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SOUTHERN WOOD PIEDMONT
WILMINGTON, NORTH CAROLINA
SEDIMENT ECOTOXICITY WORK PLAN
AND FIELD SAMPLING PLAN

JANUARY 30, 1998

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SOUTHERN WOOD PIEDMONT WILMINGTON, NORTH CAROLINA SEDIMENT ECOTOXICITY WORK PLAN AND FIELD SAMPLING PLAN

M/H-ChemRisk Project No. 16.0802397.001.003

January 30, 1998

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TABLE OF CONTENTS

SECTION PAGE

1.0 INTRODUCTION 1-1

1.1 Site Setting 1-1
1.2 Objectives and Description of Current Project 1-2
1.2.1 Objectives 1-3
1.2.2 Proposed Study Activities 1-3
1.3 Planning Documents 1-4
1.4 Certification 1-5

2.0 BACKGROUND 2-1

2.1 Site History 2-1
2.2 Site Location and Setting 2-1
2.3 Physical Characteristics 2-2
2.3.1 Hydrogeology 2-2
2.3.2 Hydrology 2-4
2.3.3 Climatology 2-5
2.4 Ecological Characteristics 2-5
2.4.1 Vegetative Communities 2-5
2.4.2 Wildlife Communities 2-6
2.5 Results from Previous Studies 2-7

3.0 DATA COLLECTION PLAN 3-1

3.1 Task 1 - Identification of Test Species and Ecotoxicity Endpoint 3-1
3.1.1 Selection of test species for preliminary evaluation 3-1
3.1.1.1 Recommendations for candidate test species 3-3
3.1.1.2 Microtox® 3-4
3.1.2 Selection of measurement endpoints for preliminary investigation 3-5
3.2 Task 2 – Sediment Characterization 3-5
3.2.1 Sediments Planned for Collection 3-6
3.2.2 Number and Locations of Sediment Samples 3-6
3.2.2.1 Control and reference sediments 3-7
3.2.3 Sediment Sampling Procedure 3-9
3.2.4 Analytical Program 3-10
3.2.4.1 Physico-Chemical characterization 3-11
3.2.4.2 Chemical Parameters 3-12
3.2.5 Ecotoxicological Testing 3-13
3.2.6 Sample Identification and Labeling 3-14
3.2.7 Equipment and Personnel Decontamination Procedures 3-15
3.2.8 Investigation Derived Wastes 3-16

3.2.9 Data Interpretation and Reporting 3-17
3.2.9.1 Sediment Sampling Program 3-18
3.2.9.2 Sediment Characterization 3-18
3.2.9.3 Screening Ecotoxicological Characterization 3-18
3.3 Task 3 – Bench-Scale Bioremediation Study 3-20
3.3.1 Sediment Collection Program 3-21
3.3.2 Bench-Scale Test Design 3-21
3.3.3 Ecotoxicity Assessment Support 3-25
3.3.4 Data Interpretation and Reporting 3-27

4.0 PROJECT ORGANIZATION 4-1

5.0 REFERENCES 5-1

LIST OF FIGURES

Figure 1-1 Study Area
Figure 2-1 Historical Sampling Locations
Figure 3-1 Flowchart of Project Tasks
Figure 3-2 Compositing Scheme for Sediment Samples
Figure 3-3 Schematic Drawing of Bench-scale Bioremediation Testing Apparatus
Figure 4-1 Project Team for SWP-Wilmington Sediment Remediation Project

LIST OF TABLES

Table 2-1 Summary of Sediment Analytical Results Collected from the former SWP Wilmington Facility
Table 3-1 Candidate Test Species for Use in the Ecotoxicity Assessment
Table 3-2 Sample Locations, Estimated Number of Samples, and Analyses
Table 3-3 Summary of Extraction and Analytical Methods, Sample Preservation, and Holding Times
Table 3-4 Frequency of SVOC Testing During Bench-Scale Testing

LIST OF APPENDICES

APPENDIX A Field Standard Operating Procedures – To Be Prepared
APPENDIX B Health and Safety Plan – To Be Prepared
APPENDIX C Quality Assurance Plan – To Be Prepared

1.0 INTRODUCTION

In support of Southern Wood Piedmont's (SWP) intent to use *in situ* bioremediation at its former wood treatment site located in Wilmington, North Carolina, the technical team of Schnabel Engineering Associates, Inc. (SEAI), McLaren/Hart-ChemRisk (M/H-ChemRisk) and Advanced BioSystems has prepared the following Work Plan/Field Sampling Plan (WP/FSP) to:

- Establish the detailed framework necessary to derive ecotoxicological-based remediation goals (EBRGs) for near-surface sediments of Greenfield Creek and drainage ditch sediments; and

- Perform bench-scale testing to ensure the efficacy of the biological treatment technology in reducing overall sediment toxicity to acceptable levels for near-surface sediments.

1.1 SITE SETTING

The SWP Site is located parallel to Front Street in downtown Wilmington, New Hanover County, North Carolina, and consists of vacant land on the Cape Fear River waterfront (Figure 1-1). The City of Wilmington owns 51.57 acres comprising the northern portion of the Site. The remaining 44.58 acres are 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.

Runoff from the Site generally flows 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 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 have been reported by NC-DENR (1995) and ViroGroup (1994).

Sediment samples collected in 1992 (ViroGroup, 1994) and 1996 (ViroGroup, 1996) showed the presence of Semivolatile organic compounds (SVOCs) within Greenfield Creek and the Site drainage ditch. M/H ChemRisk conducted both a human health risk assessment (HHRA) and Ecological Risk Assessment (ERA) for the Site which was submitted to DEHNR in May 1996. The HHRA concluded that present day surficial sediment concentrations in the creek and drainage ditch systems did not pose an unacceptable cancer and noncancer health threat. The screening-level ERA concluded that potential risks from Polycyclic Aromatic Hydrocarbon (PAH) exposures via bioaccumulation are insignificant for higher trophic organisms, while hazard quotients calculated for benthic macroinvertebrates indicate potential effects via direct contact and ingestion of sediment PAHs. Thus, with respect to remediation of surficial sediments, ecotoxicity impact concerns should prevail over human health concerns.

In December 1997, Southern Wood Piedmont signed an Consent Decree with the The North Carolina Department of Environment and Natural Resources (NC-DENR) to proceed with the remedial program at this Site. The NC-DENR will be providing regulatory oversight during the current phase and the remediation phase of this project.

1.2 Objectives and Description of Current Project

In an ecotoxicity assessment, one or more test species are used to measure the toxicity of a contaminated matrix. The toxicity responses can then be used to monitor the reduction or removal of toxic constituents due to specific remedial actions and help determine when an acceptable cleanup level has been reached. In this respect, measuring toxicity with test organisms is analogous to measuring analyte concentrations with an analytical instrument: both provide information about the presence of contaminants in a matrix. However, instead of measuring absolute concentrations of individual compounds with an instrument, an ecotoxicity assessment relies on organisms to "measure" the total *bioavailable fraction* of those contaminants.

While the proposed approach will help SWP determine when sediment cleanup is complete, it is not designed to develop a single numerical cleanup criterion *per se*. Under ideal conditions, toxicity is substantially reduced or disappears entirely when microbial degradation stops because the bioavailable fraction of hydrocarbons have been consumed or the hydrocarbons have been removed altogether. It is possible, however, that residual toxicity could still be present due to "other" contaminants (e.g., metals, pesticides, or ammonia) in the sediments.

1.2.1 Objectives

The primary objective of this project is to determine if ecotoxicity tests can be used to develop site-specific EBRGs in support of the proposed sediment *in-situ* bioremediation project. To achieve this objective, the study seeks to collect information sufficient to:

- Characterize the surficial sediments in Greenfield Creek and the adjoining ditches in terms of physico-chemical make-up, nature and extent of contamination, and intrinsic ecotoxicity.

- Assess the potential for the sediment organic contaminants to undergo bioremediation in a bench-scale laboratory study.

- Quantify the decrease or removal of toxicity from the sediments during and after the bench-scale bioremediation study.

- Identify, if necessary, the source and nature of residual toxicity left over after the bench-scale bioremediation study is terminated.

1.2.2 Proposed Study Activities

To satisfy the stated objective, the following specific project activities will be performed:

- Identify candidate benthic test species for use in the ecotoxicity testing program.

- Develop and execute a field sampling program to collect 14 representative composite sediment samples (depth: 0 to 3-in) from the creek and the ditches.

- Characterize the physico-chemical, analytical and ecotoxicological nature of the 14 sediment samples.

- Select a sensitive test species for use in developing site-specific sediment cleanup goals.

- Identify control sediments and appropriate site-specific reference sediments for use in the ecotoxicity testing program.

- Measure the removal of toxicity in the sediments during and after the bench-scale bioremediation study.

- If necessary, develop and execute a sediment Toxicity Identification and Evaluation (TIE) program to identify the source(s) of residual toxicity in the sediments used in the bench-scale study.

- Measure toxicity removal in composite surficial sediment samples collected from the creek and ditches during the *in-situ* bioremediation phase to determine acceptable cleanup levels.

1.3 PLANNING DOCUMENTS

This Work Plan/Sampling and Analysis Plan (WP/SAP) has been developed based upon a review of available site information, prior site visits, and the following documents:

- Data Summary Report for the Treated and Non-Treated Wood Storage Areas Soil Investigation, Southern Wood Piedmont Company, Wilmington, North Carolina. (Geraghty & Miller, 1993).

- Soil, Sediment, and Surface Water Assessment Workplan, Southern Wood Piedmont Company, City of Wilmington & North Carolina State Ports Authority Wilmington, North Carolina Facility. (ViroGroup, 1996).

- Human Health and Ecological Risk Assessment for the Southern Wood Piedmont Site, Wilmington, North Carolina (M/H-ChemRisk, 1996).

- North Carolina Department of Environment and Natural Resources (NC-DENR). Draft North Carolina Risk Analysis Framework. (NC-DENR, 1996).

- Expanded Site Inspection of Southern Wood Piedmont. Wilmington, New Hanover County, North Carolina. (Black&Veatch, 1997).

This WP/SAP presents the overall approach and details project activities that will be used for this project. Chapter 2 of the WP/FSP provides additional background information concerning the site, relevant to the development of the ECRGs and bioremediation program. A discussion

of the Data Collection Plan is provided in Chapter 3. It outlines the rationale underlying the number and location of sampling points and analytical parameters. Specific sample collection procedures are also addressed in this chapter. Chapter 4 is a discussion of the project management plan and Chapter 5 provides the WP/FSP references. Appendix A contains the Field Standard Operating Procedures.

Two other project-specific work plans have been developed for this study. Appendix B contains the Health and Safety Plan, which describes the expected hazards and levels of protective measures to be implemented in order to protect the safety and health of field personnel are detailed in the Health and Safety Plan. Appendix C contains the Quality Assurance Plan, which summarizes the field and laboratory quality assurance/quality control (QA/QC), chemical analytical procedures, preparation of field QC, and other relevant functions.

1.4 CERTIFICATION

This project will be performed under the direction of a Registered Environmental Consultant with a Registered Site Manager as a key person responsible for the implementation and oversight of the work. Certification (signature and seal) by either a professional engineer or a professional geologist registered in the State of North Carolina will be included in all documents relating to the ecotoxicity evaluation and remediation assessment activities performed at this Site.

2.0 BACKGROUND

2.1 SITE HISTORY

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).

2.2 SITE LOCATION AND 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 City of Wilmington owns 51.57 acres comprising the northern portion of the Site. The remaining 44.58 acres are owned by the North Carolina State Ports Authority (NCSPA). Most of the land south of the Site is undeveloped coastal prairie and wetland that drain into the Cape Fear River. The Cape Fear River estuary approximately represents the portion of the river that 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 woods, 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 former slips along the eastern shoal of the river. To the immediate north of the Site is a bulk 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.

2.3 PHYSICAL CHARACTERISTICS

2.3.1 Hydrogeology

Aquifer Systems

The site is underlain by two aquifer systems (Black & Veatch, 1997): 1) the upper sandy aquifer system located between land surface and approximately 46 feet below land surface (bls), and 2) the lower sandy aquifer system located from approximately 46 feet bls to 81 feet bls. The two aquifer systems are separated by a clay that acts as a confining unit between the two aquifer systems. This clay is approximately 4 to 15 feet thick, laterally continuous, tight, dry, and prevents flow between the two aquifer systems (Black & Veatch, 1997, ViroGroup, 1996, and Bain, 1970). Aquifers present below the principal lower aquifer system are saline and not utilized as a water source.

The upper aquifer system is composed of a water table aquifer and a semi-confined aquifer. Both the water table aquifer and the semi-confined aquifer consist of high permeability fine to coarse sand. A peaty clay separates the water table aquifer from the semi-confined aquifer.

This peaty clay consists of silt and clay with varying amounts of wood and root fragments. The peaty clay is completely water saturated demonstrating a hydraulic connection between the water table aquifer and the semi-confined aquifer in the upper aquifer system (ViroGroup, 1996).

Tidal Affects

Groundwater flow in the water table aquifer of the upper aquifer system is tidally influenced. Changes in ground water gradients and flow direction occur during the tidal cycle. These hydraulic changes retard the movement of constituents in the subsurface. An elongate water table mound exists that is at its highest elevation in the northeast corner of the site. The groundwater mound extends along the central portion of the site to the south. From this elongate groundwater mound, the groundwater flows off in all directions toward on-site drainage ditches, Greenfield Creek, and the Cape Fear River. Groundwater in the water table aquifer from off-site to the east in the vicinity of Optimist Park is flowing to the west toward the on-site drainage ditch. When water elevations rise in the surrounding surface water bodies during high tide, a groundwater inflection line develops along the drainage ditches, Greenfield Creek, and the Cape Fear River. At this tidal stage, the surface water flows into the aquifer encountering groundwater flow from the central groundwater mound. These two opposing forces result in an inflection of approximately 90 degrees in flow direction and an order of magnitude decrease in hydraulic gradient. As a result, the groundwater flow rate is reduced significantly and constituents are diluted as surface water migrates into and out of the aquifer materials adjacent to the surface water bodies. The inflection of the groundwater tends to spread the constituents with the direction of flow along the inflection line.

The groundwater flow direction and gradients in the semi-confined aquifer of the upper aquifer system are controlled by the surface water elevation of the Cape Fear River. At low tide a central groundwater mound develops in the semi-confined aquifer. Groundwater along this mound is divided and flows off toward the Cape Fear River, toward the drainage ditches, and toward Greenfield Creek. Vertical hydraulic gradients are downward from the water table aquifer along the Cape Fear River and in the central portion of the site. Upward vertical hydraulic gradients are present along Greenfield Creek and the on-site drainage ditches. During high tide the potentiometric head along the Cape Fear River rises and groundwater flow becomes southeast. An upward vertical hydraulic gradient develops along the Cape Fear River and remains upward along Greenfield Creek and the on-site drainage ditches.

Ambient Water Quality

Since the site is located adjacent to the brackish Cape Fear River and Greenfield Creek, the upper aquifer system contains saline groundwater (Class GSA). Greenfield Creek and the on-site tributaries are classified as Class SC-Swamp (salt water). The Cape Fear River is classified as a Class SC tidal saltwater. Only a small mound of fresh water (Class GA - chloride less than 250 mg/L) is present in the northern and central portion of the site. Saline water is present in the water table aquifer along the Cape Fear River, Greenfield Creek, and the on-site drainage ditches.

2.3.2 Hydrology

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 Site hydrology have been reported by NCDEHNR (1995) and ViroGroup (1994).

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.

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.

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). The authors 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.

2.3.3 Climatology

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 was been reported to be 5.0 inches (Geraghty & Miller, 1993).

2.4 ECOLOGICAL CHARACTERISTICS

Qualitative surveys of the vegetation, wildlife and aquatic communities were performed as part of the Ecological Risk Assessment at this Site (ChemRisk, 1996).

2.4.1 Vegetative Communities

Drainage Ditch – 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.

Greenfield Creek - 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. Bald cypress occurs extensively in marginal zones along

the south bank of the creek, and is common upstream from the railroad trestle. Further downstream, bald cypress is less apparent as the banks of the creek become more steep. 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. Submergent vegetation (*Elodea* sp.) was observed in the Creek at approximately 600 feet upstream from the tidal gate.

2.4.2 Wildlife Communities

Drainage Ditches - 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 (e.g., muskrats) 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 that crosses the ditch, indicating that during the time when river water passed through the tidal gate, water and flow conditions were sufficient for supporting brackish water communities.

Greenfield Creek - 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 (less than 1-in in total length) 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 were 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 preliminary ecological evaluation performed as part of the risk assessment (M/H-ChemRisk, 1996) identified several differences between the local ecological habitat and communities of the ditch/Creek system and the Cape Fear River, which likely influences potential exposure of resident or migratory biota. Collectively, observations during this evaluation included the following:

- Although several rare species were 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.

2.5 Previous Study Results

Sediments have been collected from Greenfield Creek and the drainage ditches as part of past site characterization projects. These results have been summarized in Table 2-1 and are summarized below. The sampling locations are presented on Figure 2-1.

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.

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 four metals (arsenic, copper, chromium, and lead), SVOCs and VOCs. The VOCs that were detected included dichloromethane, total xylenes, toluene, and ethyl benzene. The polycyclic aromatic hydrocarbons (PAHs) were the most commonly found SVOCs. These included benzo(a)anthracene, chrysene, fluoranthene, naphthalene and dibenz(a,h)anthracene. Phenolic compounds were not detected in any of the samples. Chromium, copper, lead and arsenic were also reported in these samples.

In 1996, thirteen sediment samples were collected 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). Additional sediment samples were also collected to address the issue of bioavailability of sediment-associated chemicals.

In 1997, five sediment samples were collected from Greenfield creek and the drainage ditches. All samples were analyzed for metals, SVOCs, VOAs, pesticides, and PCBs (BVSPC, 1997).

In summary, these investigations have indicated elevated levels of SVOCs, particularly PAHs, in a number of samples.

3.0 DATA COLLECTION PLAN

A major goal of this work plan is to design and execute a study to show that *in-situ* bioremediation of sediments in Greenfield Creek and the ditches will sufficiently reduce or remove toxicity from the surficial sediments. The ecotoxicity assessment will be restricted to surficial sediments (i.e., from 0 to 3") for the following reasons: (1) only surficial sediments form the biologically active zone; (2) they are the interphase between the bed sediments and the overlying surface water; and (3) ecotoxicity tests are not designed for use with anoxic subsurface sediments. This chapter describes the types of literature, field, analytical, and testing data that will be collected for this project. Figure 3-1 presents the flowchart of project tasks.

3.1 TASK 1 – IDENTIFICATION OF TEST SPECIES AND ECOTOXICITY ENDPOINT

Task 1 activities will occur prior to initiation of any ecotoxicity testing of sediments, bench-scale bioremediation studies, or development of EBRGs. This task will include the following two objectives:

- Identification of Test Species; and
- Identification of Suitable Ecotoxicity Endpoints

3.1.1 Selection of test species for preliminary evaluation

M/H-ChemRisk has performed a preliminary review of the published literature to develop a list of potential candidate benthic test species. A major consideration in the selection process is the anticipated brackish nature of the sediments in the creek and ditches. This eliminates strictly freshwater or salt water benthic species. Another important consideration is the availability of a standardized and recognized bioassay testing protocol. Testing methods have been proposed for a variety of benthic species, but *standardized* protocols are available for only a small fraction of these species. Benthic species for which standard test protocols are not available have been eliminated from further consideration. This eliminated many potential species from further consideration and resulted in the shortened list shown in Table 3-1.

Table 3-1 summarizes pertinent information on a number of candidate benthic test species. The table is divided into three major groups: amphipods, annelids (worms), and chironomids (midges, an insect group), using the following variables:

- Geographic range – Preference will be made to the test species whose natural geographic range overlaps with the mid-Atlantic region, including North Carolina.

- Habitat – Benthic invertebrates have evolved different strategies for living in sediments, including free burrowing and tube dwelling.

- Salinity Preference – This is a critical variable since benthic organisms show different tolerances to salinity.

- Sediment Type – Grain size, total organic carbon content, and presence of plant material can affect whether the sediment is a suitable habitat for the benthic organism.

Habitat — Free burrowing benthic invertebrates burrow throughout the sediments looking for food and shelter. As a result, they are continuously exposed to contaminants in the sediments through direct, physical contact and via ingestion. The tube dwelling benthic invertebrates have a more "sedentary" lifestyle: the organism builds a tube of mucus or other material within the sediment matrix for protection and feeding. This may limit its direct contact with the surrounding sediments. In addition, some species obtain their food by siphoning water from above the sediments into their tubes. This can further limit exposure to sediment contaminants.

It may be preferable to select a free burrowing test species since this lifestyle is expected to maximize exposure. However, it is probably premature to eliminate tube-dwelling species from further consideration. Therefore, both free burrowing and tube dwelling species will be evaluated for sensitivity during the preliminary testing program.

Salinity preferences — Salinity is a critical variable since salt (NaCl) can be toxic to some species. Of the three groups described in Table 3-1, the midges are the least salt tolerant, since they cannot survive salinities above 5 ppt and are therefore essentially a freshwater species. Several of the amphipod species are tolerant to a wide range of salinity due to their estuarine lifestyle. The worm species are expected to have narrower salinity tolerances, either in the salt water or fresh water ranges.

Site-specific salinity measurements will be necessary before a test species can be selected based on salinity tolerance. The available information suggests that site-specific salinities in the surficial sediments may be in the 0-10 ppt range.

Sediment type — Sediment type is another critical variable. Certain benthic species have narrow grain size tolerances, whereas others can thrive in a wide range of sediment types. Based on the available information, it is anticipated that most of the surficial sediments in the creek and ditches are fine-grained (silt/clay) with relatively high organic carbon levels. However, since sediments can be extremely heterogeneous, even over small distances, it is therefore preferable to select a benthic species with a high level of tolerance to a range of sediment types.

3.1.1.1 Recommendations for candidate test species

Based on the general considerations outlined above, five benthic species are highlighted in Table 3-1 as potential candidates: These are the amphipods *A. abdita, H. azteca*, and *L. plumulosus*, and the chironomids *C. riparius* and *C. tentans*. All of these species have been extensively used in past sediment toxicity work (Burton, 1991; EPA, 1994b). Detailed testing guidelines are available from US EPA and the American Society for Testing and Materials (ASTM) (EPA 1991, 1994b, 1994c; ASTM, 1997).

Benthic worms are not recommended as a test species for the following reasons:

- Worms tend to be less frequently used in sediment toxicity testing work, and therefore an extensive database on their responses during these tests may not be readily available; and

- Several of these species (e.g., *N. virens, C. capitata, T. tubifex*) have a natural association with contaminated sediments or sediments with high organic loads (ASTM, 1997).

Commercially available test organisms will be used in lieu of field-collected specimens for this project. The main reason, assuming that appropriate on-site benthic test species are available in sufficient numbers, is that their supply can be erratic and populations can fluctuate significantly over the seasons. Also, the effort necessary to collect and manually pick through sediment samples and identify the target organisms down to the genus and/or species level can be prohibitive. Finally, unless a reliable source of organisms is available from an *uncontaminated* reference area at or near the property, it is possible that the sensitivities of sub populations collected from impacted areas could vary depending on the contaminant load or sediment type. This would make the interpretation of the ecotoxicity data difficult if not impossible.

3.1.1.2 Microtox®

Since it can be time-consuming to perform a large number of sediment toxicity tests with benthic invertebrates, Microtox® will be evaluated as a "surrogate" test system for some of the anticipated invertebrate testing needs. Microtox® measures the ability of contaminants to quench the production of bioluminescence in a marine bacterium (*Photobacterium phosphoreum*). The bioluminescence of exposed bacteria is measured using a spectrophotometer and compared to controls. Microtox® can measure toxicity in interstitial water or in a sediment contact test (Brouwer et al., 1990).

The organism itself is not an appropriate site-specific test species. However, reports in the literature have shown positive correlations between inhibition of bioluminescence in *P.*

phosphoreum and toxicity measured in fish or invertebrates (Williams et al., 1986; Becker et al., 1990). In addition, under certain circumstances, Microtox® has been reported to have similar or greater sensitivity to contaminated sediments than a number of aquatic test species (They et al., 1989; Pastorok and Becker, 1990).

Microtox® testing of sediments will be performed in parallel with the benthic invertebrate toxicity testing program. Correlation analysis will be performed to determine whether Microtox® can correctly predict benthic toxicity. If such a relationship is established, Microtox® could be used routinely to monitor surficial sediment toxicity during the *in-situ* bioremediation phase.

3.1.2 Selection of measurement endpoints for preliminary investigation

Most toxicity tests with benthic invertebrates focus on acute endpoints such as mortality. Acute endpoints will be used, since there a large database available on acute toxicity, and the tests can be completed in a shorter time frame than chronic tests. To increase the sensitivity and robustness of the acute toxicity tests, the dose-response data will be used to calculate the No Observed Effects Concentration (NOEC) for each test. The NOEC is, by definition, a more sensitive endpoint than LC_{50} when toxicity is present. NOECs and LC_{50}-values will be calculated with each of these toxicity tests.

3.2 TASK 2 — SEDIMENT CHARACTERIZATION

Sediments have been collected from Greenfield Creek and its tributaries and characterized for chemical contamination in previous studies. The sediment collections to be performed as part of this Remediation Work Plan are oriented towards obtaining representative samples to satisfy the project objectives described in Section 1.2. The sediment collection plan for the bench-scale bioremediation study is discussed in Section 3.3. The standard operating procedure for collection of the sediment samples is provided in Appendix A.

3.2.1 Sediments Planned for Collection

The purpose of this study is to obtain a representative overview of the surficial sediments in the creek and ditches. It is estimated that the total length of the creek and ditches requiring remedial attention is approximately 3,300 ft (Greenfield creek ± 1,800 ft; drainage ditch ±1,000 ft; covered ditch ± 500 ft). Therefore, areal composite samples will be collected and analyzed for chemical constituents, toxicity, and tested for bioremediation potential. Composite samples are more appropriate to collect than discrete samples since for this phase of the project it is important to obtain a representative horizontal profile of the physico-chemical and ecotoxicological characteristics of the sediments.

Composite samples will be collected from the top 3" of the sediments. Biological activity by benthic invertebrates usually does not extend beyond 3", and in many cases is confined to the top 1" (Burton, 1991). Below this biologically-active layer, sediments are usually anoxic and unable to support benthic invertebrates.

3.2.2 Number and Location of Sediment Samples

Surficial sediment samples will be collected using a randomized-stratified approach following the scheme presented in Figure 3-2. Greenfield Creek will be divided into six equidistant sections, each measuring 300 ft in length. This length was selected because Greenfield Creek flows in a depositional area for most of its course through the Site and the sediments in the creek tend to be more homogeneous than those found in the ditches. Each section will then be subdivided into 30 equidistant subsections (i.e., section widths will be 10-ft). Seven of the subsections will be randomly selected within each section and sampled. Approximately 250-mL of sediment will be collected from each subsection using a quarter-point sampling scheme to yield a total of one liter of surficial sediment (3" depth) from each subsection. These will be then be composited using the "core and quarter" method (see next section). The seven subsections will then be homogenized in the field following the "core and quarter" method to form a seven liter composite sample for each 300 ft section. It is anticipated that six 7-liter

representative composite samples will be developed for Greenfield Creek in this manner. Seven liters of composite sediment sample per section will be sufficient to perform the proposed physico-chemical, analytical (including QA/QC samples), and screening ecotoxicological characterizations.

The same approach will be used for the ditches, except that they will be divided into sections measuring 200 ft in length to account for the greater expected heterogeneity of sediments. Since the ditches measure approximately 1,600 ft, this would result in 8 composite sediment samples. Therefore, the proposed surficial sediment sampling program would generate a total of 14 composite samples for analysis and toxicity testing.

3.2.2.1 Control and Reference Sediments

Many factors, besides the presence of contaminants, can result in significant responses by benthic invertebrates used in a laboratory toxicity testing program. These factors may include poor health of the test organisms, inappropriate test conditions, problems with the quality of the test water, lack of food, diseases, etc. To properly interpret ecotoxicity test data, therefore, requires that the same species be tested with control and reference sediments. The challenge is to obtain the right control and reference sediments.

Control Sediments

Control sediments are used to evaluate the health and condition of test organisms to the laboratory environment, and are tested alongside Site samples. Survival in the control sediment serves to determine the acceptability of a given test. If survival falls below a minimum threshold (e.g., 90%) at the end of a test, then the entire data set from that test is considered invalid.

Control sediments are obtained from areas from which the tests organisms have been gathered (if field collected), from other areas which are within the geochemical requirements of the test species, or can be made to order by the laboratory. In the latter case, it may be appropriate to use as control sediments those used to culture the test species in the laboratory. They are also

used to serially dilute site-specific sediments. Serial dilutions are necessary to generate dose-response curves and calculate toxicity endpoints (such as LC_{50}'s or NOEC's).

After the indicator species has been selected, a determination will be made on the appropriate control sediment to use for this species. It is expected that suitable and non-toxic control sediments will be available to determine the health of the test organisms and to use as a sediment diluent.

Reference Sediments

Reference sediments are collected in the field and are comparable to the test sediments in physical and chemical characteristics, but without site-specific contaminants. They assess the presence of "background" toxicity in sediments due to unidentified off-site sources of contamination. These off-site sources may include petroleum hydrocarbons from road runoff, pesticides from agricultural or lawn care activities, or heavy metals from atmospheric depositions.

Reference sediments are collected in the same general area and using the same techniques as those employed to obtain actual test sediments. Ideally, characteristics (such as particle size distribution or organic carbon) of the reference sediments should bracket those of the test sediments. If a wide range of characteristics is found within sediments at the Site, the characteristics of the reference sediment should be intermediate, unless the test species is affected by particle size.

During the sediment sampling program, ChemRisk will investigate potential candidate reference areas on-site. It may be necessary, however, to investigate off-site areas in the immediate vicinity of the property to find appropriate reference sampling locations.

3.2.3 Sediment Sampling Procedure

Ponar or Van Veen samplers (or other comparable equipment) will be used to collect the sediment samples. This device functions as a small dredge and has been used successfully in many studies to collect surficial sediment samples with minimal disturbance (ASTM, 1997). If the water is shallow in the creek or ditches, then stainless steel scoops may be used.

Before starting sediment sampling, the 300 foot sections within Greenfield creek, and 200 foot sections within the ditches, will be measured and marked with posts or flags. Subsections will be marked off using tape. The individual subsections to be sampled will be identified using a random numbers table, with one liter samples collected within each subsection.

Each subsample will be removed from the dredge by scooping out material that has not come into contact with the dredge walls. The field technician will visually inspect the sample to provide qualitative descriptions of color, texture, odor, presence of plants or animals, or other relevant field observations, and denote them in the field logbook.

For each subsection, and then for each section, the samples will be homogenized using the EPA Environmental Response Team guidelines (EPA 1994d), or the "core and quarter" method. The "core and quarter" method is summarized below:

- Manually remove rocks, shells, and other obvious debris from the samples.
- The sediment is placed in a stainless steel pan, then thoroughly mixed using a stainless steel spoon.
- The sediment is scraped from the sides, corners and bottom of the pan, and rolled to the middle to be mixed again.
- It is quartered and moved to the four corners of the pan. Each quarter is mixed individually, and then rolled to the center of the container and the entire sample mixed again.
- The process is repeated until the sample is fully homogenized.

- Each homogenized and composited sediment sample is transferred to the appropriate sample container, which is labeled in accordance with Section 3.2.6, and prepared for shipment to the laboratory.

The 7 liter composite sediment samples will then immediately be stored on ice to be transported to the laboratory for analytical and toxicity testing. Upon arrival to the laboratory, all sediment samples should be stored at 4°C in the dark for no longer than two weeks before they are extracted or used in ecotoxicity testing.

After the collection of sub samples within each section, the Van Veen dredge and all other equipment which has come into contact with sediment (scoops, spatulas, mixing pans, etc.) will be thoroughly cleaned to avoid cross contamination. The decontamination procedure is described in Section 3.2.7, and waste handling procedures are described in Section 3.2.8.

This sampling procedure will be repeated until all of the composite samples have been collected.

3.2.4 Analytical Program

The estimated number of samples, field QC samples (i.e., field duplicates, rinsate blanks), laboratory QC samples (i.e., MS/MSD samples) and analytical parameters are presented by location in Table 3-2. Table 3-3 summarizes the analytical methods, sample preservation requirements, and holding times. All chemical analyses will be performed by Advanced BioSystems.

Prior to performing any analytical testing of the sediments, pore water that may have settled on the surface of the sediments or in void spaces during transport and storage will be mixed back into the sample. The laboratory will then pressure sieve each composite sample through a sieve with mesh size 0.5 to 1.0 mm before chemical characterization. Sieving achieves several important goals, including removal of coarse debris (twigs, leaves, stones) and endemic macro

invertebrates, improvement of sample homogeneity and replication, and facilitation of sediment handling and sub-sampling.

Table 3-2 also lists the estimated number of field duplicates, MS/MSD samples, and rinsate blanks. Field duplicates and rinsate blanks will also be collected during the field phase for the analytical program. It is not anticipated that additional sample volume would be required for the field duplicates or MS/MSD samples since they can be subsampled from the 10 liter sediment composites. Rinsate blanks will be collected by rinsing the decontaminated sampling equipment with distilled, deioinized "analyte-free" water and collecting in a sample bottle.

3.2.4.1 Physico-chemical characterization

In order to generate data in support of the ecotoxicity assessment, the physico-chemical characteristics of the sediments will be determined. These will include particle size distribution, total organic carbon, salinity, pH, and ammonia.

Particle size distribution: Sediment particle size distribution determines the types of benthic invertebrate species that are expected to be able to survive in a given sediment.

Total organic carbon (TOC): TOC is a critical variable which regulates the bioavailability of non-ionic organic contaminants in sediments (Di Torro et al., 1991). As the name implies, TOC quantifies all organic carbon forms, including reactive particulate carbon (the fraction that equilibrates with sediment pore water). In addition, TOC is required in order to report the analytical data as normalized to sediment organic carbon content.

Salinity: Salinity must be measured to match this variable to the known salinity tolerances of the candidate benthic test species. In addition, testing sediments at salinities other than those at which they were collected can affect contaminant solubility, partitioning coefficients, and other physical and chemical characteristics. It is therefore suggested that the composite sediment samples be tested at salinities that are representative of conditions in the creek and ditches.

pH: pH affects the behavior of many chemicals (e.g., metals, ammonia) and is tolerated differently by benthic invertebrates. This variable is measured directly by inserting a pH probe in the sediment into a 1:1 mixture of sediment and distilled water.

Ammonia concentration: Ammonia can be present in sediments, irrespective of their origins or contaminant loads. It is produced when nitrogenous compounds in sediment pore water are reduced to ammonia by bacterial metabolism. This compound could be present in sediment samples from the creek and ditches due to the suburban setting of Greenfield Lake, located upstream of the Site.

Ammonia is highly toxic to aquatic organisms, including benthic invertebrates, and can lead to unexpected responses (Kohn, et al., 1994). Ammonia toxicity depends partly on the pH of the test system (temperature also plays a role): toxicity increases at higher pH's where the unionized form (NH_3) predominates over the ionized form (NH^+_4) (Bower and Bidwell, 1978). Therefore, ChemRisk recommends that the unionized form of ammonia (rather than just total ammonia) be calculated. This information will be important to determine the need for purging the sediments to remove excess ammonia before performing the benthic invertebrate toxicity tests.

3.2.4.2 Chemical Parameters

Given the wood treatment history at the site and Site characterization data, it is expected that the analytical efforts will focus on semivolatile organic compounds (SVOCs), with an emphasis on the polycyclic aromatic hydrocarbons (PAH's). Quantification of Total Petroleum Hydrocarbons (TPH) will also be performed as a generic measure of "gross" hydrocarbon contamination. TPH may also be a useful measure as an indicator of petroleum hydrocarbon degradation during the laboratory and *in-situ* bioremediation phase of the project.

The analytical methods are shown in Table 3-3. All contaminant concentrations will be reported on a dry weight basis and also normalized to TOC.

3.2.5 Ecotoxicological Testing

All ecotoxicity tests will closely follow standard test protocols published by EPA and/or ASTM in terms of test organism husbandry, experimental design considerations, and data interpretation. The ecotoxicity testing laboratory will maintain up-to-date control charts based on periodic reference toxicant testing to ensure that the sensitivity of the test organisms fall within expected ranges and do not deviate significantly over time.

In this task, an "indicator" species is selected to help in screening surficial sediments for toxicity before, during, and after *in-situ* bioremediation of the sediments at the Site. The selected test species should respond to a number of requirements, including: geographic range overlapping with North Carolina, sensitivity to site-specific contaminants, tolerance to a wide range of salinities and particle size distribution, and easy year round availability either through commercial vendors or in-house laboratory cultures. The selection process is described Section 3.1.1.

Up to three candidate test species will be selected based on the information provided in Table 3-1, and after the surficial sediments have been sampled and characterized as described earlier. Each sediment composite sample will be screened at 100% (no dilution), 50% (1:1 dilution with control sediments), and 10% (1:9 dilution with control sediments). It is expected that this "range finder" approach will bracket the range of expected acute toxicity responses and provide a qualitative estimate of the toxicity of the various sediment samples. The data will also help to rank species sensitivity and ability to discriminate between different levels of contamination.

The toxicity results and analytical data sets will be used to select the most appropriate species for use in the ecotoxicity assessment program. In order to develop dose-response curves and calculated NOECs, each sediment composite sample will be retested with the selected species.

3.2.6 Sample Identification and Labeling

Each sample container will be clearly labeled. The project number, sample identification, matrix, laboratory name, analyses required, and name of the sample collector, will be printed onto the label using non-erasable ink. In addition, the sample designated for the matrix spike/matrix spike duplicate (laboratory QC) analyses will include the letters "MS/MSD".

Each analytical sample will be assigned a unique identification number, which will consist of the following code: AAA – YY – BB – NN, where AAA represents the general sampling area (*i.e.*, SWP); YY is the last 2 digits of the sampling year (*e.g.*, 98 for 1998); BB is the sampling station; and NN represents the composite number, or other ascension code.

Valid codes for AA include SWP – Southern Wood Piedmont. Valid codes for YY range from 01 to 99. Valid codes for BB include: GC for Greenfield Creek, DD for Drainage Ditch, and CD for Covered Ditch. Valid codes for NN range from 01 to 99.

The following is an example of an acceptable sample code for the planned collections:

SWP98GC04: The composite sediment sample from the fourth section of Greenfield Creek collected in 1998.

<u>Reference Area Samples:</u>

The reference area samples will have a unique sample identification number of the following form: RA – YY – NN, where RA refers to reference area, and YY, and NN are as defined earlier.

<u>Field Duplicates:</u>

Field duplicates will be sent blind to the laboratories. A generic code for each matrix type using increasing ascension numbers starting at "01" will be used as follows: D – YY – BB – NN, where D refers to field duplicate, and YY, BB, and NN are as defined earlier. In this case, NN

is *not* the sampling station but instead represents an ascension code only. This generic code will be cross-referenced in the field notes but not provided to the laboratories (*i.e.*, not shown on the chain-of-custody forms).

Rinsate Blanks

Rinsate Blanks will be coded as follows: RB – YY – BB – NN, where RB is rinsate blank, and YY, BB and NN are as described previously. As with the field duplicates, NN is *not* the sampling station but represents an ascension code only.

Toxicity Testing

Sediments collected for toxicity testing will be coded in a similar manner to the sediments collected for chemical analysis, but will have the prefix TXA for the benthic invertebrate toxicity test, or MTX for the Microtox® test, as follows: TXA – YY – BB – NN or MTX – YY – BB – NN, where YY, BB, and NN are as defined earlier.

The following are examples of acceptable sample codes for sediments collected for toxicity testing:

TXA98DD02: benthic invertebrate toxicity test for the second sediment composite sample from the drainage ditch collected in 1998.

MTX98GC12: Microtox® test for the twelfth sediment composite sample from Greenfield Creek collected in 1998.

3.2.7 Equipment and Personnel Decontamination Procedures

A portable decontamination area will be established at the Site to contain liquid and solid waste generated during the decontamination of equipment and personnel between sampling

locations. All waste generated from decontamination will be containerized and sampled for proper disposal.

All sampling equipment will be decontaminated prior to arrival at the Site by the following procedures:

1) Clean with tap water and laboratory grade, phosphate-free detergent, using a brush, if necessary.
2) Rinse thoroughly with tap water.
3) Rinse thoroughly with distilled, deionized water.
4) Rinse twice with organic-free solvent (pesticide grade isopropanol).
5) Rinse with distilled, deionized, "analyte-free" water and allow to air dry.
6) Wrap with aluminum foil and then in plastic to prevent contamination if the equipment is to be stored or transported.

NOTE: Do not rinse with deionized water or distilled water for Step 5. If distilled, deionized, "analyte-free" water is not available, let equipment air dry as long as possible.

Once at the Site and between discrete samples the procedures as listed below can be followed:

1) Clean equipment thoroughly with tap water.
2) Rinse thoroughly with distilled, deionized water.
3) Rinse with pesticide-grade isopropanol.
4) Rinse three times with distilled, deionized, "analyte-free"water.

If at any time visual contamination is observed on the sampling equipment, a non-phosphate soap wash is required in step 1.

3.2.8 Investigation Derived Wastes

Section 5.15 of EPA (1996) describes the types of Investigation Derived Waste (IDW), its handling, and disposal. It is anticipated that the IDW that will be generated during the field sampling phase of Task 2 will include the following items:

- Personnel protective equipment (PPE) – Including disposable coveralls, gloves, booties, and other PPE required by the HASP.

- Disposable equipment – Which may include plastic sheeting and equipment covers, aluminum foil, broken or unused sample containers, sample container boxes, tape, and other related items.

- Unused sediment material

- Decontamination fluids - Any spent solvents and washwater.

- Packing and shipping materials.

Solid non-hazardous IDW, which includes PPE, disposable equipment, and packing and shipping materials, will be disposed as solid waste in a dumpster or similar container. Rinse water from decontamination of sampling equipment, which does not contain any organic solvents that were used for decontamination, will be disposed in a sanitary sewer.

Spent organic solvents used for decontamination will be containerized separately from the aqueous decontamination fluid wastes. The containers will be labeled and disposed by SWP at an appropriate treatment and disposal facility within 90 days of generation, in accordance with USEPA regulations.

Any unused sediment material, such as that adhering to the sampling equipment and not collected for analysis will be returned to the creek or ditch sediment bed in the same area that it was collected.

3.2.9 Data Interpretation and Reporting

The information generated during Task 2 will help in developing the laboratory-scale bioremediation study and in providing field bioremediation ecotoxicology support. ChemRisk will therefore perform a detailed interpretation of the results. This effort will include the following:

3.2.9.1 Sediment Sampling Program

This section will provide a detailed description of the sediment sampling procedures used in the field, and the visual observations of the sediment. Any variances from the planned Work Plan sampling procedures will be presented, and alternatives will be suggested to facilitate field sampling in the future.

This section will also describe the steps involved in identifying control and reference sediments.

3.2.9.2 Sediment Characterization

This section will provide a detailed overview of the physico-chemical data for the composited sediment samples. The data will be tabulated and graphed to facilitate interpretation. A correlation analysis will be performed to uncover statistical relationships among the various parameters. If two or more parameters are significantly correlated, then it may be possible to reduce the data set for use in the multiple regression analyses.

The Analytical Results section will provide a detailed overview of the analytical data for the composited sediment samples. The data will be tabulated and graphed to facilitate interpretation. The data will also be statistically analyzed (such as ANOVA) to identify and locate potential "hot spot" areas in the surficial sediments of the creek and ditches. To assist in the toxicity evaluation described below, the analytical data to existing sediment quality criteria (EPA, NC, FL, others). This may provide more focus when interpreting the ecotoxicity data.

Analytical results of the Control and Reference sediments will also be presented in this section.

3.2.9.3 Screening Ecotoxicological Characterization

The data from the screening ecotoxicity program will be analyzed in a number of ways. The toxicity data generated by the candidate test species will be statistically compared among each

other to determine if a given species is consistently more sensitive than the others. Since it is unlikely that the tests will provide an unambiguous response, the choice may have to rely partly on professional judgment, which will be documented during selection process.

A multiple regression analysis will be performed to identify those physico-chemical or analytical parameters which best explain the observed toxicity in each of the test species. For example, a test species could show a high level of sensitivity but may be responding to a physico-chemical variable over which we have no control. Another test species may be less sensitive but show a better response to the presence of one or more contaminants of potential concern. The latter might therefore be a better candidate as a sentinel species to monitor the progress of the *in-situ* bioremediation program.

The toxicity data from the benthic invertebrate candidate species will be correlated to the Microtox® bioluminescence inhibition data. The goal is to determine to what degree Microtox® can predict the response by benthic organisms. If a robust statistical correlation can be established, Microtox® could be used for routine monitoring purposes.

Finally, the benthic toxicity and analytical data will be compared to the sediment quality criteria discussed earlier to determine if generic sediment criteria would be of any predictive use to monitor the surficial sediments during the *in-situ* bioremediation phase.

Results of toxicity tests performed on the Control and Reference sediments will also be reported and analyzed in this section. The data pertaining to the physico-chemical characteristics and contaminant concentrations in the reference sediments will also be contrasted with the data from the composited sediment samples. Based on these interpretations, one or more candidate reference samples for use in the ecotoxicity program will be identified. Sources of potential "intrinsic" toxicity in the final reference samples will be evaluated, as well as any measures to control the manifestation of this toxicity.

3.3 TASK 3.0 — BENCH-SCALE BIOREMEDIATION STUDY

A bench-scale laboratory study will be performed prior to full-scale field bioremediation to determine how much residual toxicity is expected to remain in the sediments after *in-situ* bioremediation is completed. Residual contamination may be present from "non-targeted" chemicals, such as metals, pesticides, or ammonia. This information is required to accurately predict if *in-situ* bioremediation will result in an acceptable ecotoxicity-based cleanup goal.

Typically, when petroleum-based hydrocarbons are bioremediated, there is a rapid initial decay in chemical concentrations since bacterial metabolism quickly removes the bioavailable fractions. After these fractions are metabolized, the efficiency of contaminant removal rapidly decreases and eventually stops as the bacterial populations encounter increasingly more recalcitrant hydrocarbons.

Numerous studies with soil and sludge matrices have shown that during the bioremediation process, toxicity decreases over time or is removed entirely (e.g., Wang et al., 1990; Hund and Traunspurger, 1994), even when contaminant concentrations are not reduced to background levels. Other studies, however, have reported significant amounts of residual toxicity at the end of bioremediation (e.g., Wang and Bartha, 1990; Trudell et al., 1993; Huling et al., 1995).

Clearly, the expected toxicity response is difficult to predict *a priori* since it depends on a number of factors, including initial contaminant loadings, duration of bioremediation, addition of nutrients, physico-chemical characteristics of the soil/sediment matrix, nature of the contaminants, etc. This is why it is necessary to perform a bench-scale laboratory study prior to embarking on an ecotoxicity assessment to guide the proposed bioremediation cleanup of sediments in the field.

From the perspective of the ecotoxicity assessment, the bench-scale study will answer a number of important questions, including the following:

- What is the strength of correlation between contaminant removal and detoxification of the sediments? Is it possible to *predict* toxicity based on the analytical results?

- After bioremediation has run its course in the laboratory under optimum conditions, how much residual toxicity (if any) is still present in the sediment samples? What is the nature and extent of contaminants remaining in the sediments at that time?

- If residual toxicity is present at the end of bioremediation, can its source be identified and isolated? If so, is it something that could hinder using an ecotoxicity assessment approach to achieve an acceptable sediment cleanup in the field?

3.3.1 Sediment Collection Plan

Sediments for the bench-scale testing will be collected from the area from the creek or ditches that showed that most elevated SVOC concentrations, based upon historical data and samples collected as part of the ecotoxicity testing program. The sampling procedures, and other relevant information, are described in Section 3.2.

3.3.2 Bench-Scale Test Design

The primary project objective of the bench-scale bioremediation test design is to determine the percent biodegradation of PAHs and phenolic compounds in the sediment. All bench-scale testing will be performed by Advanced BioSystems (ABS).

The percent biodegradation will be determined by a three-step process:

1) Calculate the percent reduction of total PAHs and phenolics in the test columns' sediment (biotic and abiotic losses),

2) Calculate the percent reduction of total PAHs and phenolics in the control column sediment (abiotic losses), and

3) Calculate the percent biodegradation of total PAHs and phenolics in the sediment by subtracting the result of 2) from that of 1).

Generalized Experimental Design

The treatability study will consist of two test columns and one control column. Each column consists of a 220 mm diameter, 320 mm long Pyrex tube set in a base machined from Teflon™. An *in situ* biocolumn, 50 mm will be placed within the 220 mm column and connected so as to allow air to enter into the biocolumn and exit through the contaminated sediments at the top of the column.

ABS will document setup of the treatability study. The collected sediment shipped from the field to the facility will be kept cooled to at or below 4°C. The sediment sample will be thoroughly mixed in a 15 to 20 gallon plastic trough and sampled. A single grab sample will be collected by ABS to determine the T_0 contaminant concentrations for the sediment in all columns. This sample will be analyzed for PAHs and other SVOCs. ABS will determine the pH and dissolved oxygen levels in this same sediment.

The sediment for test columns will be amended with nutrients and an acclimated bacterial culture, and thoroughly mixed again. The type and quantity of amendments will be documented by ABS. Each column, including the control column, will be loaded with 8 liters of sediment.

One sample of water will be collected immediately before water is added to the columns. This sample will provide a measurement of the contaminant concentrations in the water at T_0 for all columns. The remaining portion of each column will contain ambient air. No T_0 air samples will be collected since system air will not be turned on and volatilization in the short time span before system startup is expected to be negligible.

Sediment and water samples will be collected and analyzed for SVOCs at T_0. No air samples will be collected since system air will not be turned on and volatilization in the short time span before system startup is expected to be negligible.

The duration of the treatability study will be 60 days. The termination date will be determined based upon the SVOC results from intermediate sediment samples. Currently, the plan is to collect this intermediate sample after 30 days of operation. ABS believes that the bioremediation process may degrade a significant amount of the PAHs and phenolics in that time period.

ABS will analyze the PAHs and other SVOCs by the GC/MS Method 8270B tests to indicate whether sufficient biodegradation has occurred within the first 30 days. On day 30, duplicate tests will be performed. Based on the results from T_0 through T_{30}, ABS and M/H-ChemRisk will

decide when to collect the final sample for Method 8270B analyses. For all chemical testing, the minimum amount of sample necessary to perform the test will be removed (approximately 5 grams) so that the impact on the columns will be minimized. Table 3-4 shows the number of and frequency at which PAHs and phenolic analyses will be performed. This table assumes that the treatability study will run for at least 60 days, even though it may be stopped sooner based on the intermediate SVOC results.

When the treatability study is discontinued, ABS will collect post-treatment water, sediment, and air samples immediately after system shutdown. The results from these samples will be used to evaluate project objectives.

During the test, an air sampling trap (XAD resin) will be utilized to collect SVOCs from the exit gases from each column. Air flow rates and totalized air flows in each column will be measured and recorded daily by ABS. The air sampling traps will adsorb contaminants from effluent gases during the treatability study. The XAD resin traps will be dismantled at the end of the study. The sampling line between the column and the sample collection trap will be as short as practical to minimize the potential for contaminant adsorption.

At the end of the test, two samples each of sediment and water will be collected from each of the three columns. System aeration will be turned off and the system allowed to equilibrate for 15 minutes before water samples are collected. Water samples will be collected by slowly siphoning all water out of the test column. The siphon rate will be slow enough to minimize the entrainment of sediments in the water stream. Approximately one liter of water will be initially removed before the sample is collected in the appropriate containers; and the remainder of the water will then be removed from the column. It will be ABS responsibility to properly handle the water collected after the treatability study. The sediment will then be decanted into a clean 5-gallon bucket and thoroughly homogenized before the post-treatment sample is collected. Again, it will be ABS responsibility to store and dispose of residual sediment after the treatability study. The same procedure will be followed to sample the control column.

Once the treatability study has been completed, the primary objective will be evaluated using a three-step procedure to estimate the percent decrease in total PAHs and chlorinated organic concentrations due to biodegradation.

1) A percent reduction in concentrations of total PAHs and phenolics in the sediment will be calculated for the test column. The concentrations of the individual PAHs and phenolics will

be totaled to provide a total PAHs and phenolics concentration present in the sediment at T_0 (C_o). The concentration of Total PAHs and phenolics in the post-treatment sediment (C_f) will be determined in the same way. The percent reduction of total PAHs and phenolics in the test columns' sediment will be calculated using the following formula:

$$\text{Percent Concentration Reduction} = \frac{C_o - C_f}{C_o}$$

2) The same procedure will be used to determine the percent decrease of total PAHs and phenolics in the control column sediment. This will provide a measure of the contaminant loss due to abiotic processes (primarily volatilization; adsorption is expected to remain constant).

3) The percent reduction of total PAHs and phenolics in the control column sediment will be subtracted from the percent total PAHs and phenolics reduction in the test columns sediment. This will provide an estimate of the percent of total PAHs and phenolics reduction in the sediment due to biological degradation.

Noncritical SVOC biodegradation will be determined using the EPA Method 8270B results for pre- and post-treatment sediment samples. Percent biodegradation will be calculated using the same 3-step procedure.

The mass of PAHs and phenolics in the water will be estimated by collecting post-treatment water samples from all columns and a single pre-treatment water sample that will be used to estimate the contaminant mass (total PAHs and phenolics) at T_0. Since clean water will be gently added to the test columns before the study begins, it is expected that the mass of total PAHs and phenolics in the pre-treatment water sample will be minimal. It is possible that PAHs and phenolics may be transferred from the sediment to the aqueous phase during the treatability study, resulting in a measurable mass of total PAHs and phenolics in the post-treatment aqueous sample. This information will be used to determine if mass transfer to the water was a significant source of contaminant loss from the sediment.

Total PAHs and phenolics mass in the exhaust air (collected on the XAD resin trap) will be determined for all columns; these results will be used to assist in interpreting whether PAHs and phenolics in the sediment were biodegraded or merely air stripped. No air samples will be collected at T_0 since the air will not yet be turned on and volatilization of PAHs and phenolics

under static conditions should be minimal. The total airflow in each column will be measured for the complete study period.

For all sediment and water analyses EPA Method 8270B will be used to determine semi-volatile concentrations. For air analyses, an XAD resin trap will be used to collect SVOCs (including PAHs); the resin will be extracted in the lab with methylene chloride and analyzed by EPA Method 8270B. Total organic concentrations will be the sum of the PAHs and phenolics that can be quantified using that method.

3.3.3 Exotoxicity Assessment Support

Much of the testing activity during Task 3 will rely on information gathered in Tasks 1 and 2, including the physico-chemical, analytical and ecotoxicological data. Since the required level and extent of this support is determined following completion of the Task 3 activities, specific work scope items can not be determined. A Sediment Remediation Work Plan Addendum will be developed describing test species and endpoints, sampling and analysis frequencies, data analysis and reporting , and related activities after the Task 3 field activities have been completed.

Conceptually, the proposed study consists of collecting representative sediment samples from the creek and ditches and subjecting them to intensive bioremediation under optimum conditions in the laboratory. From an ecotoxicity assessment perspective, the goal is not necessarily to mimic field conditions. Instead, it is expected that optimized conditions favoring bacterial metabolism will maximize the removal of petroleum hydrocarbon contaminants and toxicity. As a result, any residual toxicity measured at the end of the process would represent a "best case" situation; this means that it is unlikely for *in-situ* bioremediation to achieve <u>better</u> results than those observed in the laboratory. Therefore, these data will provide an absolute benchmark against which results from the field bioremediation phase can be compared.

Ideally, sediments used in the study should contain contamination similar in concentration and composition to that found in the surficial sediments of the creek and ditches. However,

sediments with higher levels of contamination (but similar in composition) would still fulfill the requirements of the study even though the bioremediation process may take longer to complete.

The potential heterogeneity in sediment characteristics and contaminant composition may result in the performance of a bench-scale study using more than one composite sample to determine the full range of bioremediation potentials.

The test species selected in Task 2, including Microtox® if appropriate, will be used to monitor the rate of toxicity removal over time in the sediments. The volume of sediments collected for this study should therefore be sufficient to accommodate repeated subsampling for analytical and toxicity testing purposes. Toxicity will also be measured after bioremediation has run its course (i.e., all contaminants of concern have been removed or no further significant decreases in contaminant levels are observed).

Subsamples will be tested throughout the study to be able to generate contaminant and toxicity degradation curves. These curves could be helpful in predicting effects in the field during the *in-situ* bioremediation phase of the project, and are useful for the design of the remediation system. Given the anticipated degradation curves, subsampling frequency will be higher at the start than at the end. The actual spacing between sampling events, however, could be different depending on the information generated in Task 2 and previous experiences by the team participants.

If residual toxicity is measured in one or more sediments at the end of the bench scale study, it may become necessary to perform a Toxicity Identification Evaluation (TIE). TIE's are used to isolate and identify unknown source of toxicity in surface water, industrial effluents or sediments. Procedures are available for use on contaminated sediments (Ankley and Schubauer-Berigan, 1995) and have been applied to sediment pore water (Ankley et al., 1996). A separate Work Plan Addendum will be prepared to perform the TIE if necessary.

A number of factors can lead to residual toxicity in bioremediated sediments, including the presence of pesticides or metals, partially metabolized hydrocarbons, or nitrogenous compounds from nutrient additions. If the source cannot be identified, or if it is not possible to remove it under field conditions, an evaluation of the impact of this effect on the proposed ecotoxicity assessment of the *in-situ* bioremediated sediments will be performed.

3.3.4 Data Interpretation and Reporting

The data generated in Task 3 will serve two major purposes: (1) fine-tune the design of the *in-situ* sediment bioremediation phase and (2) determine how well the proposed ecotoxicity assessment can help set an acceptable cleanup level in the surficial sediments in the creek and ditches. At the end of this task, a detailed interpretation of the results will be provided which will include, at a minimum, the following activities:

Identify relationships between contaminant removal and detoxification - A corner stone of the proposed ecotoxicity assessment is the demonstration of a link between the degradation of contaminants and a decrease in toxicity in the surficial sediments. Analytical and toxicity data collected over time during the bench-scale study will be tabulated and graphed to identify such trends. ChemRisk will perform a statistical analysis on different fractions of the contaminants of concern (for example TPH, total PAH's, high molecular weight PAH's, low molecular weight PAH's, individual PAH's, other contaminants) to determine which fraction best explains the observed toxicity responses. ChemRisk will also determine the predictive value of these data in support of the *in-situ* field bioremediation phase. Finally, a discussion will be prepared on the level and extent of residual toxicity that may still remain in the sediments at the end of the laboratory study.

Residual Toxicity Identification Evaluation (TIE) - If it becomes necessary to perform a TIE, a detailed analysis and discussion of the procedures and results, as well as a description of the potential sources for the toxicity and how these could be circumvented or eliminated during the *in-situ* field bioremediation phase will be provided.

4.0 PROJECT ORGANIZATION

Management of this project will require organizing scientific and engineering personnel and technical resources to conduct the ecotoxicity assessment and bioremediation treatability study at the SWP-Wilmington Site. The field investigation will employ pre-approved field procedures, sampling techniques, and analytical methods to accomplish data collection objectives. Effective program organization will accommodate these requirements while maintaining a manageable degree of control over all activities.

Figure 4-1 illustrates the proposed organization to accomplish this effort. The core of the technical organization is the dual Project Manager structure and the assigned Project Team. Additional individuals can be made available if warranted.

The ***Principal-in-Charge*** will be responsible for project oversight including assisting the Project Managers in procuring staff assignments, ensuring that the field team is responsive to the QA Officer and Health and Safety Officer, and providing final technical review of work products.

The ***QA Officer*** will have overall responsibility for maintaining compliance with the WP/SAP for all aspects of the project, including sampling, laboratory analysis, bench-scale testing, data processing, data quality review, and any laboratory or field audits. The QA Officer will provide unbiased monitoring and periodic auditing of the QC procedures of the Project Team. His duty is to ensure that QC procedures are being followed, that adequate documentation is provided, and that all QC problems are handled in an appropriate and expeditious manner. The QA Officer is independent of the Project Team, and provides an outside review and audit function. The responsibilities of the QA Officer are to: (1) identify the requirements of client, state, and Corporate QA policies that are relevant to the project; (2) prepare or supervise the preparation of the project QA Plan; (3) review project activities and work products to ensure compliance; (4) work with state and client certification offices; and (5) respond to client or state regulatory QA questions or policy changes.

The project ***Safety and Health Coordinator*** will be responsible for preparation of the HASP and oversee the activities of the Project Team throughout sample collection and analysis. The Safety and Health Coordinator will ensure full compliance OSHA medical and safety regulations established in the HASP.

The ***Project Manager*** will have overall responsibility for the successful, timely, and cost-effective completion of the field investigation. He will be responsible for establishing technical

and QC programs and tasks for the project. He will also be responsible for reviewing and approving all documentation and reports. He will be responsible for effective day-to-day management of the staff assigned to the work effort. These responsibilities specifically include: (1) management of all technical activities; (2) preparation of work flow diagrams, schedules, manpower allocations, and survey plans; (3) management of all project funds for labor and materials procurement; (4) review and administration of all work order changes; (5) successful accomplishment of all contractual obligations including costs, schedules, and technical performance under the assigned task; (6) management of the Project Team toward unified, productive project accomplishment; (7) format and QC of all documents and data reports; (8) direct communication and liaison with the client and NC-DEHNR; and (9) technical leadership.

The ***Field Manager*** will be responsible for collection of soil, sediment, surface water, and biota samples during the field investigation and the qualitative assessment of environmental conditions at the site. The Field Manager is responsible for implementation of the provisions of the WP/SAP, QAP, and HASP during data collection activities, and for coordination with the analytical chemistry laboratory for sample handling and transport.

5.0 REFERENCES

Ankley, G.T., M.K. Schubauer-Berigan, and J.R. Dierkes. 1991. Predicting the toxicity of bulk sediments to aquatic organisms with aqueous test fractions: pore water vs. elutriate. Environ. Toxicol. Chem. 10:1359-1366.

Ankley, G.T., and M.K. Schubauer-Berigan. 1995. Background and overview of current sediment toxicity identification evaluation procedures. J. Aquat. Ecosystem Health 4:133-149.

Ankley, G.T., M.K. Schubauer-Berigan, and J.R. Dierkes. 1996. Application of toxicity identification techniques to pore water from Buffalo River sediments. J. Great Lakes Res. 22:534-544.

ASTM. 1988. 1988 Annual Book of ASTM Standards, Volume 4.08. Standards relating to Natural Building Stones;Soil and Rock; Geotextiles.

ASTM, 1997. Annual Book of ASTM Standards, Volume11.05. E 1367-92: Standard guide for conducting 10-day static sediment toxicity tests with marine and estuarine amphipods.

ASTM, 1997. Annual Book of ASTM Standards, Volume11.05. E 1391-94: Standard guide for collection, storage, characterization, and manipulation of sediments for toxicological testing.

ASTM, 1997. Annual Book of ASTM Standards, Volume11.05. E 1525-94a: Standard guide for designing biological tests with sediments.

ASTM, 1997. Annual Book of ASTM Standards, Volume11.05. E 1611-94: Standard guide for conducting sediment toxicity tests with marine and estuarine polychaetous annelids.

ASTM, 1997. Annual Book of ASTM Standards, Volume11.05. E 1706-95b: Standard test methods for measuring the toxicity of sediment-associated contaminants with fresh water invertebrates.

American Water Works Association (AWWA). 1997. Standard Methods for the Examination of Water and Wastewater.

Barth, D.S. and T. Starks. 1985. Sediment sampling quality assurance user's guide. Office of Research and Development, Environmental Protection Agency, EPA/600/4-85/048.

Becker, S.D., Bilyard, G.R., and T.C. Ginn. 1990. Comparisons between sediment bioassays and alterations of benthic macroinvertebrate assemblages at a marine Superfund site: Commencement Bay, WA. Env. Toxicol. Chem. 9:669.

Black and Veatch Special Projects Group (BVSPC). 1997. Expanded Site Inspection of Southern Wood Piedmont, Wilmington, New Hanover County, North Carolina. Prepared under Contract No. 68-W9-0055 for the Waste management Division, USEPA.

Bower, C.E., and J.P. Bidwell. 1978. Ionization of ammonia in seawater: effects of temperature, pH, and salinity. J. Fish. Res. Board Can. 35:1012-1016.

Brouwer, H., T. Murphy, and L. McArdle. 1990. A sediment-contact bioassay with *Photobacterium phosphoreum*. Environ. Toxicol. Chem.9:1353-1358.

Burton, A.G. 1991. Assessing the toxicity of freshwater sediments. Environ. Toxicol. Chem. 10: 1585-1627.

Di Toro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Shwartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas, and P.R. Paquin. 1991. Technical basis for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. Environ. Toxicol. Chem. 10:1541-1583.

EPA. 1983. Methods for Chemical Analyses of Water and Wastes. Environmental Measurement and Support Laboratories. EPA-600/4-79-030, Revised March 1983.

EPA. 1991. Evaluation of dredged material proposed for ocean disposal. US Army Corps of Engineers, Environmental Protection Agency, EPA-503/8-91/001.

EPA. 1994a. Test methods for evaluating Solid Waste: Physical/Chemical Methods. September 1994.

EPA. 1994b. Evaluation of dredged material proposed for discharge in waters of the US – testing manual (draft). US Army Corps of Engineers, Environmental Protection Agency, EPA-823-B-94-002.

EPA. 1994c. Methods for measuring the toxicity of sediment associated contaminants using marine and estuarine isopods. EPA-600/R-94/025.

EPA. 1994d. EPA Environmental Response Team Standard Operating Procedure No. 2016: Sediment Sampling.

EPA. 1995a. QA/QC guidance for sampling and analysis of sediments, water, and tissues for dredged material evaluations. US Army Corps of Engineers, Environmental Protection Agency, EPA 823-B-95-001.

EPA. 1995b. Method 1664: N-Hexane Extractable Material (HEM) and Silica Gel Treated N-Hexane Extractable Material (SGT-HEM) by Extraction and Gravimetry (Oil and Grease and Total Petroleum Hydrocarbons). Office of Water. EPA-821/B-94-004b, April, 1995.

EPA. 1996. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, USEPA Region 4, Science and Ecosystems Support Division. May 1996.

Geraghty & Miller. 1993. *Data Summary Report for the Treated and Non-Treated Wood Storage Areas Soil Investigation, Southern Wood Piedmont Company, Wilmington, North Carolina.* Prepared by Geraghty & Miller, Inc., Raleigh, NC for Southern Wood Piedmont Company, Spartanburg, SC. NC009006. December 9.

Huling, S.G., D.F. Pope, J.E. Matthews, J.L. Sims, R.C. Sims, and D.L. Sorensen.1995. Land treatment and toxicity response of soil contaminated with wood preserving waste. Remediation (Spring 1995): 41-55.

Hund, K. and W. Traunspurger. 1994. Ecotox-evaluation strategy for soil bioremediation exemplified for a PAH-contaminated site. Chemosphere 29:371-390.

Kohn, N.P., J.Q. Word, D.K. Niyogi, L.T. Ross, T. Dillon, and D.W. Moore. 1994. Acute toxicity of ammonia to four species of marine amphipod. Mar. Environ. Res. 38:1-15.

M/H-ChemRisk. 1996. *Human Health and Ecological Risk Assessment for the Southern Wood Piedmont Site, Wilmington, North Carolina.* Report prepared Southern Wood Piedmont Company, Spartanburg, South Carolina. 29 May 1996.

NCDEHNR. 1995. Memo to C.Gurley, NC CERCLA Project Officer from S.F. Parker, Hydrogeologist; Re: Site Inspection Prioritization Southern Wood Piedmont Co., Wilmington, New Hanover County, NC. NCD 058 517 467. January 31.

NUS Corp. 1986. *Site Screening Investigation, Southern Wood Piedmont Facility, Wilmington, North Carolina.* NUS Corporation, Superfund Division. April 18.

Pastorok, R.A., and D.S. Becker. 1989. Comparative sensitivity of bioassays for assessing sediment toxicity in Pudget Sound. Oceans '89: the Global Ocean. Volume 2: Ocean Pollution, pp. 431-436.

Plumb, R.H., Jr. 1981. Procedure for handling and chemical analysis of sediment and water samples. Tech. Rep. EPA/CE-81-1 prepared by Great Lakes Laboratory, State University College at Buffalo, Buffalo, NY, for the U.S. Environmental Protection Agency/U.S. Army Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material. Published by the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

They, L.A., J.M. Thomas, W.E. Miller, and J.Q. Word. 1989. Evaluation of bioassays for designing sediment cleanup strategies at a wood treatment site. Environ. Toxicol. Chem. 8:223-230.

Trudell, M.R., J.M. Marowitch, D.G. Thomson, C.W. Fulton, and R.E. Hoffmann. 1993. *In-situ* bioremediation at a wood-preserving site in a cold, semi-arid climate: feasibility and field pilot

design, p.99-116, In: *Bioremediation of chlorinated and polycyclic aromatic hydrocarbon compounds*, Hinchee, R.E., A. Leeson, L. Semprini, and S.K. Ong (eds.), Lewis Publishers.

ViroGroup. 1994. *Phase III Groundwater Quality Assessment, Wilmington, North Carolina Facility.* Prepared for Southern Wood Piedmont Company, Spartanburg, South Carolina. ViroGroup Job No. 12-53015.00. **{Month??}**

ViroGroup. 1996. *Soil, Sediment, and Surface Water Assessment Workplan, Southern Wood Peidmont Company, City of Wilmington & North Carolina State Ports Authority Wilmington, North Carolina Facility.* Prepared for Southern Wood Piedmont Company, Spartanburg, South Carolina. ViroGroup Job No. 12-5309.00. February.

Wang, X., and R. Bartha. 1990. Effects of bioremediation on residues, activity and toxicity in soils contaminated by fuel spills. Soil Biol. Biochem. 22:501-505.

Wang, X., X. Yu, and R. Bartha. 1990. Effect of bioremediation on polycyclic aromatic hydrocarbon residues in soil. Environ. Sci. Technol. 24:1086-1089.

Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *Fishery Bull.* 77(2):339-357.

Williams, L.G., P.M. Chapman, and T.C. Ginn. 1986. A comparative evaluation of marine sediment toxicity using bacterial luminescence, oyster embryo, and amphipod sediment bioassays. Mar. Environ. Res. 19:225-249.

Table 2-1. Summary of Sediment Analytical Results Collected from the former SWP Wilmington Facility.

		Drainage Ditch[1]		Greenfield Creek[1]	
Parameters	Units	Range	Freq	Range	Freq
SEMIVOLATILES					
Acenaphthene	mg/Kg	ND – 44	71%	ND - 32	50%
Anthracene	mg/Kg	ND - 45	43%	ND - 49	33%
Benzo(a)anthracene	mg/Kg	ND - 7.4	71%	ND - 730	83%
Benzo(a)pyrene	mg/Kg	ND - 3.1	57%	ND - 660	67%
Benzo(b)fluoranthene	mg/Kg	ND - 0.75	14%	ND - 1800	67%
Benzo(k)fluoranthene	mg/Kg	ND - 4.9	57%	ND - 1.5	17%
Carbazole	mg/Kg	ND - 18	43%	ND	0%
Chrysene	mg/Kg	ND - 5.5	71%	ND - 920	83%
Dibenz(a,h)anthracene	mg/Kg	ND - 3.7	14%	ND - 0.94	17%
Fluoranthene	mg/Kg	ND - 52	71%	ND – 1,300	83%
Indeno(1,2,3-cd)pyrene	mg/Kg	ND - 2	43%	ND - 680	33%
Naphthalene	mg/Kg	ND - 44	29%	ND	0%
Phenanthrene	mg/Kg	ND - 55	57%	ND - 70	33%
VOLATILES					
Ethylbenzene	mg/Kg	ND - 0.15	14%	ND	0%
m/p-xylene	mg/Kg	ND - 0.084	57%	ND - 0.0071	33%
o-xylene	mg/Kg	ND - 0.069	14%	ND - 0.0075	33%
Toluene	mg/Kg	ND - 0.016	43%	ND - 0.0024	17%
INORGANICS					
Arsenic	mg/Kg	ND - 5.2	57%	ND - 4.65	33%
Chromium	mg/Kg	2.1 - 14	100%	ND - 5.5	83%
Copper	mg/Kg	1.9 - 48	100%	1 - 16	100%
Lead	mg/Kg	2.3 - 290	100%	ND - 14	67%

Notes:
1. Data compiled by ChemRisk (1996).

Table 3-1. Candidate test species for use in the ecotoxicity assessment

Test Species	Geographic Range	Habitat	Salinity Preferences	Sediment Type	Age of Test Organisms	Test Durat.	Endpoint Measured	Organism Source
Rhepoxinius abronius (amphipod)	Pudget Sound to southern CA (present on east coast?)	Free burrowing sand dweller	Standard= 28ppt; mortality @ <25ppt	Well-sorted fine sand to sandy silt	As uniform as possible in age and size (=adults)	10 d	Mortality; ability to rebury in clean seds after exposure	Wild populations
Eohaustorius estuarius (amphipod)	Central BC to central CA (present on east coast?)	Free burrowing sand dweller	2ppt to <28ppt	Clean fine to medium sand	As uniform as possible in age and size (=adults)	10 d	Mortality; ability to rebury in clean seds after exposure	Wild populations
Ampelisca abdita (amphipod)	ME to FL	Sediment tube dweller	20-35ppt (but OK down to 10ppt)	Fine sand and mud/silt (attracted to seds w/ high organic content)	As uniform as possible in age and size (=adults)	10 d	Mortality and growth	Wild population; lab cultures
Grandidierella japonica (amphipod)	West coast	Sediment tube dweller	16-35ppt (but best in 30-35ppt)	Fine sand to silty clay	As uniform as possible in age and size (=adults)	10 d	Mortality; ability to rebury in clean seds after exposure	Wild populations; lab cultures
Hyalella azteca (amphipod)	Lakes/ponds/streams /ditches/marshes	Free burrowing sediment dweller	0-15ppt (but OK up to 29ppt)	From 100% sand to 90% silt and clay	7-14 day old specimens	10 d	Mortality and growth	Lab cultures
					7-14 day old specimens	28 d	Mortality, growth, and maturation	Lab cultures
Leptocheirus plumulosus (amphipod)	East coast	U-shaped burrows in sediments	2-32ppt (optimum= 20 ppt)	Fine sand to silty clay	As uniform as possible in age and size (=adults)	10 d	Mortality, ability to rebury in clean seds after exposure	Wild populations; lab cultures
					Neonates (<24h old)	28 d	Mortality, growth, reproduction	Lab cultures
Neanthes arenaceodentata (polychaete worm)	Wworld wide distribution	non-permanent mucoid tubes in sediments	20-36ppt	silts and sand	2-3 weeks	10 d or 20-28 d	Mortality (10 d); mortality and growth (20-28 d)	Lab cultures; wild populations

References: Burton (1991), EPA (1991, 1994b, 1994c), and ASTM (1997)

Table 3-1 (Continued)

Test Species	Geographic Range	Habitat	Salinity Preferences	Sediment Type	Age of Test Organisms	Test Durat.	Endpoint Measured	Organism Source
Neanthes (or *Nereis*) *virens* (polychaete worm)	East coast	Burrows; free swimming	15-35ppt (but prefers saltier range)	Coarse to fine sands, clay, peat, water soaked wood, mud	Adults (?)	10 d	Mortality	Wild populations
Capitella capitata (polychaete)	World wide distribution	Free burrowing	"estuarine"	Not available	Adults (?)	Not available	Mortality	Lab cultures
Tubifex tubifex (oligochaete worm .	Lakes/ponds/streams /ditches/marshes	Free burrowing	Freshwater to estuarine (no exact salinity ranges)	Wide tolerance to grain size; preferes seds enriched w/ organic matter	Adults	28 d	Mortality; reproduction	Lab cultures
Chironomus riparius (midge)	Eutrophic lakes and streams worldwide	Sediment tube dweller	0-≤ 5ppt	Wide tolerance of grain size (>90% silt/clay to 100% sand)	First instar (<3 d old)	10-14 d Up to 30 d	Mortality; growth Emergence	Lab cultures Lab cultures
Chironomus tentans (midge)	Eutrophic lakes and streams worldwide	Sediment tube dweller	0-≤ 5ppt	Wide tolerance of grain size (>90% silt/clay to 100% sand)	Second or third instar	10 d	Mortality, growth, head capsule width	Lab cultures

Table 3-2. Sample Locations, Estimated Number of Samples, and Analyses[1].

Location/ Samples	Matrix	SVOCs	TPH	TOC	Physico-Chemical Parameters[2]	Benthic Invertebrate Toxicity	Microtox® Assay
Greenfield Creek							
- Samples	solid	6	6	6	6	6	6
- Field Duplicate	solid	1	1	1	1	1	1
- MS/MSD	solid	1	1	0	0	0	0
- Rinsate Blank	aqueous	1	1	0	0	0	0
Drainage Ditches							
- Samples	solid	8	8	8	8	8	8
- Field Duplicate	solid	1	1	1	1	1	1
- MS/MSD	solid	1	1	0	0	0	0
- Rinsate Blank	aqueous	1	1	0	0	0	0
Reference Area							
- Samples	solid	10	10	10	10	10	10
- Field Duplicate	solid	1	1	1	1	1	1
- MS/MSD	solid	1	1	0	0	0	0
- Rinsate Blank	aqueous	1	1	0	0	0	0
Control Sediment							
- Samples	solid	1	1	1	1	1	1
- Field Duplicate	solid	0	0	0	0	0	0
- MS/MSD	solid	0	0	0	0	0	0
- Rinsate Blank	aqueous	0	0	0	0	0	0

Notes:

1. Analytical Methods are summarized in Table 3. Toxicity Testing methods are presented in Table 1.
2. Geochemical Parameters include sediment particle size distribution, total organic carbon, salinity, pH, and ammonia concentration.

Table 3-3. Summary of Extraction and Analytical Methods, Sample Preservation, and Holding Times

Parameter	Sample Matrix	Analytical Procedures	Preservation	Holding Time
Polycyclic Aromatic Hydrocarbons	solid	EPA 8270	Cool, <4C	14 days extraction, 40 days analysis
Polycyclic Aromatic Hydrocarbons	aqueous	EPA 8270	Cool, <4C	14 days extraction, 40 days analysis
Total Petroleum Hydrocarbons	solid	EPA 1664	Cool, <4C	14 days extraction, 40 days analysis
Particle size distribution	solid	ASTM D422	None	14 days extraction, 40 days analysis
Total organic carbon	solid	Lloyd-Khan	Cool, <4C	14 days extraction, 40 days analysis
Salinity	aqueous	SM 2520	Cool, <4C	7 days
pH	aqueous	EPA 9040	Cool, <4C	7 days
Ammonia	aqueous	EPA 350.3	Cool, <4C	14 days extraction, 40 days analysis

Notes:
EPA 8270 and 9040 from EPA (1994a), EPA 1664 from EPA(1995b), ASTM D422 from ASTM (1988), EPA 350.3 from EPA(1983), EPA/CE81-1 from Plumb (1981), and SM 2050 from AWWA (1997).

Table 3-4. Frequency of SVOC Testing

	Time (days)									
	T_0	T_{72hr}	T_{7dys}	T_{14}	T_{21}	T_{30}	T_{37}	T_{44}	T_{51}	T_{60}
Sample	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Duplicate	✔					✔				✔
Blank	✔									

Notes:
TN = N is time in days from start of bench-scale test.

90628

Figure 1-1.
Site Location Map

N. C.

Wilmington, North Carolina Quadrangle

Quadrangle Location

Source: USGS, 1979

0 .5 1 mile

Scale 1:24000

ChemRisk®
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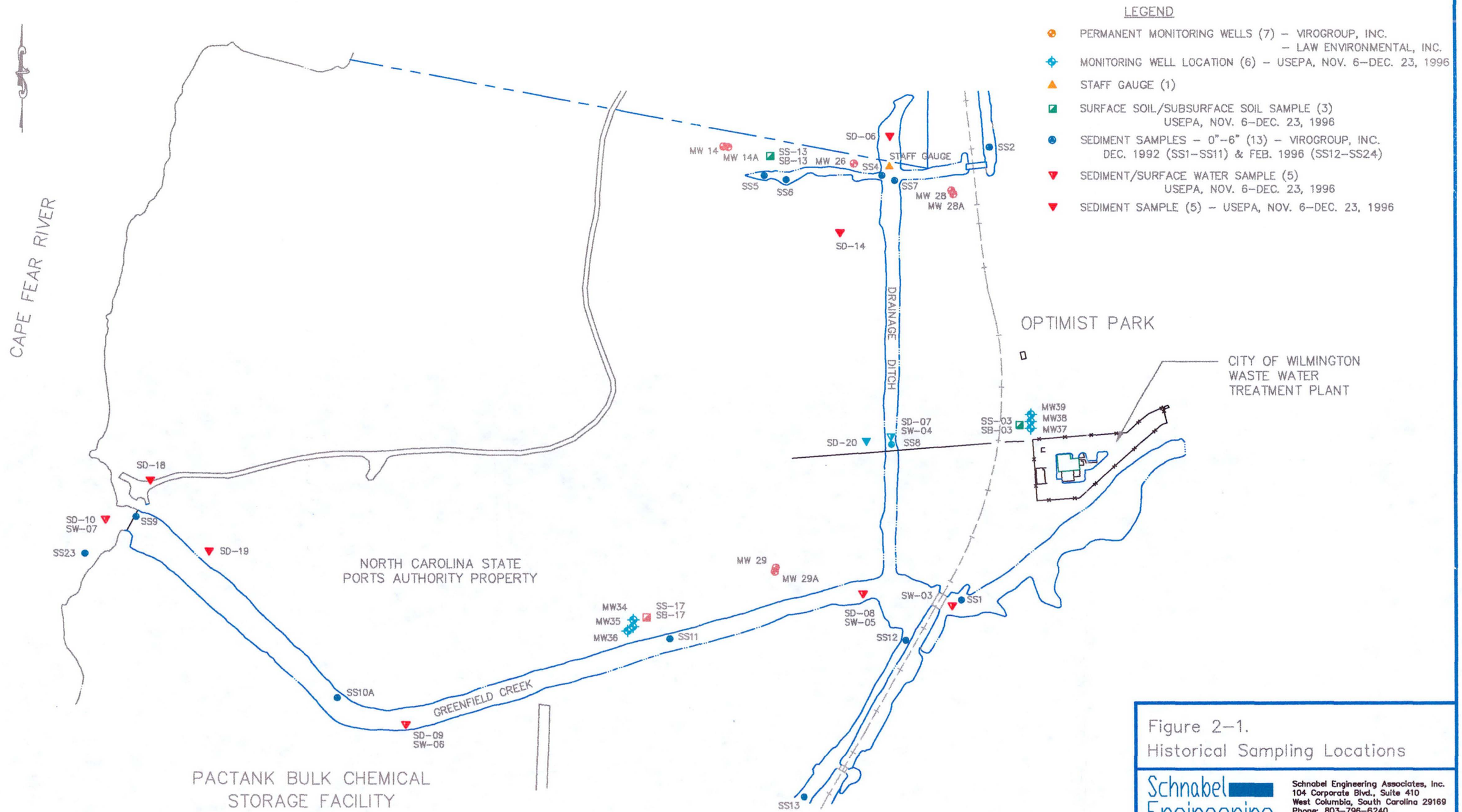

Figure 2–1.
Historical Sampling Locations

Schnabel Engineering
Schnabel Engineering Associates, Inc.
104 Corporate Blvd., Suite 410
West Columbia, South Carolina 29169
Phone: 803–796–6240
Fax: 803–796–6250

REVISIONS			CADD NO.
			979CORES
DRAWN BY	CHECKED BY	SCALE 1"=200'	FIGURE NO.
DESIGN BY	DATE	PROJECT NO.	SHEET NO.

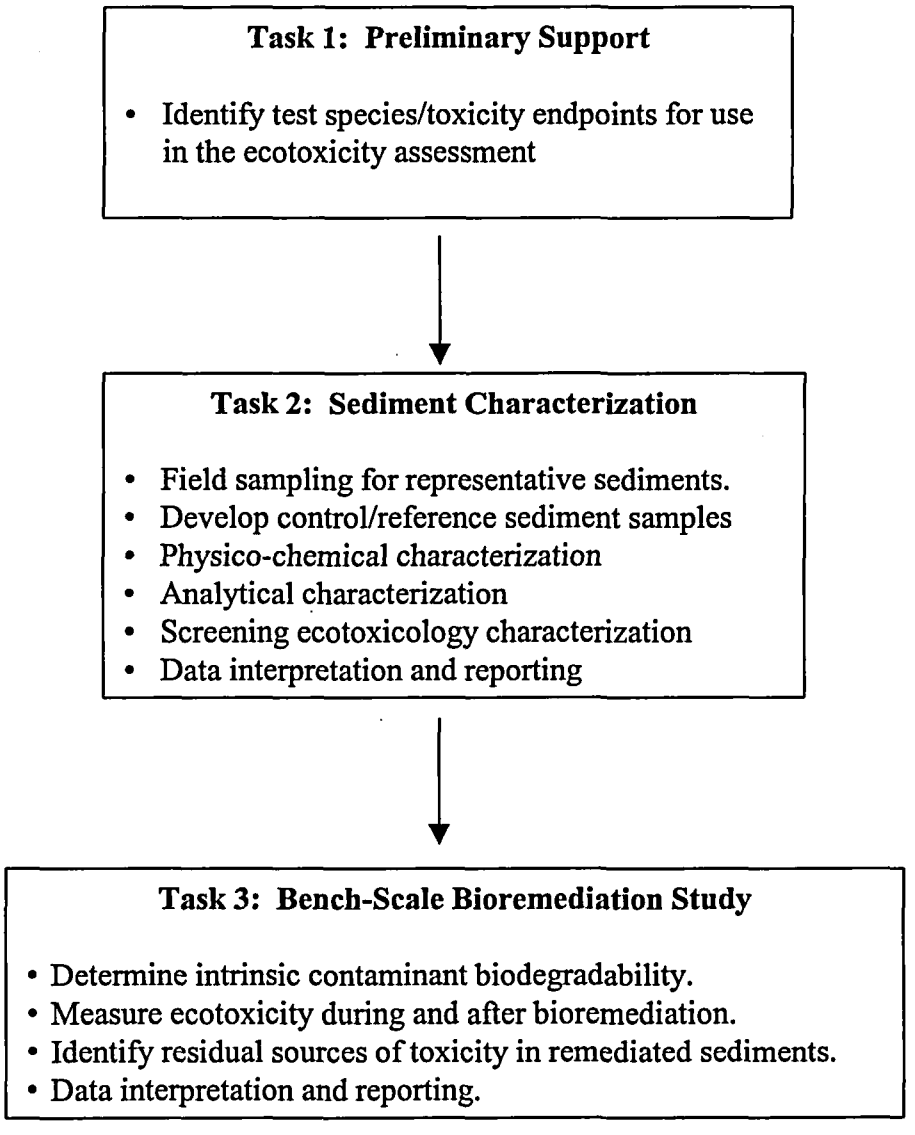

Figure 3-1. Flow chart of project tasks.

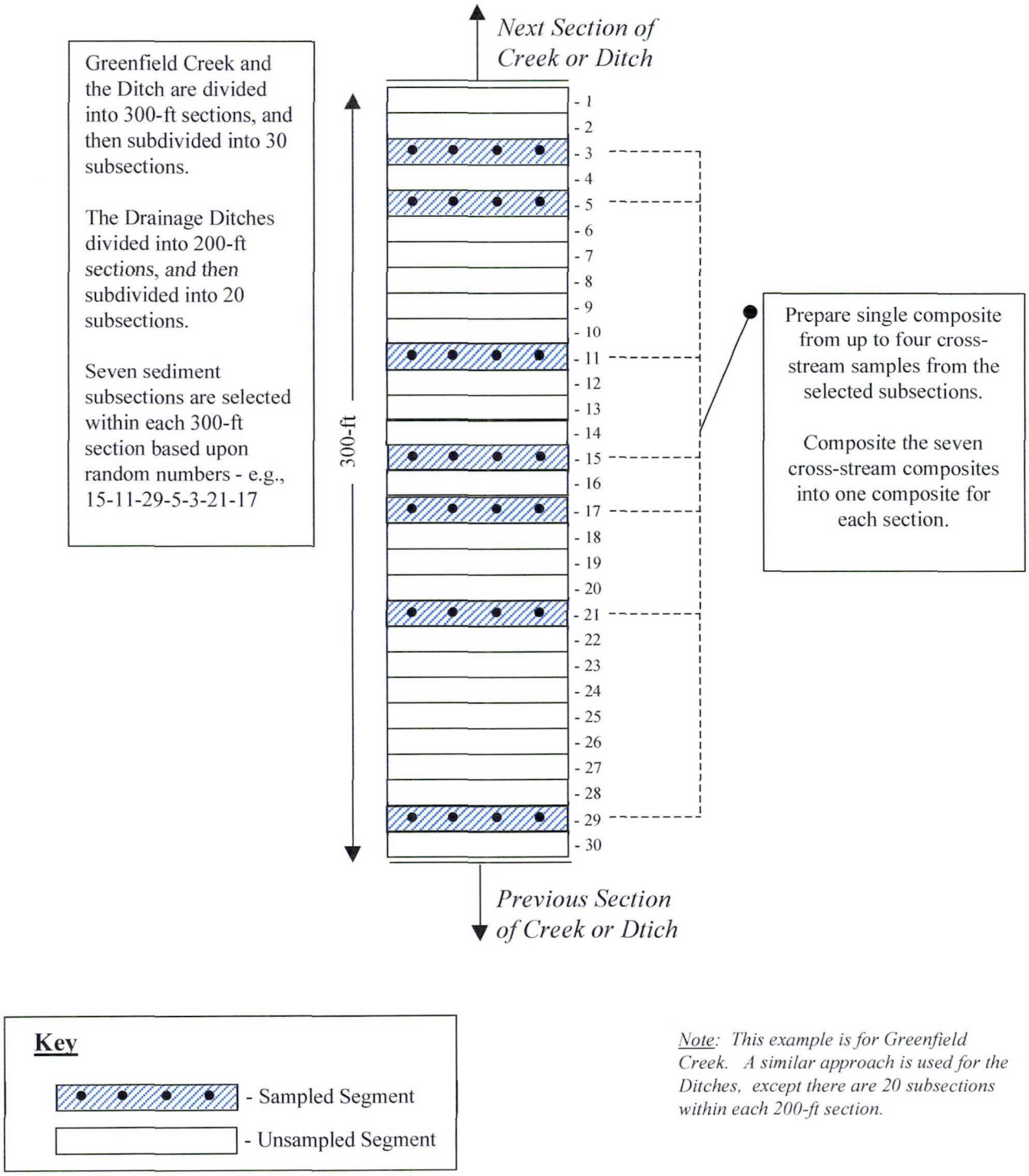

Figure 3-2. Compositing Scheme for Sediment Samples

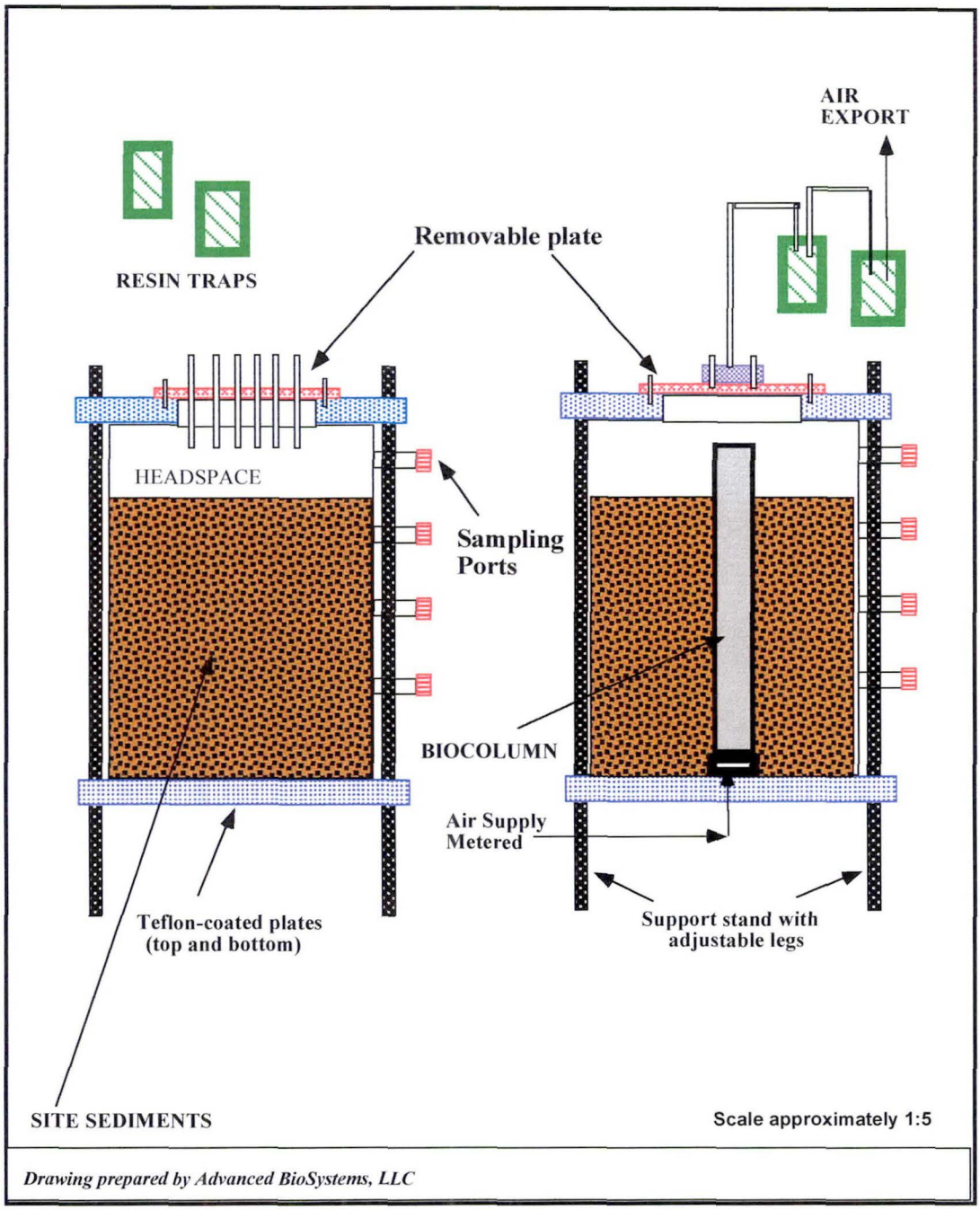

Figure 3-3. Schematic Drawing of Bench-scale Bioremediation Testing Apparatus.