIFOLIA SPOONFLOWER	SR	-	S2	G3G4

SCIENTIFIC AND COMMON NAME	STATE PROT.	FED. PROT.	STATE RANK	GLOBAL RANK
CYPRESS SAVANNA	-	-	S1	G2?
DRY-MESIC OAK--HICKORY FOREST	-	-	S5	G5
DUNE GRASS	-	-	S3	G3G4
INTERDUNE POND	-	-	S1	G2?
MARITIME DRY GRASSLAND	-	-	S2	G3
MARITIME SHRUB	-	-	S3	G4
PINE SAVANNA	-	-	S2	G3
POND PINE WOODLAND	-	-	S4	G4G5
SALT FLAT	-	-	S4	G5
SALT MARSH	-	-	S5	G5
SALT SHRUB	-	-	S4	G5
SMALL DEPRESSION POCOSIN	-	-	S1?	G2?
SMALL DEPRESSION POND	-	-	S2	G3
STREAMHEAD POCOSIN	-	-	S3	G4
TIDAL FRESHWATER MARSH	-	-	S3	G4
VERNAL POOL	-	-	S2	G3
WET PINE FLATWOODS	-	-	S3	G3G4
XERIC SANDHILL SCRUB	-	-	S4	G5
Geologic features				
BARRIER ISLAND-SIMPLE	-	-		
CENOZOIC FOSSIL	-	-		
RIDGE & SWALE	-	-		
Special animal habitats				
GULL*TERN*SKIMMER COLONY COLONIAL WATERBIRDS NESTING SITE	-	-		
WADING BIRD ROOKERY	-	-		

NC NATURAL HERITAGE PROGRAM COUNTY SPECIES LIST COVER SHEET

The county species list from the NC Natural Heritage Program is a listing of the elements (rare species, natural communities, geologic features, and special animal habitats) known to occur in a county. The information on this printout is compiled from a variety of sources, including field surveys, museums and herbaria, literature, and personal communications. The Heritage Program's Biological and Conservation Database (BCD) is dynamic, with new records being added and old records being revised as new information is received. The BCD was developed and is being maintained using methodology developed by The Nature Conservancy.

The enclosed list cannot be considered a definitive record of natural heritage elements, and it should not be considered a substitute for field surveys. When this information is used in any document, we request that the printout date be given and that the NC Natural Heritage Program be credited.

This cover sheet explains the four columns of status codes that are given on the right-hand side of the printout.

STATE PROTECTION

CODE	STATUS	CODE	STATUS
E	Endangered	P_	Proposed (E, T, or C)
T	Threatened	SR	Significantly Rare
SC	Special Concern	EX	Extirpated
C	Candidate	WL	Watch List

Plant statuses are determined by the Plant Conservation Program (NC Department of Agriculture) and the Natural Heritage Program (NC Department of Environment, Health, and Natural Resources). E, T, and SC species are protected by state law (Plant Protection and Conservation Act, 1979). C and SR designations indicate rarity and the need for population monitoring and conservation action. WL indicates a species not warranting active monitoring, but believed to of conservation concern.

Animal statuses that indicate state protection (E, T, and SC) are published in *Endangered Wildlife of North Carolina*, March 16, 1992, Nongame and Endangered Wildlife Program (NC Department of Environment, Health, and Natural Resources). SR and EX statuses are Natural Heritage Program designations. SR indicates rarity and the need for population monitoring and conservation action. WL indicates a species not warranting active monitoring, but believed to of conservation concern.

FEDERAL PROTECTION

This status is designated by the US Fish and Wildlife Service. Federally listed Endangered and Threatened species are protected under the provisions of the Endangered Species Act of 1973, as amended through the 100th Congress. Unless otherwise noted, definitions are taken from the *Federal Register*, Vol. 56, No. 225, November 21, 1991 (50 CFR Part 17).

CODE	STATUS	DEFINITION
E	Endangered	A taxon "in danger of extinction throughout all of a significant portion of its range."
T	Threatened	A taxon "likely to become an endangered species within the foreseeable future throughout all of a significant portion of its range."
P_	Proposed	A taxon proposed for official listing as endangered or threatened.
L_	Listed	A taxon officially listed as endangered or threatened.
C1	Candidate 1	A taxon under consideration for which there is sufficient information to support listing.
C2	Candidate 2	Formerly defined as a taxon under consideration for which there is insufficient information to support listing. Currently, the US Fish and Wildlife Service does not recognize this designation.
3A	Candidate 3A	A taxon formerly under consideration for listing, but for which there is "persuasive evidence of extinction."
3B	Candidate 3B	A taxon formerly under consideration for listing, but which current taxonomic understanding does not support as a distinct entity meeting the Endangered Species Act's definition of "species."
3C	Candidate 3C	A taxon formerly under consideration for listing, but which has been "proven to more abundant or widespread than previously believed and/or [which is] not subject to any identifiable threat."
T(S/A)	-	In reference to the American alligator - this species is threatened due to similarity of appearance with other rare crocodilians and is listed for trade purposes. The species is no longer biologically endangered or threatened and is not subject to Section 7 consultation.

GLOBAL AND STATE RANKS

These ranks are determined by The Nature Conservancy's system of measuring rarity and threat status. "Global" refers to worldwide ranks and "State" to statewide ranks.

STATE RANK DEFINITIONS

S1	Critically imperiled in North Carolina because of extreme rarity or otherwise very vulnerable to extirpation in the state.
S2	Imperiled in North Carolina because of rarity or otherwise vulnerable to extirpation in the state.
S3	Rare or uncommon in North Carolina.
S4	Apparently secure in North Carolina, with many occurrences.
S5	Demonstrably secure in North Carolina and essentially ineradicable under present conditions.
SA	Accidental or casual; one to several records for North Carolina, but the state is outside the normal range of the species.
SH	Of historical occurrence in North Carolina, perhaps not having been verified in the past 25 years, and suspected to be still extant in the state.
SR	Reported from North Carolina, but without persuasive documentation for either accepting or rejecting the report.
SX	Believed to be extirpated from North Carolina.
SU	Possibly in peril in North Carolina, but status uncertain; more information is needed.
S?	Unranked, or rank uncertain.
_B	Rank of breeding population in the state. Used for migratory species only.
_N	Rank of non-breeding population in the state. Used for migratory species only.
_Z_	Population is not of significant conservation concern; applies to transitory, migratory species.

GLOBAL RANK DEFINITIONS

G1	Critically imperiled globally because of extreme rarity or otherwise very vulnerable to extinction throughout its range.
G2	Imperiled globally because of rarity or otherwise vulnerable to extinction throughout its range.
G3	Either very rare and local throughout its range, or found locally in a restricted area.
G4	Apparently secure globally, although it may be quite rare in parts of its range (especially at the periphery).
G5	Demonstrably secure globally, although it may be quite rare in parts of its range (especially at the periphery).
GH	Of historical occurrence throughout its range.
GX	Believed to be extinct throughout its range.
GU	Possibly in peril, but status uncertain; more information is needed.
G?	Unranked, or rank uncertain.
G_Q	Of questionable taxonomic status.
T_	Status of subspecies or variety; the G rank refers to the species as a whole.

ADDITIONAL DEFINITIONS

Species names with 1, 2, 3, or 4 asterisks behind them indicate historic, obscure, or incidental records.

*	Historic record - the species was last observed in the county over 20 years ago.
**	Obscure record - the date and/or location of the species observation is uncertain.
***	Incidental/migrant record - the species was observed outside of its normal range or habitat.
****	Historic, Obscure, and Incidental record.

Scientific and common names listed in parentheses are synonyms listed in US Fish and Wildlife Service, 1992, Endangered and Threatened Species of the Southeastern United States (The Red Book).