
Final

Wastewater Treatment Solids Management Plan

**International Paper Cell No. 2
Riegelwood, NC**

Prepared for
Honeywell International Inc.

Submitted by



May 2008

Contents

Contents.....	i
Acronyms and Abbreviations	iv
1.0 Introduction	1-1
1.1 Background	1-1
1.2 Physical Setting	1-2
1.3 Project Objectives.....	1-3
2.0 Characterization Summary	2-1
2.1 Sampling Locations and Depths.....	2-1
2.2 Sampling Methods.....	2-2
2.3 Analytical Results	2-3
2.4 Soil Borings.....	2-4
2.5 PCB Classifications	2-4
2.6 Estimated Volumes of Wastewater Treatment Solids	2-5
3.0 Mobilization and Site Preparation	3-1
3.1 Temporary Facilities.....	3-1
3.2 Segregation of WWTS	3-1
3.3 Erosion and Sediment Controls.....	3-1
3.4 Dewatering and Water Treatment	3-2
4.0 Removal of WWTS with < 50 mg/kg Aroclor 1268	4-1
4.1 Material Segregation	4-1
4.2 Material Handling	4-1
4.3 Confirmation Sampling	4-2
4.4 Data Management	4-2
5.0 Removal of WWTS with ≥ 50 mg/kg Aroclor 1268	5-1
5.1 Overburden Removal.....	5-1
5.2 WWTS Removal.....	5-1
5.2.1 Solidification Treatability Study	5-2
5.2.2 Solidification Procedures.....	5-3
5.2.3 Confirmation Sampling	5-3
5.3 Removal of Corrugated Pipe.....	5-5
5.3.1 Data Management	5-5
5.4 Equipment Decontamination Procedures	5-5
5.5 Demobilization and Site Restoration Activities	5-6
6.0 WWTS Management at the Holtrachem Facility	6-1
6.1 Storage Location	6-1
6.2 Stockpile Design	6-1
6.3 Stockpile Construction.....	6-2
6.3.1 Site Inspection/Preparation	6-2
6.3.2 Work Zone Delineation.....	6-2
6.3.3 Erosion and Sediment Control.....	6-2
6.4 Solids Placement	6-2
6.4.1 Equipment/Procedures	6-3

	6.4.2	Quantity Verification.....	6-3
	6.4.3	Stockpile Sampling	6-3
6.5		Operation and Maintenance.....	6-3
	6.5.1	Marking.....	6-4
	6.5.2	Inspections.....	6-4
	6.5.3	Fluid Recovery	6-4
	6.5.4	Record Keeping.....	6-4
7.0		Decontamination.....	7-1
	7.1	Equipment Decontamination.....	7-1
	7.2	Worker Decontamination	7-1
	7.3	Sampling Equipment Decontamination	7-2
	7.4	Decontamination Waste Management	7-2
8.0		Health & Safety	8-1
9.0		Reporting.....	9-1
10.0		Schedule	10-1
11.0		References	11-1

Tables

2-1	Summary of Preliminary PCB Sampling Results
2-2	Summary of Preliminary TCLP Sampling Results
2-3	Summary of PCB Sampling Results
2-4	Summary of VOC, SVOC, and RCRA Metal Sampling Results
2-5	Summary of TCLP Sampling Results
5-1	Summary of Treatability Study Results

Figures

1-1	Site Location Map
1-2	Property Boundaries
2-1	Approximate Locations of Premier Borings
2-2	Aroclor 1268 Concentration (mg/kg) in Cell No. 2
2-3	Inset A Aroclor 1268 Concentration (mg/kg) in Cell No. 2
3-1	Temporary Facility Location and Extent of WWTS Excavation in Cell No. 2
3-2	Dewatering Pretreatment System P&ID
4-1	Load Identification Ticket
5-1	Engineered Stockpile Location
5-2	Engineered Stockpile Cross-Section

Appendices

- A Soil Boring Logs
- B Inspection Log
- C Project Schedule
- D Health and Safety Plan
- E Sampling and Analysis Plan
- F Quality Assurance Project Plan
- G Quality Control Plan
- H Aroclor 1268 Toxicity Studies
- I Soil Screening Level Calculations

Acronyms and Abbreviations

°F	Degrees Fahrenheit
AOC	Administrative Order on Consent
BMP	Best Management Practices
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/s	Centimeters per Second
COC	Contaminant of Concern
CPR	Contractor Production Reports
DPT	Direct Push Technology
DWM	Division of Waste Management
EE/CA	Engineering Evaluation/Cost Analysis
ft ³	Cubic Feet
ft bls	Feet Below Land Surface
gpd	Gallons per Day
gpm	Gallons per Minute
HDPE	High-Density Polyethylene
HEPA	High-efficiency Particulate Aerosol
HHRA	Human Health Risk Assessment
HSP	Health and Safety Plan
HQ	Hazard Quotient
IP	International Paper
MDL	Method Detection Limit
mg/kg	Milligrams per Kilogram
mg/m ³	Milligrams per Cubic Meter
MSDS	Material Safety Data Sheet
NCDENR	North Carolina Department of Environment and Natural Resources
NCP	National Contingency Plan
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRWQC	National Recommended Water Quality Criteria
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PEL	Permissible Exposure Limit

PPE	Personal Protective Equipment
ppm	Parts per Million
QA/QC	Quality Assurance/Quality Control
QCR	Quality Control Report
RAO	Removal Action Objective
RCRA	Resource Conservation and Recovery Act
REL	Recommended Exposure Limit
RfD	Reference Dose
SPCC	Spill Prevention, Control, and Countermeasures
SVOCs	Semi-volatile Organic Compounds
SWDS	Solid Waste Disposal Site
SWMU	Solid Waste Management Unit
SWPPP	Storm Water Prevention Pollution Plan
TSCA	Toxic Substances Control Act
TWA	Time-Weighted Average
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WWTS	Wastewater Treatment Solids
µg/L	Micrograms per Liter
yd ³	Cubic yard

1.0 Introduction

This work plan provides characterization information and procedures for excavation, segregation, transportation, and storage of wastewater treatment solids (WWTS) located in Cell No. 2 of International Paper's Riegelwood Mill North Bay Treatment Pond. The Riegelwood Mill is located in Riegelwood, Columbus County, North Carolina. Background information is provided below.

1.1 Background

International Paper (IP) operates a coated paperboard mill that has been in operation since 1951 and produces solid bleach board, bristols and market pulp. The mill has operated a permitted industrial landfill within the facility since 1963. The landfill is adjacent to a series of wastewater treatment ponds used in mill operations that ultimately discharge to the Cape Fear River (ARCADIS, 2006a). A site map is included as **Figure 1-1**, and the location of the landfill cells and the property boundaries is provided as **Figure 1-2**.

In 1994, approximately 25 acres of IP's North Bay treatment pond (the last pond within the treatment works) was bermed off and drained for development as a permitted industrial landfill. The southern portion of the bermed area was developed as Landfill Cell No. 1. The northern portion of the bermed area is scheduled to be utilized for the expansion of the landfill (Cell No. 2) in 2008 so that IP can continue operations on an uninterrupted basis.

IP formerly accepted process water generated during chlorine production from the neighboring LCP-Holtrachem (Holtrachem) facility. Holtrachem operated as a chlor-alkali facility using the mercury cell process from 1963 to 1999, when facility operations ceased. Holtrachem was originally constructed to provide chlorine gas, caustic soda, and bleach to the IP facility. Process water from the former Holtrachem facility was reportedly discharged to the northwest corner of Cell No. 2 via a 16-inch diameter, corrugated galvanized steel pipe from approximately 1963 to the late 1970s or early 1980s.

A draft Engineering Evaluation/Cost Analysis (EE/CA) for a Non-Time Critical Removal Action (NTCRA) was submitted for the Holtrachem site in July 2007 as required by the Honeywell Administrative Order on Consent (AOC) dated June 8, 2004. Holtrachem site characterization activities have indicated polychlorinated biphenyls (PCBs), specifically Aroclor 1268, as one of the primary site contaminants. A Human Health Risk Assessment (HHRA) for the Holtrachem Site was prepared by CH2M HILL and approved by the United States Environmental Protection Agency (US EPA) on May 15, 2007. The ratio of acceptable (reference) dose to exposure related dose from the site is called a Hazard Quotient (HQ). An $HQ < 1$ indicates that exposure to a chemical is not likely to have an appreciable adverse (toxic) effect. Cleanup goals are often selected based on a target $HQ = 1$ or excess lifetime cancer risk = 1×10^{-4} at Superfund Sites. Table 1 of the HHRA indicated that a HQ of 1 for a construction worker equated to a target remediation level concentration of 11 mg/kg Aroclor 1268 in subsurface soils.

More recent toxicology reviews indicate that Aroclor 1268, consisting of mostly heavier chlorinated biphenyl mixtures that are relatively less toxic (Simon, et. al., 2007 and Warren, et. al., 2004), is likely to be one to two orders of magnitude less toxic than the most toxic PCB mixtures (e.g., Aroclor 1242). PCBs are a group of mixtures containing varying amount of chlorination to biphenyl rings, often identified as Aroclor mixtures. US EPA's previously developed toxicity criteria was based on studies of moderately chlorinated and highly toxic mixtures such as Aroclor-1242, -1254 and 1258. The US EPA toxicity database called Integrated Risk Information System (IRIS) contains toxicity criteria (e.g., cancer slope factors and reference doses) based on such studies and are generally applied to all heavily-chlorinated Aroclor mixtures, although the studies indicate that Aroclor 1268 is likely less toxic. The approved HHRA presented a remedial goal option for Aroclor 1268 (based on a HQ=1) derived using the higher risk-based PCB toxicity value available in IRIS.

In February 2008, CH2M HILL recalculated the Remedial Goal Options (RGOs) for Aroclor 1268 using a construction worker scenario, and 1) the IRIS low-risk PCB toxicity value and 2) the toxicity values derived for the neurotoxicity end point as presented in the paper by Simon et. al. 2007. The revised values calculated for Aroclor 1268 at a HQ=1 are 38 mg/kg and 86 mg/kg, respectively. In addition, a soil-to-groundwater screening level was developed using US EPA's Soil Screening Guidance (US EPA, 1997). The resulting soil-to-groundwater screening level is 30.9 mg/kg (calculations provided in Appendix I). However, because EPA has not evaluated this new information, Honeywell will use a cleanup goal of 11 mg/kg during WWTS removal, as stated in the 2008 Enforcement Action Memorandum.

As described in further detail in Section 2, analytical results from samples collected from Cell No. 2 indicate the presence of Aroclor 1268 at concentrations exceeding 11 mg/kg. The US EPA has indicated WWTS exceeding background concentrations are considered part of the Holtrachem site currently regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The North Carolina Division of Waste Management (DWM) has determined that WWTS with PCB concentrations <50 mg/kg can be disposed in Cell No. 1 in accordance with the Cell No. 1 Operations Manual (Industrial Landfill Facility Permit #24-02, February 2005). Honeywell will excavate the WWTS from Cell No. 2. WWTS containing concentrations of Aroclor 1268 <50 mg/kg will be transported to IP's Cell No. 1, which is constructed to Resource Conservation and Recovery Act (RCRA) criteria (Section 4.2).

WWTS containing Aroclor 1268 concentrations of 50 mg/kg and greater will be managed by Honeywell on the Holtrachem site. Honeywell plans to temporarily contain these WWTS in an engineered stockpile located on the Holtrachem property pending implementation of a site-wide remedy.

1.2 Physical Setting

The Riegelwood Mill is located in the Coastal Plain physiographic province of North Carolina, in the Atlantic Coast Flatwoods region. Topography across the site is nearly level to gently sloping (excluding the landfill) and generally drains to the Cape Fear River. The Landfill Cell No. 2 area is located in the northern portion of the Mill, approximately 150 feet from the Cape Fear River. The sludge and soils within Cell No. 2 are surrounded by an

earthen berm that rises approximately 5 feet above the top of cell surface. There is approximately 12 feet of vertical relief across the Landfill Cell No. 2 area. Topography across the cell generally slopes to the south and east, towards local low lying areas. Stormwater drains to the southeast corner of the cell and is periodically pumped to IP's existing wastewater treatment system (ARCADIS 2006a).

Cell No. 2 is located between Cell No. 1 and the Cape Fear River. The area drains to the southeast, where collected water is pumped to IP's wastewater treatment system. Cell No. 1 is a double-lined industrial landfill permitted for the disposal of wastewater sludge generated at the Mill. Cell No. 2 was part of the overall wastewater lagoon system for the mill until it was isolated by the earthen berms.

1.3 Project Objectives

The objectives of this project include:

- Remove WWTS from IP's Cell No. 2 so that IP can use this cell to expand their landfill.
- Place WWTS containing Aroclor 1268 concentrations <50 mg/kg in IP's Landfill Cell No. 1.
- Construct an engineered stockpile on the Holtrachem property for temporary storage of WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg.
- Transport WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg to the engineered stockpile.
- Remove the pipe which formerly transported wastewater from the Holtrachem facility to Landfill Cell No. 2 and associated soils containing Aroclor 1268 concentrations ≥ 11 mg/kg.
- During the removal process, accumulated water from the excavation area will be collected and treated, as necessary, and pumped to IP's wastewater treatment system

2.0 Characterization Summary

In September 2005, Premier Environmental Services, Inc. (Premier) was contracted by IP to characterize the Landfill Cell No. 2 area. Premier utilized a direct push technology (DPT) rig to install six shallow soil borings in Cell No. 2 (Premier, 2005). The borings were advanced to terminal depths ranging from 12 to 16 feet below land surface (ft bls). A total of 25 samples were collected for laboratory analysis of polychlorinated biphenyls (PCBs) (including Aroclor 1268). Three of the samples were also analyzed for waste characterization. Analysis included volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and metals using the Toxicity Characteristic Leaching Procedure (TCLP) to determine how the WWTS in Cell No. 2 would be classified for off-site disposal. The results of the September 2005 investigation, summarized in an October 2005 report by Premier, were:

- PCBs, specifically Aroclor 1268, was detected in 10 of the 11 samples analyzed for PCBs, with the reported concentrations ranging from 0.071 mg/kg to 1,200 mg/kg. Soil samples SS2 (2 -4 ft bls; 1,200 mg/kg) and SS5 (0-2 ft bls; 26 mg/kg) were the only samples which exceeded 25 mg/kg. Only one other sample exceeded the cleanup goal of 11 mg/kg: SS3 (0-3 ft bls; 21 mg/kg).
- All TCLP analytical results were below 40 CFR 261 Subpart C hazardous criteria.
- WWTS thicknesses measured in the six borings ranged from 1 foot (SS2) to 9 feet (SS6).

The results of the 2005 PCB sampling are summarized in **Table 2-1**, and the TCLP sampling and analytical results are summarized in **Table 2-2**. A site map depicting the approximate location of the six borings advanced during the September 2005 investigation is included as **Figure 2-1**.

In April 2006, IP personnel met with US EPA Region IV personnel to discuss the October 2005 results, additional site characterization requirements, and potential remedial and waste disposal alternatives. The US EPA recommended that IP proceed with the characterization of the site using a biased sampling grid to aid in the development of the clean-up plan.

2.1 Sampling Locations and Depths

The sampling grid utilized in the investigation of WWTS within the Landfill Cell No. 2 area was based on a general understanding of how the PCBs were distributed in the surface impoundment. Process water from the former Holtrachem facility was reportedly discharged from a single drain pipe into the lagoon system at the northwestern corner of Landfill Cell No. 2. Based on the previous six borings conducted by Premier, the sample with the highest Aroclor 1268 concentration detected was collected in the northwestern portion of Landfill Cell No. 2. Based on this information, a biased sampling approach was utilized to more precisely define the extent of WWTS with Aroclor 1268 concentrations greater than 25 mg/kg. Sample locations were placed on a 50-foot square grid in the northwestern portion of Landfill Cell No. 2 where higher PCB concentrations were expected

and on a 100-foot square grid over the remainder of the cell where PCB concentrations were expected to be lower.

The sample distribution across the Landfill Cell No. 2 area was based on a square grid pattern with grid lines oriented along north-south and east-west axis. The grid lines oriented in the north-south direction were spaced 50 feet apart and were labeled alphabetically starting with the letter “C” at the western perimeter of the landfill and extending to the letter “W” at the eastern perimeter. East-west grid lines were spaced 50 feet apart and were labeled numerically starting with the number 2 at the northern perimeter of the landfill and extended up to number 16 at the southern perimeter. Sample locations were placed at the intersections of the grid lines and sample location identifications were based on the letter and number of the intersecting grid lines. The 100-foot sample grid in the eastern and southern portions of Landfill Cell No. 2 was established by placing sample locations at every other grid line intersection.

This biased sampling grid and the approximate location of the Holtrachem outfall are depicted on **Figure 2-2**. A Sludge Characterization Work Plan was prepared in June 2006 to delineate the PCB impacts in the Landfill Cell No. 2 area using the biased sampling grid (ARCADIS, 2006b).

Prior to the field sampling activities, 74 proposed soil boring locations were surveyed and staked at the designated grid intersections within the Landfill Cell No. 2 area. Several grid intersections were inaccessible due to the presence of standing water, mainly in the low lying areas along the southern and eastern portions of the cell. At locations O2 and S14, the borings were offset to the closest accessible point to the grid intersection. The ground surface elevation at each sample location was also surveyed and recorded. Surface grade elevations at the 74 locations ranged from 32.55 feet above mean sea level (ft amsl) to 18.61 ft amsl. Due to the topographic relief across the cell area, a series of vertical sample horizons were established to better correlate the sampling results between borings. A total of 12 2-foot vertical elevation horizons were set up, ranging from 32 to 30 ft amsl down to 10 to 8 ft amsl. The surface grade elevation survey data were used to correlate specific sample depth intervals at each soil boring location with the established 2-foot thick sample elevation horizons.

2.2 Sampling Methods

Probe Technology, Inc., a North Carolina licensed drilling company, was subcontracted to conduct the soil investigation. ARCADIS G&M of North Carolina, Inc. (ARCADIS), personnel supervised the field investigation, which was performed between July 24 and July 28, 2006. A DPT track-mounted drill rig was used to advance soil borings at 68 of the 74 surveyed sample locations across Cell No. 2 (**Figure 2-2**). Six soil borings were not installed due to various circumstances, including the presence of standing water at the surveyed location (SB-K2), boring refusal (SB-G5), or the fact that the boring location was outside of the former treatment pond area (SB-F5, SB-G4, SB-J2, and SB-Q2). The remaining 68 borings were advanced into the soil beneath the accumulated WWTS to a maximum depth of approximately 12 ft bls.

Samples were collected at discrete 2-foot thick intervals from the borings based on depths at which the borings crossed the established 2-foot elevation horizons. A sample was collected

from each elevation horizon encountered in the boring. At each elevation horizon, the entire 2-foot thick sample core was placed in a Ziploc® bag. The material was thoroughly mixed in the sealed bag and a representative sample was then packed into a glass sample jar for laboratory analysis. Up to 6 samples were collected from each boring advanced to a total depth of 12 ft bls. Fewer samples were collected from borings that could not be advanced to the desired depth of 12 ft bls, and 7 samples were collected from two borings advanced to approximately 14 ft bls.

A total of 375 soil and sludge samples were collected and submitted to CompuChem Laboratories in Cary, North Carolina, for analysis of Aroclor 1268 using the current US EPA Contract Laboratory Program (CLP) document OLM 04.3. In addition, four samples representing a cross section of the site (SB-I5-22-20, SB-I8-18-16, SB-Q4-24-22, and SB-U10-18-16) were submitted for waste characterization analysis of TCLP VOCs by US EPA Methods 1311/8260B, TCLP SVOCs by US EPA Methods 1311/8270C, and TCLP RCRA metals by US EPA Methods 1311/6010B/7470A. Sample SB-I8-18-16 was also analyzed for TCLP pesticides by US EPA Method 1311/8081A. Two samples (SB-I5-20-18 and SB-W10-12-25) were also collected from the residual soil below the sludge in Borings I5 and W10. These samples were submitted to CompuChem for analysis of VOCs by US EPA Method 8260B, SVOCs by US EPA Method 8270C, and RCRA metals by US EPA Methods 1311/6010B.

Boring locations were identified using a number along the north-south axis and a letter along the east-west axis. Samples were identified with a unique identification number using the following protocol:

SB-BL-E1-E2 where:

- SB = soil boring (all locations)
- BL = boring location given by grid coordinates
- E1 = elevation of the top of sample in ft amsl
- E2 = elevation of the bottom of sample in ft amsl

Using this identification method, for example, the sample collected at the intersection of grid lines K and 6 between the elevations of 14 and 12 ft amsl would be designated SB-K6-14-12.

Following sample collection, each boring was properly abandoned using hydrated bentonite pellets. Investigation derived waste (IDW), consisting of soil and sludge cores, was contained in two 55-gallon drums, which were appropriately disposed of off-site based on the results from analysis of samples.

2.3 Analytical Results

Laboratory analytical data received from CompuChem were reviewed and validated by an ARCADIS chemist to verify the completeness of the data-package deliverables. The data were validated following the rules set forth in the US EPA's *National Functional Guidelines for Inorganic Data Review* (US EPA, 2004) and *National Functional Guidelines for Organic Data Review* (US EPA, 1999). The chemist confirmed that all sample QC parameters were within established control limits and added applicable data qualifiers to the electronic data deliverables (EDDs) received from CompuChem.

Aroclor 1268 was detected at concentrations exceeding 11 mg/kg in 24 samples collected from 14 locations (L2, O2, I4, J4, H5, I5, J5, K5, I6, K6, M6, G8, M8, and I8) in the northwestern portion of Landfill Cell No. 2. The 24 samples were collected from elevation horizons ranging from 24 ft amsl to 16 ft amsl at the 14 sample locations and ranged in concentration from 13 mg/kg in Sample SB-L2-22-20 to 5,100 mg/kg in Sample SB-I6-20-18.

Aroclor 1268 was detected below 11 mg/kg in the remaining samples. The majority of the 23 samples exceeding 11 mg/kg were collected from locations in the northwestern portion of Landfill Cell No. 2.

The PCB sampling results are summarized in **Table 2-3**. A site map depicting the PCB sampling results for the 100-foot by 100-foot sampling grid area is included as **Figure 2-2**. An inset of the site map showing the PCB sampling results for the 50-foot by 50-foot sampling grid is included as **Figure 2-3**.

All samples submitted for TCLP analysis for waste characterization purposes were below 40 CFR 261 Subpart C hazardous criteria for all compounds. The two samples collected from the soil directly below the sludge layer at locations I5 and W10 were below the screening criteria for all compounds. The total VOC, SVOC, and RCRA metals sampling results are summarized in **Table 2-4**. The TCLP sampling results are summarized in **Table 2-5**.

2.4 Soil Borings

Continuous WWTS core samples were collected in 4-foot long acetate liners from each boring. Field logs were prepared for each boring documenting the depth and approximate elevation of the soil/sludge interface. DPT equipment used to collect the samples was decontaminated between each boring. Copies of the soil boring lithology logs and lithologic cross-sections are included in **Appendix A**.

Materials within Cell No. 2 are primarily sands, clayey sands, and organic sludge (secondary biological sludge from the mill wastewater treatment system). Aroclor 1268 concentrations greater than 50 mg/kg in the vicinity of Borings I6, K6, and I8 appear to be associated with a black organic sludge layer.

The material within the lagoon is thixotropic in nature, meaning that the material is stable when at rest, but becomes fluid when disturbed. Therefore, there is a potential for the WWTS to move once disturbed. The thixotropic nature of the WWTS is also an important factor in solids transportation and storage.

2.5 PCB Classifications

The North Carolina Division of Waste Management (DWM) has established a soil remediation goal of 1 mg/kg for PCBs based on US EPA policy for the cleanup of PCBs at Superfund sites. TSCA considers PCB concentrations less than 1 mg/kg to be acceptable for unrestricted access.

In addition, 40 CFR Part 761(a)(4)(i)(B)(I) specifies 25 mg/kg as the bulk PCB remediation level for low-occupancy areas. A low occupancy area is defined under 40 CFR Part 761.3 as an area where PCB remediation waste has been disposed of on-site and where occupancy

for any individual not wearing dermal and respiratory protection for a calendar year is: less than 840 hours.

The North Carolina DWM has determined that WWTS with PCB concentrations <50 mg/kg can be disposed in Cell No. 1 in accordance with the Cell No. 1 Operations Manual (Industrial Landfill Facility Permit #24-02, February 2005). WWTS with PCB concentrations < 50 mg/kg will be disposed in Cell No. 1, which is constructed with dual geosynthetic bottom liners (Section 4.2).

For the purposes of this Work Plan, WWTS within Cell No. 2 are classified based on PCB concentration:

- 1-11 mg/kg: use within the IP or Holtrachem facilities or disposal in Cell No. 1
- 12 - 49 mg/kg: disposal in Cell No. 1
- ≥ 50 mg/kg: temporary stockpiling on the Holtrachem property.

2.6 Estimated Volumes of Wastewater Treatment Solids

The volume of PCB impacted WWTS present within Landfill Cell No. 2 was estimated with the assumption that the results for each grid and elevation coordinate were consistent throughout. A total of 7 samples collected within the 100-foot grid and 7 samples collected within the 50-foot grid had reported Aroclor 1268 concentrations that exceeded 50 mg/kg. As shown on **Figures 2-2 and 2-3**, WWTS containing Aroclor 1268 concentrations greater than 50 mg/kg are located at depths ranging from 2 feet to 12 feet bls with a maximum thickness of 6 feet. The calculated volume for each 100-foot by 100-foot by 2-foot grid is approximately 741 in-place cubic yards and the calculated volume for each 50-foot by 50-foot by 2-foot grid is approximately 185 in-place cubic yards. Using this assumption, the in-place volume of material with PCB concentrations exceeding 50 mg/kg is estimated to be approximately 6,500 cubic yards.

A total of 40 samples collected within the 100-foot grid and 25 samples collected within the 50-foot grid had reported Aroclor 1268 concentrations that exceeded 1 mg/kg but were below 50 mg/kg. Using the same assumption outlined above, the in-place volume of material with PCB impacts exceeding 1 mg/kg but below 50 mg/kg is estimated to be approximately 93,500 cubic yards.

3.0 Mobilization and Site Preparation

Prior to beginning site activities, all site workers will be required to attend a training session conducted by the Wilmington Area Contractor Safety Council that includes the IP safety module. Additional health and safety information is provided in the project Health and Safety Plan (**Appendix D**).

In addition, a Pre-construction Meeting will be conducted at the site with Honeywell and IP representatives, as well as CH2M HILL subcontractors, immediately following mobilization. This meeting will be conducted to ensure all parties understand the scope of work to be performed, the anticipated schedule, roles/responsibilities, as well as to coordinate site activities prior to the start of work.

3.1 Temporary Facilities

CH2M HILL and its subcontractors will use the existing office facilities at the Holtrachem site rather than establishing office trailers and utilities at the IP property. However, temporary facilities including staging areas, fuel tanks, etc. may be required near the existing perimeter road west of Cell No. 2. **Figure 3-1** provides a general location for the proposed temporary facilities and the area designated for calciment stockpiling. However, the actual locations of temporary facilities and stockpiles will be determined at the time of mobilization and subject to IP approval.

Access roads into the Cell for excavation of the uncontaminated material will be located based on elevation differentials and field conditions at the time of removal. It is anticipated that the access roads will be constructed using available Cell No. 2 materials having Aroclor 1268 concentrations less than 11 mg/kg and physically suitable for this purpose.

3.2 Segregation of WWTS

In order to segregate WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg from WWTS containing Aroclor 1268 concentrations < 50 mg/kg, the sampling grid discussed in Section 2.0 will be re-established using a North Carolina-licensed surveyor prior to initiating the removal activities. Upon completion of the survey, orange construction fencing will be erected around the periphery of that material (including a 50-foot lateral buffer). The buffer is arbitrarily assumed at this time – confirmation sampling following removal of the WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg material will determine the actual limit of uncontaminated material.

3.3 Erosion and Sediment Controls

As part of the site's Best Management Practices (BMPs), Honeywell will be required to implement appropriate requirements of IP's existing Storm Water Pollution Prevention Plan (SWPPP) and Spill Prevention, Control, and Countermeasures (SPCC) Plan. BMPs for the

construction-related activities may include a combination of silt fence, hay bale dikes, rock ditch checks, or other combination of erosion control measures, in accordance with US EPA and NCDENR guidelines.

Since the excavation will take place within a bermed area, an Erosion and Sedimentation Control Plan has not been prepared for this activity. However, erosion control measures will be implemented as necessary to protect any perimeter levee or ditch system outside of Cell No. 2, where the current vegetative layer or BMPs are disturbed during the removal action. To protect the site's stormwater drainage system from impacts associated with a spill during WWTS transfer activities, sediment control devices, such as silt fences, will be placed along the interior haul road used to move material from Cell No. 2 to the engineered stockpile. Water trucks will be used as needed to suppress dusts on haul routes throughout the removal activities.

3.4 Dewatering and Water Treatment

Honeywell will collect and treat water generated during excavation activities and stormwater collected in the excavation during removal of WWTS. Finger trenches, berms, and other water diversion devices will be constructed to prevent stormwater from entering the excavation areas if necessary.

Sump pump(s) (e.g. 3-inch diameter) will be used to pump the water to a temporary water treatment area for pre-treatment to remove solids prior to the water being conveyed to IP's onsite treatment system. The pre-treatment system for WWTS will consist of the following steps (**Figure 3-2**):

- Collection of water in a sump located in the southeast portion of Cell No. 2.
- Addition of a coagulant (Bulab 5086 or similar)
- Addition of an organic flocculent (Bulab 5904 or similar)
- Pumping water to Settling Pond No. 1 (constructed within Landfill Cell No. 2 and lined with 10 mil polyethylene)
- Overflow to Settling Pond No. 2 (constructed within Landfill Cell No. 2 and lined with 10 mil polyethylene)
- Filtration via a bag filter system (2-stage bag filtration – 10 micron filters)
- Two-stage carbon polishing
- Filtration via a 3 micron bag filter system

Water generated within the excavation area and the overburden storage area during removal of the WWTS has the potential to contain concentrations of Aroclor 1268. Water containing PCB concentrations > 3 ug/L will not be discharged to IP's wastewater treatment system. Water samples will be collected between the carbon units and after the 3-micron bag filters to ensure that breakthrough is not occurring. A minimum of one sample from each identified location will be collected daily for the first week and a minimum of one sample from each identified location per week will be collected thereafter for analysis of PCBs including Aroclor 1268 by EPA SW-846 Method 8082.

At the completion of the removal, solids accumulated on the liners in the setting ponds will be removed, sampled at a rate of one sample per 1,000 cubic yards, and analyzed for Aroclor 1268. Solids containing <50 mg/kg will be placed in Cell No. 2. Solids containing \geq 50 mg/kg Aroclor 1268 will be transported to the engineered stockpile.

After the collected solids and the liner have been removed, soil samples will be collected from the top 12 inches beneath the former settling pond area. Samples will be collected using the procedures outlined in Section 5.2.3.

Other sediments, used bag filters, and other collected materials removed from the pre-treatment system will be temporarily stored onsite and subsequently sampled and analyzed for Aroclor 1268 to determine the disposal location, or placed on the engineered stockpile.

Water management will continue until post-excavation confirmation sampling indicates the clean-up level has been achieved. Water that is collected within the perimeter ditch system (outside of Cell No. 2) will continue to be pumped directly to IP's wastewater treatment system.

4.0 Removal of WWTS with < 50 mg/kg Aroclor 1268

This section describes the approach for the excavation and transport of an in-place volume of approximately 93,500 cubic yards of PCB-impacted WWTS with concentrations <50 mg/kg to IP's Cell No. 1.

4.1 Material Segregation

Honeywell will re-establish the sampling grid used to identify the location and depth of the WWTS containing PCB concentrations ≥ 50 mg/kg. The depth and thickness of the high concentration WWTS layer beneath the land surface will be displayed at each sampling point. Based on the sampling results presented in Section 2.0, the remainder of Cell No. 2 will be handled as material containing Aroclor 1268 at concentrations of <50 mg/kg and transported directly to Cell No. 1.

Upon completion of the survey, orange construction fencing will be erected around the periphery of that material (including a 50-foot lateral buffer) to prevent entry into that area.

4.2 Material Handling

Removal of material is expected to be performed using a long-reach (22 metric ton) excavator that will place material into 25-ton articulated dump trucks. Materials containing Aroclor 1268 concentrations of < 50 mg/kg will be loaded and transported directly to Cell No. 1. This material is expected to meet physical characteristics needed for safe transport after the dewatering procedures described in Section 3.4. Excavation of WWTS containing Aroclor 1268 above the cleanup level will discontinue vertically when "native" material is observed and the limits confirmed by IP personnel.

Landfill Cell No. 1 is constructed in accordance with Resource Conservation and Recovery Act (RCRA) requirements and includes the following layers:

- One foot of beneficial Mill by-product;
- One foot of soil;
- Leachate collection system (geonet composite and 40 mil textured HDPE geomembrane)
- Geosynthetic clay liner;
- Leachate detection system (geonet composite and 40 mil textured HDPE geomembrane)

A groundwater extraction system is also in operation which maintains a minimum distance of four feet between the liner and the water table. The extracted groundwater is discharged to IP's wastewater treatment plant.

Operation of the remaining portion of Cell No. 1 will be as described in the document “Operations Manual – International Paper Industrial Landfill Facility Permit #24-02, Riegelwood, North Carolina (February 2005)”. This document has been approved by the Solid Waste Section of the North Carolina Department of Environment and Natural Resources.

Overburden material removed from the areas containing Aroclor 1268 concentrations <11 mg/kg which has suitable structural characteristics will be placed as required over the area (within the limits of Cell No. 2) to facilitate drainage and truck traffic and/or used as material for berm construction.

A recordkeeping system will be maintained at the project site to record the approximate volume of material transported to the IP landfill. A Load Identification Ticket will be completed that will record the original grid location and corresponding sample interval, for example, S-12 (20-18), date, and estimated volume (**Figure 4-1**). All loads leaving Cell No. 2 for the IP landfill will be recorded. These loads will be summarized by CH2M HILL on a daily log maintained at the project site. The actual in-place volume of material removed from Cell No. 2 will be based on a post-excavation survey.

4.3 Confirmation Sampling

Upon completion of excavation activities, confirmation samples will be collected from the base of the excavation at each grid node in the <50 mg/kg excavation areas (confirmation sampling in the ≥ 50 mg/kg areas is addressed in Section 5.2.3). Samples will be collected from a 0-12 inch soil interval. The samples will be sent to a North Carolina-certified laboratory for analysis of Aroclor 1268 by US EPA SW-846 Method 8082.

All confirmation sampling will comply with the Sampling and Analysis Plan (SAP) (see **Appendix E**) and the Quality Assurance Project Plan (QAPP)(see **Appendix F**). Due to personnel health and safety concerns, confirmation samples may be collected from the bucket of excavation equipment. Sampling equipment will be decontaminated in accordance with Section 5.4 between sample locations to minimize the potential for cross-contamination. Sample material will be selected from a portion of the recovered material that is relatively undisturbed and not in contact with the excavation equipment.

4.4 Data Management

Analytical data from confirmation samples will be validated and loaded into the Locus Focus database for the Holtrachem site. All data management will be conducted in accordance with the QAPP.

Copies of the validated data will be provided to IP as electronic data deliverables (EDDs). The EDDs will be reviewed by ARCADIS database management personnel and checked for compatibility with IP’s formatting requirements. Copies of the analytical results will also be provided to US EPA and NCDENR.

5.0 Removal of WWTS with ≥ 50 mg/kg Aroclor 1268

This section describes the conceptual approach for the excavation and transfer of an in-place volume of approximately 6,500 cubic yards of PCB-impacted WWTS with concentrations ≥ 50 mg/kg to an engineered stockpile to be constructed on the Holtrachem site and operated by Honeywell (Section 6). Honeywell will manage the impacted WWTS and any waters generated either from continual dewatering or stormwater during excavation until the final Holtrachem site-wide remedy is implemented.

5.1 Overburden Removal

Based on the existing characterization data, the estimated lateral extent of materials with PCBs ≥ 50 mg/kg is shown in **Figure 3-1**. As indicated by the available analytical data, there are approximately 7,500 cubic yards of overburden material with concentrations < 50 mg/kg.

Overburden material removed from grid locations containing Aroclor 1268 concentrations ≥ 50 mg/kg will be removed and placed in stockpiles located within Cell No. 2. The stockpiles will be constructed within a bermed area lined with 10 mil polyethylene. A separate stockpile will be constructed for each grid section where Aroclor 1268 was detected at concentrations ≥ 50 mg/kg. Material management samples will be collected from each stockpile at a rate of 1 sample per 1,000 cubic yards of material and analyzed for Aroclor 1268 by US EPA SW-846 Method 8082. Overburden analyzed to contain Aroclor 1268 concentrations < 50 mg/kg will be transported to Cell No. 1. The remaining overburden will be transported to the engineered stockpile located on the Holtrachem property.

5.2 WWTS Removal

WWTS containing PCB concentrations ≥ 50 mg/kg will be solidified if necessary prior to removal from Cell No. 2. The haul road from Cell No. 2 to the engineered stockpile and all sediment/erosion controls will be inspected daily. Honeywell will immediately remove any spilled material from the haul roads to the engineered stockpile.

Based on the analytical and elevation data previously collected and presented in **Figures 2-1 and 2-2** and due to the thixotropic nature of the WWTS, it is anticipated that WWTS containing PCB concentrations ≥ 50 mg/kg will be solidified within Cell No. 2. Solidification will allow the material to be stockpiled at the Holtrachem facility, rather than requiring the use of temporary storage containers. In order to determine the most appropriate amendment and the amount of amendment required, CH2M HILL conducted a bench-scale treatability study.

5.2.1 Solidification Treatability Study

On June 6, 2007, CH2M HILL mobilized to the facility and collected approximately ten gallons of representative sludge from Cell No. 2 by advancing hand augers to the target depth. The sludge was transported to the Holtrachem facility laboratory for sample preparation and analysis.

Five stabilizers were amended to the sludge during the treatability study to determine the most appropriate amendment for full-scale use:

- Portland Type I
- Hydrated lime
- Mintek Calciment (fluidized bed ash)
- Synthetic Polymer
- Saw dust

Twelve stabilization tests were conducted. The sludge was split into jars and mixed with a stabilizer based on percent by weight as follows:

- 5% Portland Type I
- 10% Portland Type I
- 20% Portland Type I
- 5% Hydrated Lime
- 10% Hydrated Lime
- 5% Mintek Calciment
- 10% Mintek Calciment
- 15% Mintek Calciment
- 1% Polymer
- 2% Polymer
- 10% Saw Dust
- 1% Polymer plus Saw Dust

Results

The results of the treatability study are summarized in **Table 5-1**. Each of the Portland Type I tests exhibited stabilizing effects, producing a stackable material suitable for transport; however, the extent of stabilization was similar among the tests. The addition of more stabilizing agent did not appear to yield a more stable product. Of the three Portland Type I tests conducted, only the 20% sample increased in temperature.

Each of the hydrated lime tests exhibited stabilizing effects, becoming noticeably more dry and stiff. The 10% hydrated lime test yielded a significantly drier and stiffer product than the 5% hydrated lime test. Both hydrated lime test samples increased in temperature.

The addition of mintek calciment to sludge also yielded a drier, stiffer product in each of the amendment mixtures. The best results were achieved with the addition of 15% of mintek calciment. The 10% and 15% mintek calciment samples exhibited an increase in temperature.

When polymer was added to the sludge, the product was stiff; however, it was observed that the water simply absorbed to the polymer. The volume of the sample increased, but was compactable. No temperature change was observed in the polymer samples.

The addition of 10% saw dust resulted in quick stabilization of the sludge and an increase in volume. It was noted that this material was compactable. There was no temperature change observed in the saw dust sample.

The polymer/saw dust blend resulted in the absorption of water, similar to the polymer samples. The product was stackable.

Based on the results of the treatability study, mintek calciment has been selected as the solidification agent based on a cost analysis. A representative sample of the calciment will be collected and analyzed for TCLP VOCs, SVOCs, and RCRA metals prior to use. The calciment is being added only to thicken the WWTS to a soil-like consistency; therefore, addition of the calciment to the WWTS is not expected to limit future treatment options.

5.2.2 Solidification Procedures

Solidification will be accomplished by mixing calciment with the WWTS using a long-stick excavator. The results of the bench-scale treatability study described above indicate a mixture of 5% to 15% calciment and WWTS is required to achieve solidification such that the material can be stockpiled on the Holtrachem property and to treat the WWTS such that there are no free liquids. If the WWTS is observed to be sufficiently dry during excavation, then a field determination will be made as to whether an amendment will be needed to provide a stackable material. The solidified material will then be loaded directly into dump trucks and transported to the Holtrachem site.

The actual volume of WWTS to be transported to the engineered stockpile will likely be greater than the estimated 6,500 in-place cubic yards and will depend primarily on the amount of amendment required for material solidification. A total volume of approximately 6,800 to 7,500 cubic yards is estimated based on a 5% to 15% addition of calciment. Engineered stockpile specifications are discussed in Section 6.0.

After the appropriate amount of amendment has been added, the solidified material will be excavated and transported to the engineered stockpile on the Holtrachem facility. This process will be repeated until all the material containing Aroclor 1268 concentrations ≥ 50 mg/kg has been removed and stockpiled at the Holtrachem facility.

5.2.3 Confirmation Sampling

Post-excavation sampling will be performed to confirm that WWTS with PCB concentrations ≥ 11 mg/kg has been removed. The approximate extent of confirmation sampling within Cell No. 2 is the dashed area shown on **Figure 3-1**.

A 50 ft buffer area has been established around WWTS concentrations containing Aroclor 1268 concentrations ≥ 50 mg/kg. Excavation of material containing Aroclor 1268 concentrations ≥ 50 mg/kg will begin in the highest concentration areas and continue outward. Confirmation samples will be collected from the excavation sidewalls and grid bottom to confirm WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg have been removed. When confirmation samples indicate material containing Aroclor 1268 concentrations ≥ 50 mg/kg has been removed, the remaining buffer material will be excavated and transported to Cell No. 1.

Confirmation samples will be collected from the ≥ 50 mg/kg excavation using the following methods:

1. Overlay a square-based (maximum dimensions of 50 feet by 50 feet) grid system over the excavated area.
2. Divide the sampling grid into quadrants and mark out sampling points within the center of each quadrant.
3. Composite four discrete grab samples from the surface (0 to 6 inches below grade) in each quadrant of the removal area.
4. Collect sidewall samples from the elevation that corresponds to the highest PCB concentrations based on existing data from that grid. These samples will be collected as discrete grab samples.

Samples will be sent to a North Carolina-certified laboratory for analysis of Aroclor 1268 by US EPA SW-846 Method 8082.

If detected concentrations in the bottom confirmation soil samples exceed 11 mg/kg, an additional 1-foot interval will be solidified and removed from the grid section and confirmation samples will be re-collected from the newly excavated area. In the event sidewall samples contain elevated concentrations of PCBs, the areal extent of the confirmation sampling will be extended by an appropriate distance based on the analytical results and the sidewall confirmation sampling repeated.

Bottom of excavation confirmation samples will be identified with a unique designation using the following protocol:

SB-B-QN-XY-C where:

SB = soil boring (all locations)

B = bottom

QN = quadrant number

XY = approximate depth interval below pre-excavation ground surface in feet

C = composite

Sidewall excavation confirmation samples will be identified with a unique designation using the following protocol:

SB-W-QN-XY-G where:

SB = soil boring (all locations)

W = sidewall

QN = quadrant number

XY = average depth interval below pre-excavation ground surface in feet

G = grab

Due to personnel health and safety concerns, confirmation samples may be collected from the bucket of excavation equipment. The bucket will be decontaminated in accordance with the SAP between sample locations to minimize the potential for cross-contamination.

Sample material will be selected from a portion of the recovered material that is relatively undisturbed and not in contact with the excavation equipment.

5.3 Removal of Corrugated Pipe

Honeywell will remove the 16-inch diameter, corrugated galvanized steel pipe, formerly used for transport of Holtrachem process water, located on IP's property and any sludge or soil material with PCB concentrations > 11 mg/kg associated with the pipe. The excavated materials will be analyzed for Aroclor 1268 by EPA SW-846 Method 8082. Soils containing concentrations of Aroclor 1268 < 50 mg/kg will be transported to Cell No. 1. Soils containing concentrations of Aroclor 1268 ≥ 50 mg/kg will be transported to the engineered stockpile along with the pipe.

Following removal of the pipe, soil samples will be collected from the sidewalls and floor of the piping trench to determine the residual concentrations of Aroclor 1268. Soil samples will be collected from the sidewalls and along the base of piping trench at intervals of 50 feet. The pipe sampling results will be compared with the cleanup goal of 11 mg/kg.

5.3.1 Data Management

Analytical data from confirmation samples will be validated and loaded into the Locus Focus database for the Holtrachem site. All data management will be conducted in accordance with the QAPP.

Copies of the validated data will be provided to IP as electronic data deliverables (EDDs). The EDDs will be reviewed by ARCADIS database management personnel and checked for compatibility with IP's formatting requirements. Copies of the analytical results will also be provided to US EPA and NCDENR.

5.4 Equipment Decontamination Procedures

All vehicles and equipment will enter the IP mill in clean condition with all safety equipment in working condition (e.g., backup alarms). Equipment deliveries will be coordinated at least one week in advance with IP personnel to determine the best transportation route within the IP facility and to arrange entry inspections.

Loaded dump trucks will exit Cell No. 2 at only up to two locations. A loader or excavator will load each truck and, when loaded, each truck will proceed to the engineered stockpile. Prior to exiting, the vehicle will be inspected and all loose soil on the exterior of the truck bed and tires will be removed by shovel. The truck will then proceed to the decontamination station.

The decontamination station will be installed in the vicinity of the exit area near the perimeter road and will likely consist of a cattle guard-type recessed basin and a holding tank, with road base providing graded access on each end. Trucks will be able to ingress and egress across the decontamination station, if needed. The decontamination pad will be equipped with a pressure washer to expedite the decontamination process. Decontamination fluids will be collected and returned to the excavation dewatering network. As needed, sediment trapped in the decontamination basin will be sampled to

determine the appropriate disposal location. Sediment requiring transportation to the engineered stockpile will be loaded directly into the dump trucks.

Non-disposable sampling equipment will be decontaminated within the decontamination station. Equipment will be decontaminated in accordance with the EE/CA Field Sampling Plan (FSP):

1. Physically remove grit or visible contamination using a brush or scrub pad.
2. Wash equipment thoroughly with non-phosphate detergent wash (i.e., Alconox®) or other phosphate-free detergent.
3. Rinse thoroughly with tap water.
4. Rinse with deionized water.

In accordance with 40 CFR 761.79(b) and 761.79(c), any equipment, including excavation equipment, trucks, hand tools and non-disposable sampling equipment, coming into contact with sediment containing PCB concentrations ≥ 50 mg/kg will be decontaminated as stated above. Wipe samples will then be collected from the decontaminated equipment. Wipe sampling is described in additional detail in the SAP. Equipment will be considered appropriately decontaminated and may be removed from the site when wipe sample results are ≤ 10 $\mu\text{g}/100\text{ cm}^2$.

Wipe samples will be collected using a risk based approach. One wipe sample will be collected from each side or section of equipment that was in contact with soil containing PCB concentrations ≥ 50 mg/kg and composited into a single sample for analysis using EPA Method 8082. For example, for dump trucks, one wipe sample from each sidewall and bottom, totaling five single wipes, will be composited either in the field or by the laboratory for a single composited result. Decontamination and wipe sampling will be documented in the daily Quality Control Reports (QCRs) and/or Contractor Production Reports (CPRs). If sample results are greater than $10\text{ }\mu\text{g}/100\text{ cm}^2$, decontamination and wipe sampling will be repeated.

5.5 Demobilization and Site Restoration Activities

Honeywell will decontaminate all equipment at the completion of the excavation.

After all removal activities have been completed and WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg transferred to the engineered stockpile and WWTS containing Aroclor 1268 concentrations <50 mg/kg transferred to Cell No. 1, the temporary facilities will be removed. Areas disturbed during the removal action will be visually inspected, and damage will be repaired to the satisfaction of IP.

6.0 WWTS Management at the Holtrachem Facility

WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg will be temporarily stored on the Holtrachem site pending implementation of the site-wide removal action. WWTS storage time on the Holtrachem site is dictated by paragraph 16.q. of the 2008 AOC.

6.1 Storage Location

The solidified WWTS will be stored in an engineered stockpile constructed on the Old Cell Building pad as shown on **Figure 5-1**. A three-foot high berm will be constructed (using overburden materials containing Aroclor 1268 concentrations <11 mg/kg) around the perimeter of the Old Cell Building. Approximately 1,600 cubic yards of overburden will be required. An air monitoring program is currently in place at the Old Cell Building. That program will be modified such that the required air monitoring will be conducted at the perimeter of the pad.

Should the amount of material requiring storage exceed the capacity of the engineered stockpile, identical stockpiles can be constructed over the closed mercury vault and/or the closed North Pond. Stockpiles will be constructed as described below.

6.2 Stockpile Design

The engineered stockpile is expected to have a foot print of approximately 20,790 square feet and is expected to be constructed to a height of approximately 10 feet. Providing for a 3 foot vertical to 1 foot horizontal slope (discussed in Section 6.4), these dimensions will provide approximately 7,400 cubic yards of storage space. As discussed in Section 5.2.2, approximately 6,800 to 7,200 cubic yards of material (allowing for a 5% to 10% addition of calciment) is expected to be transported to the Holtrachem facility.

After the berm has been constructed, a 40-mil high-density polyethylene (HDPE) liner will be placed over the Old Cell Building pad with the edges of the HDPE liner extending over the berm, as shown on **Figure 5-2**. The liner will be placed in a manner that avoids tearing or ripping and conforms to the pad.

After the solidified WWTS have been placed in the engineered stockpile, a 40-mil HDPE liner will be placed over the stockpile to prevent stormwater from contacting the solidified materials. The seams of the top liner will be loosely sealed as deemed appropriate during construction to allow any gases generated to escape without allowing stormwater to enter the stockpile. The liners will then be weighted using clean overburden material or similar material to prevent slipping. A silt fence will be constructed around the liner and to prevent the overburden from running off of the liner during a storm event. A cross section of the proposed engineered stockpile is provided as **Figure 5-2**.

Fluids will be recovered from the engineered stockpile using a sump pump as necessary. The recovered fluids will be discharged to the Holtrachem stormwater treatment system.

6.3 Stockpile Construction

The engineered stockpile will be constructed as described below.

6.3.1 Site Inspection/Preparation

A site inspection will be conducted prior to construction to identify the access and egress routes and to ensure that access to the engineered stockpile construction site is free from obstructions. Identified obstructions will be removed from the routes. The location of the temporary facilities described in Section 6.3.3 will also be identified during the site inspection. Prior to placement of the liner, any rebar on the surface of the pad will be removed as well as any items which may compromise the integrity of the liner. A minimum 2-inch thick layer of clean overburden will be placed over the Old Cell Building pad to ensure a relatively level surface for construction and to ensure that any structural components on the pad, such as broken concrete, will not tear the liner. The engineered stockpile will be constructed to the west of the pit located within the Old Cell Building. The pit may be used as a sump to collect fluids from natural dewatering of the stored material. If necessary, water will be pumped from a collection point within the liner to the pit. A sump pump can then be placed within the pit to collect fluids and transfer them to the Holtrachem onsite treatment system.

6.3.2 Work Zone Delineation

After initial preparation activities are complete, work zones will be defined and barriers constructed to prevent unauthorized persons from entering the work area. The work zones will allow enough room for equipment and workers to move safely within the construction area. Non-workers will not be allowed to enter the work area.

The work zones will be established in accordance with the Project Health and Safety Plan (HSP) (GeoSyntec, 2004) including Hot Zones, Exclusion Zones, Contamination-Reduction Zones, and Support Zones.

6.3.3 Erosion and Sediment Control

Erosion and sediment controls will be implemented as required in the Stormwater Pollution Prevention Plan (SWPPP) for the Holtrachem property. As noted previously, a 40-mil HDPE liner will be placed both above and below the solidified WWTS to prevent the stored material from contacting stormwater. Stormwater is expected to flow off of the stockpile liner and to the existing stormwater system. As stated in Section 6.2, a silt fence will be installed around the engineered stockpile to prevent the clean overburden weighting the liner from running off during a storm event.

6.4 Solids Placement

The solidified WWTS will be placed within the engineered stockpile as described below.

6.4.1 Equipment/Procedures

As discussed in Section 4.2, solidified WWTS will be loaded into dump trucks at Cell No. 2 and transported to the Holtrachem site. The trucks will dump the solidified WWTS into the engineered stockpile. A long-stick excavator or loader will then be used to move the solidified WWTS within the engineered stockpile. Stockpiled solids are expected to reach a height of approximately 10 feet and will be placed at an angle not to exceed a 3 foot vertical: 1 foot horizontal slope.

A pre-fabricated 40-mil HDPE liner will be provided to cover the Old Cell Building pad, welded, folded and delivered to the site as a single piece. Information regarding the material specifications, manufacturing, and QA/QC will be submitted to US EPA and NCDENR prior to the liner being delivered to the site. An entrance ramp, approximately 40 feet long x 12 feet wide, will be constructed of clean material. Trucks will roll onto the ramp and dump at the end of the ramp. The waste pile will be spread and stacked using the stockpile management equipment.

6.4.2 Quantity Verification

The amount of solidified soil will be tracked using the load identification tickets and tracking logs for WWTS removed from Cell No. 2 for soils transported to the engineered stockpile (**Figure 4-1**). Once the solidified WWTS are in place, the stockpile will be measured to confirm the volume of solidified WWTS.

6.4.3 Stockpile Sampling

Composite samples will be collected from the engineered stockpile at a rate of one sample per 1,000 cubic yards of WWTS. With the exception of samples analyzed for volatile organic compounds (VOCs), grab samples will be collected from randomly selected truck loads and composited. The grab samples will be transferred to a clean stainless steel bowl for mixing prior to placement in the sample bottle. The composite sample will be sent to a NC-certified laboratory for analysis of semi-volatile organic compound (SVOCS), RCRA metals, pesticides, and dioxins. Samples collected for analysis of VOCs will be discrete grab samples from randomly selected truck loads.

Stockpile samples will be identified with a unique identification number using the following protocol:

ESP-#-C (or G) where:

- ESP = engineered stockpile
- # = unique sequential stockpile number
- C = composite
- G = grab

6.5 Operation and Maintenance

During the time the solidified WWTS are stored on the Holtrachem site, regular inspections of the engineered stockpile will be conducted as described below.

6.5.1 Marking

Signs will be posted with Mark M_L (shown below) every 100 feet around the periphery of the storage area indicating PCB containing materials are being stored within the engineered stockpile. Mark M_L shall be as shown below, letters and striping on a white or yellow background and shall be sufficiently durable to equal or exceed the life of the stockpile. The size of the mark shall be at least 15.25 cm (6 inches) on each side.



(40 CFR 761.40)

6.5.2 Inspections

The engineered stockpile will be inspected on a weekly basis throughout the storage period. The structure will be inspected for any movement of the berm, shifting of the liner, ponding of stormwater on top of the liner, or obvious tears in the liner. Labels will also be replaced as needed. Any potential problems identified during the inspections will be rectified immediately.

6.5.3 Fluid Recovery

If required, sump pump(s) (i.e. 3-inch diameter) will be used to pump water within the liner to the pit located in the Old Cell Building, then to the Holtrachem treatment system.

Water is not expected to accumulate at a significant rate within the liner. Therefore, water is not expected to be removed on a continuous basis. If water is removed from the engineered stockpile, it will be containerized (in drums or a tank) and analyzed for Aroclor 1268 prior to any discharge or disposal.

6.5.4 Record Keeping

The inspections and any corrective measures implemented will be documented on the inspection logs included in **Appendix B**. Copies of the inspection logs will be kept in a bound notebook onsite. Electronic copies of the inspection logs will be kept in CH2M HILL's Charlotte office.

7.0 Decontamination

Any equipment coming into contact with the solidified WWTS will be decontaminated prior to leaving the site in accordance with the decontamination procedures outlined below.

7.1 Equipment Decontamination

Heavy equipment coming into contact with the solidified WWTS will be decontaminated using a high pressure wash. Decontamination will take place on a plastic-lined decontamination pad. Prior to exiting, the vehicle will be inspected and all loose soil on the exterior of the truck bed and tires will be removed by shovel. The truck will then proceed to the decontamination station.

The decontamination station will be installed in the vicinity of the exit area near the haul road and will likely consist of a cattle guard-type recessed basin and a holding tank, with road base providing graded access on each end. Trucks will be able to ingress and egress across the decontamination station, if needed. The decontamination pad will be equipped with a pressure washer to expedite the decontamination process.

At the end of the project, prior to demobilization, all equipment surfaces that came into contact with PCB-impacted materials will be decontaminated in accordance with the requirements of the self-implementing decontamination procedures (40 CFR 761.79). Wipe samples will be collected for rush turnaround analysis of Aroclor 1268.

In accordance with 40 CFR 761.79(b) and 761.79(c), any equipment, including excavation equipment, trucks, hand tools, and non-disposable sampling equipment, coming into contact with sediment containing PCB concentrations ≥ 50 mg/kg will be decontaminated as stated above. Wipe samples will be collected after the equipment has been decontaminated. Wipe sampling is described in additional detail in the SAP. Equipment will be considered appropriately decontaminated and may be removed from the site when wipe sample results are ≤ 10 $\mu\text{g}/100\text{ cm}^2$.

Wipe samples will be collected using a risk based approach. One wipe sample will be collected from each side or section that was in contact with soil containing PCB concentrations ≥ 50 mg/kg and composited into a single sample for analysis using EPA Method 8082. For example, for dump trucks, one wipe sample from each sidewall and bottom, totaling five single wipes, will be composited either in the field or by the laboratory for a single composited result. Decontamination and wipe sampling will be documented in the daily QCRs and/or CPRs. If sample results are greater than $10\text{ }\mu\text{g}/100\text{ cm}^2$, decontamination and wipe sampling will be repeated.

7.2 Worker Decontamination

Please refer to the project Health and Safety Plan in **Appendix D** for worker decontamination procedures.

7.3 Sampling Equipment Decontamination

Decontamination of sampling equipment will be performed in accordance with the EE/CA Field Sampling Plan (FSP).

7.4 Decontamination Waste Management

Decontamination fluids will be collected and placed into a holding tank for subsequent treatment via the onsite system. As needed, sediment trapped in the decontamination basin will be removed and sampled to determine the appropriate disposal location. Disposable materials will be stored within the engineering stockpile, separate from soils.

8.0 Health & Safety

All work activities will be conducted in accordance with the Project HSP. Prior to going into the field, all personnel must sign the employee signoff sheet located in the HSP.

Daily safety meetings will be conducted by onsite personnel. All workers will be required to attend these safety meetings prior to beginning work activities. Workers will coordinate and inform the onsite staff of the work to take place that day. The site safety coordinator will conduct a supplemental health and safety meeting before beginning work each day to discuss the specific work for the day.

The storage location is within a site Hot Zone. Therefore, work activities conducted within the Hot Zone such as engineered stockpile construction and WWTS placement (by the equipment operator for example) will be in compliance with the safety requirements outlined in the HSP. The appropriate PPE levels will be determined based on air monitoring.

In the event of an emergency, injured personnel should be taken to New Hanover Regional Hospital. For a full discussion of health and safety, as well as a map to the hospital, refer to the Project HSP.

9.0 Reporting

During the removal action, weekly reports will be submitted to US EPA and NC DENR. For each reporting period, the weekly reports will be submitted each Tuesday and will include the following information:

- Summary of activities conducted
- Plans and procedures completed under the Work Plan during the reporting period
- Number and type of personnel and equipment used (i.e. two dump trucks and drivers, 4 equipment operators, 1 supervisor, etc.)
- Summary of health and safety activities and incidents
- Estimated volume of WWTS moved into the engineered stockpile
- Estimated volume of WWTS disposed in Cell No. 1
- Volume, description, and location of any waste disposed off-site (not anticipated)
- Description of samples collected
- Results of analytical data received
- Information related to any spills and corrective actions taken
- Remaining capacity of stockpile
- Planned activities for the following week
- Updates to the project schedule including information regarding percentage of completion, unresolved delays which may impact the schedule, and a description of efforts made to mitigate delays.

In addition, a summary report will be prepared within 30 days of completion of the excavation and engineered stockpile construction activities described in this work plan. The report will include a summary of solidification activities, solids transportation, stockpiling, confirmation sample results, decontamination sampling results, and an estimate of total costs incurred. A discussion of removal and disposal options for materials handled on-site or off-site and a listing for the ultimate materials destination will also be included. The report will also include photographs, the load identification tickets, manifests (if material is disposed off-site), invoices, bills, contracts, permits, and as-built drawings (including pre- and post-survey information and in-place cubic yardage of materials removed from the Cell). The report will conform with the requirements of Section 300.165 of the National Contingency Plan (NCP) and the *Superfund Removal Procedures: Removal Response Reporting – POLREPS and OSC Reports* guidance document. Copies of the report will be submitted to US EPA and NC DENR.

The final report will include the following certification signed by a person who supervised or directed the preparation of the report:

“Under penalty of law, I certify that to the best of my knowledge, after appropriate inquiries of all relevant persons involved in the preparation of the report, the information submitted is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.”

After the removal action is completed (i.e. contractor demobilization), the reporting frequency will be reduced from weekly to monthly. The monthly report, which will document the stockpile inspections, will be combined with the monthly report submitted for the Holtrachem Site. A brief description of inspection activities and results will be included in the Monthly Status Report submitted to US EPA. Copies of the weekly inspection logs will also be submitted to US EPA as an attachment to the monthly progress report.

Within 30 days after the WWTS are permanently disposed of, the final report will be modified to include the disposal information.

10.0 Schedule

WWTS solidification and engineered stockpile construction activities are expected to begin in May 2008. Work will be conducted six days per week with 10-hour work days. A copy of the proposed project schedule is included in **Appendix C**.

11.0 References

- ARCADIS G&M of North Carolina, Inc. 2006a. DRAFT TSCA Risk-Based Disposal Application for PCB Remediation Wastes. September.
- ARCADIS G&M of North Carolina, Inc. (ARCADIS), 2006b. Sludge Characterization Work Plan, International Paper Riegelwood Mill, Riegelwood, North Carolina. June 27.
- Black & Veatch Special Projects Corporation (Black & Veatch), 1996. Final Site Inspection Prioritization Report. Federal Paper Board, Riegelwood, Columbus County, North Carolina. US EPA ID NCD000605303, WasteLAN No. 02523. Prepared for the Waste Management Division, U.S. Environmental Protection Agency. May 8.
- CH2M HILL, 2007. *Draft Report Human Health Risk Assessment*, LCP-Holtrachem Site, Riegelwood, NC. March 2007.
- GeoSyntec Consultants (GeoSyntec), 2005. Screening Level Ecological Risk Assessment (SLERA) Steps 1 and 2, LCP-Holtrachem Site, Riegelwood, North Carolina. June 12.
- GeoSyntec Consultants (GeoSyntec), 2004. Engineering Evaluation/Cost Analysis Field Sampling Plan, LCP-Holtrachem Site, Riegelwood, North Carolina. October.
- North Carolina Department of Environment and Natural Resources (NC DENR), 2005. Guidelines for Establishing Remediation Goals at RCRA Hazardous Waste Sites. Division of Waste Management – Hazardous Waste Section. May 2005.
- Premier Environmental Services, Inc. (Premier), 2005. Draft Report of Limited Sludge Sampling and Analysis, International Paper Riegelwood Mill, Riegelwood, North Carolina. October 25.
- US EPA, 2004. US EPA Contract Laboratory Program, National Functional Guidelines for Inorganic Data Review. US EPA Office of Emergency and Remedial Response, US EPA 540/R-01/008, October 2004.
- US EPA, 1999. US EPA Contract Laboratory Program, National Functional Guidelines for Organic Data Review. US EPA Office of Emergency and Remedial Response, US EPA 540/R-99/008, October 1999.
- US EPA, 1996. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response, US EPA 540/R-96/018. July 1996.

Tables

Table 2-1

Summary of Preliminary PCB Sampling Results - Premier, October 2005 Report, Landfill Cell No. 2

WWTS Management Work Plan

LCP-Holtrachem Site, Riegelwood, NC

Constituents	Sample ID: Sample Depth (ft bls):	SS1-2-4 2 - 4	SS1-4-8 4 - 8	SS2-0-2 0 - 2	SS3-0-3 0 - 3	SS4-0-2 0 - 2	SS5-0-2 0 - 2	SS5-10-12 10 - 12	SS6-0-2 0 - 2	SS6-4-6 4 - 6	SS6-6-8 6 - 8	SS6-8-9 8 - 9
PCBs (mg/kg) (USEPA Method 8082)												
Aroclor 1016	9/21/2005	<120	<0.74	<0.75	<4.4	<0.098	<4.0	<0.044	<0.81	<0.42	<0.20	<0.96
Aroclor 1221	9/21/2005	<120	<1.5	<1.5	<8.9	<0.200	<8.1	<0.089	<1.6	<0.85	<0.41	<2.0
Aroclor 1232	9/21/2005	<120	<0.74	<0.75	<4.4	<0.098	<4.0	<0.044	<0.81	<0.42	<0.20	<0.96
Aroclor 1242	9/21/2005	<120	<0.74	<0.75	<4.4	<0.098	<4.0	<0.044	<0.81	<0.42	<0.20	<0.96
Aroclor 1248	9/21/2005	<120	<0.74	<0.75	<4.4	<0.098	<4.0	<0.044	<0.81	<0.42	<0.20	<0.96
Aroclor 1254	9/21/2005	<120	<0.74	<0.75	<4.4	<0.098	<4.0	<0.044	<0.81	<0.42	<0.20	<0.96
Aroclor 1260	9/21/2005	<120	<0.74	<0.75	<4.4	<0.098	<4.0	<0.044	<0.81	<0.42	<0.20	<0.96
Aroclor 1268	9/21/2005	1,200	2.6	2.1	21	<0.098	26	0.071	1.6	1.6	0.29	1.4

Notes:

mg/kg = milligrams per kilogram

Results shaded in blue are above 50 mg/kg.

Results in bold are above 25 mg/kg.

Laboratory analyses completed by Columbia Analytical Services

Table 2-2**Summary of Preliminary TCLP Sampling Results - Premier, October 2005 Report, Landfill Cell No. 2**

WWTS Management Work Plan

LCP-Holtrachem Site, Riegelwood, NC

Constituents	Sample ID: Sample Depth (ft bls):	SS3-0-3 0 - 3	SS5-0-2 0 - 2	SS6 Composite n/a
<u>TCLP Metals (mg/L)</u> (USEPA Method 1311/6010/7470)				
Arsenic		<0.500	<0.500	<0.500
Barium		<1.00	<1.00	<1.00
Cadmium		<0.100	<0.100	<0.100
Chromium		<0.100	<0.100	<0.100
Lead		<0.100	<0.100	<0.100
Mercury		<0.00300	<0.00300	<0.00300
Selenium		<0.500	<0.500	<0.500
Silver		<0.100	<0.100	<0.100
<u>TCLP VOCs (mg/L)</u> (USEPA Method 1311/8260)				
Benzene		<0.050	<0.050	<0.050
2-Butanone		<0.100	<0.100	<0.100
Carbon Tetrachloride		<0.050	<0.050	<0.050
Chlorobenzene		<0.050	<0.050	<0.050
Chloroform		<0.050	<0.050	<0.050
1,2-Dichloroethane		<0.050	<0.050	<0.050
1,1-Dichloroethene		<0.050	<0.050	<0.050
Tetrachloroethene		<0.050	<0.050	<0.050
Trichloroethene		<0.050	<0.050	<0.050
Vinyl Chloride		<0.050	<0.050	<0.050
<u>TCLP SVOCs (mg/L)</u> (USEPA Method 1311/8270)				
1,4-Dichlorobenze		<0.100	<0.100	<0.100
2,4-Dinitrotoluene		<0.100	<0.100	<0.100
Hexachlorobenzene		<0.100	<0.100	<0.100
Hexachlorobutaniene		<0.100	<0.100	<0.100
Hexachloroethane		<0.100	<0.100	<0.100
2-Methylphenol		<0.100	<0.100	<0.100
3+4-Methylphenol		<0.100	<0.100	<0.100
Nitrobenzene		<0.100	<0.100	<0.100
Pentachlorophenol		<0.500	<0.500	<0.500
Pyridine		<0.500	<0.500	<0.500
2,4,6-Trichlorophenol		<0.100	<0.100	<0.100
2,4,5-Trichlorophenol		<0.100	<0.100	<0.100

Notes:

mg/L = milligrams per liter

ft bls = feet below land surface

n/a = not applicable

Laboratory analyses completed by Columbia analytical Services

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTs Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
C6	30-28	< 1 J
C6	28-26	1.4 J
C6	26-24	< 1 J
C6	24-22	< 1
C6	22-20	< 1 J
C6	20-18	< 1
C8	30-28	< 1 J
C8	28-26	< 1 J
C8	26-24	< 1
C8	24-22	< 1 J
C8	22-20	< 1
C8	20-18	< 1
C10	32-30	< 1 J
C10	30-28	< 1 J
C10	28-26	< 1
C10	26-24	< 1 J
C10	24-22	< 1
C10	22-20	< 1
E6	30-28	< 1 J
E6	28-26	< 1 J
E6	26-24	< 1 J
E6	24-22	< 1 J
E6	22-20	< 1 J
E8	30-28	< 1 J
E8	28-26	< 1 J
E8	26-24	< 1 J
E8	24-22	< 1
E8	22-20	< 1 J
E8	20-18	< 1
E10	30-28	< 1 J
E10	28-26	< 1 J
E10	26-24	< 1
E10	24-22	< 1 J
E10	22-20	< 1 J
E10	20-18	< 1
E12	30-28	< 1 J
E12	28-26	< 1 J
E12	26-24	< 1 J
E12	24-22	< 1
E12	22-20	< 1
G6	28-26	< 1 J
G6	26-24	< 1 J
G6	24-22	< 1 J
G6	22-20	< 1 J

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTs Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
G6	20-18	< 1 J
G6	18-16	< 1 J
G8	30-28	16 J
G8	28-26	3.2 J
G8	26-24	< 1 J
G8	24-22	< 1
G8	22-20	< 1 J
G8	20-18	< 1 J
G10	26-24	< 1 J
G10	24-22	< 1 J
G10	22-20	< 1 J
G10	20-18	< 1 J
G10	18-16	< 1 J
G10	16-14	< 1 J
G12	26-24	< 1 J
G12	24-22	< 1 J
G12	22-20	< 1 J
G12	20-18	< 1 J
G12	18-16	< 1 J
G12	16-14	< 1 J
H4	28-26	11 J
H4	26-24	1.9 J
H4	24-22	1 J
H4	22-20	< 1 J
H4	20-18	< 1
H4	18-16	< 1 J
H5	26-24	1.7 J
H5	24-22	16 J
H5	22-20	4,100 J
H5	20-18	18 J
H5	18-16	39 J
H5	16-14	6.1 J
I4	28-26	< 1 J
I4	26-24	< 1 J
I4	24-22	< 1 J
I4	22-20	72 J
I4	20-18	280 J
I4	18-16	830
I4	16-14	3.1 J
I5	26-24	4.3 J
I5	24-22	6.4 J
I5	22-20	780 J
I5	20-18	3.6 J
I6	26-24	< 1 J

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTS Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
I6	24-22	< 1 J
I6	22-20	21 J
I6	20-18	5,100 J
I6	18-16	3,600 J
I6	16-14	46 J
I8	26-24	< 1 J
I8	24-22	< 1 J
I8	22-20	< 1 J
I8	20-18	1,800 J
I8	18-16	3,600 J
I8	16-14	1.5 J
I10	26-24	< 1 J
I10	24-22	< 1 J
I10	22-20	5.7 J
I10	20-18	< 1 J
I10	18-16	2.3 J
I10	16-14	< 1
I12	22-20	< 1 J
I12	20-18	1.2 J
I12	18-16	< 1 J
I12	16-14	< 1 J
J3	26-24	< 1 J
J3	24-22	< 1 J
J3	22-20	< 1 J
J3	20-18	< 1 J
J3	18-16	< 1 J
J3	16-14	< 1 J
J4	28-26	< 1 J
J4	26-24	2.9 J
J4	24-22	< 1
J4	22-20	16 J
J4	20-18	6.1 J
J4	18-16	< 1 J
J5	24-22	< 1 J
J5	22-20	82 J
J5	20-18	< 1 J
J5	18-16	< 1 J
K3	28-26	< 1 J
K3	26-24	< 1 J
K3	24-22	< 1 J
K3	22-20	< 1 J
K3	20-18	< 1 J
K3	18-16	< 1 J
K4	26-24	< 1 J

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTs Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
K4	24-22	< 1 J
K4	22-20	< 1 J
K4	20-18	< 1 J
K4	18-16	1.2 J
K4	16-14	< 1 J
K5	24-22	< 1 J
K5	22-20	120 J
K5	20-18	1.3 J
K5	18-16	< 1 J
K6	24-22	1 J
K6	22-20	< 1
K6	20-18	< 1 J
K6	18-16	600 J
K6	16-14	400 J
K6	14-12	1 J
K8	24-22	1.8 J
K8	22-20	< 1 J
K8	20-18	1.9 J
K8	18-16	< 1 J
K8	16-14	< 1 J
K8	14-12	< 1 J
K10	24-22	< 1 J
K10	22-20	< 1
K10	20-18	< 1 J
K10	18-16	< 1
K10	16-14	< 1 J
K10	14-12	< 1
K12	22-20	< 1
K12	20-18	< 1
K12	18-16	< 1 J
K12	16-14	< 1
K12	14-12	< 1 J
K12	12-10	< 1
L2	28-26	1.3 J
L2	26-24	< 1 J
L2	24-22	< 1 J
L2	22-20	13 J
L2	20-18	1.1 J
L2	18-16	< 1
L3	24-22	< 1 J
L3	22-20	< 1 J
L3	20-18	< 1 J
L3	18-16	1.1 J
L3	16-14	< 1 J

Table 2-3

Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2

WWTs Management Work Plan

LCP-Holtrachem Site, Riegelwood, NC

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
L3	14-12	< 1
L4	24-22	2.7 J
L4	22-20	< 1 J
L4	20-18	< 1
L4	18-16	< 1 J
L4	16-14	< 1 J
L4	14-12	< 1
L5	24-22	< 1 J
L5	22-20	2.5 J
L5	20-18	< 1 J
L5	18-16	< 1 J
M2	26-24	< 1
M2	24-22	< 1
M2	22-20	< 1
M2	20-18	< 1
M2	18-16	< 1
M2	16-14	< 1
M3	24-22	1.4 J
M3	22-20	< 1 J
M3	20-18	< 1 J
M3	18-16	< 1 J
M3	16-14	< 1 J
M3	14-12	< 1 J
M4	24-22	1.2 J
M4	22-20	< 1 J
M4	20-18	< 1 J
M4	18-16	< 1 J
M4	16-14	< 1 J
M4	14-12	< 1
M5	22-20	< 1 J
M5	20-18	< 1 J
M5	18-16	< 1
M5	16-14	< 1
M6	22-20	1.1 J
M6	20-18	< 1 J
M6	18-16	820 J
M6	16-14	< 1 J
M8	24-22	1.8 J
M8	22-20	< 1 J
M8	20-18	28 J
M8	18-16	< 1 J
M8	16-14	1.4 J
M8	14-12	< 1 J
M8	12-10	< 1

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTS Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
M10	22-20	2 J
M10	20-18	< 1
M10	18-16	< 1 J
M10	16-14	< 1
M10	14-12	< 1
M10	12-10	< 1
M12	22-20	< 1 J
M12	20-18	< 1
M12	18-16	< 1
M12	16-14	< 1
M12	14-12	< 1
M14	22-20	< 1 J
M14	20-18	< 1
M14	18-16	< 1 J
M14	16-14	< 1 J
M14	14-12	< 1 J
M14	12-10	< 1
O2	24-22	42 J
O2	22-20	< 1 J
O2	20-18	< 1 J
O2	18-16	< 1 J
O2	16-14	< 1
O2	14-12	< 1
O4	24-22	3.2 J
O4	22-20	< 1 J
O4	20-18	< 1 J
O4	18-16	< 1 J
O4	16-14	< 1 J
O4	14-12	< 1
O6	22-20	2.6 J
O6	20-18	1.6 J
O6	18-16	< 1 J
O6	16-14	< 1
O6	14-12	< 1 J
O6	12-10	< 1 J
O8	22-20	4.7 J
O8	20-18	6.9 J
O8	18-16	< 1 J
O8	16-14	< 1
O8	14-12	< 1
O8	12-10	< 1
O10	22-20	2 J
O10	20-18	< 1
O10	18-16	< 1 J

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTs Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
O10	16-14	< 1
O10	14-12	< 1 J
O10	12-10	< 1
O12	22-20	< 1 J
O12	20-18	< 1
O12	18-16	< 1
O12	16-14	< 1
O12	14-12	< 1
O12	12-10	< 1
O14	22-20	< 1
O14	18-16	2.5 J
O14	14-12	< 1
O14	12-10	< 1 J
Q4	26-24	< 1 J
Q4	24-22	< 1 J
Q4	22-20	< 1 J
Q4	20-18	< 1
Q4	18-16	< 1 J
Q4	16-14	< 1
Q6	22-20	1.1 J
Q6	20-18	22 J
Q6	18-16	< 1 J
Q6	16-14	2.5 J
Q6	14-12	< 1 J
Q8	20-18	4.5 J
Q8	18-16	5.6 J
Q8	16-14	< 1 J
Q8	14-12	< 1
Q10	20-18	< 1 J
Q10	18-16	4.2 J
Q10	16-14	< 1 J
Q10	14-12	< 1 J
Q10	12-10	< 1 J
Q10	10-8	< 1 J
Q12	22-20	< 1 J
Q12	20-18	< 1
Q12	18-16	< 1
Q12	16-14	< 1
Q12	14-12	< 1 J
Q12	12-10	< 1
Q14	22-20	< 1 J
Q14	20-18	< 1
Q14	18-16	< 1 J
Q14	16-14	< 1

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTs Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
Q14	14-12	< 1
Q14	12-10	< 1
S6	22-20	< 1 J
S6	20-18	2 J
S6	18-16	< 1 J
S6	16-14	< 1
S6	14-12	1.5 J
S6	12-10	< 1
S8	22-20	1.3 J
S8	20-18	< 1
S8	18-16	< 1 J
S8	16-14	< 1
S8	14-12	< 1 J
S8	12-10	< 1
S10	20-18	< 1 J
S10	18-16	< 1
S10	16-14	< 1
S10	14-12	< 1
S12	20-18	< 1
S12	16-14	< 1
S12	14-12	< 1
S14	18-16	1.2 J
S14	14-12	< 1
S14	10-8	< 1 J
U6	28-26	< 1 J
U6	26-24	< 1
U6	24-22	< 1
U6	22-20	< 1
U6	20-18	< 1
U6	18-16	< 1
U8	18-16	< 1 J
U8	16-14	4.1 J
U8	14-12	< 1
U8	12-10	< 1
U10	20-18	< 1 J
U10	18-16	2.9 J
U10	16-14	< 1 J
U10	14-12	< 1
U10	12-10	< 1
U12	20-18	< 1
U12	18-16	< 1 J
U12	16-14	< 1 J
U12	14-12	< 1 J
U12	12-10	< 1

Table 2-3**Summary of PCB Sampling Results - July 2006 Investigation, Landfill Cell No. 2***WWTS Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Soil Boring	Elevation Interval (ft amsl)	Aroclor 1268 (mg/kg)
U12	10-8	< 1
U14	18-16	< 1 J
U14	16-14	< 1
U14	14-12	< 1 J
U14	12-10	< 1
U14	10-8	< 1
U16	20-18	< 1 J
U16	18-16	< 1 J
U16	16-14	< 1
U16	14-12	< 1 J
U16	12-10	< 1
U16	10-8	< 1 J
W8	24-22	< 1
W8	22-20	< 1 J
W8	20-18	< 1
W8	18-16	< 1
W8	16-14	< 1
W8	14-12	1.5 J
W10	20-18	< 1 J
W10	18-16	< 1 J
W10	16-14	< 1 J
W10	14-12	6 J
W10	12-11	< 1 J

Notes:

Results shaded are above 50 mg/kg.

Results in bold are above 25 mg/kg.

ft amsl - feet above mean sea level (approximate)

mg/kg - milligram per killogram

< - Result is less than the given reporting limit

J - value is estimated

Table 2-4**Summary of VOC, SVOC, and RCRA Metal Sampling Results – July 2006 Investigation, Landfill Cell No. 2***WWTS Management Work Plan**LCP-Holtrachem Site, Riegelwood, NC*

Constituents	NC IHSB SRG ^a (ug/kg)	USEPA Industrial Soil PRG ^b (ug/kg)	SB-I5-20-18 (5.8 - 7.8 ft bls)	SB-I6-20-18 (5.7 - 7.7 ft bls)	SB-W10-12-11 (8.6 - 9.6 ft bls)
<u>Volatile Organic Compounds (ug/kg)</u> (USEPA Method 8260)					
Acetone	2,800,000	5,500,000	< 14	15 J	< 15
Carbon Disulfide	72,000	720,000	< 5.7	1.2 J	< 6.1
Chloroform	220	470	< 5.7	0.75 J	< 6.1
Trichloroethene	53	110	< 5.7	0.76 J	< 6.1
Toluene	132,000	520,000	< 5.7	1.1 J	< 6.1
Tetrachloroethene	480	1,300	< 5.7	1.4 J	< 6.1
Chlorobenzene	30,000	530,000	< 5.7	26	< 6.1
<u>Semi-Volatile Organic Compounds (ug/kg)</u> (USEPA Method 8270)					
1,3-Dichlorobenzene	106,000	600,000	< 5.7	200	< 6.1
1,4-Dichlorobenzene	3,400	7,900	< 5.7	770 D	< 6.1
1,2-Dichlorobenzene	220,000	600,000	< 5.7	3.8 J	< 6.1
1,2,4-Trichlorobenzene	12,400	220,000	< 5.7	97	< 6.1
<u>RCRA Metals (ug/kg)</u> (USEPA Method 6010)					
Arsenic	4,400	1,600	0.27 B	NS	<0.24
Barium	NV	67,000,000	10 B	NS	9.9 B
Cadmium	7,400	450,000	<0.02	NS	0.03 U
Chromium (Total)	24,000,000	450,000	3.9	NS	2.8
Lead	400,000	800,000	3.2	NS	2.1
Mercury	4,600	310,000	0.049	NS	0.023 B
Selenium	78,000	5,100,000	<0.20	NS	0.22 B
Silver	78,000	5,100,000	<0.07	NS	<0.07

Notes:^a NC HWS SSL - North Carolina Inactive Hazardous Sites Branch Soil Remediation Goals (NCDENR, January 2006)^b USEPA Region IX Industrial Soil Preliminary Remediation Goal (USEPA 2004)

< - Result is less than the given reporting limit

J - value is estimated

D - sample reanalyzed at a higher dilution.

B - above the method detection limit and below the reporting detection limit, value is estimated

NS - not sampled for specified analysis

NV - no value given

ug/kg - microgram per kilogram

ft bls - feet below land surface

Table 2-5**Summary of TCLP Sampling Results – July 2006 Investigation, Landfill Cell No. 2**

WWTS Management Work Plan

LCP-Holtrachem Site, Riegelwood, NC

Constituents	USEPA TCLP Regulatory Level	SB-I5-22-20 (3.8 - 5.8 ft bls)	SB-I8-18-16 (8.5 - 10.5 ft bls)	SB-Q4-24-22 (1.8 - 3.8 ft bls)	SB-U10-18-16 (1 - 3 ft bls)
<u>TCLP VOCs (mg/L)</u> (USEPA Method 1311/8260)					
Chlorobenzene	100	< 0.025	0.1	< 0.025	< 0.025
<u>TCLP SVOCs (mg/L)</u> (USEPA Method 1311/8270)					
1,4-Dichlorobenzene	7.5	0.0044 J	0.0075 J	< 0.050	< 0.050
<u>TCLP RCRA Metals (mg/L)</u> (USEPA Method (1311/6010/7470))					
Arsenic	5.0	0.0188 B	0.0205 B	0.0159 B	0.0179 B
Barium	100	0.748 B	1.12 B	0.137 B	0.778 B
Cadmium	1.0	0.0022 B	0.0033 B	< 0.0004	0.001 B
Chromium	5.0	0.0187 B	0.0105 B	< 0.0005	0.0136 B
Lead	5.0	0.0798 B	0.208 B	0.528 B	0.005 B
Mercury	0.2	< 0.0001	0.00012 B	< 0.0001	0.00084 B
Selenium	1.0	0.0093 B	0.0083 B	0.0106 B	0.0093 B
Silver	5.0	< 0.0003	< 0.0003	< 0.0003	0.00036 B
<u>TCLP Pesticides (mg/L)</u> (USEPA Method (1311/8081))	NA	NS	ND	NS	NS

Notes:

< - Result is less than the given reporting limit

J - value is estimated

B - above the method detection limit and below the reporting detection limit, value is estimated

TCLP - Toxicity Characteristic Leaching Procedure

NA - not applicable

ND - no constituents detected above reporting limit

NS - not sampled for specified analysis

mg/L - milligrams per liter

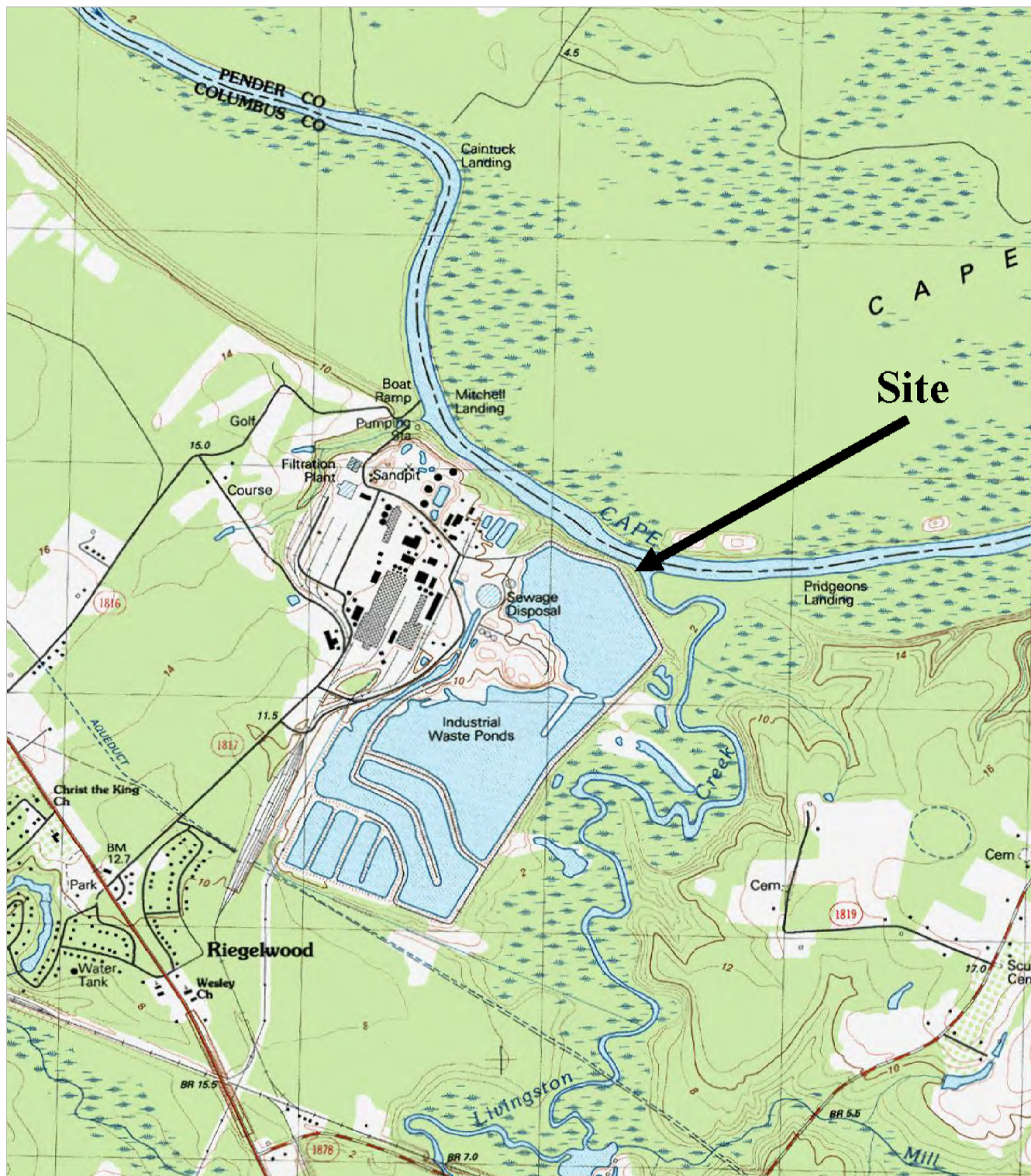
ft bls - feet below land surface

Table 5-1
Summary of Treatability Study Results
WWTS Management Work Plan
LCP-Holtrachem Site, Riegelwood, NC

Additive	1% By Weight	2% By Weight	5% By Weight	10% By Weight	15% By Weight	20% By Weight
Portland Type 1 -High Cost	N/A	N/A	Sludge Weight = 260 g Portland Weight = 13 g No temperature change Stackable, will continue to set overnight.	Sludge Weight = 200 g Portland Weight = 20 g No temperature change Stackable, will continue to set overnight.	N/A	Sludge Weight = 220 g Portland Weight = 44 g Temperature increase 3°F Stackable, will continue to set overnight.
Hydrated Lime (Provided by IP) -Moderate Cost	N/A	N/A	Sludge Weight = 220 g Lime Weight = 11 g Temperature increase 3°F Noticeably more stiff and dry. Will continue to set overnight.	Sludge Weight = 250 g Lime Weight = 25 g Temperature increase 3°F Very stiff, very dry. Will continue to set overnight.	N/A	N/A
Mintek Calciment (Fluidized bed ash) -Moderate Cost	N/A	N/A	Sludge Weight = 250 g Calciment = 12.5 g No temperature change Noticeably more stiff and dry.	Sludge Weight = 240 g Calciment = 24 g Temperature increase 3°F Noticeably more stiff and dry.	Sludge Weight = 250 g Calciment = 37.5 g Temperature increase 3°F Very stiff, very dry. Best results.	N/A
Polymer -A17High Cost	Sludge Weight = 260 g Polymer Weight = 2.6 g No temperature change Stiff, water absorbed	Sludge Weight = 230 g Polymer Weight = 4.6 g No temperature change Stiff. Volume increased, but will compact.	N/A	N/A	N/A	N/A
Saw Dust -Low Cost	N/A	N/A	N/A	Sludge Weight = 170 g Saw Dust Weight = 17 g No temperature change. Quick solidification. Volume increased, but will compact.	N/A	N/A
1% Polymer + Saw Dust	Rough mix - water is absorbed, stackable.					

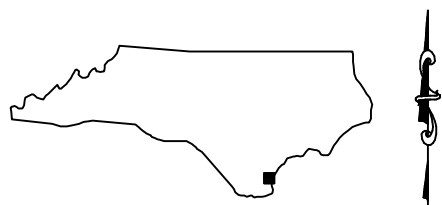
*Progress Energy was contacted regarding the utilization of fly ash from their Wilmington, NC plant; however, internal approval is required for distribution. Fly ash should be considered when construction begins.
-Moderate to low cost (dependent on transportation cost)

Figures



NOT TO SCALE

ORIGINAL DRAWING BASED ON
FIGURE FROM ARCADIS DATED 9/18/2006



VICINITY MAP

SOURCE: TOPOGRAPHY TAKEN FROM USGS 7.5 MINUTE QUADRANGLE
SOUTHWESTERN LUMBERTON, NC MAP

FIGURE 1-1
SITE LOCATION MAP
INTERNATIONAL PAPER
RIEGELWOOD, NORTH CAROLINA

CH2MHILL



INTERNATIONAL PAPER PROPERTY BOUNDARIES

AERIAL PHOTO TAKEN FROM GOOGLE EARTH
SCALE APPROXIMATELY 1"=2000'

LEGEND

- = INTERNATIONAL PAPER BOUNDARY
- = HOLTRACHEM BOUNDARY
- = INTERNATIONAL PAPER LANDFILL CELLS



INSET A

AERIAL PHOTO TAKEN FROM GOOGLE EARTH
SCALE APPROXIMATELY 1" = 600'

BOUNDARIES BASED ON COLUMBUS COUNTY GIS 11-1-2007

DSGN	GMH		
DR	GMH		
CHK	KEH		
APVD			
		NO.	DATE

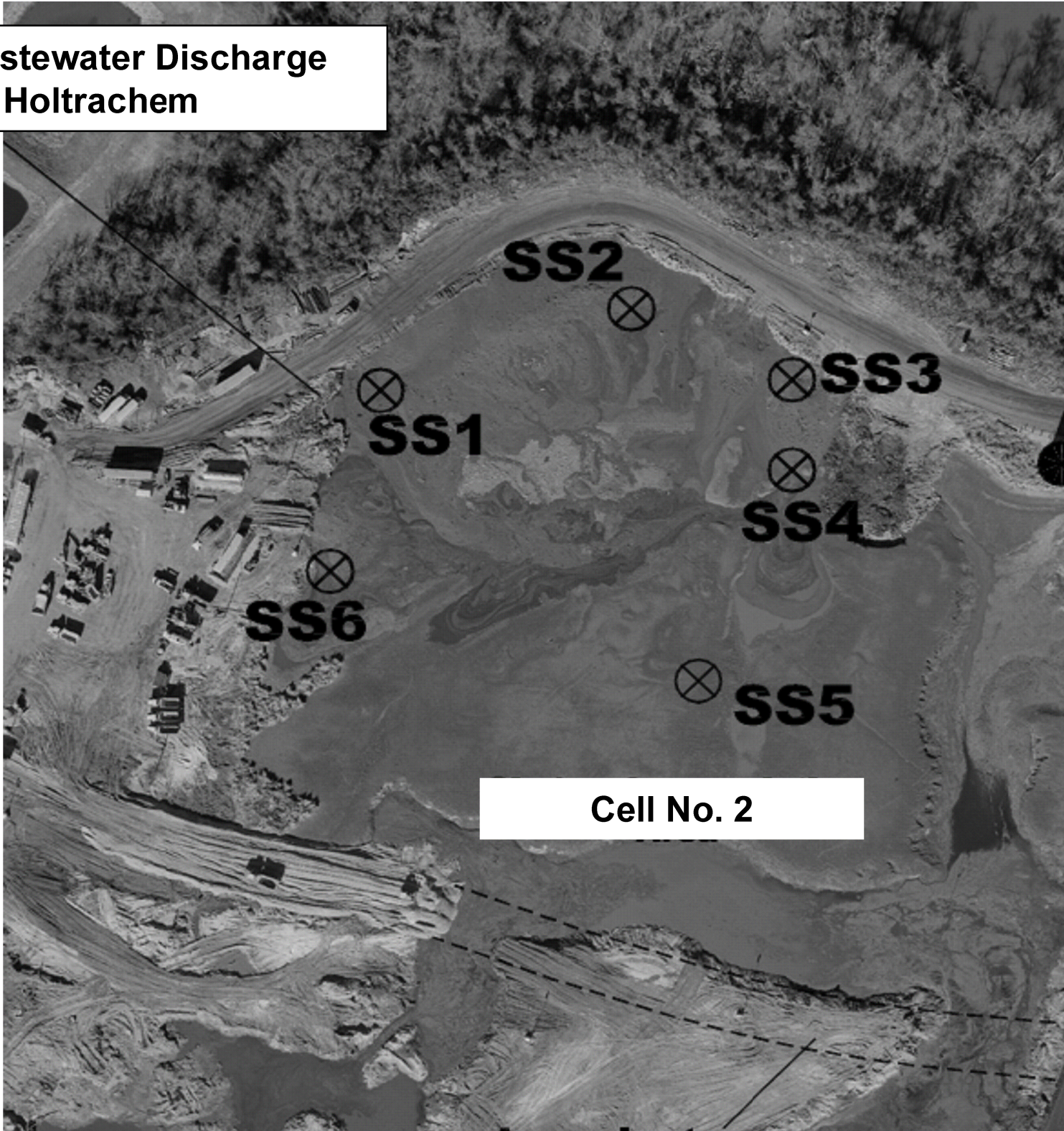
CH2MHILL

WWTS MANAGEMENT WORK PLAN
LCP-HOLTRACHEM SITE, RIEGELWOOD, NC

PROPERTY BOUNDARIES

SHEET	FIGURE 1-2
DWG	FIGURE 1-2
DATE	NOV. 2007
PROJ	365628.HW.50.51

Wastewater Discharge
for Holtrachem



DRAWING CREATED BY ARCADIS-US

NOT TO SCALE

DSGN	GMH							
DR	GMH							
CHK	KEH							
APVD								
		NO.	DATE	REV			BY	APVD



APPROXIMATE LOCATIONS OF
PREMIER BORINGS
WWTS MANAGEMENT WORK PLAN
LCP-HOLTRACHEM SITE, RIEGELWOOD, NC

FIGURE 2-1	
DWG 2-1	
DATE	NOV. 2007
PROJ	327350.HW.20.26



22-20 Locations > 11 mg/kg

Locations > 11 mg/kg

Notes:
Locations O2 and S14 were
offset from the grid during
sampling due to surface
obstructions (⊗).

DRAWING CREATED BY ARCADIS-US

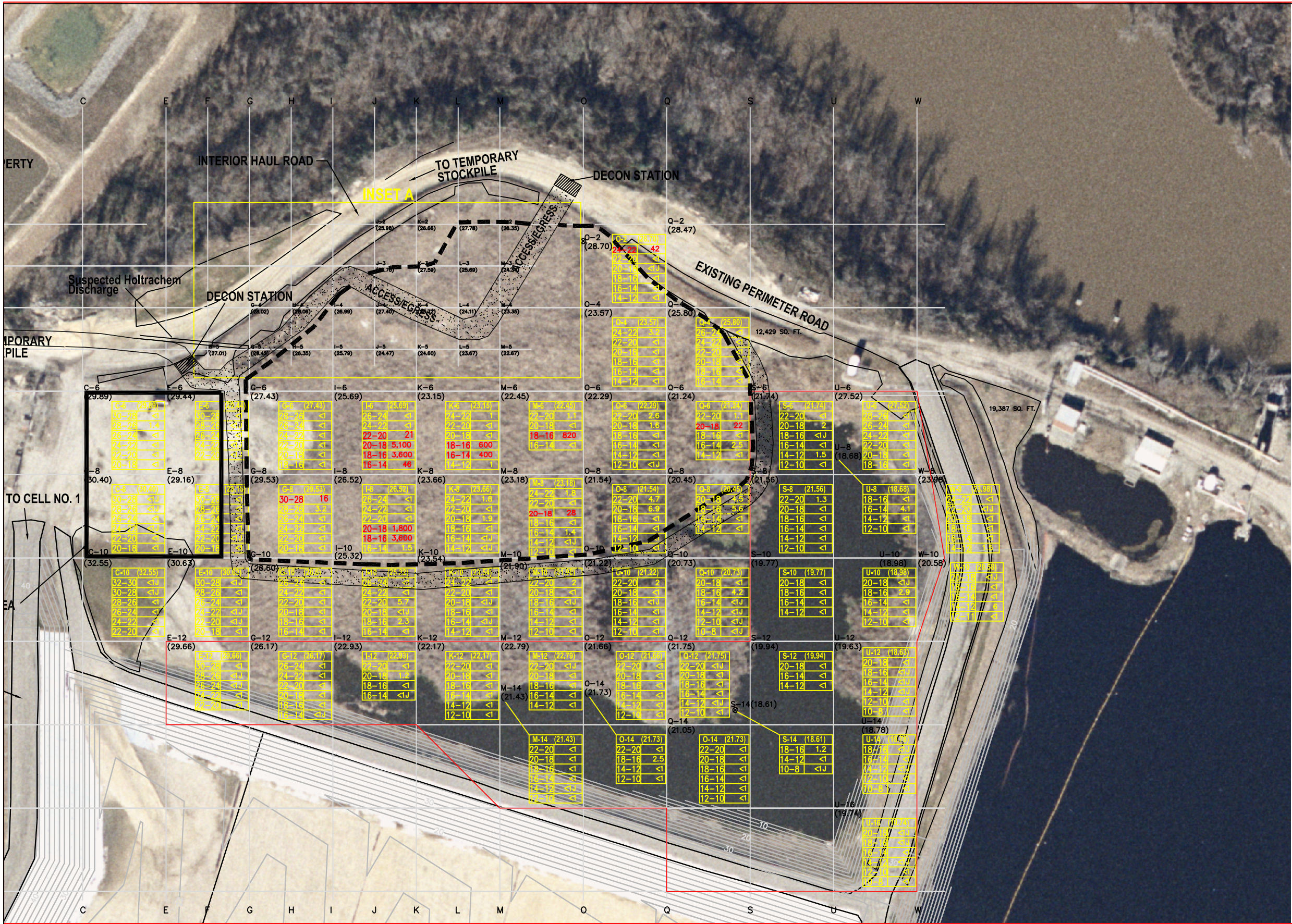
DSGN	ARCADIS	NO.	DATE	REV.	BY	APVD.
DR	GMH					
CHK	KEH					
APVD	CB					

EBL\Honeywell\Acme\WWTS Mgmt Plan\IP Material Work Plan\CADD\Figure2-3.dwg



INSET A (SEE FIGURE 2-2) AROCLOR 1268
CONCENTRATIONS (MG/KG) IN CELL NO. 2
WWTS MANAGEMENT WORKPLAN
LCP-HOLTRACHEM RIEGELWOOD, NC

SHEET	FIGURE 2-3
DWG	2-3
DATE	NOV. 2007
PROJ	327350.HW.30.36



LEGEND

- APPROXIMATE EXTENT OF SOIL/SLUDGE EXCAVATION DEPTH VARIES
- OVERBURDEN STORAGE AREA
- ACCESS ROAD

22-20 Locations > 11 mg/kg

Area of Initial Sludge Dewatering

Notes:
Locations O2 and S14 were offset from the grid during sampling due to surface obstructions (⊗).

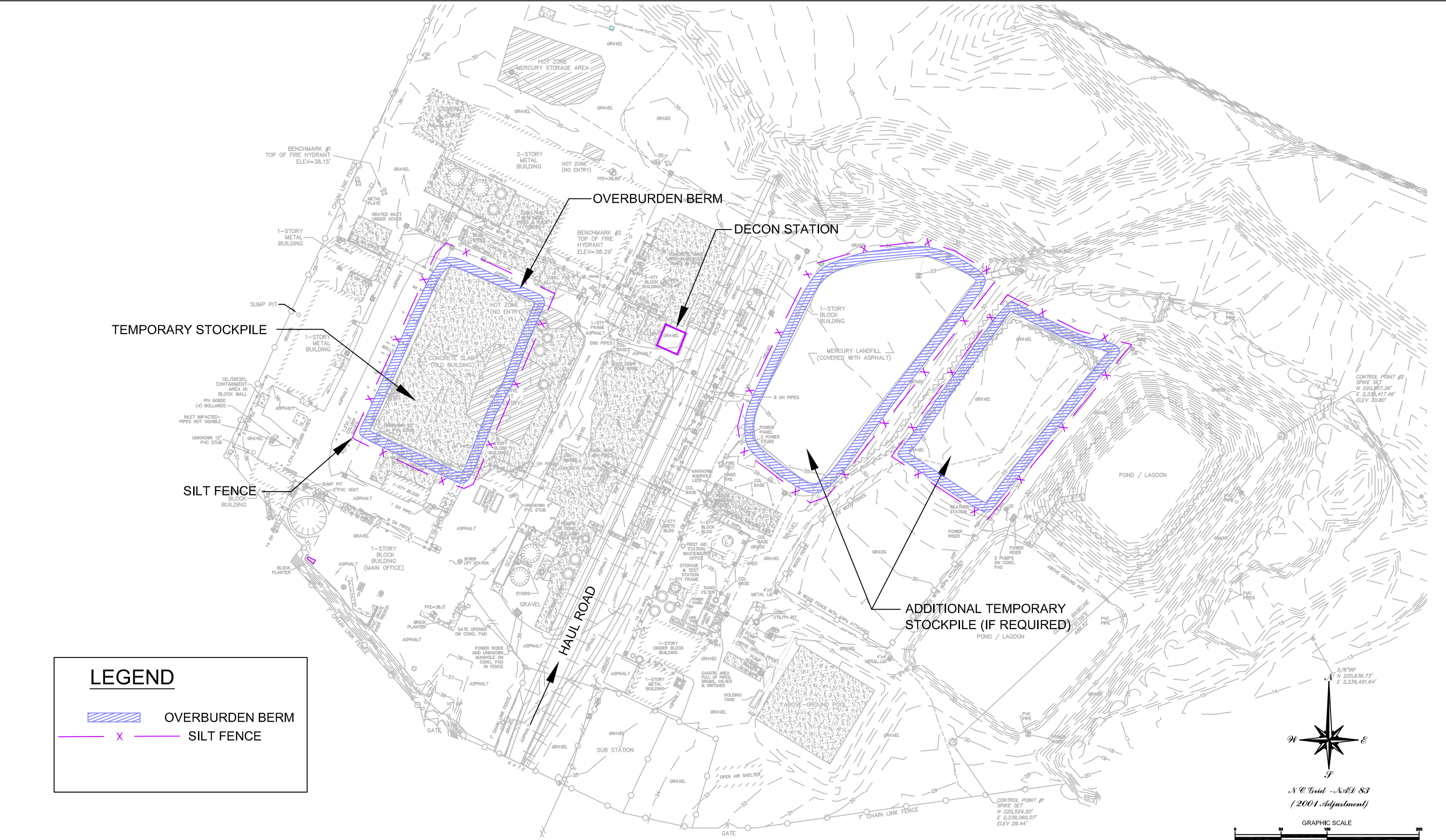
DRAWING CREATED BY ARCADIS-US

DSGN	ARCADIS						
DR	GMH						
CHK	KEH						
APVD	CB						
		NO.	DATE	REV	BY	APVD	



TEMPORARY FACILITY LOCATION AND EXTENT OF
WWTS EXCAVATION IN CELL NO. 2
WWTS MANAGEMENT WORK PLAN
LCP- HOLTRACHEM SITE RIEGELWOOD, NC

SHEET	FIGURE 3-1
DWG	3-1
DATE	NOV. 2007
PROJ	327350.HW.30.36



LEGEND

OVERBURDEN BERM

X

SILT FENCE

N

E

S

5/8"RF
N 220,636.73"
E 2,239,451.64"

N C Grid - NAD 83
(2001 Adjustment)

GRAPHIC SCALE

0 50 100 200
1" = 100'

BASE MAP TAKEN FROM LAND SURVEY BY TAYLOR,WISEMAN & TAYLOR MARCH/APRIL, 2006

DSGN	GMH								
DR	GMH								
CHK	KEH								
APVD		NO.	DATE	REV		BY	APVD		



ENGINEERED STOCKPILE LOCATION
WWTS MANAGEMENT WORK PLAN
LCP-HOLTRACHEM SITE, RIEGELWOOD, NC

SHEET	5-1
DWG	5-1
DATE	NOV. 2007
PROJ	327350.HW.20.26

Figure 4-1
Load Identification Ticket
IP Riegelwood Mill/LCP-Holtrachem Site
Riegelwood, North Carolina

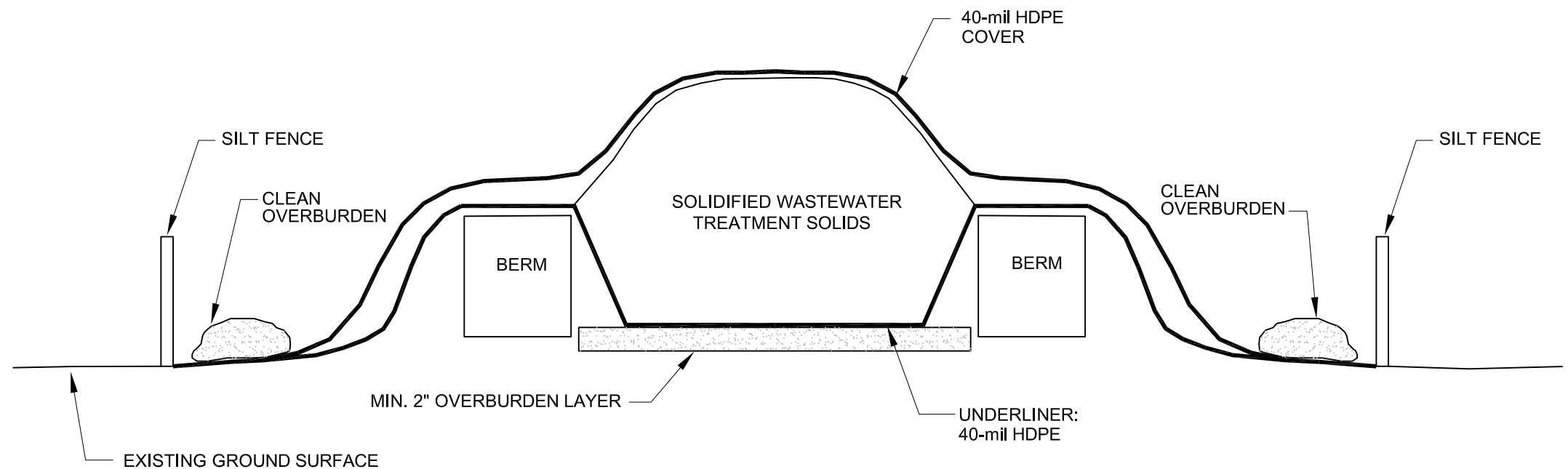
Load Number _____

Date _____

Original Grid Location and Sample Interval _____

Destination _____

Estimated Quantity _____



NOT TO SCALE

NOTES:

HDPE = HIGH DENSITY POLYETHYLENE

BERMS CONSTRUCTED FROM OVERBURDEN
CONTAINING <11 mg/kg AROCLOR 1268

DSGN	GMH					EE/CA REPORT <i>LCP-HOLTRACHEM SITE, RIEGELWOOD, NC</i>	ENGINEERED STOCKPILE CROSS SECTION WWTS MANAGEMENT WORK PLAN	SHEET	FIGURE 5-2
DR	GMH							DWG	FIGURE 5-2
CHK	KEH							DATE	NOV. 2007
APVD								PROJ	365628.HW.50.51
		NO.	DATE						
EBL\Honeywell\Acme\WWTS\ Mamt Plan\IP Material Work Plan\CADD\Fiaure5-2.dwg									

APPENDIX A

Soil Boring Logs



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-C6**

TOTAL DEPTH: **12'**

ELEVATION **29.89'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sand: Light grey to brown medium-grained sand with some coarse gravel some red molting		
			Sand: Brown fine-grained clean sand		
-5			ClayeySand: Light brown clayey sand low stiffness low plasticity		
			ClayeySand: Light brown clayey sand (<15%) low stiffness low plasticity		
-10			Sand: Light brown medium-grained sand		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-C8**

TOTAL DEPTH: **14'**

ELEVATION **30.40'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Silt: Sandy silt with gravel dry brittle		
			Clay: Sandy silt stiff compact		
-5			Silt: Brown sandy silt with gravel dry brittle		
			Sludge: Black sludge no odor		
			Sand: Fine-grained sand saturated		
-10			Clay: Clay with fine-grained sand fine sand (30%) stiff low plasticity		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-C10**

TOTAL DEPTH: **14'**

ELEVATION **32.55**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sand: Sand with silt and gravel well graded		
			Sand: Brown fine to medium-grained sand fairly well graded		
-5			BlackSand: Black silty sand very stiff with sandy slurry		
			Sand: Brown fine to medium-grained sand very well graded		
-10			Clay: Reddish brown sandy clay high moisture low plasticity low stiffness		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-E6**

TOTAL DEPTH: **10'**

ELEVATION **29.44'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark grey medium-grained sand with organic material fines (<15%)		
			GravellySand: Sandy gravel		
			ClayeySand: Dark grey clayey sand low plasticity low stiffness low moisture		
			Sand: Light grey fine-grained sand poorly graded fines (<15%)		
-5			ClayeySand: Light brown clayey sand moderate plasticity low stiffness low moisture content		
			SAND: Light grey medium-grained sand saturated slurry		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-E8**

TOTAL DEPTH: **14'**

ELEVATION **29.16'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Clayey fine-grained sand clay (15%) varying color compact stiff		
-5			ClayeySand: Brown silty fine-grained sand		
			Clay: Light grey sandy clay moderately stiff low plasticity		
-10			ClayeySand: Brown silty fine-grained sand		
			Clay: Light grey sandy clay red molting moderately stiff low plasticity		
			ClayeySand: Light grey silty fine-grained sand saturated		
-15			Clay: Reddish brown sandy clay moderately stiff low plasticity		
			Clay: Black silt		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-E10**

TOTAL DEPTH: **12'**

ELEVATION **30.85'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Blacksnady silt with organic material		
			GravellySand: Gravelly sand		
			Sand: Brown fine to medium-grained sand fairly well graded		
-5			BlackSand: Black material		
			Sand: Brown fine to medium-grained sand fairly well graded		
-10			Sludge: Black sandy sludge		
			Sand: Dark grey fine to medium-grained sand fairly well graded		
			ClayeySand: Silty sand with small gravel well graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-E12**

TOTAL DEPTH: **8'**

ELEVATION **29.66'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sand: Brown fine to medium-grained sand fines (<15%)		
			SAND: Light grey medium to coarse-grained sand well graded black stains at 2.5', 3.0' moderate odor		
-5			BlackSand: Black fine to medium-grained sand with faint odor		
			Clay: Orange sandy clay grey molting stiff no moisture		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-G6**

TOTAL DEPTH: **12'**

ELEVATION **27.43'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**

SITE LOCATION: **Rieglewood, NC**

JOB NO.: **NC106010.**

LOGGED BY: **R. Gerber**

PROJECT MANAGER: **C. Bertz**

DATES DRILLED: **7/25/06**

DRILLING CO.: **Probe Technology, Inc.**

DRILLER: **Kirk Pinska**

RIG TYPE: **Geoprobe**

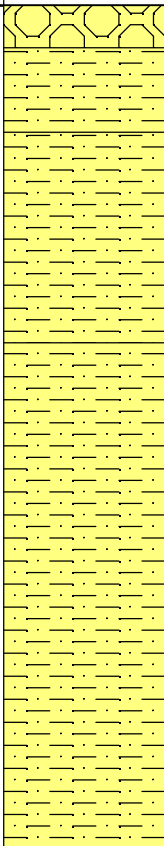
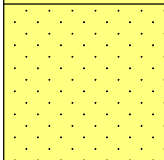
METHOD OF DRILLING: **Direct Push Technology**

SAMPLING METHODS: **Macrocore**

HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Gravelly Sand: Light grey sand with gravel		
			Clayey Sand: Brown clayey sand moderate plasticity		
			CLAYEYSAND: Clayey medium-grained sand faint odor		
			CLAYEYSAND: Brown clayey medium-grained sand with dark brown mottling no plasticity faint odor, faint black coloring		
-5					
-10			Sand: Light grey coarse-grained sand with no signs of sludge		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-G8**

TOTAL DEPTH: **12'**

ELEVATION **29.53'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Clay: Brown sandy silt (40% sand)		
			SILT: Light brown silty sand black staining no odor		
-5			GravellySand: Brown medium to coarse-grained gravelly sand well graded saturated		
-10			ClayeySand: Brown silty sand (30% silt) low stiffness		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-G10**

TOTAL DEPTH: **12'**

ELEVATION **26.60'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark organic material		
			ClayeySand: Dark brown clayey fine-grained sand low plasticity		
			Sand: Dark brown medium-grained sand slurry		
-5			Sand: Fine to medium-grained clean sand 1" black layer at 5.2'		
			ClayeySand: Light brown fine-grained sandy silt		
			Sand: Dark brown medium-grained sand slurry		
			ClayeySand: Light brown fine-grained sandy silt		
-10			ClayeySand: Dark grey sandy silt moderate stiffness		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-G12**

TOTAL DEPTH: **12'**

ELEVATION **26.17'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION



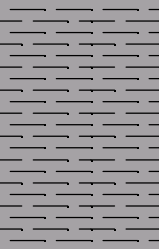
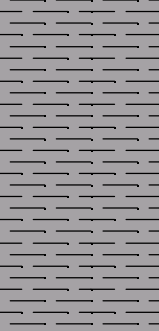
DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Black silty sand with organic material moderate moisture		
			Sand: Dark gery fine-grained sand poorly graded		
-5			Clay: Reddish brown clay sand (15%) moderate plasticity		
-10			Clay: Reddish brown clay sand (25%) moderate plasticity		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-H4**

TOTAL DEPTH: **12'**

ELEVATION **28.06'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material		
			Sand: light brown to orange fine to medium-grained sand fines (<15%)		
			BlackSand: Black stained sand		
			CLAYEYSAND: Dark brown clayey sand with organic material		
-5					
			Sand: Light grey medium to coarse-grained sand fines (<15%)		
			OrganicSand: Organic material		
			Sand: Medium-grained sand and water slurry mix		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-H5**

TOTAL DEPTH: **12'**

ELEVATION **26.35'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Black silty sand with organic material fines (15%)		
			BlackSand: Dark brown clayey fine-grained sand black staining moderate odor		
			Sludge: Black sludge strong odor		
-5			BlackSand: Dark grey fine to medium-grained sand strong odor		
			Sand: Brown fine to medium-grained sand poorly graded		
-10					

NOTES:

Page 1 of 2



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-I4**

TOTAL DEPTH: **12'**

ELEVATION **26.99'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown clayey sand with black staining low plasticity low stiffness strong odor		
			BlackSand: Dark brown sandy clay moderate plasticity black substance at 4.5		
-5			Clay: Dark brown sandy clay black at 4.5		
			Sludge: Black substance with little noticable sediment strong odor		
-10			Clay: Dark brown sandy clay moderate plasticity		
			Sludge: Black substance with little noticable sediment strong odor		

NOTES:

Page 1 of 2

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	Blows / ft.	PID ppm	BORING COMPLETION	WELL DESCRIPTION
10	<div><div></div><div></div></div>							
			Sand: Dark brown medium-grained sand					



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-I5**

TOTAL DEPTH: **12'**

ELEVATION **25.79'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/24/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sludge: Brownish black very fine-grained sandy (15%) clay (sludge) moist medium soft		
			ClayeySand: Grey clayey fine-grained sand (70%) very moist		
-5			Clay: Dark grey fine-grained sandy (20%) clay medium soft moist		
			ClayeySand: Grey to brown clayey medium-grained sand (60-80%) medium loose moist to saturated		
			Clay: Dark brown sandy clay		
-10			ClayeySand: Greyish brown clayey medium grained-sand (80%) medium loose moist		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-I6**

TOTAL DEPTH: **12'**

ELEVATION **25.69'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**

SITE LOCATION: **Rieglewood, NC**

JOB NO.: **NC106010.**

LOGGED BY: **R. Gerber**

PROJECT MANAGER: **C. Bertz**

DATES DRILLED: **7/25/06**

DRILLING CO.: **Probe Technology, Inc.**

DRILLER: **Kirk Pinska**

RIG TYPE: **Geoprobe**

METHOD OF DRILLING: **Direct Push Technology**

SAMPLING METHODS: **Macrocore**

HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sand: Brown fine-grained sand with some clay no plasticity medium stiffness		
			ClayeySand: Clayey fine-grained sand moderate plasticity black areas and petroleum odor		
-5			BlackSand: Black medium to coarse-grained clean sand strong odor (black soil at 9.0 with very strong odor and oily sheen)		
			Sludge: Black sand with sludge		
-10			Sand: Light grey medium to coarse-grained clean sand no odor		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-I8**

TOTAL DEPTH: **12'**

ELEVATION **26.52'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown organic material		
			ClayeySand: Brown silty fin-grained sand moderate plasticity		
-5			BlackSand: Brown silty fin-grained sand moderate plasticity moderate odor		
			Sand: Brown fine to medium-grained sand		
			Sludge: Black sandy sludge strong odor sheen at 7.0'		
-10			Clay: Dark brown fine-grained sandy silt stiff		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-I10**

TOTAL DEPTH: **12'**

ELEVATION **25.32'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown fine-grained silty sand moderate moisture		
			Clay: Black sandy silt		
			BlackSand: Black sandy slurry moderate odor		
-5			Clay: Light brown fine-grained sandy silt moderate stiffness		
			BlackSand: Black sandy slurry faintodor		
-10			Clay: Reddish brown fine-grained sandy clay low plasticity low stiffness		
			Clay: Dark grey sandy silt moderate stiffness		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-I12**

TOTAL DEPTH: **12'**

ELEVATION **22.93'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Brownish black silty sand with organic material		
			Sludge: Black sludge moderate odor		
-5			Sand: Fine to medium-grained sand saturated		
			Sand: Black sandy slurry (suspect sluff from above) not sampled		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-J3**

TOTAL DEPTH: **12'**

ELEVATION **26.70'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown clayey fine-grained sand high moisture		
			BlackSand: Black layey fine-grained sand high moisture faint odor		
-5			Sand: Light brown fine-grained sand fines (<15%)		
			Sludge: Black sludge		
			Sand: Dark brown fine-grained sand fines (<15%) poorly graded		
			Sludge: Black sludge and sand strong odor		
-10			Sand: Dark brown fine-grained sand fines (<15%) poorly graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-J4**

TOTAL DEPTH: **12'**

ELEVATION **27.40'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown clayey sand low plasticity low stiffness black staining and faint odor		
			ClayeySand: Dark brown clayey sand black stainings		
-5			BlackSand: Black staining		
			ClayeySand: Brown clayey sand moderate plasticity moderate stiffness		
-10			BlackSand: Medium-grained sand with balck staining		
			Sand: Light grey fine to medium-grained sand poorly graded moisture		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-J5**

TOTAL DEPTH: **8'**

ELEVATION **24.47'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/24/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark grey clayey fine-grained sand low to moderate moisture		
			Sludge: Black sludge		
			ClayeySand: Dark grey clayey sand with red mottling high moisture		
-5			Sand: Grey fine to medium-grained sand low clay content high moisture		
			ClayeySand: Dark grey clayey sand moderate moisture		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K3**

TOTAL DEPTH: **12'**

ELEVATION **27.49'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material		
			BlackSand: Black fine to medium-grained sand faint odor moderate plasticity		
-5			Sand: Dark brown medium to coarse grained sand		
			Sludge: Black sludge strong odor		
			Sand: Dark brown medium to coarse grained sand		
			BlackSand: Black fine to medium-grained sand faint odor moderate plasticity		
-10			Sand: Light brown fine-grained sand trace (<15%) fines		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K4**

TOTAL DEPTH: **12'**

ELEVATION **25.72'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with some organic material moderate plasticity		
			Sludge: Black solid material moderate plasticity		
-5			Sand: Brown fine to medium-grained sand with trace fines (<15%) color varies down unit black staining from 5.5' to 7.5'		
-10			Sand: Light grey coarse-grained sand poorly graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K5**

TOTAL DEPTH: **8'**

ELEVATION **24.60'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Brown silty sand stiff low moisture		
			Clay: Light brown sandy silt medium plasticity		
			Sludge: Sludge		
			ClayeySand: Brown silty sand stiff low moisture		
-5			Sludge: Black sludge sulfur smell		
			ClayeySand: Light brown clayey fine-grained sand moderately stiff moderate moisture		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K6**

TOTAL DEPTH: **10'**

ELEVATION **23.15'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/24/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material low plasticity low stiffness		
			ClayeySand: Dark brown clayey sand (higher clay content) moderate plasticity moderate stiffness		
-5			Sludge: Black sludge layer sulfur odor		
-10			ClayeySand: Light grey clayey sand low plasticity moderate stiffness		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K8**

TOTAL DEPTH: **12'**

ELEVATION **23.66'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**

SITE LOCATION: **Rieglewood, NC**

JOB NO.: **NC106010.**

LOGGED BY: **R. Gerber**

PROJECT MANAGER: **C. Bertz**

DATES DRILLED: **7/26/06**

DRILLING CO.: **Probe Technology, Inc.**

DRILLER: **Kirk Pinska**

RIG TYPE: **Geoprobe**

METHOD OF DRILLING: **Direct Push Technology**

SAMPLING METHODS: **Macrocore**

HAMMER WT./DROP: **NA**

☞ Water level during drilling

☛ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: dark brown silty sand with organic material		
			Sludge: Black sandy sludge strong odor		
-5			Sand: Grey fine to medium-grained clean sand well graded		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K10**

TOTAL DEPTH: **12'**

ELEVATION **23.54'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown silty sand saturated		
			ClayeySand: Reddish brown fine-grained silty sand low moisture		
			OrganicSand: Black sand slurry with organic material no odor		
-5			ClayeySand: Reddish brown fine-grained silty sand low moisture		
			Clay: Grey sandy clay low plasticity moderate stiffness		
			Sand: Grey fine to medium-grained sand		
-10			ClayeySand: Dark grey silty sand		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-K12**

TOTAL DEPTH: **12'**

ELEVATION **22.17'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Black organic material		
			ClayeySand: Brown silty fine-grained sand hard compacted		
			Sand: Black sandy slurry faint odor (suspect sluff from above)		
-5			Clay: Reddish light brown sandy clay low plasticity very stiff		
			OrganicSand: Black sandy slurry faint odor organic material (suspect sluff from above)		
			Clay: Reddish light brown sandy clay low plasticity very stiff		
-10			Clay: Black sandy silt		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-L2**

TOTAL DEPTH: **12'**

ELEVATION **27.78'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material moderate moisture		
			Sludge: Black sandy sludge strong odor		
-5			Sand: Dark brown medium-grained sand fines (<15%) poorly graded		
			Sludge: Black sandy sludge strong odor		
-10			Sand: Light grey fine to medium-grained sand		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-L3**

TOTAL DEPTH: **12'**

ELEVATION **25.69'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling

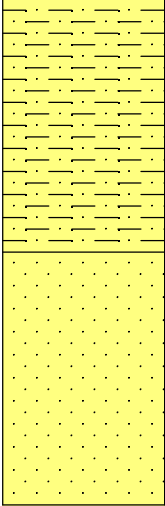


Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material		
			ClayeySand: Brown clayey sand with black staining faint odor low plasticity low stiffness black staining from 4.5'-6.0'		
-5			ClayeySand: Light gray clayey sand odor gets stronger down unit low plasticity low stiffness		

NOTES:

Page 1 of 2

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	Blows / ft.	PID ppm	BORING COMPLETION	WELL DESCRIPTION
-10								
			Sand: Light gray fine-grained clean sand					
NOTES:								



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-L4**

TOTAL DEPTH: **12'**

ELEVATION **24.11'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown fine to medium-grained sand with organic material		
-5			Sand: Dark brown fine-grained sand with no fines color varies down unit		
-10			Sand: Dark grey medium to coarse-grained sand saturated		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-L5**

TOTAL DEPTH: **8'**

ELEVATION **23.67'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark grey clayey fine to medium-grained sand low plasticity low moisture		
			Sludge: Black sludge sulfur smell		
-5			BlackSand: Light brown clayey fine-grained sand		
			ClayeySand: Light brown clayey sand low plasticity low moisture content		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M2**

TOTAL DEPTH: **12'**

ELEVATION **26.35'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material		
			OrganicSand: Dark grey to black fine to medium-grained sand faint odor		
			OrganicSand: Dark brown clayey sand with organic material		
-5			Sand: Dark grey fine to medium-grained sand fines (<15%)		
			Sludge: Black sludge strong odor		
-10			Sand: Light grey fine-grained sand clean poorly graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M3**

TOTAL DEPTH: **12'**

ELEVATION **24.34'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark clayey sand (like topsoil)		
-5			Sand: Light brown fine to medium-grained sand trace fines (<15%) color varies down unit saturated from 9.5' to 12.0'		

NOTES:

Page 1 of 2

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	Blows / ft.	PID ppm	BORING COMPLETION	WELL DESCRIPTION
-10								
NOTES:								



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M4**

TOTAL DEPTH: **12'**

ELEVATION **23.35'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown to black well-graded sand with organic material		
-5			Sand: Brown poorly-graded fine-grained sand no fines color varies down unit		
-10			Sand: dark grey coarse-grained sand high moisture		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M5**

TOTAL DEPTH: **8'**

ELEVATION **22.67'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/24/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Brown clayey sand (high clay content) high plasticity very stiff low moisture slufur odor at 1.5		
-5			ClayeySand: Light grey clayey sand moderate plasticity moderate stiffness low moisture		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M6**

TOTAL DEPTH: **8'**

ELEVATION **22.45'**

PROJECT INFORMATION

PROJECT: **IP Riegglewood Mill**
SITE LOCATION: **Riegglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/24/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark organic-rich sand		
			ClayeySand: Dark clayey sand moderate plasticity moderte stiffness high moisture		
-5			Sludge: Very dark sludge sulfur smell		
			BlackSand: Fine-grained sand with some clay and some sludge content		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M8**

TOTAL DEPTH: **12'**

ELEVATION **23.18'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Black sandy organic material		
			Clay: Dark brown fine-grained sandy clay low plasticity low stiffness moderate moisture		
-5			Sludge: Black sludge strong odor		
			Sand: Light grey medium-grained clean sand well graded high moisture		

NOTES:

Page 1 of 2

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	Blows / ft.	PID ppm	BORING COMPLETION	WELL DESCRIPTION
-10								
			Sand: Light grey medium-grained sand poorly graded saturated					



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M10**

TOTAL DEPTH: **12'**

ELEVATION **21.90'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark organic material		
			ClayeySand: Grey clayey sand low plasticity low stiffness		
			Sand: Light brown fine to medium-grained sand		
-5			Sand: Coarse-grained sand		
			Clay: Dark grey fine-grained sandy clay moderate plasticity		
			Sand: Light brown fine to medium-grained sand saturated below 9		
-10			Clay: Dark grey sandy clay fines (<25%) low plasticity moderate stiffness		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M12**

TOTAL DEPTH: **12'**

ELEVATION **22.79'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Black silty sand with organic material		
			ClayeySand: Brown silty fine-grained sand fines (25%)		
			Sand: Sandy slurry (sluff)		
-5			Sand: Light grey medium-grained sand clean		
			Clay: Red brown sandy clay low plasticity low stiffness		
			Clay: Black sandy silt		
			Sand: Light grey medium-grained sand clean		
-10			Clay: Black silt no odor		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-M14A**

TOTAL DEPTH: **12'**

ELEVATION **21.43'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Clay: Dark brown sandy silty clay fines sand (15%) medium stiffness		
-5			Sludge: Dark brown medium-grained sandy clay mixed sludge slight odor		
			ClayeySand: Medium grey clayey sand		
			Clay: Olive brown sandy silty clay fine sand (20%) medium stiffness moist		
-10			Clay: Olive orange brown sandy silty clay fine sand (10%) medium stiffness moist		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-O2**

TOTAL DEPTH: **12'**

ELEVATION **28.70'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: dark brown silty sand stiff		
			OrganicSand: Organic material		
			Sand: Brown fine-grained sand ome areas of faint odor		
-5			Sand: Grey very fine-grained sand poorly graded high moisture		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-04**

TOTAL DEPTH: **12'**

ELEVATION **23.56'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Organic material		
			Sand: Light brown to grey fine to medium-grained sand fines (<15%)		
-5			BlackSand: Sand mixed with balck material no odor		
			Sand: Light brown to grey fine to medium-grained sand fines (<15%)		
			BlackSand: Sand mixed with balck material no odor		
-10			Sand: Light brown to grey fine to medium-grained sand fines (<15%)		
			Sand: Grey coarse-grained sand poorly graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-O6**

TOTAL DEPTH: **12'**

ELEVATION **22.29'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/25/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Organic material (topsoil)		
			ClayeySand: Light brown clayey sand high moisture content		
			Sand: Dark brown medium-grained sand slurry mix		
-5			Sludge: Black solid sludge strong odor		
			Sand: Dark brown medium-grained sand slurry mix		
			Sludge: Black sandy sludge strong odor		
-10			Sand: Dark grey finr to medium-grained sand saturated		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-08**

TOTAL DEPTH: **12'**

ELEVATION **21.54'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Black silty organic material smoe coarse particles		
-5			Sand: Light grey fine to medium-grained silty sand poorly graded		
-10			Sand: Light grey medium to coarse-grained sand saturated		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-O10**

TOTAL DEPTH: **12'**

ELEVATION **21.22'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark sandy organic material		
			BlackSand: Black clayey fine-grained sand moderate odor		
			Sand: Light grey fine-grained sand well graded dark color from 8-9		
-5					
-10					
			ClayeySand: Dark clayey fine-grained sand low plasticity		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-O12**

TOTAL DEPTH: **12'**

ELEVATION **21.66'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/27/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown silty clay high organic content moist medium soft		
			ClayeySand: Yellow brown to light grey clayry fine-grained sand medium stiffness moist		
			ClayeySand: Clayey medium-grained sand very moist loose		
-5			ClayeySand: Orange to olive brown clayey medium-grained sand (80% sand) medium stiffness moist		
			ClayeySand: Grey clayey sand (80% sand) medium stiffness moist		
-10			ClayeySand: Orange to light olive brown clayey sand		
			Clay: Dark greyish brown silty clay fines (10%) medium stiffness moist		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-O14**

TOTAL DEPTH: **12'**

ELEVATION **21.73'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**

☞ Water level during drilling

☛ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown silty sand with organic material		
			Sand: Light grey fine to medium-grained sand fairly well graded		
-5			Sand: Coarse-grained sand well graded saturated		
			Clay: Grey sandy clay moderate plasticity moderate stiffness		
-10			Clay: Reddish brown sandy clay moderate plasticity high stiffness		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-Q4**

TOTAL DEPTH: **12'**

ELEVATION **25.80'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown clayey sand with organic material high moisture		
			ClayeySand: light brown silty sand high moisture		
-5			Sludge: Black material faint odor		
			Sand: Light brown fine to medium-grained sand fines (<15%)		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-Q6**

TOTAL DEPTH: **8'**

ELEVATION **21.24'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Brown clayey sand with organic material		
			Sludge: Black sludge strong odor		
			Sand: Black stained medium-grained sand faint odor		
			BlackSand: Black sand saturated strong odor		
-5			Sand: Light grey fine to medium-grained sand fines (<15%)		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-Q8**

TOTAL DEPTH: **8'**

ELEVATION **20.45'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sludge: Black saturated sludge strong odor		
-5			ClayeySand: Grey silty fine to medium-grained sand well sorted		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-Q10**

TOTAL DEPTH: **12'**

ELEVATION **20.73'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark organic material		
			ClayeySand: Light brown clayey sand		
			Sludge: Black sandy sludge strong odor		
-5			Sand: Grey fine to medium-grained sand saturated		
-10					

NOTES:

Page 1 of 2



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-Q12**

TOTAL DEPTH: **12'**

ELEVATION **21.75'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Gravelly Sand: Gravel		
			Sand: Brown fine-grained sand		
			Black Sand: Black flakey material no odor		
			Sand: Light grey fine-grained sand clean		
-5			Sand: Grey fine to medium-grained sand fairly well graded		
			Sand: Sandy slurry (suspect sluff from above)		
-10			Sand: Grey fine to medium-grained sand fairly well graded		

NOTES:

Page 1 of 2



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-Q14**

TOTAL DEPTH: **12'**

ELEVATION **21.05'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark brown silty sand with organic material		
-5			ClayeySand: Light brown silty fine-grained sand poorly graded saturated color varies down unit		
-10			Clay: Greenish gery sandy clay moderate plasticity moderate stiffness		

NOTES:

Page 1 of 2



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-S6**

TOTAL DEPTH: **12'**

ELEVATION **21.74'**

PROJECT INFORMATION

PROJECT: **IP Riegglewood Mill**
SITE LOCATION: **Riegglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling

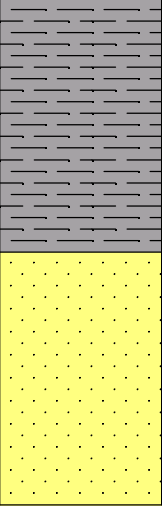


Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Brownish black medium to coarse-grained sand		
			Sand: Light grey fine to medium-grained sand		
-5			Clay: Light grey sandy clay moderatey stiff low plasticity		

NOTES:

Page 1 of 2

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	Blows / ft.	PID ppm	BORING COMPLETION	WELL DESCRIPTION
-10								
			Sand: Grey medium-grained sand saturated					



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-S8**

TOTAL DEPTH: **12'**

ELEVATION **21.56'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**

☞ Water level during drilling

☛ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Dark organic material		
			Clay: Grey sandy clay stiff high plasticity low moisture		
			OrganicSand: Black organic material		
-5			ClayeySand: Light grey silty sand fines (<15%) low plasticity		
			Clay: Sandy clay		
			Sludge: Black material		
-10			Sand: Light grey fine to medium-grained sand fines (<15%) well sorted saturated below 9.5		

NOTES:

Page 1 of 2



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-S10**

TOTAL DEPTH: **8'**

ELEVATION **19.77'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/26/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Organic material		
			BlackSand: Black medium-grained sand moderate smell		
			Sand: Light grey medium-grained sand no odor		
			Clay: Grey clay stiff high plasticity		
-5					

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-S12**

TOTAL DEPTH: **8'**

ELEVATION **19.94'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Black silty sand saturated		
			Sand: Black sandy sluff from above		
-5			Clay: Grey clay stiff high plasticity high moisture		

NOTES:



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-S14**

TOTAL DEPTH: **12'**

ELEVATION **18.61'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sludge: Black sludge with sand faint odor		
-5			Sand: Grey fine-grained sand saturated		
-10			Sand: Fine-grained sand high moisture		
			Clay: Greyish green sandy clay low stiffness moderate plasticity high moisture		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-U6**

TOTAL DEPTH: **12'**

ELEVATION **27.52'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Organic material		
			Sludge: Black material with brown fine-grained sand no odor		
			OrganicSand: Brown fine-grained sand with black organic material		
-5					
			Sand: Brown fine-grained sand clean		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-U8**

TOTAL DEPTH: **8'**

ELEVATION **18.68'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**

SITE LOCATION: **Rieglewood, NC**

JOB NO.: **NC106010.**

LOGGED BY: **R. Gerber**

PROJECT MANAGER: **C. Bertz**

DATES DRILLED: **7/28/06**

DRILLING CO.: **Probe Technology, Inc.**

DRILLER: **Kirk Pinska**

RIG TYPE: **Geoprobe**

METHOD OF DRILLING: **Direct Push Technology**

SAMPLING METHODS: **Macrocore**

HAMMER WT./DROP: **NA**

≡ Water level during drilling

▼ Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown clayey medium-grained sand (25% clay)		
			Sludge: Black sludge strong odor		
			ClayeySand: Dark brown clayey medium-grained sand (25% clay)		
			Sludge: Black sludge strong odor (suspect sluff)		
-5			BlackSand: Fine-grained sand with some black staining poorly graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-U10**

TOTAL DEPTH: **8'**

ELEVATION **18.98'**

PROJECT INFORMATION

DRILLING INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			BlackSand: Dark brown sand with black staining well graded		
			Sludge: Black sludge very strong odor		
			Sand: Grey medium-grained sand clean well graded		
			Sludge: Black sludge very strong odor		
-5			Sand: Light grey fine-grained sand clean high moisture		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-U12**

TOTAL DEPTH: **12'**

ELEVATION **19.53'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Organic material		
			BlackSand: Grey fine to medium-grained sand balck stains with moderate odor saturated		
-5			Sand: Grey fine to medium-grained sand fines (<15%) saturated		
-10			Sand: Coarse-grained sand well graded		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-U14**

TOTAL DEPTH: **12'**

ELEVATION **18.78'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			OrganicSand: Brown silty sand with organic material		
			Sludge: Dark grey fine-grained sand and sludge moderate odor		
-5					
			Sand: Grey medium-grained sand saturated		
-10					

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-U16**

TOTAL DEPTH: **12'**

ELEVATION **19.74'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			BlackSand: Dark grey sand black staining well graded very loose		
			Sludge: Black sludge with sand moderate odor		
-5			BlackSand: Dark grey sand black staining well graded very loose		
			Sludge: Black dense sludge moderate odor		
			OrganicSand: Organic material		
			BlackSand: Dark grey sand black staining well graded very loose		
			Sludge: Black sludge with sand moderate odor		
-10			BlackSand: Dark grey sand black staining well graded very loose		
			OrganicSand: Organic material		
			Sludge: Black sludge material strong odor		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300

Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-W8**

TOTAL DEPTH: **12'**

ELEVATION **23.98'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/28/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			ClayeySand: Dark brown silty sand		
			Sludge: Sandy sludge layer		
			Sand: Medium (50%) to coarse (15%) sand well graded		
			BlackSand: Sandy sluff with moderate odor		
-5			Sand: Medium (50%) to coarse (15%) sand well graded		
			Sludge: Black sludge with sand strong odor		
			Sand: Medium (50%) to coarse (15%) sand well graded		
-10			Sludge: Black sludge strong odor		

NOTES:

Page 1 of 1



ARCADIS

Infrastructure, buildings, environment, communications

801 Corporate Center Drive, Suite 300
Raleigh, North Carolina 27607

BORING LOG

BOREHOLE NO.: **SB-W10**

TOTAL DEPTH: **12'**

ELEVATION **20.58'**

PROJECT INFORMATION

PROJECT: **IP Rieglewood Mill**
SITE LOCATION: **Rieglewood, NC**
JOB NO.: **NC106010.**
LOGGED BY: **R. Gerber**
PROJECT MANAGER: **C. Bertz**
DATES DRILLED: **7/24/06**

DRILLING INFORMATION

DRILLING CO.: **Probe Technology, Inc.**
DRILLER: **Kirk Pinska**
RIG TYPE: **Geoprobe**
METHOD OF DRILLING: **Direct Push Technology**
SAMPLING METHODS: **Macrocore**
HAMMER WT./DROP: **NA**



Water level during drilling



Static Groundwater Level

DEPTH	SOIL SYMBOLS	USCS	SOIL DESCRIPTION	SAMP. #	BORING COMPLETION
0			Sand: Greyish brown clayey medium-grained sand moist medium loose high organic content		
			Sand: Orange to grey clayey sand 90% medium-grained very loose		
-5			Sludge: Dark grey clayey sludge very moist medium stiff		
			BlackSand: Dark grey clayey sand saturated sulfur odor		
-10			Sand: Light grey clayey medium-grained sand saturated loose		

NOTES:

Page 1 of 1

APPENDIX B

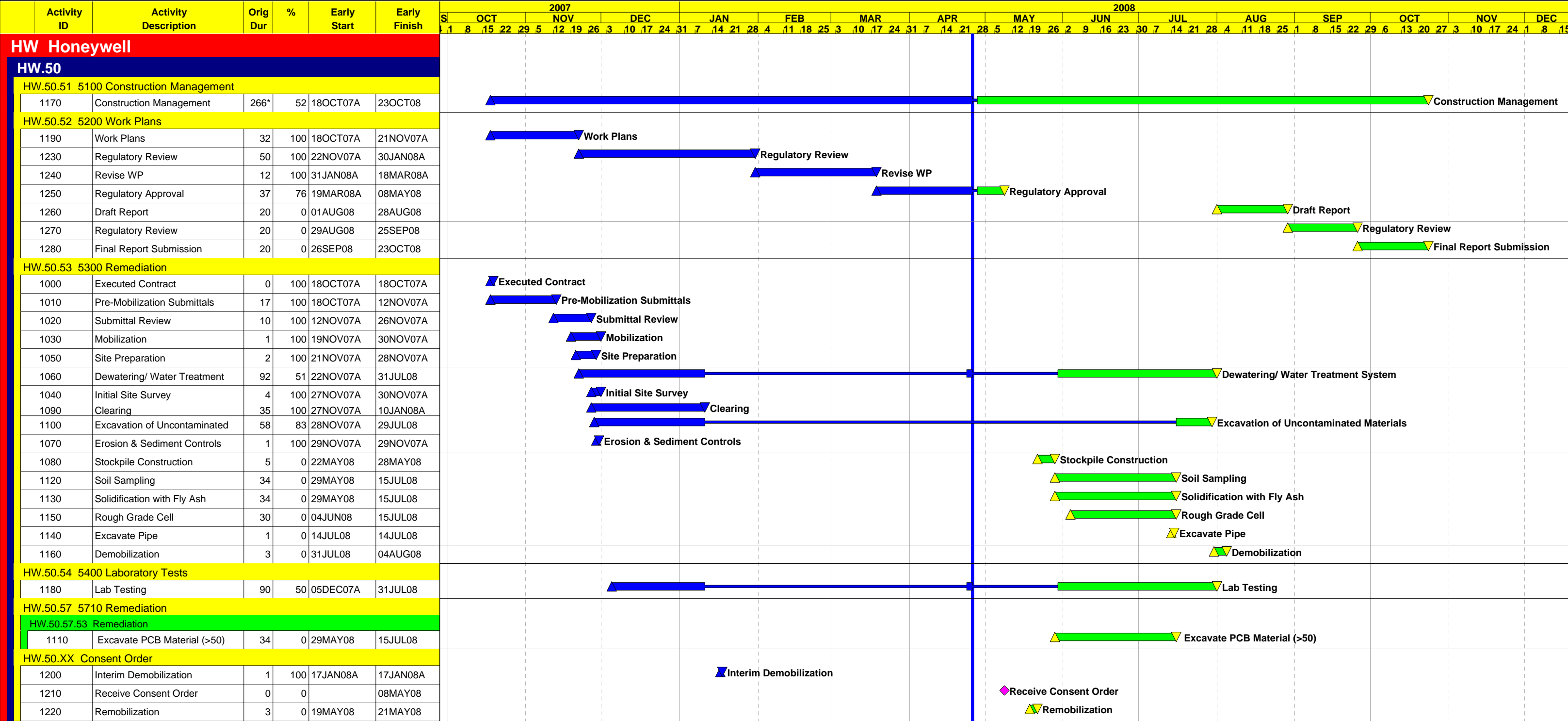
Inspection Log

Appendix B
Weekly Inspection Log
Temporary Storage Cell
LCP-Holtrachem Site
Riegelwood, North Carolina

[illegible]

APPENDIX C

Project Schedule



APPENDIX D

Health and Safety Plan

Acme – Riegelwood
Health and Safety Plan
Riegelwood, North Carolina
Remedial Construction

Prepared for
Honeywell International Inc.

November 2007rev0208

Prepared by



HEALTH AND SAFETY PLAN
Acme – Riegelwood – LCP Holtrachem
NC SH 87 (on State Road 1817)
Riegelwood, North Carolina

PHONE

Project Number: 365628

Project Manager (PM): Dennis Ewing/ATL678-530-4111 x540

Construction Mgr/Safety Coordinator (SC): Marshall Linton/KN 865-483-9032 - office
865-403-9826 cell

Honeywell H&S Program Manager (HSPM): Bill Berlett(773) 693-3800 x-316
cell: (847) 770-0209

Project H&S Manager (HSM): Bill Berlett/CHISee above

Preparation Date: November 8, 2007

Expiration Date: June 30, 2008

APPROVALS

Project Manager:

(DATE)

Safety Coordinator

(DATE)

Honeywell Program or Project Health and Safety Manager:



CIH/CSP

November 8, 2007
(DATE)

This Health and Safety Plan is valid only for this specific project as described in Section 3.0. It is not to be used for other projects or subsequent phases of this project without the written approval of the Honeywell Program Health and Safety Manager. **A copy of this plan is to be maintained at the site at all times.**

Change Management Form

Honeywell Project HS&E Change Management Form

*This evaluation form should be reviewed on a **continuous** basis to determine if the current site health and safety plan adequately addresses ongoing project work, and should be completed whenever new tasks are contemplated or changed conditions are encountered..*

Project Task: Removal of PCB impacted sediment
Project Number: 365628 Project Manager: Dennis Ewing/ ATL
Name: Acme-LCP Holtrachem- Riegelwood, North Carolina Safety Coordinator Marshall Linton/KNV

<i>Evaluation Checklist</i>		Yes	No
1.	Have the CH2MHILL staff listed in the original HSP/FSI changed?		
2.	Has a new subcontractor been added to the project?		
3.	Is any chemical or product to be used that is not listed in Attachment 2 of the plan?		
4.	Have additional tasks been added to the project, which were not originally addressed in the plan?		
5.	Have new contaminants or higher than anticipated levels of original contaminants been encountered?		
6.	Have other safety, equipment, activity or environmental hazards been encountered that are not addressed in the plan?		

If the answer is "YES" to Question 3, an HSP/FSI revision is NOT needed. Please take the following actions:

- ◆ Add the chemical to Attachment 2;
- ◆ Ensure employees handling the chemical are trained; and
- ◆ Ensure training documentation is added to Attachment 3.

If the answer is "YES" to Questions 1, 2 or 4-6, an HSP/FSI revision MAY BE NEEDED. Please contact Bill Berlett (773-693-3800 x316) directly.

Emergency Contacts

24-hour CH2M HILL Emergency Beeper – (720) 286-4911

CH2M HILL Occupational Health Nurse – 1-800-756-1130

Medical Emergency – 911 Fire/Spill Emergency -- 911 Security & Police – 911 Local Facility Emergency Response Number: SC to insert number if applicable International Paper:	CH2M HILL Medical Consultant Health Resources Dr. Jerry H. Berke, M.D., M.P.H. 600 West Cummings Park, Suite 3400 Woburn, MA 01801-6350 1-781-938-4653 (8 am to 11 pm EST) 1-800-350-4511 (after hours and on weekends) (After hours calls will be returned within 20 minutes)
Client Contact Name: Mark Kamilow Company: Honeywell Title: Remediation Manager Phone: 973-455-2119	Site Contact Name: Acie Croom Company: CH2M HILL Title: Project Manager Phone: 910-655-1393
Honeywell Health, Safety & Environment Program Manager (HSPM) Name: Bill Berlett/CHI Phone: 773-693-3800 x 316 Cell: 847-770-0209 Fax: 773-693-3823	Environmental Compliance Coordinator (ECC) Name: Lisa Schwann/ATL Phone: 770-604-9182 x561
Project Health & Safety Manager (HSM) Name Bill Berlett/CHI Phone: See above	Safety Coordinator (SC) Name: Marshall Linton/KNV Office Phone: 865-483-9032 Cell Phone: 865-403-9826
Project Manager (PM) Name: Dennis Ewing/ATL Office Phone: 678-530-4111 x540 Cell Phone: 678-447-1222	Regional Human Resources Department (Workers' Compensation Contact) Name: Cindy Bauder/WDC Phone: 703/471-6405 ext. 4243
Federal Express Dangerous Goods Shipping Phone: 800/238-5355 CH2M HILL Emergency Number for Shipping Dangerous Goods Phone: 800/255-3924	Worker's Compensation: Contact Regional HR dept. to have form completed or contact Albert Jerman after hours: 303-741-5927 Automobile Accidents: Rental: Linda Anderson/DEN 720-286-2401 CH2M HILL owned vehicle: Zurich Insurance Co. 800-987-3373
Facility Alarms: N/A	Evacuation Assembly Area(s): TBD by SC
Facility/Site Evacuation Route(s): TBD by SC – Refer to Figure 4 in the 11/04 GeoSyntec HASP	

Hospital Name/Address:

New Hanover Regional Hospital

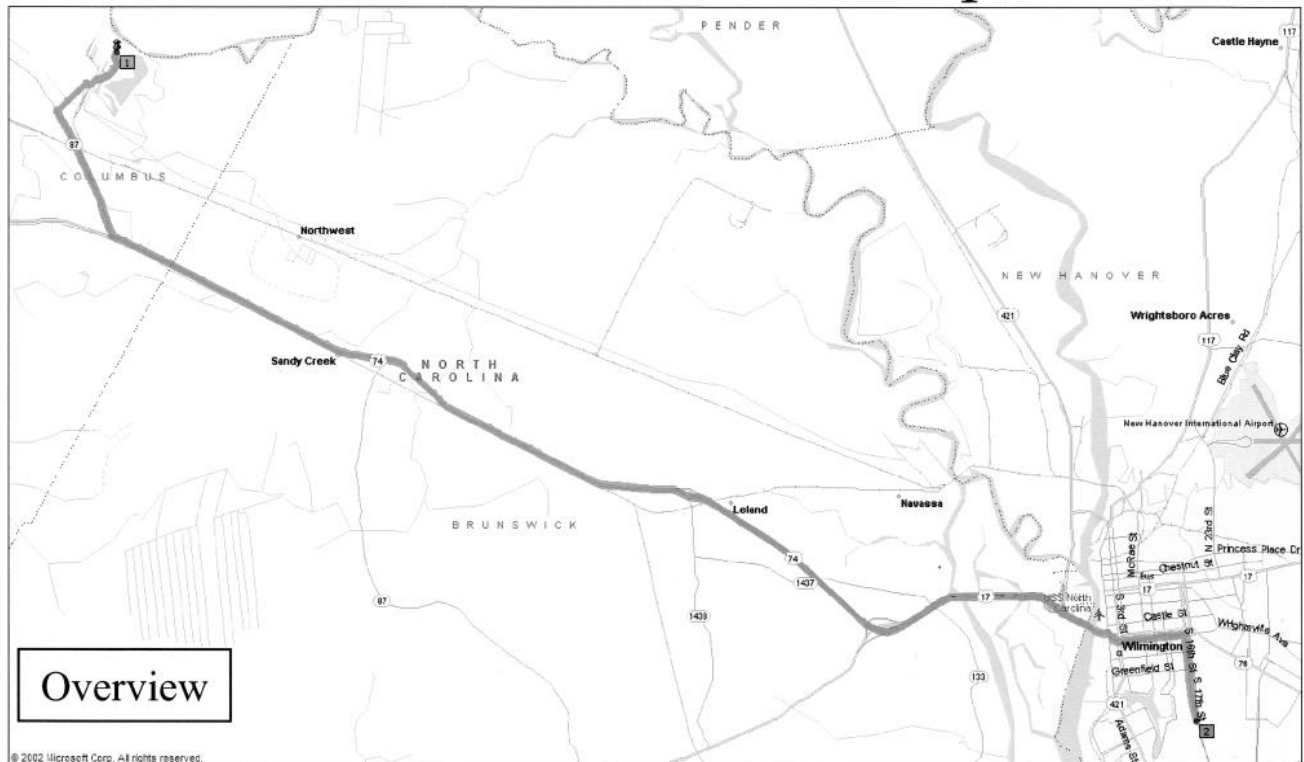
910-343-7000

Directions to Hospital

Taken from GeoSyntec HASP dated 11/04:

From the site, proceed south (left) on SR-87. Turn east (left) on US-74/76 to Wilmington. Continue East on US-76/17 and into Wilmington. Turn right (south) on 16th Street, which merges with 17th Street. New Hanover Regional Hospital will be on left. Total distance 23 miles.

Directions from Site to Hospital



Exit Site and proceed south (left) on SR-87.
Turn east (left) on US-74/76 to Wilmington.
Continue east on US-76/17.
Turn right (south) on 16th Street, which merges with 17th Street.
New Hanover Regional Hospital will be on left.
Total distance – 23 miles.



GEOSYNTEC CONSULTANTS

ATLANTA, GEORGIA

FIGURE NO.

5

PROJECT NO.: GS3150

DOCUMENT NO.: GA040606

FILE: DIRECTIONS TO HOSPITAL.PPT

Site Map

This page is reserved for a Site Map.

Note locations of Support, Decontamination, and Exclusion Zones; site telephone; first aid station; evacuation routes; and assembly areas.



INTERNATIONAL PAPER PROPERTY BOUNDARIES
 AERIAL PHOTO TAKEN FROM GOOGLE EARTH
 SCALE APPROXIMATELY 1" = 200'



INSET A
 AERIAL PHOTO TAKEN FROM GOOGLE EARTH
 SCALE APPROXIMATELY 1" = 800'

Contents

Change Management Form.....	iii
Emergency Contacts	iv
Site Map	vii
Acronyms and Abbreviations	xii
1.0 Introduction.....	1-1
1.1 About This Document.....	1-1
1.2 Site Background.....	1-1
1.3 Description of Tasks.....	1-2
1.3.1 Hazwoper-Regulated Tasks.....	1-2
1.3.2 Non-Hazwoper-Regulated Tasks.....	1-3
1.3.3 Environmental-Regulated Tasks and Conditions.....	1-3
1.3.4 Honeywell Permit Required Tasks	1-3
1.4 Task Hazard Analysis.....	1-3
1.5 Environmental Impacts	1-3
2.0 Hazard Controls and Safe Work Practices.....	2-1
2.1 Administrative Controls.....	2-1
2.1.1 HS&E Plans	2-1
2.1.2 Job Hazard Analysis	2-1
2.1.3 Safety Meetings.....	2-1
2.1.4 Self-Assessments	2-2
2.1.5 Site Compliance/ Audits.....	2-2
2.1.6 Interventions	2-2
2.2 Project-Specific Hazards and Controls.....	2-3
2.2.1 Earthmoving Equipment.....	2-3
2.2.2 Excavation (Reference CH2M HILL SOP HS-32, <i>Excavations</i>) ...	2-3
2.2.3 Respiratory Protection.....	2-4
2.2.4 Exposure to Public Vehicular Traffic.....	2-5
2.2.5 Noise Hazards.....	2-6
2.3 General Hazards and Controls.....	2-6
2.3.1 General Practices and Housekeeping.....	2-6
2.3.2 Hazard Communication.....	2-7
2.3.3 Shipping and Transportation of Chemical Products.....	2-7
2.3.4 Lifting.....	2-7
2.3.5 Fire Prevention.....	2-8
2.3.6 Electrical.....	2-8
2.3.7 Stairways and Ladders	2-9
2.3.8 Heat Stress	2-10
2.3.9 Cold Stress	2-12
2.3.10 Compressed Gas Cylinders.....	2-13
2.3.11 Procedures for Locating Buried Utilities.....	2-13
2.3.12 Confined Space Entry	2-13
2.3.13 Backing Field Vehicles	2-14
2.3.14 Driving in Areas with Tall Grass/Brush.....	2-14
2.3.15 Severe Weather	2-14
2.3.16 Working On or Above Water.....	2-15

2.4	Biological Hazards and Controls	2-16
2.4.1	Snakes.....	2-16
2.4.2	Poison Ivy and Poison Sumac.....	2-17
2.4.3	Ticks	2-18
2.4.4	Bees and Other Stinging Insects	2-18
2.4.5	Bloodborne Pathogens.....	2-18
2.4.6	Mosquito Bites	2-18
2.4.7	Spiders.....	2-19
2.5	Chemicals of Potential Concern	2-20
2.6	Potential Routes of Exposure.....	2-22
3.0	Roles and Responsibilities	3-1
3.1	CH2M HILL Staff Responsibilities.....	3-1
3.1.1	Project Manager.....	3-1
3.1.2	Project Health and Safety Manager	3-2
3.1.3	Safety Coordinator	3-2
3.1.4	CH2M HILL Employees	3-4
3.2	CH2M HILL Employee Medical Surveillance, Training, & Drug Testing.....	3-4
3.3	CH2M HILL Subcontractors	3-6
3.4	Third Parties.....	3-8
4.0	Personal Protective Equipment.....	4-1
4.1	PPE Specifications	4-1
4.2	Reasons for Changing Level of Protection.....	4-2
4.2.1	Upgrade	4-2
4.2.2	Downgrade.....	4-2
5.0	Air Monitoring/Sampling.....	5-1
5.1	Air Monitoring Specifications.....	5-1
5.2	Calibration	5-1
5.3	Air Sampling	5-2
6.0	Decontamination	6-1
6.1	Decontamination Requirements.....	6-1
6.2	Diagram of Personnel Decontamination Line	6-2
6.3	Collection and Disposal of Decontamination Wastes	6-2
7.0	Spill Containment and Notification	7-1
7.1	SPCC Regulated Facility.....	7-1
7.2	Non-SPCC Regulated Facility.....	7-1
7.2.1	Equipment	7-1
7.2.2	Emergency Spill Event.....	7-2
7.2.3	Non-Emergency Spill Event.....	7-2
7.2.4	Cleanup.....	7-2
7.2.5	Notification and Reporting	7-2
8.0	Site-Control Procedures	8-1
9.0	Hazwoper Compliance Plan.....	9-1
10.0	Incident Reporting and Investigation	10-1
10.1	Definitions	10-1
10.1.1	Incident	10-1
10.1.2	Near-Miss	10-1
10.1.3	Serious Incidents.....	10-1
10.2	Incident Notification and Communication.....	10-1
10.3	Incident Reporting.....	10-2

10.4	Incident Investigation	10-3
10.5	Corrective Actions	10-3
11.0	Emergency Preparedness	11-1
11.1	Pre-Emergency Planning.....	11-1
11.2	Emergency Equipment and Supplies	11-2
11.3	Incident Response.....	11-2
11.4	Evacuation Procedures	11-2
11.5	Emergency Medical Treatment	11-2
12.0	Recordkeeping	12-1

Tables

1-1	Task Hazard Analysis Table	1-3
1-2	Environmental Impacts Table.....	1-4
2-1	Symptoms and Treatment of Heat Stress.....	2-7
2-2	Symptoms and Treatment of Cold Stress.....	2-9
2-3	Snakebite Response Measures	2-13
2-4	Chemicals of Potential Concern Summary Table	2-17
4-1	PPE Specifications	4-1
5-1	Air Monitoring Specifications.....	5-1
6-1	Possible Decontamination Procedures	6-1
7-1	Minimum Spill Kit Equipment List	7-1
12-1	Recordkeeping Requirements.....	12-1

Figures

6-1	Personnel Decontamination Line	6-3
-----	--------------------------------------	-----

Attachments

1	Employee Signoff Form
2	Job Hazard Analysis
3	Daily Tailgate Safety Briefing Form
4	Pre-Task Safety Plan
5	Project Activity Self-Assessment Checklists
6	Safe Work Observation Form
7	Project-Specific Chemical Product Hazard Communication Form
8	Applicable Material Safety Data Sheets
9	Chemical-Specific Training Form
10	Biological Hazard Information
11	Drug Testing Hospital Kit Notice
12	Incident Report Form and Root Cause Investigation Information

Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
APR	air-purifying respirator
cm	centimeter
CNS	central nervous system
COPC	chemical of potential concern
CPR	cardiopulmonary resuscitation
Cr	chromium
dBA	decibel (A-weighted scale)
DEET	N,N-diethyl-meta-toluamide
DOT	Department of Transportation
ECC	Environmental Compliance Coordinator
GFCI	ground fault circuit interrupter
Hazwoper	Hazardous waste operations and emergency response
Honeywell	Honeywell International Inc.
HR	heart rate
HS&E	health, safety, and environment
HSM	Health and Safety Manager
HSPM	Health and Safety Program Manager
IDLH	immediately dangerous to life and health
IRF	incident report form
JHA	job hazard analysis
LID	Legal and Insurance Department
MSDS	material safety data sheet
NIOSH	National Institute for Occupational Safety and Health
NSC	National Safety Council
OSHA	Occupational Safety and Health Administration

PAH	poly-aromatic hydrocarbon
PAPR	powered air-purifying respirator
PCB	poly-chlorinated biphenyl
PCE	tetrachlorethene
PEL	permissible exposure limit
PFD	personal flotation device
PIP	photoionization potential
PM	Project Manager
PPE	personal protective equipment
ppm	parts per million
PTSP	pre-task safety plan
RES	Remediation and Environmental Services
RQ	reportable quantity
SC	Safety Coordinator
SCBA	self-contained breathing apparatus
SOP	standard of practice
SPCC	spill prevention, control, and countermeasures
SSR	Subcontractor Safety Representative
TCE	trichloroethene
TLV	threshold limit value
TSDF	treatment, storage, and disposal facility

1.0 Introduction

1.1 About This Document

This Task-Specific Health, Safety and Environment Plan (HS&E Plan) has been prepared as a supplement to the GeoSyntec Project Health and Safety Plan (HASP) that was approved November 10, 2004 and accepted by the US Environmental Protection Agency (EPA). This HS&E Plan covers only CH2M HILL and CH2M HILL subcontractor employees. CH2M HILL personnel and subcontractors must sign both the GeoSyntec HASP and either this Task-Specific CH2M HILL HS&E Plan or their own Task Specific HASP after reading/reviewing both plans.

This Health, Safety and Environment (HS&E) Plan will be kept on the site during all field activities conducted under the Honeywell International Inc. (Honeywell) Alliance program. The plan will be amended or revised as project activities or conditions change or when supplemental information becomes available. The plan adopts, by reference, the Standards of Practice (SOPs) in the CH2M HILL *Health, Safety, and Environmental Protection (HS&E) Program Manual*. In addition, this plan adopts procedures in the project Work Plan and incorporates applicable elements of Honeywell's HS&E requirements. The Safety Coordinator (SC) is to be familiar with the SOPs contained in the HS&E Program Manual and the contents of this plan. The project Health and Safety Manager (HSM) must review and approve any changes to this plan.

CH2M HILL personnel and subcontractors must sign the CH2M HILL Employee Sign-Off Form included in Attachment 1 after reading/reviewing this HS&E Plan.

1.2 Site Background

LCP-Holtrachem is an inactive chlor-alkali manufacturing facility located in Riegelwood, Columbus County, North Carolina. The Site encompasses approximately 24 acres and is bounded by International Paper (IP) on three sides. The Site operated as a chlor-alkali facility using the mercury cell process from 1963 to 1999, when facility operations ceased. The Site was originally constructed to provide chlorine gas, caustic soda, and bleach to the adjacent IP facility. Other products were sold or were used in-house by Holtrachem. Unused products and byproducts were discharged to air and wastewater.

An Engineering Evaluation/Cost Analysis (EE/CA) for a Non-Time Critical Removal Action (NTCRA) is currently being prepared for the site as required by the Honeywell Administrative Order on Consent (AOC) dated June 8, 2004. Site characterization activities have indicated that Aroclor 1268 is one of the primary site contaminants.

Wastewater was discharged to IP's wastewater treatment system for treatment of process water generated during chlorine production. IP personnel have indicated that until the late

1970s or early 1980s, Holtrachem's process water was discharged to IP's North Bay treatment pond. Subsequently, Holtrachem's discharge was relocated to the head of IP's treatment works.

As part of IP's mill operations, a non-hazardous industrial waste landfill and wastewater treatment works are operated on site. In 1994, approximately 25 acres of the North Bay treatment pond (the last pond within the treatment works) was bermed off and drained for development as a permitted industrial landfill. The southern portion of the bermed area was developed as Landfill Cell No. 1 and is expected to reach its capacity in 2007. The northern portion of the bermed area is scheduled to be utilized for the expansion of the landfill (Cell No. 2) in the near future so that IP can continue operations on an uninterrupted basis. IP has indicated they would like to be ready to begin the expansion by January 1, 2008; therefore, this scope of work must be complete by that time.

Analytical results from samples collected from Cell No. 2 indicate the presence of Aroclor 1268 at concentrations exceeding the Toxic Substances Control Act (TSCA) bulk remediation disposal limits. The wastewater treatment solids (WWTS) containing Aroclor 1268 concentrations above the disposal limits within Cell No. 2 require removal prior to construction of IP's landfill. Due to the presence of Aroclor 1268, the United States Environmental Protection Agency (US EPA) has indicated the WWTS exceeding the disposal criteria are considered part of the Holtrachem site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). WWTS containing Aroclor 1268 concentrations greater than 50 milligrams per kilogram (mg/kg) will be temporarily contained in an engineered stockpile located on the Holtrachem site pending implementation of a site-wide remedy in approximately 2008 to 2009. The remaining material in the Cell will be excavated and transported to IP's landfill.

1.3 Description of Tasks

Refer to project documents (e.g., Field Project Start-up Form or the project Work Plan) for detailed task information. A task hazard analysis has been performed for each task and is included below while project-specific hazard controls are provided in the next section. Tasks other than those listed below require an approved amendment or revision to this plan before tasks begin. Refer to Hazwoper Compliance Plan Section of this HS&E Plan for procedures related to "clean" tasks that do not involve hazardous waste operations and emergency response (Hazwoper).

1.3.1 Hazwoper-Regulated Tasks

The following tasks are regulated under the 29 CFR 1910.120 and/or 1926.65 (OSHA's Hazwoper Standards).

- Conduct contractor oversight
- Maintain truck log
- Collect confirmatory soil samples

- PCB Waste Management oversight
- Implement provisions of this HASP

1.3.2 Non-Hazwoper-Regulated Tasks

Under specific circumstances, the training and medical monitoring requirements of federal or state Hazwoper regulations are not applicable. It must be demonstrated that the tasks can be performed without the possibility of exposure in order to use non-Hazwoper-trained personnel. The following tasks are considered non-hazardous.

- Site visits – visitors must stay out of the exclusion and contamination reduction zones.

1.3.3 Environmental-Regulated Tasks and Conditions

Project tasks and site conditions that can impact the environment and are otherwise subject to environmental regulation are included in Section 1.3. These items are also known as the environmental aspects of the project (activities that can interact with the environment). Environmental impacts relating to each task or condition are also presented in Section 1.3, which is used to evaluate the project's significant impacts and control measures specified in Hazard Controls and Safe Work Practices section of this HS&E Plan.

All personnel shall: (1) implement control measures described in Hazard Control Section; (2) obtain appropriate environmental training (e.g., Waste Management or Dangerous Goods Shipping) and (3) seek assistance from the regional Environmental Compliance Coordinator (ECC) for all environmental questions or issues.

1.3.4 Honeywell Permit Required Tasks

The following tasks require a Honeywell permit: Not applicable at this site at this time.

1.4 Task Hazard Analysis

Table 1-1 presents the hazard analysis for work to be conducted under this HS&E Plan.

1.5 Environmental Impacts

Table 1-2 summarizes the potential environmental impacts of the work to be conducted under this HS&E Plan.

TABLE 1-1
Task Hazard Analysis Table

Tasks	POTENTIAL HAZARDS (Refer to Hazard Control Section for additional information)																				
	Aerial Lifts	Back Injury (Bending/Lifting)	Biological Hazards	Buried Utilities	Cold Stress	Confined Space Entry	Electrical	Elevated Work Areas/Falls	Entanglement	Excavations	Fires	Flying Debris/Objects	Gas Cylinders	Hand and Power Tools	Heat Stress	Heavy Equipment Exposure	Ionizing Radiation	Lockout-Tagout	Noise	Radio-Frequency Radiation	Respiratory Protection
Contractor oversight-maintain truck log		X	X							X				X	X	X			X		X
Collect confirmatory soil samples		X	X							X				X	X	X			X		X
PCB waste management oversight		X	X	X					X	X				X	X	X			X		X
Implement provisions of HASP			X							X				X	X	X			X		X

TABLE 1-2
Environmental Impacts Table

Tasks/Conditions	Potential Impacts						
	Air Pollution	Land Pollution	Land Disposal	Noise Pollution	Water Pollution	Resource Depletion	Human Hazard
Chemical/Petroleum Storage or Transport	X	X			X		X
Coastal and Wetland Resources Disturbed		X			X	X	
Cultural and Historic Resources Disturbed						X	
Waste (Haz/Non-Haz) Mgmt, Transport and Disposal	X	X	X	X	X		X

2.0 Hazard Controls and Safe Work Practices

This section provides safe work practices and control measures used to reduce or eliminate potential hazards. These practices and controls are to be implemented by the party in control of either the site or the particular hazard. CH2M HILL employees and subcontractors must remain aware of the hazards affecting them regardless of who is responsible for controlling the hazards. CH2M HILL employees and subcontractors who do not understand any of these provisions should contact the SC for clarification. In addition to the hazard controls specified in this section, the following are required for Honeywell projects.

2.1 Administrative Controls

2.1.1 HS&E Plans

CH2M HILL requires HS&E plans for all field projects and subcontractors are required to submit detailed Job Hazard Analysis for their activities. The HS&E plan provides a risk analysis of each task and identifies the potential hazards and control measures (including personal protective equipment (PPE) and air monitoring requirements) for each task.

2.1.2 Job Hazard Analysis

An Activity Hazard Analysis (AHA) is required by CH2M HILL for all tasks unless the HSM specifically determines it is unnecessary. The AHA provides a step-by-step analysis of the activity being performed and identifies the equipment and control measures necessary to conduct the work safely. Each AHA must be reviewed by the work team immediately prior to conducting the work. The AHA can be a source of information for the daily safety meeting. Project-specific AHAs are provided in Attachment 2. The contractor shall develop and implant AHAs for their specific project tasks.

2.1.3 Safety Meetings

CH2M HILL requires that the safety coordinator conduct daily safety meetings to discuss with the field team the task to be performed that day and the potential hazards and mitigation measure. The safety meeting can be used to review the AHA with the team. A Daily Tailgate Safety Briefing Form is included in Attachment 3. All site contractor personnel shall join the daily safety tailgate meeting and actively participate in the discussions. Each worker shall sign daily rosters to indicate their participation in the meeting.

A Pre-Task Safety Plan (PTSP) must be developed each day prior to performing specific work tasks. Each member or each work group performing the tasks must be included in the planning so all are aware of the task hazards and controls. The number of work groups may

and will vary each day depending on site activities. A copy of a PTSP is included in Attachment 4.

2.1.4 Self-Assessments

Project Activity Self-Assessment Checklists are contained in Attachment 5. These checklists provide a method of verifying compliance with established safe work practices, regulations, and industry standards pertaining to hazardous activities. The checklists can be used by any CH2M HILL employee who may be exposed to a hazardous activity or by the SC when providing oversight of a subcontractor performing a hazardous activity. Self-assessments shall be completed prior to subjecting CH2M HILL staff to hazardous operations for any reason.

Self-assessment checklists should be completed as follows: initially, then at least weekly throughout the duration of the project.

If hazardous conditions exist or are apparent during the self-assessment, immediately notify the employees in the area and do not continue work in that area until the conditions are safe. If an imminent danger situation (immediately life threatening or would cause serious injury) exists, immediately stop work, warn all personnel in danger and notify the appropriate safety representative and the CH2M HILL SC. Non-compliance issues identified during the self-assessment shall be immediately rectified. If corrective action assistance is required, the HSM should be contacted for guidance.

Any site-specific requirements outlined in this HS&E Plan that are more stringent than those contained in the self-assessment checklists are to take precedence. The self-assessment checklists are based upon minimum regulatory compliance and some site-specific requirements may be more stringent. The self-assessment checklists, including documented corrective actions, shall be made part of the permanent project records and maintained by the SC.

2.1.5 Site Compliance/Audits

In order to ensure compliance with requirements contained in the Honeywell Remediation and Environmental Services (RES) Health and Safety Manual, Specification 01620, and with this HS&E Plan, audits will be conducted by a HS&E professional as follows: at least one compliance audit will be conducted for the remedial construction project.

2.1.6 Interventions

Honeywell requires that we intervene whenever we see someone exhibiting an unsafe behavior or working in unsafe conditions. When such a situation is observed, an intervention is performed by talking to the person about how the task could be done more safely. Safe Work Observation forms must be completed on a weekly basis, at a minimum, by the SC or FTL. Each completed form must be maintained with the HS&E Plan field documents, and then transferred to project files upon the completion of the field work. A copy of a Safe Work Observation form is included in Attachment 6.

2.2 Project-Specific Hazards and Controls

The following sections describe potential hazards and control measures that may be encountered during site activities.

2.2.1 Earthmoving Equipment

(Reference CH2M HILL SOP HSE-306, *Earthmoving Equipment*)

- Only authorized personnel are permitted to operate earthmoving equipment.
- Maintain safe distance from operating equipment and stay alert of equipment movement. Avoid positioning between fixed objects and operating equipment and equipment pinch points, remain outside of the equipment swing and turning radius. Pay attention to backup alarms, but not rely on them for protection. Never turn your back on operating equipment.
- Approach operating equipment only after receiving the operator's attention. The operator shall acknowledge your presence and stop movement of the equipment. Caution shall be used when standing next to idle equipment; when equipment is placed in gear it can lurch forward or backward. Never approach operating equipment from the side or rear where the operator's vision is compromised.
- When required to work in proximity to operating equipment, wear high-visibility vests to increase visibility to equipment operators. For work performed after daylight hours, vests shall be made of reflective material or include a reflective stripe or panel.
- Do not ride on earthmoving equipment unless it is specifically designed to accommodate passengers. Only ride in seats that are provided for transportation and that are equipped with seat belts.
- Stay as clear as possible of all hoisting operations. Loads shall not be hoisted overhead of personnel.
- Earthmoving equipment shall not be used to lift or lower personnel.
- If equipment becomes electrically energized, personnel shall be instructed not to touch any part of the equipment or attempt to touch any person who may be in contact with the electrical current. The utility company or appropriate party shall be contacted to have line de-energized prior to approaching the equipment.

2.2.2 Excavation (Reference CH2M HILL SOP HS-32, *Excavations*)

- Do not enter the excavations unless completely necessary, and only after the competent person has completed the daily inspection and has authorized entry.
- Follow all excavation entry requirements established by the competent person.
- Do not enter excavations where protective systems are damaged or unstable.
- Do not enter excavations where objects or structures above the work location may become unstable and fall into the excavation.
- Do not enter excavations with the potential for a hazardous atmosphere until the air has been tested and found to be at safe levels.

- Do not enter excavations with accumulated water unless precautions have been taken to prevent excavation cave-in.
- H&S Self-Assessment Checklist – Excavations, found in Attachment 5 of this plan, should be used to evaluate excavations prior to entry.

2.2.3 Respiratory Protection

This section applies only if air monitoring action levels are triggered. It is not anticipated that respiratory protection will be needed. Requirements for respiratory protection include:

- Respirator users must have completed appropriate respirator training within the past 12 months. Level C training is required for air-purifying respirators (APR) use and Level B training is required for supplied-air respirators (SAR) and self-contained breathing apparatus (SCBA) use. Specific training is required for the use of powered air-purifying respirators (PAPR).
- Respirator users must complete the respirator medical monitoring protocol and be approved for the specific type of respirator to be used.
- Tight-fitting facepiece respirator (negative or positive pressure) users must have passed an appropriate fit test within past 12 months.
- Respirator use shall be limited to those activities identified in this plan. If site conditions change, the HSM shall be notified to amend the respiratory protection requirements.
- Tight-fitting facepiece respirator users shall be clean-shaven and shall perform a user seal check before each use.
- Canisters/cartridges shall be replaced according to the change-out schedule specified in this plan. Respirator users shall notify the SC of any detection of vapor or gas breakthrough. The SC shall report any breakthrough events to the HSM.
- Respirators in regular use shall be inspected before each use and during cleaning.
- Respirators in regular use shall be cleaned and disinfected as often as necessary to ensure they are maintained in a clean and sanitary condition.
- Respirators shall be properly stored to protect against contamination and deformation.
- Field repair of respirators shall be limited to routine maintenance. Defective respirators shall be removed from service.
- When breathing air is supplied by cylinder or compressor, the SC shall verify the air meets Grade D air specifications.
- The SC shall complete the H&S Self-Assessment Checklist – Respiratory Protection included in Attachment 5 of this plan to verify compliance with CH2M HILL's respiratory protection program.

Refer to CH2M HILL HSE SOP-121, Respiratory Protection, for additional information.

2.2.4 Exposure to Public Vehicular Traffic

The following precautions must be taken when working around traffic, and in or near an area where traffic controls have been established by a contractor.

- Exercise caution when exiting traveled way or parking along street – avoid sudden stops, use flashers, etc.
- Park in a manner that will allow for safe exit from vehicle, and where practicable, park vehicle so that it can serve as a barrier.
- All staff working adjacent to traveled way or within work area must wear reflective/high-visibility safety vests.
- Eye protection should be worn to protect from flying debris.
- Remain aware of factors that influence traffic related hazards and required controls – sun glare, rain, wind, flash flooding, limited sight-distance, hills, curves, guardrails, width of shoulder (i.e., breakdown lane), etc.
- Always remain aware of an escape route -- behind an established barrier, parked vehicle, guardrail, etc.
- Always pay attention to moving traffic – never assume drivers are looking out for you
- Work as far from traveled way as possible to avoid creating confusion for drivers.
- When workers must face away from traffic, a “buddy system” should be used, where one worker is looking towards traffic.
- When working on highway projects, obtain a copy of the contractor’s traffic control plan.
- Work area should be protected by a physical barrier – such as a K-rail or Jersey barrier.
- Review traffic control devices to ensure that they are adequate to protect your work area. Traffic control devices should: 1) convey a clear meaning, 2) command respect of road users, and 3) give adequate time for proper traffic response. The adequacy of these devices are dependent on limited sight distance, proximity to ramps or intersections, restrictive width, duration of job, and traffic volume, speed, and proximity.
- Either a barrier or shadow vehicle should be positioned a considerable distance ahead of the work area. The vehicle should be equipped with a flashing arrow sign and truck-mounted crash cushion. All vehicles within 40 feet of traffic should have an orange flashing hazard light atop the vehicle.
- Except on highways, flaggers should be used when 1) two-way traffic is reduced to using one common lane, 2) driver visibility is impaired or limited, 3) project vehicles enter or exit traffic in an unexpected manner, or 4) the use of a flagger enhances established traffic warning systems.

- Lookouts should be used when physical barriers are not available or practical. The lookout continually watches approaching traffic for signs of erratic driver behavior and warns workers. Vehicles should be parked at least 40 feet away from the work zone and traffic. Minimize the amount of time that you will have your back to oncoming traffic.

Refer to CH2M HILL HSE SOP-216, Traffic Control, for additional information.

2.2.5 Noise Hazards

Previous surveys indicate that heavy equipment such as drilling or excavation equipment may produce continuous and impact noise at or above the action level of 85 decibels (dBA). All CH2M HILL personnel within 25 feet of operating equipment, or near an operation that creates noise levels high enough to impair conversation, shall wear hearing protective devices (either muffs or plugs). Personnel will wash their hands with soap and water prior to inserting ear plugs to avoid initiating ear infections.

Refer to CH2M HILL HSE SOP-108, Hearing Conservation Program, for additional information.

2.3 General Hazards and Controls

2.3.1 General Practices and Housekeeping

General “good housekeeping” practices include:

- Site work should be performed during daylight hours whenever possible. Work conducted during hours of darkness require enough illumination intensity to read a newspaper without difficulty.
- Good housekeeping must be maintained at all times in all project work areas.
- Common paths of travel should be established and kept free from the accumulation of materials.
- Keep access to aisles, exits, ladders, stairways, scaffolding, and emergency equipment free from obstructions.
- Provide slip-resistant surfaces, ropes, and/or other devices to be used.
- Specific areas should be designated for the proper storage of materials.
- Tools, equipment, materials, and supplies shall be stored in an orderly manner.
- As work progresses, scrap and unessential materials must be neatly stored or removed from the work area.
- Containers should be provided for collecting trash and other debris and shall be removed at regular intervals.
- All spills shall be quickly cleaned up. Oil and grease shall be cleaned from walking and working surfaces.

Refer to CH2M HILL HSE SOP-209, General Practices, for additional information.

2.3.2 Hazard Communication

The SC is to perform the following:

- Complete an inventory of chemicals brought to the site by CH2M HILL using Attachment 7.
- Confirm that an inventory of chemicals brought on site by CH2M HILL subcontractors is available.
- Request or confirm locations of Material Safety Data Sheets (MSDSs) from the client, contractors, and subcontractors for chemicals to which CH2M HILL employees potentially are exposed.
- Copies of all applicable MSDSs will be placed in Attachment 8.
- Before or as the chemicals arrive on site, obtain an MSDS for each hazardous chemical.
- Label chemical containers with the identity of the chemical and with hazard warnings, and store properly.
- Give employees required chemical-specific hazard communication training using Attachment 9.
- Store all materials properly, giving consideration to compatibility, quantity limits, secondary containment, fire prevention, and environmental conditions.

Refer to CH2M HILL HSE SOP-107, Hazard Communication, for additional information.

2.3.3 Shipping and Transportation of Chemical Products

Chemicals brought to the site might be defined as hazardous materials by the U.S. Department of Transportation (DOT). All staff who ship the materials or transport them by road must receive CH2M HILL training in shipping dangerous goods. All hazardous materials that are shipped (e.g., via Federal Express) or are transported by road must be properly identified, labeled, packed, and documented by trained staff. Contact the HSM or the Equipment Coordinator for additional information.

Refer to CH2M HILL's Procedures for Shipping and Transporting Dangerous Goods for additional information.

2.3.4 Lifting

Proper lifting techniques must be used when lifting any object:

- Plan storage and staging to minimize lifting or carrying distances.
- Split heavy loads into smaller loads.
- Use mechanical lifting aids whenever possible.
- Have someone assist with the lift -- especially for heavy or awkward loads.
- Make sure the path of travel is clear prior to the lift.

Refer to CH2M HILL HSE SOP-112, Lifting, for additional information.

2.3.5 Fire Prevention

Fire prevention measures include the following:

- Fire extinguishers shall be provided so that the travel distance from any work area to the nearest extinguisher is less than 100 feet. When 5 gallons or more of a flammable or combustible liquid is being used, an extinguisher must be within 50 feet. Extinguishers must:
 - be maintained in a fully charged and operable condition,
 - be visually inspected each month, and
 - undergo a maintenance check each year.
- The area in front of extinguishers must be kept clear.
- Post “Exit” signs over exiting doors, and post “Fire Extinguisher” signs over extinguisher locations.
- Combustible materials stored outside should be at least 10 feet from any building.
- Solvent waste and oily rags must be kept in a fire resistant, covered container until removed from the site.
- Flammable/combustible liquids must be kept in approved containers, and must be stored in an approved storage cabinet.

Refer to CH2M HILL HSE SOP-208, Fire Prevention, for additional information.

2.3.6 Electrical

Electrical safety measures include:

- Only qualified personnel are permitted to work on unprotected energized electrical systems.
- Only authorized personnel are permitted to enter high-voltage areas.
- Do not tamper with electrical wiring and equipment unless qualified to do so. All electrical wiring and equipment must be considered energized until lockout/tagout procedures are implemented.
- Inspect electrical equipment, power tools, and extension cords for damage prior to use. Do not use defective electrical equipment, remove from service.
- All temporary wiring, including extension cords and electrical power tools, must have ground fault circuit interrupters (GFCIs) installed.
- Extension cords must be:
 - equipped with third-wire grounding.

- covered, elevated, or protected from damage when passing through work areas.
 - protected from pinching if routed through doorways.
 - not fastened with staples, hung from nails, or suspended with wire.
- Electrical power tools and equipment must be effectively grounded or double-insulated UL approved.
- Operate and maintain electric power tools and equipment according to manufacturers' instructions.
- Maintain safe clearance distances between overhead power lines and any electrical conducting material unless the power lines have been de-energized and grounded, or where insulating barriers have been installed to prevent physical contact. Maintain at least 10 feet from overhead power lines for voltages of 50 kV or less, and 10 feet plus ½ inch for every 1 kV over 50 kV.
- Temporary lights shall not be suspended by their electric cord unless designed for suspension. Lights shall be protected from accidental contact or breakage.
- Protect all electrical equipment, tools, switches, and outlets from environmental elements.

Refer to CH2M HILL HSE SOP-206, Electrical, for additional information.

2.3.7 Stairways and Ladders

Safety guidelines pertaining to stairways and ladders include the following:

- Stairway or ladder is generally required when a break in elevation of 19 inches or greater exists.
- Personnel should avoid using both hands to carry objects while on stairways; if unavoidable, use extra precautions.
- Personnel must not use pan and skeleton metal stairs until permanent or temporary treads and landings are provided the full width and depth of each step and landing.
- Ladders must be inspected by a competent person for visible defects prior to each day's use. Defective ladders must be tagged and removed from service.
- Ladders must be used only for the purpose for which they were designed and shall not be loaded beyond their rated capacity.
- Only one person at a time shall climb on or work from an individual ladder.
- User must face the ladder when climbing; keep belt buckle between side rails
- Ladders shall not be moved, shifted, or extended while in use.
- User must use both hands to climb; use rope to raise and lower equipment and materials
- Straight and extension ladders must be tied off to prevent displacement

- Ladders that may be displaced by work activities or traffic must be secured or barricaded
- Portable ladders must extend at least 3 feet above landing surface
- Straight and extension ladders must be positioned at such an angle that the ladder base to the wall is one-fourth of the working length of the ladder
- Stepladders are to be used in the fully opened and locked position
- Users are not to stand on the top two steps of a stepladder; nor are users to sit on top or straddle a stepladder
- Fixed ladders ≥ 24 feet in height must be provided with fall protection devices.
- Fall protection should be considered when working from extension, straight, or fixed ladders greater than six feet from lower levels and both hands are needed to perform the work, or when reaching or working outside of the plane of ladder side rails.

Refer to CH2M HILL HSE SOP-214, Stairways and Ladders, for additional information.

2.3.8 Heat Stress

Prevention measures to avoid heat stress include:

- Drink 16 ounces of water before beginning work. Disposable cups and water maintained at 50°F to 60°F should be available. Under severe conditions, drink 1 to 2 cups every 20 minutes, for a total of 1 to 2 gallons per day. Do not use alcohol in place of water or other nonalcoholic fluids. Decrease your intake of coffee and caffeinated soft drinks during working hours.
- Acclimate yourself by slowly increasing workloads (e.g., do not begin with extremely demanding activities).
- Use cooling devices, such as cooling vests, to aid natural body ventilation. These devices add weight, so their use should be balanced against efficiency.
- Use mobile showers or hose-down facilities to reduce body temperature and cool protective clothing.
- Conduct field activities in the early morning or evening and rotate shifts of workers, if possible.
- Avoid direct sun whenever possible, which can decrease physical efficiency and increase the probability of heat stress. Take regular breaks in a cool, shaded area. Use a wide-brim hat or an umbrella when working under direct sun for extended periods.
- Provide adequate shelter/shade to protect personnel against radiant heat (sun, flames, hot metal).
- Maintain good hygiene standards by frequently changing clothing and showering.

- Observe one another for signs of heat stress. Persons who experience signs of heat syncope, heat rash, or heat cramps should consult the SC to avoid progression of heat-related illness.

Symptoms and treatment of heat stress are summarized in Table 2-1.

TABLE 2-1
Symptoms and Treatment of Heat Stress

Type of Heat Stress	Signs and Symptoms	Treatment
Heat Syncope	Sluggishness or fainting while standing erect or immobile in heat.	Remove to cooler area. Rest lying down. Increase fluid intake. Recovery usually is prompt and complete.
Heat Rash	Profuse tiny raised red blister-like vesicles on affected areas, along with prickling sensations during heat exposure.	Use mild drying lotions and powders, and keep skin clean for drying skin and preventing infection.
Heat Cramps	Painful spasms in muscles used during work (arms, legs, or abdomen); onset during or after work hours.	Remove to cooler area. Rest lying down. Increase fluid intake.
Heat Exhaustion	Fatigue, nausea, headache, giddiness; skin clammy and moist; complexion pale, muddy, or flushed; may faint on standing; rapid thready pulse and low blood pressure; oral temperature normal or low	Remove to cooler area. Rest lying down, with head in low position. Administer fluids by mouth. Seek medical attention.
Heat Stroke	Red, hot, dry skin; dizziness; confusion; rapid breathing and pulse; high oral temperature.	Cool rapidly by soaking in cool—but not cold—water. Call ambulance, and get medical attention immediately!

Monitoring Heat Stress

These procedures should be considered when the ambient air temperature exceeds 70°F, the relative humidity is high (>50 percent), or when workers exhibit symptoms of heat stress.

- The heart rate (HR) should be measured by the radial pulse for 30 seconds, as early as possible in the resting period.
- The HR at the beginning of the rest period should not exceed 100 beats/minute, or 20 beats/minute above resting pulse.
- If the HR is higher, the next work period should be shortened by 33 percent, while the length of the rest period stays the same.
- If the pulse rate still exceeds 100 beats/minute at the beginning of the next rest period, the work cycle should be further shortened by 33 percent.
- The procedure is continued until the rate is maintained below 100 beats/minute, or 20 beats/minute above resting pulse.

Refer to CH2M HILL HSE SOP-211, Heat and Cold Stress, for additional information.

2.3.9 Cold Stress

Prevention measures to avoid cold stress include:

- Be aware of the symptoms of cold-related disorders, and wear proper, layered clothing for the anticipated fieldwork. Appropriate rain gear is a must in cool weather.
- Consider monitoring the work conditions and adjusting the work schedule using guidelines developed by the U.S. Army (wind-chill index) and the National Safety Council (NSC).
- Wind-Chill Index is used to estimate the combined effect of wind and low air temperatures on exposed skin. The wind-chill index does not take into account the body part that is exposed, the level of activity, or the amount or type of clothing worn. For those reasons, it should only be used as a guideline to warn workers when they are in a situation that can cause cold-related illnesses.
- NSC Guidelines for Work and Warm-Up Schedules can be used with the wind-chill index to estimate work and warm-up schedules for fieldwork. The guidelines are not absolute; workers should be monitored for symptoms of cold-related illnesses. If symptoms are not observed, the work duration can be increased.
- Persons who experience initial signs of immersion foot, frostbite, hypothermia should consult the SC to avoid progression of cold-related illness.
- Observe one another for initial signs of cold-related disorders.
- Obtain and review weather forecast – be aware of predicted weather systems along with sudden drops in temperature, increase in winds, and precipitation.

Symptoms and treatment of cold stress are summarized in Table 2-2.

TABLE 2-2
Symptoms and Treatment of Cold Stress

Type of Cold Stress	Signs and Symptoms	Treatment
Immersion (Trench) Foot	Feet discolored and painful; infection and swelling present.	Seek medical treatment immediately.
Frostbite	Blanched, white, waxy skin, but tissue resilient; tissue cold and pale.	Remove victim to a warm place. Re-warm area quickly in warm—but not hot—water. Have victim drink warm fluids, but not coffee or alcohol. Do not break blisters. Elevate the injured area, and get medical attention.
Hypothermia	Shivering, apathy, sleepiness; rapid drop in body temperature; glassy stare; slow pulse; slow respiration.	Remove victim to a warm place. Have victim drink warm fluids, but not coffee or alcohol. Get medical attention.

Refer to CH2M HILL HSE SOP-211, Heat and Cold Stress, for additional information.

2.3.10 Compressed Gas Cylinders

Safety measures pertaining to handling compressed gas cylinders include:

- Valve caps must be in place when cylinders are transported, moved, or stored.
- Cylinder valves must be closed when cylinders are not being used and when cylinders are being moved.
- Cylinders must be secured in an upright position at all times.
- Cylinders must be shielded from welding and cutting operations and positioned to avoid being struck or knocked over; contacting electrical circuits; or exposed to extreme heat sources.
- Cylinders must be secured on a cradle, basket, or pallet when hoisted; they may not be hoisted by choker slings.

2.3.11 Procedures for Locating Buried Utilities

Local Utility Mark-Out Service:

Name:	North Carolina One Call Center
Phone:	1-800-632-4949

Procedures for locating buried utilities include:

- Contact your local utility location service.
- Where available, obtain utility diagrams for the facility.
- Review locations of sanitary and storm sewers, electrical conduits, water supply lines, natural gas lines, and fuel tanks and lines.
- Review proposed locations of intrusive work with facility personnel knowledgeable of locations of utilities. Check locations against information from utility mark-out service.
- Where necessary (e.g., uncertainty about utility locations), excavation or drilling of the upper depth interval should be performed manually.
- Monitor for signs of utilities during advancement of intrusive work (e.g., sudden change in advancement of auger or split spoon).
- When the client or other onsite party is responsible for determining the presence and locations of buried utilities, the SSC should confirm that arrangement.

2.3.12 Confined Space Entry

(Not applicable for Remedial Construction activities.)

No confined space entry will be permitted. Confined space entry requires additional health and safety procedures, training, and a permit. If conditions change such that confined-space entry is necessary, contact the HSM to develop the required entry permit.

When planned activities will not include confined-space entry, permit-required confined spaces accessible to CH2M HILL personnel are to be identified before the task begins. The SSC is to confirm that permit spaces are properly posted or that employees are informed of their locations and hazards.

Refer to CH2M HILL SOP HS-203, Confined Space Entry, for additional information.

2.3.13 Backing Field Vehicles

The following precautions shall be implemented to prevent incidents during backing of field vehicles:

- Avoid backing whenever possible. The SC will be responsible for determining when “backing” is allowed. If extensive backing is required, alarms that sense when an object is close by must be used.
- If backing is required, there MUST BE a spotter. If a spotter is not available, the driver MUST walk completely around the vehicle before backing up.
- When “backing” is likely to be a part of the activities, it must be discussed in the daily safety briefings to remind staff of the hazards and controls.
- Learn your vehicle’s blind spots.

2.3.14 Driving in Areas with Tall Grass/Brush

Driving in areas with tall grass/brush can present a potential fire hazard if the grass/brush gets caught under and/or remains in contact with the vehicle exhaust system. Employees should exercise the following precautions:

- When stopping vehicle, ensure it is in an area where grass is not tall.
- Do not leave vehicle idling once stopped.
- When possible, try to drive through areas where grass is not tall or grass has been beaten down.
- Ensure that a fire extinguisher is available for each vehicle.
- Keep fire extinguisher readily available in passenger area of vehicle while driving.
- Keep fire extinguisher outside of vehicle upon stopping.
- Address fire hazards and controls in daily safety briefings as appropriate.

2.3.15 Severe Weather

The following precautions should be taken in the event of severe weather:

- Identify "Take Shelter" areas before starting project.
If it is necessary to seek shelter, notify the Project Manager and Client Representative.
- Work may proceed in light rain, although workers should wear rain gear.
- Exposure to slips, trips and falls is increased during rainy and snowing conditions.
- Take cover in field vehicle during adverse weather conditions (e.g., high winds, heavy rain, or lightning).
- Work shall cease and cover sought in the event of lightning or tornado warnings.

2.3.16 Working On or Above Water

(Not applicable for Remedial Construction activities.)

The following precautions should be taken when working on or above water:

- Safe means of boarding or leaving the boat or platform must be provided to prevent slipping and falling.
- All persons participating in boating operations will be directed by the SSC.
- All personnel shall wear a Personal Flotation Device (PFD) at all times while on the water.
- The boating team will include at least one person qualified in First Aid.
- Team Leader has final authority on operations with regards to weather and water conditions
- All operations involving boating will be directed by qualified and experienced boater.
- A Safe Boating Checklist will be completed at the frequency specified in Section 2 of this plan (and will be included in Attachment 5).
- Boat/barge must be equipped with adequate railing.
- Boat/barge must be operated according to U.S. Coast Guard regulations (speed, lightning, right-of-way, etc.).
- Staff should be instructed on safe use and operation of boat prior to use.
- Work requiring the use of a boat will not take place at night or during inclement weather.
- Shut off engine before refueling.
- Do not smoke while refueling.
- Fall protection should be provided to prevent personnel from falling into water. Where fall protection systems are not provided and the danger of drowning exists, U.S. Coast Guard-approved PFDs, or life jacket, shall be worn.

- Inspect PFDs prior to use. Do not use defective PFDs.
- A life-saving skiff must be provided for emergency rescue.
- A minimum of one ring buoy with 90 feet of 3/8-inch solid-braid polypropylene (or equal) rope must be provided for emergency rescue.
- Use sampling and other equipment according to the manufacturers' instructions.

Refer to CH2M HILL HSE SOP-404, In-water, Wetland and Coastal Work, for additional information.

2.4 Biological Hazards and Controls

2.4.1 Snakes

Each year, about 9,000 people are bitten by poisonous snakes in the U.S. Only about 15-25% actually receive venom, and U.S. deaths from snakebites only total about 12-15 people annually. In 2002, there were only 9 snakebite deaths in the US. Most snakebite deaths occur in small, young children whose lack of body mass and immune system development make them more susceptible to snake venom. However, a far larger number of people suffer medical complications ranging from mild to serious problems from improper treatment than the number who die. Therefore, knowing what to do to avoid snakebites, and how to properly treat them if they occur, is critical to preventing permanent injury or death.

Snakes typically are found in underbrush and tall grassy areas. If you encounter a snake, stay calm and look around; there may be other snakes. Turn around and walk away on the same path you used to approach the area. If a person is bitten by a snake, wash and immobilize the injured area, keeping it lower than the heart if possible. Seek medical attention immediately. **DO NOT** apply ice, cut the wound, or apply a tourniquet. Try to identify the type of snake: note color, size, patterns, and markings.

Table 2-3 summarizes the measures to be taken (and NOT to be taken) in the event of a snakebite.

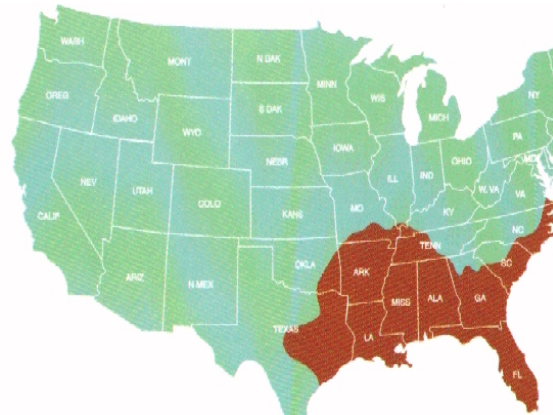
TABLE 2-3
Snakebite Response Measures

Things to Do	Things NOT to Do
<ul style="list-style-type: none"> • Move victim, and everybody else, away from snakes. • Identify the snake - kill it ONLY if necessary. • Lie the victim down with the bite area at or just slightly below the heart level. • Calm the victim by explaining the facts about snakebites. • Immobilize the bite area with a splint and sling, if possible. 	<ul style="list-style-type: none"> • Do not cut and suck the wound, either manually or orally. • Do not apply a tight, narrow band tourniquet - these cause amputations! • Do not apply ice or heat packs, and do not use a stun gun on the bite area. • Do not give the victim any food or drink, and this applies especially to alcohol! • Do not allow the victim to become alarmed,

-
- Remove constricting jewelry or clothing unless the victim resists.
 - Get professional medical help as quickly as possible.
- excited or agitated, as this will only increase blood flow and the chances of getting poison to the heart.
 - Do not allow victim to exercise vigorously, including running.
 - If you must kill the snake, then do NOT touch its head for at least one hour. If you must kill a snake for identification purposes, then completely remove its head and bury it. Snake heads have been documented as capable of biting and injecting poison an hour or more after decapitation.
 - Do not waste valuable time on unimportant acts like trying to find a snake to identify or kill it. Hemotoxic poison will start to enter the blood stream within 30 minutes, and neurotoxic poison works even faster.
-

Following the above protocols (Table 2-3) will greatly reduce the chances of serious complications from snakebites. Bear in mind that few people die from poisonous snakebites and the vast majority of snakebite victims are not even venomized. Snakes generally reserve their venom for prey they intend to eat. Snakebites are more a nuisance than a serious medical problem in most cases.

Water moccasin snakes are prevalent in the site area. Below is a picture for identification – be sure to show picture to site personnel. The Cottonmouth snake is related to the [copperhead](#) but more dangerous. Venom is highly toxic with severe tissue destruction. Bites are fairly frequent in the southern United States. Color dark or nearly black, especially in adult of the species. There is a clear difference in the appearance of adult cottonmouths and juvenile snakes of the species.



2.4.2 Poison Ivy and Poison Sumac

Poison ivy, poison oak, and poison sumac typically are found in brush or wooded areas. They are more commonly found in moist areas or along the edges of wooded areas. Become

familiar with the identity of these plants. Wear protective clothing that covers exposed skin and clothes. Avoid contact with plants and the outside of protective clothing. If skin contacts a plant, wash the area with soap and water immediately. If the reaction is severe or worsens, seek medical attention. Additional information and photographs of each are provided in Attachment 10.

2.4.3 Ticks

Ticks typically are in wooded areas, bushes, tall grass, and brush. Ticks are black, black and red, or brown and can be up to one-quarter inch in size. Wear tightly woven light-colored clothing with long sleeves and pant legs tucked into boots; spray **only outside** of clothing with permethrin or permethrin and spray skin with only DEET; and check yourself frequently for ticks.

If bitten by a tick, grasp it at the point of attachment and carefully remove it. After removing the tick, wash your hands and disinfect and press the bite areas. Save the removed tick. Report the bite to human resources. Symptoms of tick-borne diseases include chills, fever, headache, fatigue, stiff neck, and bone pain. Other symptoms include:

- Lyme Disease - A rash might appear that looks like a bullseye with a small welt in the center.
- Rocky Mountain Spotted Fever - A rash of red spots may appear under the skin 3-10 days after the tick bite.

If any of these symptoms appear, seek medical attention.

2.4.4 Bees and Other Stinging Insects

Bee and other stinging insects may be encountered almost anywhere and may present a serious hazard, particularly to people who are allergic. Watch for and avoid nests. Keep exposed skin to a minimum. Carry a kit if you have had allergic reactions in the past, and inform the SSC and/or buddy. If a stinger is present, remove it carefully with tweezers. Wash and disinfect the wound, cover it, and apply ice. Watch for allergic reaction; seek medical attention if a reaction develops.

2.4.5 Bloodborne Pathogens

Exposure to bloodborne pathogens may occur when rendering first aid or cardiopulmonary resuscitation (CPR), or when coming into contact with landfill waste or waste streams containing potentially infectious material. Hepatitis B vaccination must be offered before the person participates in a task where exposure is a possibility.

Refer to CH2M HILL HSE SOP-202, Bloodborne Pathogens, for additional information regarding exposure controls and PPE.

2.4.6 Mosquito Bites

Due to the recent detection of the West Nile Virus in the Southeastern United States it is recommended that preventative measures be taken to reduce the probability of being bitten

by mosquitoes whenever possible. Mosquitoes are believed to be the primary source for exposure to the West Nile Virus as well as several other types of encephalitis. The following guidelines should be followed to reduce the risk of these concerns for working in areas where mosquitoes are prevalent.

- Stay indoors at dawn, dusk, and in the early evening.
- Wear long-sleeved shirts and long pants whenever you are outdoors.
- Spray clothing with repellents containing permethrin or DEET since mosquitoes may bite through thin clothing.
- Apply insect repellent sparingly to exposed skin. An effective repellent will contain 35% DEET (N,N-diethyl-meta-toluamide). DEET in high concentrations (greater than 35%) provides no additional protection.
- Repellents may irritate the eyes and mouth, so avoid applying repellent to the hands.
- Whenever you use an insecticide or insect repellent, be sure to read and follow the manufacturer's DIRECTIONS FOR USE, as printed on the product.

Note: Vitamin B and "ultrasonic" devices are NOT effective in preventing mosquito bites.

Symptoms of Exposure to the West Nile Virus

The West Nile Virus incubation period is from 3-15 days. Most infections are mild, and symptoms include fever, headache, and body aches, occasionally with skin rash and swollen lymph glands. More severe infection may be marked by headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, paralysis, and, rarely, death.

If you have any questions or to report any suspicious symptoms, contact the project HSM.

2.4.7 Spiders

Black Widow

Description

The female black widow spider is almost twice the size of its male counterpart. Although both are considered venomous, only the female spider is able to bite and envenomate humans. During the summer months, the female black widow spider is the most venomous. The spider undergoes multiple moltings throughout the year and often changes color. The female is most often shiny black in color and has a rounded abdomen with a red distinctive hourglass on its ventral surface. Occasionally, two red spots may be seen instead of the hourglass configuration.

Symptoms

When bitten by a black widow spider, the symptoms usually begin with a pinprick sensation, followed by the appearance of mild swelling and redness around the bite wound. It is not unusual for the patient to be unaware of the bite until a local reaction has occurred. Close evaluation of the site may reveal two fang marks. The first hour after the bite, pain

often increases around the area of the bite and spreads to the entire body. Upper extremity bites usually lead to spasm of the upper trunk muscles; bites of the lower extremity often lead to abdominal spasms.

Other common symptoms include an abnormal sensation in the extremities (i.e., prickling or burning), deep tendon reflexes, headache, anxiety, nausea, vomiting, tremor, restlessness, and seizures may also be seen. Symptoms usually resolve within 24-48 hours

General treatment includes local wound care, a tetanus shot, and pain medication if needed. Airway, breathing, and circulation should be monitored closely.

Prevention

Wear gloves, heavy garments that are fully buttoned, and protective footwear when working in areas where spiders commonly inhabit (i.e., dark and protected spaces such as wells, rock and wood piles, pipes, gloves, boots, etc.)

Brown Recluse

Description

The brown recluse spider is approximately 1 centimeters (cm) in body length, with a leg span of up to 2.5 cm. The color of these spiders is usually tan to brown.

Symptoms

Envenomation is initially painless for most victims. Within the first few hours, pain and redness occur at the site of the bite. The bite mark may resemble a bullseye and is most often 1-5 cm in diameter. Over the next few days, the bite area will ulcerate and spread in diameter and into the fatty tissue below. In one week after the bite a large area of skin and tissue can be involved. Surgical intervention is usually required to remove the bite area.

Systemic reactions, while uncommon, can occur in some individuals. These symptoms usually occur within 2 days of the bite and can include fever, chills, rash, nausea, vomiting, and possible renal failure.

General treatment includes local wound care, tetanus inoculation, immobilization, elevation, observation, and surgical removal of the wound.

Prevention

Wear gloves, heavy garments that are fully buttoned, and protective footwear when working in areas where spiders commonly inhabit (i.e., dark and protected spaces such as wells, rock and wood piles, pipes, gloves, boots, etc.)

Additional information regarding spiders can be found in Attachment 10.

2.5 Chemicals of Potential Concern

Table 2-4 summarizes information pertaining to chemicals of potential concern (COPCs) at the project site.

Table 2-4

Contaminant	Location and Maximum ^a Concentration (ppm)	Exposure Limit ^b	IDLH ^c	Symptoms and Effects of Exposure	PIP ^d (eV)
Aroclor 1268 (Limits as PCBs)	GW: 0.76 ug/L (MW-16) SB: 3,800 mg/kg (Site #1 Surface) SB: 5,100 mg.kg - IP property - Grid I6 SD: 85.6 mg/kg (WSED-1) SW: 0.0423 ug/L (RIVER-UP-1)	0.001 mg/m ³	5 mg/m ³ Ca Skin	Irritation of the eyes, chloracne, liver damage, reproductive effects, carcinogen	UK
Mercury	GW: 65.2 ug/L (MW-18) SB: 11,000 mg/kg* (mixed soil 0-10 ft bgs) *elemental mercury detected SS: 1,300 mg/kg (LC-47) SD: 30 mg/kg (WSED-4)	0.05 mg/m ³	10 mg/m ³ Skin	Skin and eye irritation, cough, chest pain, difficult breathing, bronchitis, pneumontitis, tremors, insomnia, irritability, indecision, headache, fatigue, weakness, GI disturbance	UK

Workers may also be exposed to chemicals used during sampling and remediation activities. MSDSs are required for all virgin (i.e., non-contaminant) chemicals brought to the site. These MSDSs are presented as Attachment 8.

A summary of the personal protective equipment required to minimize exposure to environmental contaminants and virgin chemicals is presented in Section 4.

2.6 Potential Routes of Exposure

Potential routes of exposure include the following:

- **Dermal:** Skin contact with contaminated media. This route of exposure is minimized through proper use of PPE, as specified in Personal Protective Equipment Section of this plan.
- **Inhalation:** Inhalation of vapors and contaminated particulates. This route of exposure is minimized through proper respiratory protection and monitoring, as specified in the PPE and Air Monitoring/Sampling Sections of this plan, respectively.
- **Ingestion:** Inadvertent ingestion of contaminated media. This route should not present a concern if good hygiene practices are followed (e.g., wash hands and face before drinking or smoking).

3.0 Roles and Responsibilities

3.1 CH2M HILL Staff Responsibilities

3.1.1 Project Manager

The CH2M HILL project manager (PM) is responsible for providing adequate resources (budget and staff) for project-specific implementation of the HS&E management process. The PM has overall management responsibility for the tasks listed below. The PM may delegate specific tasks to other staff, as described in sections that follow, but retains ultimate responsibility for completion of the following in accordance with this HS&E Plan:

- Incorporate standard terms and conditions, and contract-specific HS&E roles and responsibilities in the contract with the client.
- Budget for the appropriate level of HS&E oversight during field activities. Contact the HSM for budget requirements and guidelines.
- Manage the site and interface with third parties in a manner consistent with our contract and subcontract agreements and the applicable standard of reasonable care.
- Ensure that the overall, project-specific HS&E goals are fully and continuously implemented.
- Ensure that CH2M HILL's SC is completing all duties outlined in this HS&E Plan.
- Promoting a safety culture with onsite CH2M HILL personnel and setting the example for safe behavior.

The PM has the following additional responsibilities when subcontractors are hired:

- Incorporate standard terms and conditions, and contract-specific HS&E roles and responsibilities in subcontract agreements (including flow-down requirements to lower-tier subcontractors).
- Select safe and competent subcontractors by implementing the CH2M HILL Subcontractor Management Program. This program includes the review of subcontractor pre-qualification questionnaires, training and medical monitoring records, and site-specific safety procedures prior to the start of subcontractor's field operations.
- Ensure that acceptable certificates of insurance, including CH2M HILL as named additional insured, are secured as a condition of subcontract award.
- Maintain copies of subcontracts and subcontractor certificates of insurance, bond, contractor's license, training and medical monitoring records, and project-specific HS&E procedures in the project file accessible to site personnel.

- Provide adequate oversight of subcontractor HS&E practices per the HS&E Plan.

3.1.2 Project Health and Safety Manager

The CH2M HILL Project Health and Safety manager (HSM) is responsible to:

- Support the SC's oversight of HS&E practices and interfaces with onsite third parties per the HS&E Plan.
- Conduct audits, as necessary, to assess site conditions and review HS&E program implementation.
- Assist the PM with HS&E budget guidelines.
- Assist with program implementation as needed.

The HSM has the following additional responsibilities when subcontractors are hired:

- Ensure that subcontractor pre-qualification questionnaires are reviewed and assist as applicable in the acceptance or rejection.
- Review and accept or reject subcontractor training records and site-specific safety procedures prior to start of subcontractor's field operations.
- Support the SC's oversight of subcontractor's (and lower-tier subcontractor's) HS&E practices per the HS&E Plan.

3.1.3 Safety Coordinator

The Safety Coordinator (SC) shall be onsite for the duration of onsite work and is responsible for verifying that the project is conducted in a safe manner including the following obligations:

- Verify that this HS&E Plan is current and amended when project activities or conditions change.
- Verify that CH2M HILL site personnel and subcontractors read this HS&E Plan and sign the CH2M HILL Employee Sign-Off Form included in Attachment 1.
- Verify compliance with the requirements of this HS&E Plan, applicable contractor health and safety plan(s) and any federal, state, and local regulations.
- Review and understand contractual obligations regarding HS&E roles and responsibilities.
- Manage the site and interfacing with third parties in a manner consistent with our contract/subcontract agreements and the applicable standard of reasonable care.
- Ensure that programs are effectively functioning to prevent and control hazards on the project.
- Verify that all CH2M HILL employees working in the field have the appropriate level of HS&E training, medical surveillance, and drug and alcohol testing for their job duties

including required specialty training (e.g., fall protection, confined space entry) identified in the Hazard Controls and Safe Work Practices Section of this HS&E Plan.

- Conduct an HS&E orientation for all CH2M HILL team members prior to entering the project work areas and deliver field HS&E training as needed based on project-specific hazards and activities.
- Maintain active and visible involvement using open communication with employees regarding safety issues on the project.
- Verify that safety meetings are conducted and document in the project file as needed throughout the course of the project (e.g., as tasks or hazards change).
- Attend Contractor safety meetings and ask questions about access to work areas, safety hazards, precautions and other general safety issues.
- Post required information onsite. An Occupational Safety and Health Administration (OSHA) job-site poster is required at sites where project field offices, trailers, or equipment-storage boxes are established. Contact the HSM for posters.
- Maintain HS&E records and documentation.
- Act as the project “Hazard Communication Coordinator” and perform the responsibilities outlined in the Hazard Communication section of this HS&E Plan.
- Act as the project “Emergency Response Coordinator” and perform the responsibilities outlined in the Emergency Preparedness section of this HS&E Plan.
- Verify that project HS&E forms, permits and self-assessment checklists are being used as outlined in this plan.
- Ensure that the Drug Testing Hospital Kit is available onsite in the event of a serious injury involving hospital, ambulance, or paramedic care. The hospital kit must accompany the injured employee to the hospital so they will get drug tested. For additional information on the Drug Testing Hospital Kits, refer to Attachment 11.
- Verify appropriate PPE use, availability, and training.
- Inform the HSM of any project incident, ensure that an Incident Report Form (IRF) is completed and conduct incident investigations as outlined in the Incident Reporting and Investigation section of this HS&E Plan.
- Facilitate OSHA or other government agency inspections including accompanying inspector and providing all necessary documentation and follow-up.
- Report all incidents to the HSM and/or the Honeywell HSPM immediately. Depending on the type and severity of incident, we may have to report it to Honeywell within hours of occurrence. The Honeywell HSPM will determine what needs to be reported, the timing of the reporting, and coordinate client notification so local and Corporate Honeywell personnel are appropriately notified.

The SC has the following additional responsibilities when subcontractors are hired:

- Verify that project files available to site personnel include copies of executed contracts and certificates of insurance; bond; contractors license; training, medical monitoring, and drug and alcohol testing records; and project-specific HS&E procedures prior to start of subcontractor's field operations.
- Verify that ongoing training, medical monitoring, and drug and alcohol testing requirements are being met (e.g., 8-hour refresher, random drug testing programs, etc).
- Perform oversight and/or assessments of subcontractor HS&E practices per this HS&E plan and verify that project activity self-assessment checklists have been completed (Attachment 5).

3.1.4 CH2M HILL Employees

All personnel are assigned responsibility for safe and healthy operations. This concept is the foundation for involving all employees in identifying hazards and providing solutions. For any operation, individuals have full authority to stop work and initiate immediate corrective action or control. In addition, each worker has a right and responsibility to report unsafe conditions/practices. This right represents a significant facet of worker empowerment and program ownership. Through shared values and a belief that all accidents are preventable, our employees accept personal responsibility for working safely. Each employee is responsible for the following:

- Perform work in a safe manner without injury, illness or property damage.
- Perform work in accordance with company policies, and report near misses, injuries, illnesses, and unsafe conditions.
- Report all incidents, include near misses, immediately to supervisor, and file proper forms with a human resources representative. Contact your HS&E Manager and the Honeywell HSPM to ensure client reporting procedures are met. It is important to do incident notification immediately because, depending on the type of incident, we may be required to report to Honeywell within hours of the event.
- Report all hazardous conditions and/or hazardous activities immediately to a supervisor for corrective action.
- Intervene when an unsafe behavior and/or condition is observed.
- Complete an HS&E orientation prior to being authorized to enter the project work areas.
- Inspect assigned PPE to ensure the absence of defects and proper function.

3.2 CH2M HILL Employee Medical Surveillance, Training, & Drug Testing

Employees assigned to this project will have the following minimum training.

- 40-hour hazardous waste operations training

- 3-day on-the-job experience
- 8-hour annual hazardous waste refresher training.
- Employees who are in an onsite supervisor role will complete 8 hours of hazardous waste supervisor training
- Drug-Free Workplace training (when drug testing is required)
- Honeywell Program orientation
- Site-specific training/orientation – Review GeoSyntec’s 11/04 HASP

Employees designated as SC will also have completed a 12-hour safety coordinator course. The safety coordinator training course meets the requirements of 29 CFR 1910.120 for on-site supervisor training. An SC must be present during all tasks performed in exclusion or decontamination zones.

The SC and additional designated employees, as necessary, will be certified in first aid and CPR by the American Red Cross, or equivalent. At least one first aid/CPR designated employee must be present during all tasks performed in exclusion or decontamination zones. Certain tasks (e.g., confined-space entry) and contaminants (e.g., lead) may require additional training. Additional training requirements are addressed in the specific hazard sections of this plan.

Employees who perform work activities in the decontamination or exclusion zone shall be enrolled in and have a current medical clearance as required by the medical surveillance program for hazardous waste workers

Pregnant employees shall consult with the Corporate Consulting Physician prior to performing site activities and obtain a physician’s statement of the employee’s ability to perform hazardous activities before being assigned fieldwork.

Drug testing is required for CH2M HILL employees who engage in certain activities at Honeywell sites (e.g., activities involving heavy equipment or drill rigs). Employees who conduct fieldwork may be required to pass an initial 5-panel drug screen and an alcohol screen two weeks prior to starting field activities. These staff will also be required to enroll in a random testing program for the duration of their work on Honeywell, and will be subject to post-incident and "for cause" testing. Contact the HSM to determine if drug testing is required. If site conditions change and/or additional tasks are added, contact the HSM to determine drug and alcohol testing requirements.

Based on specific work activities/tasks, subcontractor personnel may be required to be drug and alcohol screened prior to conducting their field activities. Please contact the Health and Safety Program Manager (HSPM) for details and to determine if subcontractor personnel require drug testing.

Refer to CH2M HILL HSE SOP-113, Medical Surveillance, SOP-110, Training, and SOP-105, Drug-Free Workplace, for additional information.

3.3 CH2M HILL Subcontractors

The table(s) below list the name of each subcontractor, the subcontractor safety representative, and a description of the subcontracted activities to be performed at the site.

Subcontractor	Shamrock
Subcontractor Safety Rep	TBD
Subcontractor Onsite Tasks	Remedial Construction activities in accordance with the Work Plan

Subcontractor	
Subcontractor Safety Rep	
Subcontractor Onsite Tasks	

The subcontractors listed above are covered by this HS&E Plan and must be provided a copy of this document. However, this plan does not address hazards associated with the tasks and equipment for which the subcontractors have been engaged (e.g., drilling, excavation work, electrical). Subcontractors are responsible for the health and safety procedures specific to their work, and are required to submit these procedures to CH2M HILL for review before the start of field work. Subcontractors must comply with all established health and safety plan(s) for this project. The CH2M HILL SC should verify that subcontractor employee training, medical clearance, and fit test records are current and must monitor and enforce compliance with the established HS&E Plan(s). CH2M HILL's oversight does not relieve subcontractors of their responsibility for effective implementation and compliance with the established plan(s).

CH2M HILL team members should endeavor to observe subcontractors' safety performance. This endeavor should be reasonable, and include observation of hazards or unsafe practices that are both readily observable and occur in common work areas. CH2M HILL is not responsible for exhaustive observation for hazards and unsafe practices. The SC is responsible for confirming subcontractor performance against both the subcontractor's task specific safety procedures and applicable self-assessment checklists, as provided in Attachment 5.

HS&E related communications with CH2M HILL subcontractors should be conducted as follows:

- Brief subcontractors on the provisions of this plan, and require them to sign the CH2M HILL HS&E Plan Employee Sign-Off Form, included in Attachment 1.

- Request subcontractor(s) to brief project team on the hazards and precautions related to their work.
- When non-compliant or unsafe conditions or practices are observed, notify the subcontractor safety representative and require corrective action – the subcontractor is responsible for determining and implementing necessary controls and corrective actions.
- When repeat non-compliant or unsafe conditions are observed, notify the subcontractor safety representative and stop affected work until adequate corrective measures are implemented.
- When an apparent imminent danger exists, immediately remove all affected personnel, notify subcontractor safety representative, stop affected work until adequate corrective measures are implemented, and notify the Project Manager, HSM, and SC as appropriate.
- Document all verbal HS&E related communications in project field logbook, daily reports, or other records.

Subcontractors are responsible to:

- Comply with all local, state, and federal HS&E standards; and project/owner HS&E requirements.
- Provide a qualified subcontractor safety representative (SSR) to oversee the subcontractor activities and conduct safety inspections for their work.
- Conduct site-specific orientations for all subcontractor employees.
- Actively participate in the project HS&E program and attend all required safety meetings.
- Meet training, medical monitoring, and drug and alcohol testing requirements for their staff.
- Intervene when they observe unsafe behaviors and/or conditions.
- Maintain equipment and supplies necessary to complete activities in a safe manner.
- Notify the CH2M HILL SC of any injury or incident, including near-misses, immediately and submit reports to CH2M HILL within 24 hours. Additionally, all incidents must be reported to the HSM and Honeywell HSPM immediately so we can meet Honeywell's incident reporting requirements.

Refer to CH2M HILL HSE SOP-215, Contracts, Subcontracts, and HSE Management Practices, for additional information.

3.4 Third Parties

The table(s) below list the name of each third party, the third party safety representative, and a description of the third party activities being performed at the site which have the potential to impact CH2M HILL's activities.

Third Party	None anticipated – Possible EPA oversight representative
Third Party Safety Rep	
Third Party Onsite Tasks	

This HS&E Plan does not cover parties who do not have a contractual relationship with CH2M HILL. CH2M HILL is not responsible for the health and safety or means and methods of a third party's work, and we must never assume such responsibility through our actions (e.g., advising on HS&E issues). In addition to this plan, CH2M HILL staff should review third parties' safety plans so that we remain aware of appropriate precautions that apply to us. Except in unusual situations when conducted by the HSM, CH2M HILL must never comment on or approve a third party's safety procedures. Self-assessment checklists, provided in Attachment 5, are to be used by the SC to review the third party's performance ONLY as it pertains to evaluating CH2M HILL employee and subcontractor exposure and safety.

HS&E related communications with third parties should be conducted as follows:

- Request the third party to brief CH2M HILL employees and subcontractors on the precautions related to the contractor's work.
- When an apparent third party's non-compliant or unsafe condition or practice poses a risk to CH2M HILL employees or subcontractors:
 - Notify the third party's safety representative
 - Request that the third party determine and implement corrective actions
 - If needed, stop affected CH2M HILL work until the third party corrects the condition or practice. Notify the client, Project Manager, and HSM as appropriate.
- If apparent third party's non-compliant or unsafe conditions or practices are observed, inform the third party's safety representative. CH2M HILL's obligation is limited strictly to informing the third party of the observation – the third party is solely responsible for determining and implementing necessary controls and corrective actions.
- If an apparent imminent danger is observed, immediately warn the third party's employee(s) in danger and notify the third party's safety representative. CH2M HILL's obligation is limited strictly to immediately warning the affected individual(s) and

informing the third party of our observation – the third party is solely responsible for determining and implementing necessary controls and corrective actions.

- Document all verbal HS&E related communications in project field logbook, daily reports, or other records.

Refer to CH2M HILL HSE SOP-215, Contracts, Subcontracts, and HSE Management Practices, for additional information.

4.0 Personal Protective Equipment

The PPE hazard assessment performed by the HSM requires the following PPE for use during site activities. The PPE required by the table will be evaluated periodically by the SC to ensure the adequacy based on air monitoring results or changes to expected site conditions. The SC shall coordinate all changes with the HSM. Refer to CH2M HILL HSE SOP-117, Personal Protective Equipment, and SOP-121, Respiratory Protection, for additional information.

4.1 PPE Specifications

PPE requirements for the project are summarized in Table 4-1.

Table 4-1				
Task	Level	Body	Head	Respirator ^b
General site entry Contractor oversight; PCB waste mgmt oversight; truck logging; site walk-throughs	D	The PPE specifications in Section 7.2.5 "Level D Personal Protective Equipment" of the GeoSyntec Project HASP will be followed Work clothes; orange reflective safety vest at all times; steel-toe, leather work boots; work gloves; hard hat, safety glasses		None required
Confirmatory soil sampling	Modified D	The PPE specifications in Section 7.2.4 "Modified Level D Personal Protective Equipment" of the GeoSyntec Project HASP will be followed Coveralls: Polycoated Tyvek® or equivalent; orange reflective safety vest at all times; Boots: Steel-toe, chemical-resistant boots OR steel-toe, leather work boots with outer rubber boot covers Gloves: Inner surgical-style nitrile & outer chemical-resistant nitrile gloves		None required
Tasks requiring upgrade	C	The PPE specifications in Section 7.2.3 "Level C Personal Protective Equipment" of the GeoSyntec Project HASP will be followed		APR, full face, with mercury vapor/chlorine cartridges
Tasks requiring upgrade Not authorized for current activities	B	The PPE specifications in Section 7.2.2 "Level B Personal Protective Equipment" of the GeoSyntec Project HASP will be followed		

^a Modifications are as indicated. CH2M HILL will provide PPE only to CH2M HILL employees.

^b No facial hair that would interfere with respirator fit is permitted.

^c Hardhat and splash-shield areas are to be determined by the SC.

^d Ear protection should be worn when conversations cannot be held at distances of 3 feet or less without shouting.

^e Cartridge change-out schedule will be established by the HSM and at a minimum shall be at least every 8 hours (or one work day), except if relative humidity is > 85%, or if organic vapor measurements are > midpoint of Level C range (refer to Section 5)--then at least every 4 hours. If encountered conditions are different than those anticipated in this HS&E Plan, contact the HSM.

During all sampling activities listed above, air monitoring for mercury using a Jerome Mercury Vapor Analyzer (MVA), or equivalent, and organic vapor monitoring with a photoionization detector (PID) will be performed in accordance with Section 5.1 “Air Monitoring Specifications” of this HASP.

4.2 Reasons for Changing Level of Protection

Reasons for upgrading or downgrading the level of PPE are provided below.

4.2.1 Upgrade

Potential reasons for upgrading PPE level are listed below. *Note: Performing a task that requires an upgrade to a higher level of protection (e.g., Level D to Level C) is permitted only when the PPE requirements have been approved by the HSM, and an SC qualified at that level is present.*

- Request from individual performing tasks.
- Change in work tasks that will increase contact or potential contact with hazardous materials.
- Occurrence or likely occurrence of gas or vapor emission.
- Known or suspected presence of dermal hazards.
- Instrument action levels (Section 5) exceeded.

4.2.2 Downgrade

Potential reasons for downgrading PPE level are listed below.

- New information indicating that situation is less hazardous than originally thought.
- Change in site conditions that decreases the hazard.
- Change in work task that will reduce contact with hazardous materials.

5.0 Air Monitoring/Sampling

Air monitoring and sampling must be performed to verify that our employees are not be exposed to harmful levels of airborne contaminants and that airborne contaminants are not migrating into public areas.

Refer to CH2M HILL SOP HSE-207, *Exposure Assessment for Airborne Chemical Hazards*, for additional information

5.1 Air Monitoring Specifications

Air monitoring specifications are summarized in Table 5-1

Air Monitoring Instrument	Level D	Level C	Level B
Jerome Mercury Vapor Analyzer (MVA), or equivalent During activities that may impact mercury impacted soils (placement of clean fill and liner over former mercury cell area)	<0.025 mg/m ³	0.025 – 0.25 mg/m ^{3(a)}	>0.25 mg/m ³
MiniRAE Photoionization Detector (PID), or equivalent Initially and periodically throughout the day	<5 ppm	>5 – 25 ppm (b)	>25 ppm
MIE Miniram Model PDM-3 dust meter, or equivalent Continuous – upwind/downwind datalog readings each day	<3 mg/m ³	3 – 5 mg/m ³ (b)	>5 mg/m ³

Note a: Respirator cartridges (Mersorb® or equivalent) must be available at all times, and used when Level C action level for mercury is exceeded.

Note b: Respirator cartridges (combination organic vapor and P100 filter) must be available at all times, and used when Level C action level for organic vapors or dust is exceeded.

5.2 Calibration

Instruments will be function tested in accordance with the respective manufacturer's instructions for proper instrument use and maintenance. The instrument vendor or the CH2M HILL warehouse staff will ensure equipment has been calibrated in accordance with manufacturer's specifications.

All direct reading instruments will be function tested daily by the SC using span gas, prior to performing work activities and after the completion of the daily activities.

5.3 Air Sampling

Sampling, in addition to real-time monitoring, may be required by other OSHA regulations where there may be exposure to certain contaminants. Air sampling typically is required when site contaminants include lead, cadmium, arsenic, asbestos, beryllium, hexavalent chromium, benzene, methylene chloride, vinyl chloride and certain volatile organic compounds. Air sampling methods will be National Institute for Occupational Safety and Health (NIOSH) or OSHA-certified and samples analyzed by a laboratory that is accredited by the American Industrial Hygiene Association (AIHA) for the compound specific method.

The HSM will develop and specify a sampling approach that includes the number and frequency of sampling events. This approach will be included in this section. The HSM shall interpret all air sampling results and modify the requirements of this HS&E Plan, based on the interpretation. Written notification of air sampling results will be provided to the CH2M HILL site employees and maintained in their HS&E records.

6.0 Decontamination

The SC must establish the specific decontamination procedures for the specific site tasks. The SC must monitor the decontamination procedures, and should modify any procedures found to be ineffective. The SC must ensure that procedures are established for disposing of materials generated on the site.

Refer to CH2M HILL HSE SOP-506, Decontamination, for additional information.

6.1 Decontamination Requirements

A personal decontamination station to wash work boots and remove loose soil from work clothes shall be placed in the CRZ prior to site exit. Potential decontamination procedures are provided in Table 6.1 – applicable procedures should be incorporated based on site conditions at the discretion of the SC.

The contractor shall install and maintain a truck equipment decontamination area in accordance with the provisions described in the Work Plan.

TABLE 6-1
Possible Decontamination Procedures

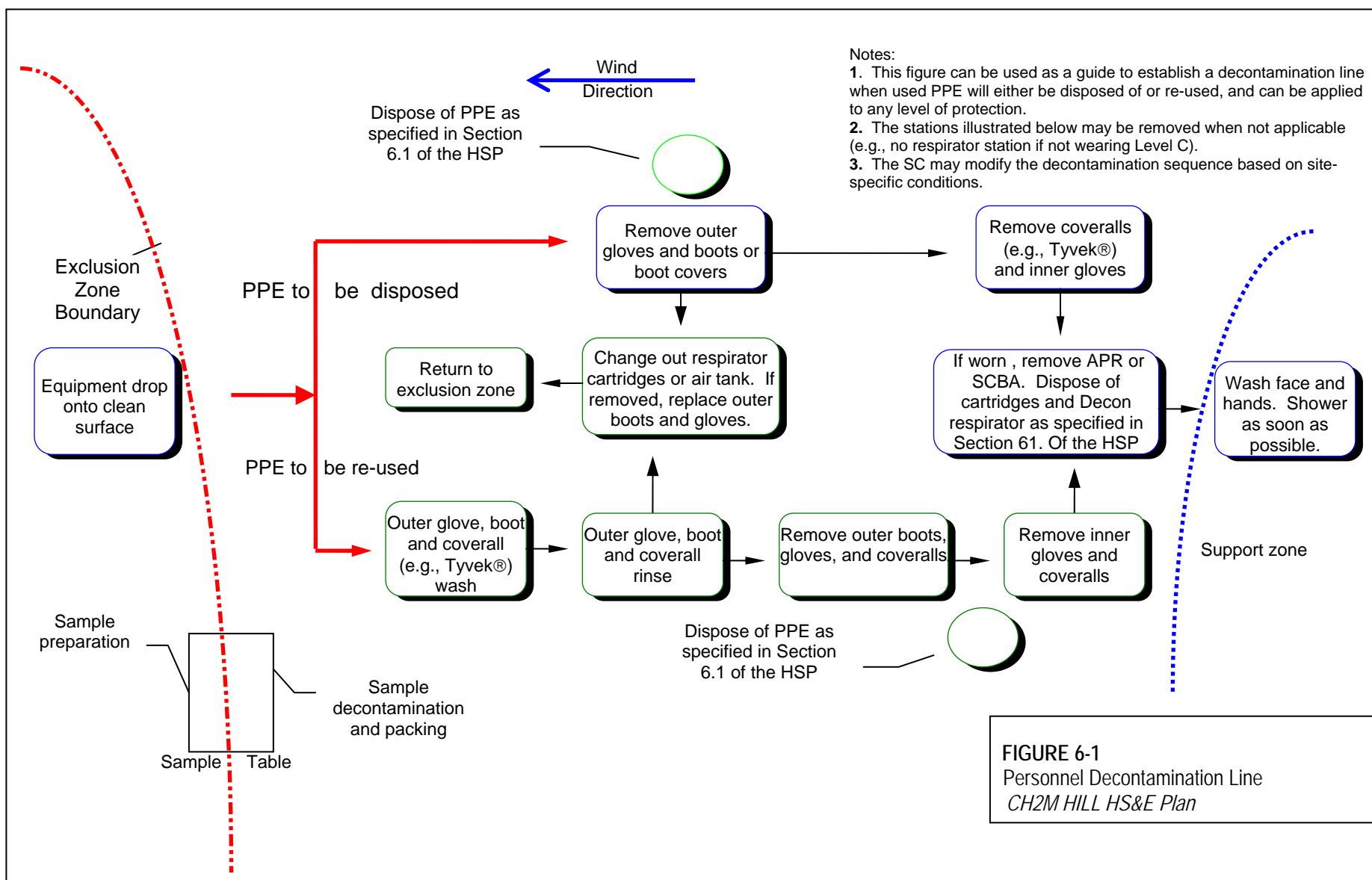
Personnel	Sample Equipment	Heavy Equipment
<ul style="list-style-type: none">• Boot wash/rinse• Glove wash/rinse• Outer-glove removal• Body-suit removal• Inner-glove removal• Respirator removal• Hand wash/rinse• Face wash/rinse• Shower• Disposal of PPE in municipal trash, or containment for disposal• Disposal of personnel rinse water to facility or sanitary sewer, or containment for offsite disposal	<ul style="list-style-type: none">• Wash/rinse equipment• Solvent-rinse equipment• Contain solvent waste for offsite disposal	<ul style="list-style-type: none">• Power wash• Steam clean• Dispose of equipment rinse water to facility or sanitary sewer, or contain for offsite disposal

6.2 Diagram of Personnel Decontamination Line

Figure 6-1 illustrates a conceptual establishment of work zones, including the decontamination line. Work zones are to be modified by the SC to accommodate task-specific requirements. No eating, drinking, or smoking is permitted in contaminated areas or in exclusion and decontamination zones. The SC should establish areas for these activities.

6.3 Collection and Disposal of Decontamination Wastes

Contaminated materials, PPE, and fluids shall be managed according to waste management procedures specified in the project Work Plan. If no such guidance is available, please contact the ECC for additional information and procedures.



7.0 Spill Containment and Notification

This section describes spill containment and notification requirements.

7.1 SPCC Regulated Facility

If the client facility is subject to a Spill Prevention, Control and Countermeasures (SPCC) Plan, a copy must be obtained and all spill prevention and response must conform to client SPCC requirements. If the client does not have an SPCC Plan and the project requires storage of more than 1,320 gallons of petroleum in 55-gallon containers or greater, a project-specific SPCC plan will be prepared.

7.2 Non-SPCC Regulated Facility

Projects not subject to SPCC requirements shall comply with this section. All onsite personnel shall be trained to follow the procedures described in this section.

7.2.1 Equipment

Field staff should obtain client approval for use of client-owned spill containment equipment. If client equipment is not available, the minimum spill equipment that shall be made available in the project's support zone is described in Table 7-1. Additional contaminant-specific spill response information may be included in the chemical MSDS.

TABLE 7-1
Minimum Spill Kit Equipment List

Spill Kit Contents
<ul style="list-style-type: none">• Absorbent material (kitty litter or vermiculite)• Neutralizers (for chemical spills)• Sodium Carbonate (acid spills)• Citric Acid (base spills)• Absorbent socks and pads• Safety Goggles• Protective Gloves• Tyvek Suit• Waste Containers and Labels

7.2.2 Emergency Spill Event

The release of an unknown hazardous material is considered an emergency spill event. Implement the following procedures during an emergency spill event:

1. Evacuate the area and go upwind
2. Warn others and direct them upwind
3. Immediately contact the onsite Safety Coordinator who will contact the HSM for direction

7.2.3 Non-Emergency Spill Event

A non-emergency spill event includes incidental releases that do not pose a significant safety or health hazard where chemical hazards are known and CH2M HILL personnel can safely implement the following procedures as a first responder:

1. Stop the source of the spill
2. Contain the spill material. If there is a chance the spill will reach nearby drains or waterways, block them off to keep the spill away
3. Contact the onsite Safety Coordinator

7.2.4 Cleanup

Clean up the spilled material wearing the proper PPE identified in the HS&E Plan equipment table if the spilled material is less than 5 gallons and hazards are known. Spills larger than 5 gallons must be cleaned up by a qualified subcontractor since CH2M HILL personnel are not trained to implement OSHA spill response requirements. Dispose of spill debris according to the Waste Management Plan or as directed by the ECC.

7.2.5 Notification and Reporting

All spills are considered an “incident” and shall be reported internally according to procedures in HSE SOP-111, Incident Reporting and Investigation. Since many spills may require agency reporting within 24 hours, it is very important that internal notification occur immediately. The following summarizes required actions:

1. **Immediately** notify the onsite Safety Coordinator
2. SC notifies the HSM
3. HSM notifies the PM, who notifies the client
4. HSM notifies the Legal Department of a serious incident
5. HSM, ECC, and client shall determine if the incident is reportable to an agency

8.0 Site-Control Procedures

The following site control procedures shall be implemented at the site:

- The SC and Contractor's H&S site representative will conduct a site safety briefing before starting field activities or as tasks and site conditions change.
- Topics for the site safety briefing include general discussion of the HS&E plan, site-specific hazards, locations of work zones, PPE requirements, equipment, special procedures, and emergencies.
- The SC will record attendance at safety briefings in a logbook and document the topics discussed.
- All site visitors shall log in and out of a site visitor log book to be maintained by the SC and/or the contractors H&S representative. All site visitors shall review the HASP and sign off the plan acceptance form. All site visitors shall be escorted at all times by either a representative from either CH2M HILL or the Contractor. Appropriate PPE shall be made available and offered to all site visitors.
- Establish support, decontamination, and exclusion zones. Delineate with flags or cones as appropriate. Support zone should be upwind of the site. Use access control at entry and exit from each work zone.
- Establish onsite communication consisting of the following:
 - Line-of-sight and hand signals
 - Air horn
 - Two-way radio or cellular telephone if available
- Establish offsite communication.
- Establish and maintain the "buddy system."
- Initial air monitoring shall be conducted by the SC using an appropriate level of PPE.
- The SC is to conduct periodic inspections of work practices to determine the effectiveness of this plan. Deficiencies are to be noted, reported to the HSM, and corrected.

Refer to CH2M HILL HSE SOP-510, Site Control, for additional information.

9.0 Hazwoper Compliance Plan

Certain parts of the site work are covered by state or federal Hazwoper standards and therefore require training and medical monitoring. Anticipated Hazwoper tasks (Section 1.3.1) might occur consecutively or concurrently with respect to non-Hazwoper tasks. This section outlines procedures to be followed when approved activities specified in Section 1.3.2 do not require 24- or 40-hour training. Non-Hazwoper-trained personnel also must be trained in accordance with all other state and federal OSHA requirements.

- In many cases, air sampling, in addition to real-time monitoring, must confirm that there is no exposure to gases or vapors before non-Hazwoper-trained personnel are allowed on the site, or while non-Hazwoper-trained staff are working in proximity to Hazwoper activities. Other data (e.g., soil) also must document that there is no potential for exposure. The HSM must approve the interpretation of these data. Refer to subsections 2.5 and 5.3 for contaminant data and air sampling requirements, respectively.
- When non-Hazwoper-trained personnel are at risk of exposure, the SC must post the exclusion zone and inform non-Hazwoper-trained personnel of the:
 - Nature of the existing contamination and its locations
 - Limitations of their access
 - Emergency action plan for the site
- Periodic air monitoring with direct-reading instruments conducted during regulated tasks also should be used to ensure that non-Hazwoper-trained personnel (e.g., in an adjacent area) are not exposed to airborne contaminants.
- When exposure is possible, non-Hazwoper-trained personnel must be removed from the site until it can be demonstrated that there is no longer a potential for exposure to health and safety hazards.
- Procedures for remediation treatment system start-ups are as follows: Once a treatment system begins to pump and treat contaminated media, the site is, for the purposes of applying the Hazwoper standard, considered a treatment, storage, and disposal facility (TSDF). Therefore, once the system begins operation, only Hazwoper-trained personnel (minimum of 24 hour of training) will be permitted to enter the site. All non-Hazwoper-trained personnel must not enter the TSDF area of the site.

Refer to CH2M HILL HSE SOP-220, Site-Specific Written Safety Plans, for additional information.

10.0 Incident Reporting and Investigation

This section describes the notification and investigation requirements pertaining to a site incident. Refer to CH2M HILL HSE SOP-111, Incident Reporting and Investigation, for additional information.

10.1 Definitions

10.1.1 Incident

An incident is an undesired event that results or could have resulted in an injury, illness, damage to assets or environment harm. The following events shall be considered incidents:

- Injury or illness to a CH2M HILL employee or CH2M HILL subcontractor employee
- Injury or illness to a third party that was caused by a CH2M HILL activity
- Hazardous substance exposure
- Damage to property or equipment
- Motor vehicle accident
- Fire or explosion
- Spill or release
- Environmental issue permit violation
- A “near-miss”

10.1.2 Near-Miss

A near-miss occurs when an intervening factor prevented an injury, damage to property, or environmental harm from occurring. Examples of near-miss situations include: a hard hat or other PPE prevented an injury; secondary containment or emergency shutoff prevented a spill; or an alert co-worker prevented an accident.

10.1.3 Serious Incidents

The HSM and Legal and Insurance Department (LID) shall determine if an event should be considered as a serious incident after reviewing the initial incident facts. The general criteria for serious incidents include:

- Intervention by external emergency response organizations
- Hospitalization
- Spills and releases of hazardous substances exceeding the reportable quantity (RQ)
- Potential violations of law or regulation
- Estimated property damage in excess of \$10,000

10.2 Incident Notification and Communication

Injury Reporting

- If a CH2M HILL employee is injured immediately notify their group leader.

- Call the CH2M HILL Occupational Health Nurse

1-800-756-1130

- In case of emergency call 911.

Incident Notification and Reporting

- Upon any other project incident (fire, spill, , near miss, death, etc.), immediately notify the PM and HSM. Call emergency beeper number if HSM is unavailable.
- Notify and submit reports to client as required in contract.
- Serious Incidents must be reported in accordance with CH2M HILL Standard of Practice, *Serious Incident Reporting Process*, immediately. Serious incidents are those that involve any of the following:
 - Work related death, or life threatening injury or illness of a CH2M HILL employee, subcontractor, or member of the public
 - Kidnap/missing person
 - Acts or threats of terrorism
 - Event that involves a fire, explosion, or property damage that requires a site evacuation or is estimated to result in greater than \$ 500,000 in damage.

Spill or release of hazardous materials or substances that involves a significant threat of imminent harm to site workers, neighboring facilities, the community or the environment

All CH2M HILL and subcontractors' employees shall immediately report any incident in which they are involved to their direct supervisor, and the supervisor shall inform the CH2M HILL SC. The SC shall then contact the PM, HSM, and the Honeywell HSPM immediately. Immediate reporting is critical because there are certain types of incidents that must be reported to Honeywell within hours of occurrence. The Honeywell HSPM will help the team determine what needs to be reported to Honeywell, how quickly it needs to be reported to Honeywell, and who at Honeywell (local, corporate, etc) needs to be notified.

Incident communications regarding serious incidents (regardless of the party involved) shall be considered sensitive in nature and must be controlled in a confidential manner. Internal communications regarding a serious incident may be conducted with affected project, regional, and Business Group staff but must be kept to a minimum. Communication should be oral whenever possible. If e-mail communications are necessary they shall be sent as confidential emails following the procedure provided in section 6.2.2 of CH2M HILL HSE SOP-111, Incident Reporting and Investigation. A LID representative shall direct all internal and external communications, including internal incident reporting, agency reporting, client notification, and incident investigations.

10.3 Incident Reporting

The PM or the HSPM will be responsible to ensure that the incident is entered into Honeywell's event tracking system and an IRF is completed within 24 hours of any incident. The HSPM can assist with complying with entering information into Honeywell's event tracking system. CH2M HILL's requirements can be met by entering an electronic IRF directly into the IRF database. The electronic IRF is found on the CH2M HILL HS&E web page under Tools and Forms>Electronic Tools and Forms. If unable to submit an IRF electronically, the SC shall complete the hardcopy IRF provided in Attachment 12 and fax the IRF to the human resources representative (for CH2M HILL employee injuries), the PM,

or the HSM (for all other incidents) for database entry. A copy of the hard-copy form should also be sent to the Honeywell HSPM. **An IRF for a serious incident shall not be initiated until directed by a representative of the LID.**

When additional or updated information becomes available that was not included in the original IRF the PM shall forward such information to the human resources representative (for CH2M HILL employee injuries) or the HSM (for all other incidents) so that the IRF may be updated. Updates to IRF reports should also be sent to the Honeywell HSPM.

CH2M HILL staff shall comply with all applicable statutory incident reporting requirements such as those required by Federal agencies (EPA, OSHA, etc) and local authorities (police).

10.4 Incident Investigation

Incident investigations are to be initiated and completed as soon as possible, but no later than 72 hours after the incident has occurred. The level and type of investigation will be determined by Honeywell and/or the Honeywell HSPM. **All serious incidents shall be investigated as directed by a representative of the LID.** The HSM/ECC may conduct the investigation directly or may delegate this function to the SC or other party, depending on the extent of the incident and staff availability.

The Incident Investigation Guideline provided in Attachment 12 shall be followed when documenting an investigation. Typically, minor incident investigations will be completed by the HSM/ECC by including the investigation facts in the IRF. The HSM/ECC may require completion of a separate investigation report or the Root Cause Analysis Form for more extensive investigations. The HSM/ECC shall ensure that the PM and SC are made aware of investigation findings and all corrective actions, and shall verify that corrective actions are implemented to prevent further incidents.

10.5 Corrective Actions

All corrective actions recommended from the incident investigation report shall be taken to prevent recurrence of the incident. The PM or SC should hold a review meeting to discuss the incident and the corrective actions. The responsible supervisors shall be assigned to carry out the corrective actions and shall inform the SC upon successful implementation of all corrective actions.

11.0 Emergency Preparedness

An emergency may be an injury to a worker, an explosion, evacuation, fire, or chemical release. Employees must know what to do if an emergency occurs. This requires pre-planning and communication of these plans to employees.

Refer to CH2M HILL HSE SOP-106, Emergency Planning, for additional information.

11.1 Pre-Emergency Planning

The SC shall perform the following pre-emergency planning tasks before starting field activities and coordinate emergency response with CH2M HILL onsite parties, the facility, and local emergency-service providers as appropriate.

- Coordinate with property owner and/or review the facility emergency and contingency plans where applicable. Have a copy readily available at the site for review and attach a copy to this HS&E Plan.
- Complete and post the Emergency Contacts form provided in the front matter of this document. The SC should confirm that all information provided on the Emergency Contacts form is accurate and appropriately updated.
- Confirm and post evacuation routes, assembly areas and route to hospital.
- Determine what onsite communication equipment is available (e.g., two-way radio, air horn)
- Determine what offsite communication equipment is needed (e.g., nearest telephone, cell phone)
- Communicate emergency procedures to all field staff prior to field activities.
- Post “Exit” signs above exit doors and post “Fire Extinguisher” signs above locations of extinguishers in field trailers.
- Keep areas near exits and extinguishers free of obstructions.
- Designate one vehicle as the emergency vehicle, place hospital directions and map inside, and keep keys in ignition during field activities
- Where appropriate and acceptable to the client, inform emergency room and external emergency response organizations of anticipated types of site emergencies.
- Rehearse the emergency response plan before site activities begin, including driving the route to the hospital.
- Emergency drills should be performed periodically, but at least once per year. Upon completion of each drill, the SC shall evaluate the effectiveness of the emergency plan.

Any problems or concerns identified during the evaluation must be corrected immediately.

11.2 Emergency Equipment and Supplies

The SC shall verify that appropriate emergency equipment and supplies are available, as needed, and in proper working order and mark the locations of the equipment on the site map when a map is provided. The following equipment and supplies are typically required:

- Fire Extinguishers
- First aid kit
- Bloodborne pathogen kit
- Personal eye wash station
- Potable water

11.3 Incident Response

The following actions shall be taken in the event of a fire, explosion, or chemical release:

- Shut down CH2M HILL operations and evacuate the immediate area
- Notify appropriate response personnel
- Account for personnel at the designated assembly area(s)
- Assess the need for site evacuation, and evacuate the site as warranted

11.4 Evacuation Procedures

Typical evacuation procedures include the following:

- Evacuation routes and assembly areas will be designated by the SC before work begins
- Personnel will assemble at the assembly area(s) upon hearing the emergency signal for evacuation
- The SC and a “buddy” will remain on the site after the site has been evacuated (if safe) to inform local responders of the nature and location of the incident
- The SC will account for all personnel at the assembly area
- The SC will write up a report as soon as possible after the emergency the following the guidelines provided in the Incident Report Section of the HS&E Plan.

11.5 Emergency Medical Treatment

The following actions shall be taken in the event of a medical emergency:

- Get medical attention immediately.
- Notify appropriate emergency response authorities listed on the Emergency Contacts form, as necessary.
- Prevent further injury.
- Initiate first aid and CPR where feasible.
- Make certain that the injured person is accompanied to the emergency room.

The SC will assume control during a medical emergency until the ambulance arrives or until the injured person is admitted to the emergency room. If the injured is a CH2M HILL employee, the SC or PM must accompany the injured CH2M HILL employee to the emergency room and to any follow-up appointments until the injured is released to full duty.

If there is doubt about whether medical treatment is necessary, or if the injured person is reluctant to accept medical treatment, contact the CH2M HILL medical consultant. When contacting the medical consultant, state that the situation is a CH2M HILL matter, and give your name and telephone number, the name of the injured person, the extent of the injury or exposure, and the name and location of the medical facility where the injured person was taken.

The SC shall ensure that all injuries are reported according to the guidelines in the Incident Reporting and Investigation Section of this HS&E Plan.

12.0 Recordkeeping

The following records (see Table 12-1) shall be maintained as indicated. Refer to CH2M HILL SOP HSE-15 for complete recordkeeping requirements and additional information.

TABLE 12-1
Recordkeeping Requirements

Record	Location	Duration
Medical and Exposure Records	Medical & Training Administrator	Employment + 30 years
HS&E Plans	Project File; MTA	Project duration + 5 years
HS&E Training Records	Project File; HandS Database	Employment + 30 years
Environmental Documentation (permits, approvals, manifests)	Project File; HS&E Archive	Project duration + 5 years

Attachment 1
Employee Signoff Form

EMPLOYEE SIGNOFF FORM**Health, Safety and Environment Plan**

The CH2M HILL project employees and subcontractors listed below have been provided with a copy of this HS&E Plan, have read and understood it, and agree to abide by its provisions.

Project Name: Acme - Riegelwood, North Carolina - LCP **Project Number:** 365628
Holtrachem - Remedial Construction

EMPLOYEE NAME (Please print)	EMPLOYEE SIGNATURE	COMPANY	DATE

Attachment 2
Job Hazard Analysis

JOB/TASK NAME: Confirmatory soil sampling – oversight of remedial action excavation-loading - IDW Management		DATE: 11-07	NEW ____ REVISED ____	PAGE ____ OF ____
ASSOCIATE(S)/JOB TITLE PERFORMING THE JOB/TASK:		SUPERVISOR(S): Marshall Linton Robert Custance		ANALYSIS PERFORMED BY:
PROJECT NAME AND JOB/TASK LOCATION: Honeywell – Acme Holtrachem – Remedial Construction – Riegelwood, North Carolina		DEPARTMENT(S):		REVIEWED BY: Bill Berlett
PERSONAL PROTECTIVE EQUIPMENT:		SHIFT (if applicable):		APPROVED BY: Bill Berlett
<u>JOB STEPS</u>		<u>POSSIBLE HAZARDS</u>		<u>PROCEDURE/ACTION TO CONTROL OR ELIMINATE</u>
1.	Mobilization and travel between grids	Vehicle Operation 1) Opening/closing doors, windows and trunk 2) Loading objects 3) Driving 4) Parking 5) Distractions 6) Emergency preparedness	1) Keep fingers and hands free from pinch points 2) Use a golfer lift (raise one leg) while removing items from trunk. 3) Follow the Smith System's "5 keys of Safe Driving". a) Aim high in steering b) Get the Big picture c) Keep your eyes moving d) Leave yourself an out e) Make sure others see you 4) Park in a manner that will allow for safe exit from vehicle, and where practicable, park vehicle so that it can serve as a barrier 5) <u>Do not</u> do the following while driving: a) Talk on a mobile phone b) Eat or drink c) Take your eyes off of the road to adjust radio 6) Wear seat belt, maintain a first aid kit, and inform others of travel plans.	
		Traffic 1) Struck by	1) The following precautions must be taken when working around traffic: a) Exercise caution when exiting traveled way or parking along street – avoid sudden stops, use flashers, etc. b) Park in a manner that will allow for safe exit from vehicle, and where practicable, park vehicle so that it can serve as a barrier. c) Wear reflective/high-visibility safety vests. d) Eye protection should be worn to protect from flying debris. e) Remain aware of factors that influence traffic related hazards and required controls – sun glare, rain, wind, flash flooding, limited sight-distance, hills, curves, guardrails, width of shoulder, etc. f) Always remain aware of an escape route -- behind an established barrier, parked vehicle, guardrail, etc. g) Always pay attention to moving traffic – never assume drivers are looking out for you	
2.	Sampling and IDW Management	Slip/ Trip/ Fall 1) Walking 2) Sampling	1) Precautions to take while sampling excavations – depths of excavation will be no greater than 4 feet below ground surface – otherwise samples will be collected using backhoe bucket: a) Maintain housekeeping (i.e. hoses, debris, standing water, etc.) i. Store sampling equipment out of the way when it is not in use ii. Be aware of placement of tools, hoses from equipment and other equipment iii. Clean up any spills before continuing work	

		Chemical Exposure 1) Field instrument calibration chemicals, sample preservative chemicals, decontamination solutions, untreated groundwater, equipment gasoline and oil	1) Review the "Site Specific Health and Safety Plan". a) Contaminants of Concern Table b) Refer to Personal Protective Equipment Schedule c) Refer to air monitoring d) Personal hygiene i. No eating, drink or smoking. ii. Wash hands and face after performing task 2) To prevent exposure from chemicals: a) Review Material Safety Data Sheet (MSDS). b) Utilize Personal Protective Equipment identified in this Health and Safety Plan c) Label all bottles and containers d) Store chemicals in properly labeled containers
3.	Material Handling and IDW Management	Lifting Objects (sample coolers, compressors) 1) Back Strain 2) Crushed appendages, scrapes, abrasions and cuts	1) Utilize a material handling device or a buddy to lift any object >25 pounds. For all other manual lifting, follow these recommendations: a) Stand with your feet at least shoulder distance apart. b) Position your feet to face the direction of travel. c) Slightly bend your knees. d) Start to squat, bending your hips and knees, not your waist. e) Keep load close to body and raise yourself using your leg and hip muscles. f) Tighten your stomach muscles as you lift. g) Avoid twisting movements. 2) Prevent crush hazards by: a) Not positioning fingers or toes under object b) Wearing steel toed or safety toed boots 3) Prevent abrasions, scrapes and cuts by: a) Being aware of sharp edges and other parts of stainless steel wells b) If sample containers break, clean up broken glass and dispose of in a puncture proof container. c) Decontamination procedures must also be followed if the broken container contained chemical preservative or untreated groundwater.

PRINT NAME

SIGNATURE

Supervisor Name: _____

Date: _____

Safety Officer Name: _____

Date: _____

Employee Name(s): _____

Date: _____

Date: _____

Date: _____

Date: _____

Date: _____

Activity:	Date:
	Project:
Description of the work:	Site Supervisor:
	Site Safety Officer:
	Review for latest use: Before the job is performed.

Work Activity Sequence (Identify the principal steps involved and the sequence of work activities)	Potential Health and Safety Hazards (Analyze each principal step for potential hazards)	Hazard Controls (Develop specific controls for each potential hazard)

Equipment to be used (List equipment to be used in the work activity)	Inspection Requirements (List inspection requirements for the work activity)	Training Requirements (List training requirements including hazard communication)

PRINT NAME

SIGNATURE

Supervisor Name: _____

Date/Time: _____

Safety Officer Name: _____

Date/Time: _____

Employee Name(s): _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Date/Time: _____

Attachment 3
Daily Tailgate Safety Briefing Form

CH2M HILL Daily Tailgate Safety Briefing Form		
Project Name:		Project Number:
Date:	Start Time:	Completed Time:
Site Location:		
Type of Work (general):		
Safety Issues		
Tasks (this shift):		
PPE Requirements:		
Chemical Hazards:		
Air Monitoring Requirements:		
Physical Hazards:		
Control Measures:		
Hazard Communication Overview (MSDSs):		
Special Topics (i.e., incidents, near misses, etc.)		
Daily Checklist		
HSE Plan up to date and present onsite?	Yes	No
Air monitoring equipment present, working, and calibrated?	Yes	No
Personnel training current?	Yes	No
Hospital Route Map and Emergency Phone Numbers posted onsite?	Yes	No
PPE present and worn by personnel?	Yes	No
Comments:		
Attendees		
Print Name	Sign Name	
Meeting conducted by:		

Attachment 4
Pre-Task Safety Plan

CH2MHILL

Pre-Task Safety Plan (PTSP)

Project: _____ Location: _____ Date: _____		
Supervisor: _____ Job Activity: _____ _____		
Task Personnel: _____ _____ _____ _____		
List Tasks: _____ _____ _____ _____		
Tools/Equipment Required for Tasks (ladders, scaffolds, fall protection, cranes/rigging, heavy equipment, power tools): _____ _____ _____		
Potential H&S Hazards, including chemical, physical, safety, biological and environmental (check all that apply):		
___ Chemical burns/contact	___ Trench, excavations, cave-ins	___ Ergonomics
___ Pressurized lines/equipment	___ Overexertion	___ Chemical splash
___ Thermal burns	___ Pinch points	___ Poisonous plants/insects
___ Electrical	___ Cuts/abrasions	___ Eye hazards/flying projectile
___ Weather conditions	___ Spills	___ Inhalation hazard
___ Heights/fall > 6 feet	___ Overhead Electrical hazards	___ Heat/cold stress
___ Noise	___ Elevated loads	___ Water/drowning hazard
___ Explosion/fire	___ Slips, trip and falls	___ Heavy equipment
___ Radiation	___ Manual lifting	___ Aerial lifts/platforms
___ Confined space entry	___ Welding/cutting	___ Demolition
Other Potential Hazards (Describe): _____ _____ _____ _____		

Hazard Control Measures (Check All That Apply):			
PPE <input type="checkbox"/> Thermal/lined <input type="checkbox"/> Eye <input type="checkbox"/> Dermal/hand <input type="checkbox"/> Hearing <input type="checkbox"/> Respiratory <input type="checkbox"/> Reflective vests <input type="checkbox"/> Flotation device	Protective Systems <input type="checkbox"/> Sloping <input type="checkbox"/> Shoring <input type="checkbox"/> Trench box <input type="checkbox"/> Barricades <input type="checkbox"/> Competent person <input type="checkbox"/> Locate buried utilities <input type="checkbox"/> Daily inspections	Fire Protection <input type="checkbox"/> Fire extinguishers <input type="checkbox"/> Fire watch <input type="checkbox"/> Non-spark tools <input type="checkbox"/> Grounding/bonding <input type="checkbox"/> Intrinsically safe equipment	Electrical <input type="checkbox"/> Lockout/tagout <input type="checkbox"/> Grounded <input type="checkbox"/> Panels covered <input type="checkbox"/> GFCI/extension cords <input type="checkbox"/> Power tools/cord inspected
Fall Protection <input type="checkbox"/> Harness/lanyards <input type="checkbox"/> Adequate anchorage <input type="checkbox"/> Guardrail system <input type="checkbox"/> Covered opening <input type="checkbox"/> Fixed barricades <input type="checkbox"/> Warning system	Air Monitoring <input type="checkbox"/> PID/FID <input type="checkbox"/> Detector tubes <input type="checkbox"/> Radiation <input type="checkbox"/> Personnel sampling <input type="checkbox"/> LEL/O2 <input type="checkbox"/> Other	Proper Equipment <input type="checkbox"/> Aerial lift/ladders/scaffolds <input type="checkbox"/> Forklift/heavy equipment <input type="checkbox"/> Backup alarms <input type="checkbox"/> Hand/power tools <input type="checkbox"/> Crane with current inspection <input type="checkbox"/> Proper rigging <input type="checkbox"/> Operator qualified	Welding & Cutting <input type="checkbox"/> Cylinders secured/capped <input type="checkbox"/> Cylinders separated/upright <input type="checkbox"/> Flash-back arrestors <input type="checkbox"/> No cylinders in CSE <input type="checkbox"/> Flame retardant clothing <input type="checkbox"/> Appropriate goggles
Confined Space Entry <input type="checkbox"/> Isolation <input type="checkbox"/> Air monitoring <input type="checkbox"/> Trained personnel <input type="checkbox"/> Permit completed <input type="checkbox"/> Rescue	Medical/ER <input type="checkbox"/> First-aid kit <input type="checkbox"/> Eye wash <input type="checkbox"/> FA-CPR trained personnel <input type="checkbox"/> Route to hospital	Heat/Cold Stress <input type="checkbox"/> Work/rest regime <input type="checkbox"/> Rest area <input type="checkbox"/> Liquids available <input type="checkbox"/> Monitoring <input type="checkbox"/> Training	Vehicle/Traffic <input type="checkbox"/> Traffic control <input type="checkbox"/> Barricades <input type="checkbox"/> Flags <input type="checkbox"/> Signs
Permits <input type="checkbox"/> Hot work <input type="checkbox"/> Confined space <input type="checkbox"/> Lockout/tagout <input type="checkbox"/> Excavation <input type="checkbox"/> Demolition <input type="checkbox"/> Energized work	Demolition <input type="checkbox"/> Pre-demolition survey <input type="checkbox"/> Structure condition <input type="checkbox"/> Isolate area/utilities <input type="checkbox"/> Competent person <input type="checkbox"/> Hazmat present	Inspections: <input type="checkbox"/> Ladders/aerial lifts <input type="checkbox"/> Lanyards/harness <input type="checkbox"/> Scaffolds <input type="checkbox"/> Heavy equipment <input type="checkbox"/> Cranes and rigging	Training: <input type="checkbox"/> Hazwaste <input type="checkbox"/> Construction <input type="checkbox"/> Competent person <input type="checkbox"/> Task-specific (THA) <input type="checkbox"/> Hazcom
Field Notes: _____ _____ _____ _____ _____			

Name (Print): _____

Signature: _____

Date: _____

Attachment 5

Project Activity Self-Assessment Checklists

CH2MHILL

H&S Self-Assessment Checklist – HAND AND POWER TOOLS

This checklist shall be used by CH2M HILL personnel **only** and shall be completed at the frequency specified in the project's HSP/FSI.

This checklist is to be used at locations where: 1) CH2M HILL employees are exposed to hand and power tool hazards and/or 2) CH2M HILL provides oversight of subcontractor personnel who are exposed to hand and power tool hazards.

SSC or DSC may consult with subcontractors when completing this checklist, but shall not direct the means and methods of hand and power tool use nor direct the details of corrective actions. Subcontractors shall determine how to correct deficiencies and we must carefully rely on their expertise. Items considered to be imminently dangerous (possibility of serious injury or death) shall be corrected immediately or all exposed personnel shall be removed from the hazard until corrected.

Completed checklists shall be sent to the HS&E Staff for review.

Project Name: _____ Project No.: _____

Location: _____ PM: _____

Auditor: _____ Title: _____ Date: _____

This specific checklist has been completed to:

- ☐ Evaluate CH2M HILL employee exposure to hand and power tool hazards.
☐ Evaluate a CH2M HILL subcontractor's compliance with hand and power tool requirements.
Subcontractors Name: _____

- Check "Yes" if an assessment item is complete/correct.
- Check "No" if an item is incomplete/deficient. Deficiencies shall be brought to the immediate attention of the subcontractor. Section 3 must be completed for all items checked "No."
- Check "N/A" if an item is not applicable.
- Check "N/O" if an item is applicable but was not observed during the assessment.

Numbers in parentheses indicate where a description of this assessment item can be found in Standard of Practice HS-50.

SECTION 1

Yes No N/A N/O

SAFE WORK PRACTICES (3.1)

- | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|
| 1. All tools operated according to manufacturer's instructions and design limitations. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. All hand and power tools maintained in a safe condition and inspected and tested before use. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Defective tools are tagged and removed from service until repaired. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. PPE is selected and used according to tool-specific hazards anticipated. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Power tools are not carried or lowered by their cord or hose. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Tools are disconnected from energy sources when not in use, servicing, cleaning, etc. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Safety guards remain installed or are promptly replaced after repair. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Tools are stored properly. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Cordless tools and recharging units both conform to electrical standards and specifications. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. Tools used in explosive environments are rated for such use. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. Knife or blade hand tools are used with the proper precautions. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. Consider controls to avoid muscular skeletal, repetitive motion, and cumulative trauma stressors. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

H&S Self-Assessment Checklist – HAND AND POWER TOOLS

<u>SECTION 2</u>		<u>Yes</u>	<u>No</u>	<u>N/A</u>	<u>N/O</u>
GENERAL (3.2.1)					
13. PPE is selected and used according to tool-specific hazards anticipated.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
14. Tools are tested daily to assure safety devices are operating properly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
15. Damaged tools are removed from service until repaired.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
16. Power operated tools designed to accommodate guards have guards installed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
17. Rotating or moving parts on tools are properly guarded.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
18. Machines designed for fixed locations are secured or anchored.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
19. Floor and bench-mounted grinders are provided with properly positioned work rests.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
20. Guards are provided at point of operation, nip points, rotating parts, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
21. Fluid used in hydraulic-powered tools is approved fire-resistant fluid.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
ELECTRIC-POWERED TOOLS (3.2.2)					
22. Electric tools are approved double insulated or grounded and used according to SOP HS-23.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
23. Electric cords are not used for hoisting or lowering tools.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
24. Electric tools are used in damp/ wet locations are approved for such locations or GFCI installed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
25. Hand-held tools are equipped with appropriate on/off controls appropriate for the tool.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
26. Portable, power-driven circular saws are equipped with proper guards.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
ABRASIVE WHEEL TOOLS (3.2.3)					
27. All employees using abrasive wheel tools are wearing eye protection.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
28. All grinding machines are supplied with sufficient power to maintain spindle speed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
29. Abrasive wheels are closely inspected and ring-tested before use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
30. Grinding wheels are properly installed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
31. Cup-type wheels for external grinding are protected by the proper guard or flanges.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
32. Portable abrasive wheels used for internal grinding are protected by safety flanges.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
33. Safety flanges are used only with wheels designed to fit the flanges.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
34. Safety guards on abrasive wheel tools are mounted properly and of sufficient strength.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
PNEUMATIC-POWERED TOOLS (3.2.4)					
35. Tools are secured to hoses or whip by positive means to prevent disconnection.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
36. Safety clips or retainers are installed to prevent attachments being expelled.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Safety devices are installed on automatic fastener feed tools as required.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
38. Compressed air is not used for cleaning unless reduced to < 30 psi, with PPE, and guarded.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
39. Manufacturer's safe operating pressure for hoses, pipes, valves, etc. are not exceeded.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
40. Hoses are not used for hoisting or lowering tools.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
41. All hoses >1/2-inch diameter have safety device at source to reduce pressure upon hose failure.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
42. Airless spray guns have required safety devices installed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
43. Blast cleaning nozzles are equipped with operating valves, which are held open manually.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
44. Supports are provided for mounting nozzles when not in use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
45. Air receiver drains, handholes, and manholes are easily accessible.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
46. Air receivers are equipped with drainpipes and valves for removal of accumulated oil and water.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
47. Air receivers are completely drained at required intervals.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
48. Air receivers are equipped with indicating pressure gauges.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
49. Safety, indicating, and controlling devices are installed as required.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
50. Safety valves are tested frequently and at regular intervals to assure good operating condition.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

SECTION 2 (continued)**Yes No N/A N/O****LIQUID FUEL-POWERED TOOLS (3.2.5)**

- | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|
| 51. Liquid fuel-powered tools are stopped when refueling, servicing, or maintaining. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 52. Liquid fuels are stored, handled, and transported in accordance with SOP HS-21 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 53. Liquid fuel-powered tools are used in confined spaces in accordance with SOP HS-17. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 54. Safe operating pressures of hoses, valves, pipes, filters, and other fittings are not exceeded. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

POWDER-ACTUATED TOOLS (3.2.6)

- | | | | | |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| 55. Only trained employee operates powder-actuated tools. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 56. Powder-actuated tools are not loaded until just prior to intended firing time. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 57. Tools are not pointed at any employee at any time. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 58. Hands are kept clear of open barrel end. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 59. Loaded tools are not left unattended. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 60. Fasteners are not driven into very hard or brittle materials. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 61. Fasteners are not driven into easily penetrated materials unless suitable backing is provided. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 62. Fasteners are not driven into spalled areas. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 63. Powder-actuated tools are not used in an explosive or flammable atmosphere. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 64. All tools are used with correct shields, guards, or attachments recommended by manufacturer. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

JACKING TOOLS (3.2.7)

- | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|
| 65. Rated capacities are legibly marked on jacks and not exceeded. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 66. Jacks have a positive stop to prevent over-travel. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 67. The base of jacks are blocked or cribbed to provide a firm foundation, when required. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 68. Wood blocks are placed between the cap and load to prevent slippage, when required. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 69. After load is raised, it is cribbed, blocked, or otherwise secured immediately. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 70. Antifreeze is used when hydraulic jacks are exposed to freezing temperatures. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 71. All jacks are properly lubricated. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 72. Jacks are inspected as required. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 73. Repair or replacement parts are examined for possible defects. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 74. Jacks not working properly are removed from service and repaired or replaced. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

HAND TOOLS (3.2.8)

- | | | | | |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| 75. Wrenches are not used when jaws are sprung to the point of slippage. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 76. Impact tools are kept free of mushroomed heads. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 77. Wooden handles of tools are kept free of splinters or cracks and are tightly fitted in tool. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

SECTION 3

Complete this section for all items checked "No" in Sections 1 or 2. Deficient items must be corrected in a timely manner.

Item #	Corrective Action Planned/Taken	Date Corrected

Auditor: _____ Project Manager: _____

This checklist shall be used by CH2M HILL personnel **only** and shall be completed at the frequency specified in the project's HSP/FSI.

This checklist is to be used at locations where: 1) CH2M HILL employees are potentially exposed to the hazards of earthmoving equipment operations, 2) CH2M HILL employees are operating earthmoving equipment, and/or 3) CH2M HILL provides oversight of a subcontractor operating earthmoving equipment.

The CH2M HILL Safety Coordinator may consult with subcontractors operating earthmoving equipment when completing this checklist, but shall not direct the means and methods of equipment operations nor direct the details of corrective actions. Earthmoving equipment subcontractors shall determine how to correct deficiencies and we must carefully rely on their expertise. Items considered to be imminently dangerous (possibility of serious injury or death) shall be corrected immediately or all exposed personnel shall be removed from the hazard until corrected.

Project Name: _____ Project No.: _____

Location: _____ PM: _____

Auditor: _____ Title: _____ Date: _____

This specific checklist has been completed to:

- ☐ Evaluate CH2M HILL employee exposures to earthmoving equipment hazards (complete Section 1).
☐ Evaluate CH2M HILL employees operating earthmoving equipment (complete entire checklist).
☐ Evaluate CH2M HILL subcontractor's compliance with earthmoving equipment safety requirements (complete entire checklist). Subcontractors Name: _____

- Check "Yes" if an assessment item is complete/correct.
- Check "No" if an item is incomplete/deficient. Deficiencies shall be brought to the immediate attention of the earthmoving equipment subcontractor. Section 3 must be completed for all items checked "No."
- Check "N/A" if an item is not applicable.
- Check "N/O" if an item is applicable but was not observed during the assessment.

Numbers in parentheses indicate where a description of this assessment item can be found in Standard of Practice HSE-27.

SAFE WORK PRACTICES (3.1)**SECTION 1****Yes No N/A N/O**

1. Personnel maintaining safe distance from operating equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Positioning personnel in close proximity to operating equipment is avoided	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Personnel wearing high-visibility and/or reflective vests when close to operating equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Personnel approach operating equipment safely	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Personnel riding only in seats of equipment cab and using seat belts	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Personnel not positioned under elevated portions of equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Personnel not positioned under hoisted loads	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Personnel not hoisted by equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Personnel do not to approach equipment that has become electrically energized	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Personnel wearing appropriate PPE, per HSP/FSI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

EQUIPMENT SAFETY REQUIREMENTS PRIOR TO OPERATING EQUIPMENT (3.2.1)	<u>SECTION 2</u>	Yes	No	N/A	N/O
11. Only qualified and authorized personnel operating equipment		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Daily safety briefing/meeting conducted with equipment operators		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Daily inspection of equipment conducted and documented		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. Modifications and attachments used approved by equipment manufacturer		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Backup alarm or spotter used when backing equipment		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Operational horn provided on bi-directional equipment		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Seat belts are provided and used		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. Rollover protective structures (ROPS) provided		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. Braking system capable of stopping full payload		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. Headlights and taillights operable when additional light required		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21. Brake lights in operable condition		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. Cab glass provides no visible distortion to the operator		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23. All machine guards are in place		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. Hauling equipment (dump trucks) provided with cab shield or canopy		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25. Dump truck beds provided with positive means of support during maintenance or inspection		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26. Dump truck operating levers provided with latch to prevent accidental dumping		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27. Air monitoring conducted per HSP/FSI for hazardous atmospheres		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EQUIPMENT PLACEMENT (3.2.2)					
28. Equipment position on firm/level surface, outriggers used		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29. Location of underground utilities identified		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. Safe clearance distance maintained while working under overhead power lines		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. Safe distance is maintained while traveling under power lines		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32. Warning system used to remind operator of excavation edge		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33. Unattended equipment visibly marked at night		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34. Tools lowered/parking brake set when not in use, wheels chocked when parked on incline		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EQUIPMENT OPERATION (3.2.3)					
35. Equipment operated on safe roadways and grades		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36. Equipment operated at safe speed		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37. Operators maintain unobstructed view of travel path		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38. Equipment not operated during inclement weather, lightning storms		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
39. Equipment started and moved safely		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
40. Operators keep body parts inside cab during operation		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
41. Vehicle occupants in safe position while loading/unloading		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
42. Signal person visible to operator when required		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
43. Equipment used for hoisting done according to equipment manufacturer specifications		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
44. Lifting and hauling capacities are not exceeded		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EQUIPMENT MAINTENANCE (3.2.4)					
45. Defective components repaired immediately		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
46. Suspended equipment or attachments supported prior to work under or between		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
47. Lockout/tagout procedures used prior to maintenance		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
48. Tires on split rims removed using safety tire rack or cage		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
49. Good housekeeping maintained on and around equipment		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EXCAVATING AT HAZARDOUS WASTE SITES (3.2.5)					
50. Waste disposed of according to HSP/FSI		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
51. Appropriate decontamination procedures being followed, per HSP/FSI		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 3

Complete this section for all items checked “No” in Sections 1 or 2. Deficient items must be corrected in a timely manner.

Item #	Corrective Action Planned/Taken	Date Corrected
--------	---------------------------------	----------------

[illegible]

Auditor: _____ Project Manager: _____

This checklist shall be used by CH2M HILL personnel **only** and shall be completed at the frequency specified in the project's HSP/FSI.

This checklist is to be used at locations where: (1) CH2M HILL employees enter excavations (complete Sections 1 and 3), and/or (2) CH2M HILL oversight of an excavation subcontractor is required (complete entire checklist).

SC may consult with excavation subcontractors when completing this checklist, but shall not direct the means and methods of excavation operations nor direct the details of corrective actions. Excavation subcontractors shall determine how to correct deficiencies and we must carefully rely on their expertise. Conditions considered imminently dangerous (possibility of serious injury or death) shall be corrected immediately or all exposed personnel shall be removed from the hazardous area until corrected.

Project Name: _____ Project No.: _____

Location: _____ PM: _____

Auditor: _____ Title: _____ Date: _____

This specific checklist has been completed to:

- ☐ Evaluate CH2M HILL employee exposures to excavation hazards
☐ Evaluate a CH2M HILL subcontractor's compliance with excavation HS&E requirements
Subcontractor Name: _____

- Check "Yes" if an assessment item is complete/correct.
- Check "No" if an item is incomplete/deficient. Deficiencies shall be brought to the immediate attention of the excavation subcontractor. Section 3 must be completed for all items checked "No."
- Check "N/A" if an item is not applicable.
- Check "N/O" if an item is applicable but was not observed during the assessment.

Numbers in parentheses indicate where a description of this assessment item can be found in Standard of Practice HSE-32.

SECTION 1**Yes No N/A N/O****EXCAVATION ENTRY REQUIREMENTS (4.1)**

- | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|
| 1. Personnel have completed excavation safety training | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Competent person has completed daily inspection and has authorized entry | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Personnel are aware of entry requirements established by competent person | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Protective systems are free from damage and in stable condition | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Surface objects/structures secured from falling into excavation | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Potential hazardous atmospheres have been tested and found to be at safe levels | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Precautions have been taken to prevent cave-in from water accumulation in the excavation | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Personnel wearing appropriate PPE, per HSP/FSI | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

	SECTION 2	Yes	No	N/A	N/O
GENERAL (4.2.1)					
9. Daily safety briefing/meeting conducted with personnel		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Excavation and protective systems adequately inspected by competent person		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Defective protective systems or other unsafe conditions corrected before entry		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Guardrails provided on walkways over excavation 6' (1.8m) or deeper		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Barriers provided at excavations 6' or deeper when excavation not readily visible		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. Barriers or covers provided for wells, pits, shafts, or similar excavation 6' (1.8 m) or deeper		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Earthmoving equipment operated safely (use earthmoving equipment checklist in HS-27)		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
PRIOR TO EXCAVATING (4.2.2)					
16. Dig permit obtained where required by client/facility		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Location of underground utilities and installations identified		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. Excavation area evaluated for OE/UXO hazards		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. Soils characterized prior to excavation where contamination may be present		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. USDA (or local equivalent) soil permit obtained for soil transport, where required		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21. Excavation area checked for wetlands, endangered species, cultural/historic resources		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. ACOE/CWA 404 (or local equivalent) permit obtained for wetlands, where required		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23. Stockpile management plan prepared		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. Waste discharge/NPDES (or local equivalent) permit obtained for excavation dewatering		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25. Stormwater pollution prevention or erosion & sediment control plan prepared, where required)		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EXCAVATING ACTIVITIES (4.2.3)					
26. Rocks, trees, and other unstable surface objects removed or supported		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27. Exposed underground utility lines supported		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28. Undermined surface structures supported or determined to be in safe condition		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29. Warning system used to remind equipment operators of excavation edge		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. Stockpile, excavation covers, liners, silt fences in place, where required		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. Fugitive dust suppressed		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EXCAVATION ENTRY (4.2.4)					
32. Trenches > 4' (1.2 m) deep provided with safe means of egress within 25' (7.6 m)		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33. Structure ramps designed and approved by competent person		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34. Potential hazardous atmospheres tested prior to entry		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
35. Rescue equipment provided where potential for hazardous atmospheres exists		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36. Ventilation used to control hazardous atmospheres and air tested frequently		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37. Appropriate respiratory protection used when ventilation does not control hazards		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38. Precautions taken to prevent cave-in from water accumulation in excavation		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
39. Precautions taken to prevent surface water from entering excavation		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
40. Protection provided from falling/rolling material from excavation face		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
41. Spoil piles, equipment, materials restrained or kept at least 2' (61 cm) from excavation edge		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EXCAVATION PROTECTIVE SYSTEMS (4.2.5)					
42. Protective systems used for excavations 5' (1.5 m) or deeper, unless stable rock		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
43. Protective systems for excavation deeper than 20' (6.1 m) designed by registered PE		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
44. If soil unclassified, maximum allowable slope is 34 degrees		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
45. Protective systems free from damage		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
46. Protective system used according to manufacturer's recommendations and not subjected to loads exceeding design limits		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
47. Protective system components securely connected to prevent movement or failure		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
48. Cave-in protection provided while entering/exiting shielding systems		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
49. Personnel removed from shielding systems when installed, removed, or vertical movement		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

<u>SECTION 2 (Continued)</u>	<u>Yes</u>	<u>No</u>	<u>N/A</u>	<u>N/O</u>
PROTECTIVE SYSTEM REMOVAL AND BACKFILLING (4.2.6)				
50. Protective system removal starts and progresses from excavation bottom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
51. Protective systems removed slowly and cautiously	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
52. Temporary structure supports used if failure of remaining components observed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
53. Backfilling taking place immediately after protective system removal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
54. Backfill certified clean when required by client or local regulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EXCAVATING AT HAZARDOUS WASTE SITES (4.2.7)				
55. Waste disposed of according to HSP and RCRA regulations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
56. Appropriate decontamination procedures being followed, per HSP	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
EXCAVATING AT POTENTIAL ORDNANCE EXPLOSIVES SITES (4.2.8)				
57. OE plan prepared and approved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
58. OE/UXO avoidance provided, routes and boundaries cleared and marked	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
59. Personnel remain inside the marked boundary	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
60. Earthmoving equipment does not excavate closer than 1' (30.5 cm) to anomalies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Auditor: _____ Project Manager: _____

This checklist shall be used by CH2M HILL personnel **only** and shall be completed at the frequency specified in the project's HSP/FSI.

This checklist is to be used at locations where: 1) CH2M HILL employees are potentially exposed to hazards associated with waste management operations (complete Sections 1 and 3), and/or 2) CH2M HILL oversight of a hazardous waste management subcontractor is required (complete entire checklist).

SSEC/DSEC may consult with hazardous waste management subcontractors when completing this checklist, but shall not direct the means and methods of hazardous waste management operations nor direct the details of corrective actions. Waste management subcontractors shall determine how to correct deficiencies and we must carefully rely on their expertise. Items considered to be imminently dangerous (possibility of serious injury or death) shall be corrected immediately or all exposed personnel shall be removed from the hazard until corrected.

Completed checklists shall be sent to the Health and Safety Manager for review.

Project Name: _____ Project No.: _____

Location: _____ PM: _____

Auditor: _____ Title: _____ Date: _____

This specific checklist has been completed to:

- ☐ Evaluate CH2M HILL employee exposure to hazardous waste.
- ☐ Evaluate a CH2M HILL subcontractor's compliance with the hazardous waste management requirements.
- Subcontractors Name: _____

- Check "Yes" if an assessment item is complete/correct.
- Check "No" if an item is incomplete/deficient. Deficiencies shall be brought to the immediate attention of the subcontractor. Section 3 must be completed for all items checked "No."
- Check "N/A" if an item is not applicable.
- Check "N/O" if an item is applicable but was not observed during the assessment.

Numbers in parentheses indicate where a description of this assessment item can be found in Standard of Practice HS-80.

SECTION 1**PERMITS AND NOTIFICATIONS (7.0)**

1. Client site has an EPA ID Number or RCRA permit.
2. CH2M activities comply with client's RCRA permit.

Yes No N/A N/O

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

ACCUMULATION (8.0)

3. LQG — accumulates hazardous waste for up to 90 days.
4. SQG — accumulates hazardous waste for up to 180 days.
5. CESQGs — no limit on accumulation unless it exceeds 1,000kg.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

CONTAINERS (8.1)

6. Hazardous wastes are packaged according to DOT requirements.
7. Container inspections are documented in writing using the Container Inspection Checklist.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

<u>SECTION 2</u>	<u>Yes</u>	<u>No</u>	<u>N/A</u>	<u>N/O</u>
MARKING AND LABELING (8.2)				
Uncharacterized Waste (8.2.1)				
8. Containers of unknown wastes are marked with a description of the contents.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. The accumulation start date is marked on the container.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Containers are marked with a unique identifier.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Non-classified label used for unclassified waste.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Non-Hazardous Waste (8.2.2)				
12. All containers must be marked and labeled, including non-regulated waste.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Non-Hazardous Waste label includes generator name, address, and description of waste.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hazardous Waste (8.2.3)				
14. Hazardous waste identified with yellow Hazardous Waste label.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. The accumulation start date marked and visible on the container.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Containers labeled according to DOT requirements.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Building/Storage Area Marking (8.2.4)				
17. Hazardous waste storage areas labeled.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ACCUMULATION AREAS (8.3)				
Satellite Accumulation Area (8.3.1)				
18. Up to 55 gal. of hazardous waste or 1 qt. of acutely haz. waste accumulated for unlimited time.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. Accumulation area at or near the point of generation.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. Area under control of waste generator.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
90-Day Accumulation Area (8.3.2)				
21. Hazardous waste >55 gal. stored for 90 days in managed accumulation area.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. Accumulation area is used only for storage of waste.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23. Container requirements have been followed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. Emergency spill response procedures posted and spill kit available.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25. Fire extinguisher, water supply, telephone, and alarm are located in accumulation area.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26. Emergency shower/eyewash station available, tested and functioning.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27. Accumulation area is locked when authorized personnel are not available.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28. Appropriate signs posted at the entrance.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29. Secondary containment provided for liquid hazardous waste.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. Weekly inspections logged into book using Accumulation Area Inspection Log Sheet.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. "NO SMOKING OR OPEN FLAME" signs posted.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32. Prior to closure all containers, liners, or containment devices removed or decontaminated.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CONTINGENCY PLAN AND EMERGENCY PROCEDURES (9.0)				
33. Contingency plans and emergency procedures have been incorporated in work plans.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TRAINING (10.0)				
34. Personnel handling hazardous waste have appropriate training.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Yes	No	N/A	N/O
SECTION 3				
OFFSITE DISPOSAL (11.0)				
35. Disposal facilities identified using the procedures in HSE-79.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36. Disposal facilities evaluated under Waste Subcontractor Qualification Procedure in HSE-84.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37. Waste characterization, sampling, and analysis procedures in HSE-79 followed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Evaluate Land Disposal Restrictions (11.3)				
Identification of Treatment Standards (11.3.1)				
38. Waste characterized and waste codes determined.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
39. LDR exemptions identified.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
40. Alternate treatment standards evaluated.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
41. Waste determined to be wastewater or non-wastewater.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
42. Treatment standards identified.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
43. Universal Treatment Standards (UTS) identified.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Confirm Final Disposal Options (11.4)				
44. Disposal facilities waste profile forms have been completed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
45. Client signatures have been obtained on waste profile forms.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
46. Signed waste profile forms and enclosures have been submitted to the disposal facility.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
OFFSITE TRANSPORT (12.0)				
47. Transporter has documented H&S and monitoring program and written spill response plan.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
48. Transporter is permitted in the state and has disposal facilities listed on their permit.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
49. Transporter can service origin and destination state and disposal facility.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
50. Transporter can meet proposed shipment schedule.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
51. Disposal facility accepted waste and issued approval letter.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Manifesting (12.1)				
52. Manifest and LDR notification/certification form completed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
53. Manifest includes reference no., shipping name, hazard class, ID no., and packaging group.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
54. DOT trained staff completed manifest.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
55. Manifest is for the state where the waste will be disposed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
56. Pre-shipment manifest review completed.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
57. Original signed manifest returned to client within 35 days of ship date.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
58. Waste shipments tracked using Waste Tracking Form.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Waste Pickup (12.2)				
59. Signed shipping papers have been delivered to project site.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
60. Individual assigned to supervise pickup and ensure transporter signs manifest.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
61. Onsite representative must not sign any shipping documents unless authorized under contract.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RECORDKEEPING AND REPORTING (13.0)				
Copies of Waste Profiles (13.1)				
62. Two copies of completed, signed profile forms(s) and documentation for CH and client files.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Copies of Shipping Documents (13.2)				
63. Keep copy of all manifests in project file.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
64. Manifest copies distributed to agencies, client and project file.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Recordkeeping (13.2.1)				
Copies of the following documents should be maintained by the client and CH2M HILL for at least 3 years from the date the hazardous waste was accepted by the initial transporter.				
65. Manifests signed by the disposal facility.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
66. LDR notification and certification forms (must be retained for 5 years)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
67. Biennial reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
68. Exception reports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
69. Hazardous waste characterization information.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 3

Complete this section for all items checked “No” in Sections 1 or 2. Deficient items must be corrected in a timely manner.

[illegible]

This checklist shall be used by CH2M HILL personnel **only** and shall be completed at the frequency specified in the project's HSP/FSI.

This checklist is to be used at locations where: 1) CH2M HILL employees are exposed to PCB hazards and/or 2) CH2M HILL provides oversight of subcontractor personnel who are engaged in PCB operations.

SC-HW or SC-C may consult with subcontractors when completing this checklist, but shall not direct the means and methods of asbestos operations nor direct the details of corrective actions. Subcontractors shall determine how to correct deficiencies, and we must carefully rely on their expertise. Items considered to be imminently dangerous (possibility of serious injury or death) shall be corrected immediately, or all exposed personnel shall be removed from the hazard until corrected.

Completed checklists shall be sent to the HS&E Staff for review.

Project Name: _____ Project No.: _____

Location: _____ PM: _____

Auditor: _____ Title: _____ Date: _____

This specific checklist has been completed to:

- ☐ Evaluate CH2M HILL compliance with the PCB standards and requirements
- ☐ Evaluate a CH2M HILL subcontractor's compliance with the PCB standards and requirements
- Subcontractors Name: _____

- Check "Yes" if an assessment item is complete/correct.
- Check "No" if an item is incomplete/deficient. Deficiencies shall be brought to the immediate attention of the subcontractor. Section 3 must be completed for all items checked "No."
- Check "N/A" if an item is not applicable.
- Check "N/O" if an item is applicable but was not observed during the assessment.

Numbers in parentheses indicate where a description of this assessment item can be found in Standard of Practice HSE-82.

SECTION 1

STORAGE AND TRANSPORT (6.0)

	<u>Yes</u>	<u>No</u>	<u>N/A</u>	<u>N/O</u>
1. PCB wastes stored for less than 30 days .	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. PCB waste containing < 50ppm, stored for <30 days is stored in non-leaking containers.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. PCB waste containing < 50ppm, stored for <30 days has SPCC plan in place for liquids.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Liquid PCB waste containing < 50ppm, stored for <30 days is managed in DOT-approved drums or stationary bulk storage tanks.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. PCB waste containing < 50ppm, stored for <30 days has the generic ID number, "40 CFR PART 761" is written on manifests, records and reports if the facility does not have an EPA ID number.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. PCB wastes stored for more than 30 days have an EPA ID number.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. PCB wastes stored for 30 days or more have adequate roof and walls to keep rainfall from waste.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. PCB wastes stored for 30 days or more have 6-inch continuous curb around the items with a containment volume equal to greater than twice the largest PCB item.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Containment area is constructed of cement or non-porous material.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 2		Yes	No	N/A	N/O
10. No drains, expansion joints or other openings located in the containment area which could allow liquid to escape.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Storage area not located within a 100-year floodplain.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. PCB equipment and containers are stored in storage area for no longer than 1 year.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Covers and liners are provided for bulk PCB remediation waste, PCB bulk product waste can be stored of up to 180 days.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
STORAGE OPTIONS (6.2)					
14. Refer to HSE-85 for DOT container/packaging requirements applicable to PCB storage.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LABEL (6.3)					
15. Regulated PCB wastes are marked and labeled using EPA approved labels.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MANIFEST (6.4)					
16. PCB-regulated waste transported with a manifest		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Uniform hazardous waste manifest (EPA Form 8700-22) states the serial or ID number of the PCB waste, the date of removal from service, and the weight in kilograms of the waste.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TRANSPORT (6.5)					
18. PCB wastes must be marked, labeled, and transported in compliance with DOT requirements.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DISPOSAL PROCEDURES (7.0)					
19. Disposal options have been determined based on the PCB item and concentration.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. PCB concentrations for non-liquids have been determined based on a dry weight basis.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21. PCB concentrations for liquids have been determined based on a wet weight analysis.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. Consult disposal requirements of PCB waste < 50 ppm.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23. EPA must be notified at least 30 days prior to clean up.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. Cleanup levels have been determined based on the kind of material and potential exposure left after cleanup has been completed.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25. PCB bulk product waste disposal options determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26. PCB small capacitors disposal options determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27. Remediation waste disposal options determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28. Consulted EPA Regional Administrator for approval for risk-based cleanup, storage, or disposal of PCB remediation waste.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29. Maintain written record of all sampling and analysis of PCBs for 5 years from the date of the waste generation.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. Liquid PCB waste concentrations and disposal options determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. PCB articles concentrations and disposal option determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32. Electrical equipment PCB concentrations and disposal option determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33. Radioactive PCB waste concentrations and disposal option determined.		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Auditor: _____ Project Manager: _____

This checklist is provided as a method of verifying compliance with the OSHA respiratory protection standard. It shall be used at locations where CH2M HILL personnel are using respiratory protection, or are required to perform oversight of a subcontractor using respiratory protection, or both.

CH2M HILL staff shall not direct the means and methods of subcontractor use of respiratory protection nor direct the details of corrective actions. The subcontractor must determine how to correct deficiencies and CH2M HILL staff must carefully rely on their expertise. Items considered to be imminently dangerous (possibility of serious injury or death) must be corrected immediately or all exposed personnel must be removed from the hazard until corrected.

Completed checklists must be sent to the appropriate regional health and safety program manager for review.

Project Name: _____ Project No.: _____

Location: _____ PM: _____

Auditor: _____ Title: _____ Date: _____

This specific checklist has been completed to (check only one of the boxes below):

- ☐ Evaluate CH2M HILL compliance with its respiratory protection program (SOP HS-08)
☐ Evaluate a CH2M HILL subcontractor's compliance with its respiratory protection program
Subcontractor's Name: _____

- Check "Yes" if an assessment item is complete or correct.
- Check "No" if an item is incomplete or deficient. Section 2 must be completed for all items checked "No."
- Check "N/A" if an item is not applicable.
- Check "N/O" if an item is applicable but was not observed during the assessment.

Numbers in parentheses indicate where a description of this assessment item can be found in Standard of Practice HS-08.

	<u>SECTION 1</u>	<u>Yes</u>	<u>No</u>	<u>N/A</u>	<u>N/O</u>
TRAINING (6.1)					
1.	Respirator users have completed appropriate training on the respirator to be used	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.	Training is current within the past 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.	Attachment 1 of SOP HS-08 distributed to employees using respirators voluntarily	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MEDICAL EVALUATION (6.2)					
4.	Respirator users completed medical evaluation protocol	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.	Respirator use does not exceed any physician's written recommendation limitations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.	Respirator users know to report any medical signs or symptoms related to respirator use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
FIT TESTING (6.3)					
7.	Respirator users of tight-fitting facepieces have passed a fit test	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.	Fit test is current within the past 12 months	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.	Respirator users know to have new fit test performed if any change affects respirator fit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 1 (Continued)	Yes	No	N/A	N/O
RESPIRATOR SELECTION (6.4)				
10. All feasible engineering controls have been considered in reducing exposure levels	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Appropriate respiratory protection and limitations are specified in HSP/FSI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Cartridge or canister change-out schedule is specified in HSP/FSI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPIRATOR USE (6.5)				
13. Respirator use is limited to those specified in HSP/FSI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. HSM notified of changes in site conditions that may alter effectiveness of specified respirators	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Respirator users of tight-fitting facepieces are cleanly shaven	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Respirator users of tight-fitting facepieces perform user seal check before each use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Cartridges or canisters replaced according to change-out schedule in HSP/FSI	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. Respirator users informed to report any gas or vapor breakthrough to SSC/DSC	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. SSC/DSC knows to report any gas or vapor breakthrough to HSM	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. Personnel not entering IDLH areas until standby-person established with appropriate equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPIRATOR INSPECTION (6.6)				
21. Respirators in regular use are inspected before each use and during cleaning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21. Emergency response respirators are inspected and documented monthly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. Defective respirators are taken out of service or repaired	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPIRATOR CLEANING AND DISINFECTING (6.7)				
23. Respirators in regular use are cleaned and disinfected as necessary	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. Emergency and transferred respirators are cleaned and disinfected after use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPIRATOR STORAGE (6.8)				
25. Respirators are properly stored to prevent contamination and deformation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26. Emergency respirators are accessible and clearly marked as emergency respirators	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RESPIRATOR REPAIRS (6.9)				
27. Respirator repair is limited to routine maintenance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28. Respirators beyond routine repair are removed from service	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BREATHING AIR SUPPLIED BY CYLINDER (6.10.1)				
29. Cylinders are marked with NIOSH approval label	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. Certificate of analysis meets Grade D specifications	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. Certificate of analysis is kept onsite	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BREATHING AIR SUPPLIED BY COMPRESSOR (6.10.2)				
32. Breathing air meets Grade D specifications	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33. Compressor intake is located away from exhaust gases	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34. Compressor is provided with sorbent filters	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
35. Sorbent filter change-out documentation is kept on the compressor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36. High temperature or carbon monoxide alarm provided on oil-lubricated compressors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37. If high temperature alarm is used alone, carbon monoxide levels are monitored	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38. Practical measures taken to control carbon monoxide levels on non oil-lubricated compressors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Auditor: _____ Project Manager: _____

Attachment 6
Safe Work Observation Form

Safe Work Observation Form			
Project:		Observer:	
		Date:	
Position/Title of worker observed:		Background Information/ comments:	
Task/Observation Observed: _____			
<ul style="list-style-type: none"> ❖ Identify and reinforce safe work practices/behaviors ❖ Identify and improve on at-risk practices/acts ❖ Identify and improve on practices, conditions, controls, and compliance that eliminate or reduce hazards ❖ Proactive PM support facilitates eliminating/reducing hazards (do you have what you need?) ❖ Positive, corrective, cooperative, collaborative feedback/recommendations 			
Actions & Behaviors	Safe	At-Risk	Observations/Comments
Current & accurate Pre-Task Planning/Briefing (Project safety plan, STAC, AHA, PTSP, tailgate briefing, etc., as needed)			Positive Observations/Safe Work Practices:
Properly trained/qualified/experienced			
Tools/equipment available and adequate			
Proper use of tools			Questionable Activity/Unsafe Condition Observed:
Barricades/work zone control			
Housekeeping			
Communication			
Work Approach/Habits			
Attitude			
Focus/attentiveness			Observer's Corrective Actions/Comments:
Pace			
Uncomfortable/unsafe position			
Inconvenient/unsafe location			
Position/Line of fire			
Apparel (hair, loose clothing, jewelry)			
Repetitive motion			Observed Worker's Corrective Actions/Comments:
Other...			

Attachment 7
Project-Specific Chemical Product Hazard
Communication Form

Attachment 8
Applicable Material Safety Data Sheets

Attachment 9
Chemical-Specific Training Form

CHEMICAL-SPECIFIC TRAINING FORM

Location:

Project # :

HCC:

Trainer:

TRAINING PARTICIPANTS:

NAME	SIGNATURE	NAME	SIGNATURE

REGULATED PRODUCTS/TASKS COVERED BY THIS TRAINING:

The HCC shall use the product MSDS to provide the following information concerning each of the products listed above.

- ☐ Physical and health hazards
- ☐ Control measures that can be used to provide protection (including appropriate work practices, emergency procedures, and personal protective equipment to be used)
- ☐ Methods and observations used to detect the presence or release of the regulated product in the workplace (including periodic monitoring, continuous monitoring devices, visual appearance or odor of regulated product when being released, etc.)

Training participants shall have the opportunity to ask questions concerning these products and, upon completion of this training, will understand the product hazards and appropriate control measures available for their protection.

Copies of MSDSs, chemical inventories, and CH2M HILL's written hazard communication program shall be made available for employee review in the facility/project hazard communication file.

Attachment 10
Biological Hazard Information

Tick-Borne Pathogens

There are six tick-borne pathogens that present a significant field hazard, and in some areas account for more than half of our serious field incidents. These procedures should be applied during any field activity where vegetation is present.

Hazard Control

The methods for controlling exposure to ticks include, in order of most-preferred to least:

- Avoiding tick habitats and ceasing operations in heavily infested areas
- Reducing tick abundance through habitat disruption or application of acaricide
- Personal protection through use of repellants and protective clothing
- Frequent tick inspections and proper hygiene

Vaccinations are not available and preventative antibiotic treatment after a bite is generally not recommended.

Avoidance and Reduction of Ticks

To the extent practical, tick habitats should be avoided. In areas with significant tick infestation, consider stopping work and withdrawing from area until adequate tick population control can be achieved. Stopping and withdrawing should be considered as seriously as entering an area without proper energy control or with elevated airborne contaminants – tickborne pathogens present risk of serious illness!

In areas where significant population density or infestation exists, tick reduction should be considered. Tick reduction can be achieved by disrupting tick habitats and/or direct population reduction through the use of tick-toxic pesticides (Damminix, Dursban, Sevin, etc.).

Habitat disruption may include only simple vegetative maintenance such as removing leaf litter and trimming grass and brush. Tick populations can be reduced between 72 and 100% when leaf litter alone is removed. In more heavily infested areas, habitat disruption may include grubbing, tree trimming or removal, and pesticide application (Damminix, Dursban, Sevin, etc.). This approach is practical in smaller, localized areas or perimeter areas that require occasional access. Habitat controls are to be implemented with appropriate health and safety controls, in compliance with applicable environmental requirements, and may be best left to the property owner or tenant, or licensed pesticide vendor. Caution should be exercised when using chemical repellents or pesticides in or around areas where environmental or industrial media samples will be collected for analysis.

Personal Protection

After other prevention and controls are implemented, personal protection is still necessary in controlling exposure to ticks. Personal protection must include all of the following steps:

- So that ticks may be seen on your clothing wear light-colored clothing. Full-body New Tyvek (paper-like disposable coveralls) may also be used.
- To prevent ticks from getting underneath clothing tuck pant legs into socks or tape to boots.
- Wear long-sleeved shirts, a hat, and high boots.
- Apply DEET repellent to exposed skin or clothing per product label.

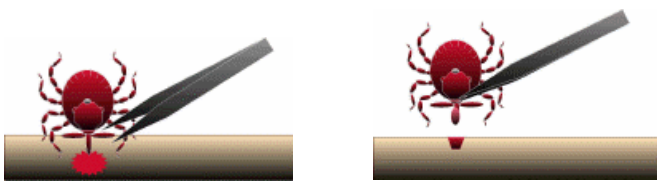
- Apply permethrin repellent to the outside of boots and clothing before wearing, per product label.
- Frequently check for ticks and remove from clothing.
- At the end of the day search your entire body for ticks (particularly groin, armpits, neck and head) and shower.
- To prevent pathogen transmission through mucous membranes or broken/cut skin, wash or disinfect hands and/or wear surgical-style nitrile gloves anytime ticks are handled.

Pregnant individuals and individuals using prescription medications should consult with their physician and/or pharmacists before using chemical repellents. Because human health effects may not be fully known, use of chemical repellents should be kept to a minimum frequency and quantity. Always follow manufacturers' use instructions and precautions. Wash hands after handling, applying, or removing protective gear and clothing. Avoid hand-to-face contact, eating, drinking, smoking, etc. when applying or using repellents. Remove and wash clothes per repellent product label. Chemical repellents should not be used on infants and children.

Vaccinations are generally not available for tick-borne pathogens. Although production of the LYMERix™ lyme disease vaccination has been ceased, vaccination may still be considered under specific circumstances and with concurrence from the consulting physician. Preventative antibiotic treatment in non-ill individuals who have had a recent tick bite is recommended in specific cases only.

Tick Removal

1. Use fine-tipped tweezers or shield your fingers with a tissue, paper towel, or nitrile gloves.
2. Grasp the tick as close to the skin surface as possible and pull upward with steady, even pressure. Do not twist or jerk the tick; this may cause the mouthparts to break off and remain in the skin. (If this happens, remove mouthparts with tweezers. Consult your healthcare provider if infection occurs.)



3. Do not squeeze, crush, or puncture the body of the tick because its fluids (saliva, hemolymph, gut contents) may contain infectious organisms. Releasing these organisms to the outside of the tick's body or into the bite area may increase the chance of infectious organism transmission.
4. Do not handle the tick with bare hands because infectious agents may enter through mucous membranes or breaks in the skin. This precaution is particularly directed to individuals who remove ticks from domestic animals with unprotected fingers. Children, elderly persons, and immunocompromised persons may be at greater risk of infection and should avoid this procedure.

5. After removing the tick, thoroughly disinfect the bite site and wash your hands with soap and water.
6. You may wish to save the tick for identification in case you become ill. Your doctor can use the information to assist in making an accurate diagnosis. Place the tick in a plastic bag and put it in your freezer. Write the date of the bite on a piece of paper with a pencil and place it in the bag.

Note: Folklore remedies such as petroleum jelly or hot matches do little to encourage a tick to detach from skin. In fact, they may make matters worse by irritating the tick and stimulating it to release additional saliva, increasing the chances of transmitting the pathogen. These methods of tick removal should be avoided. In addition, a number of tick removal devices have been marketed, but none are better than a plain set of fine tipped tweezers.

First-Aid and Medical Treatment

Tick bites should always be treated with first-aid. Clean and wash hands and disinfect the bite site after removing embedded tick. Consult a healthcare professional if infection or symptoms and effects of tick-borne illnesses are develop.

Medical treatment for tick-borne infections include antibiotics and other medical interventions. Diagnosis of specific illness involves both clinical and laboratory confirmations. Preventative antibiotic treatment in non-ill individuals who have had a recent tick bite is recommended in specific cases only.

Previously infected individuals are not conferred immunity – re-infection from future tick bites can occur even after a person has contracted a tick-borne disease.

Hazard Recognition

An important step in controlling tick related hazards is understanding how to identify ticks, their habitats, their geographical locations, and signs & symptoms of tick-borne illnesses.

Tick Identification

There are five varieties of hard-bodied ticks that have been associated with tick-borne pathogens. These tick varieties include:

- Deer (Black Legged) Tick (eastern and pacific varieties)
- Lone Star Tick
- Dog Tick
- Rocky Mountain Wood Tick

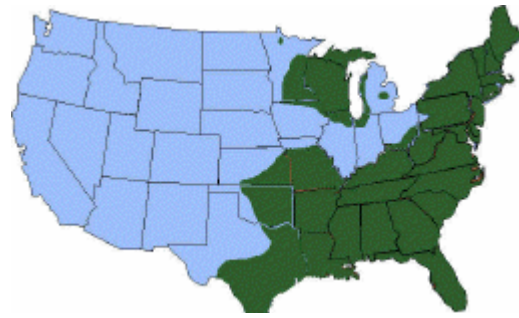
These varieties and their geographical locations are illustrated on the following page.

Tick Habitat

In eastern states, ticks are associated with deciduous forest and habitat containing leaf litter. Leaf litter provides a moist cover from wind, snow, and other elements. In the north-central states, is generally found in heavily wooded areas often surrounded by broad tracts of land cleared for agriculture. On the Pacific Coast, the bacteria are transmitted to humans by the western black-legged (deer) tick and habitats are more diverse. Here, ticks have been found in habitats with forest, north coastal scrub, high brush, and open grasslands. Coastal tick populations thrive in areas of high rainfall, but ticks are also found at inland locations.



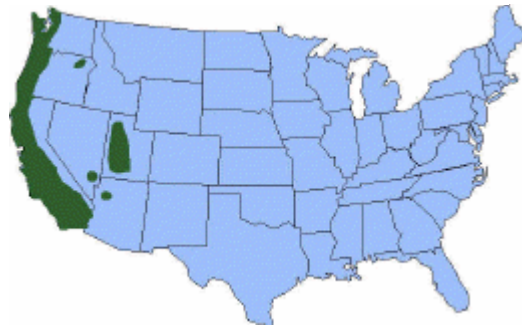
Deer Tick



Distribution of Deer Tick (dark green)



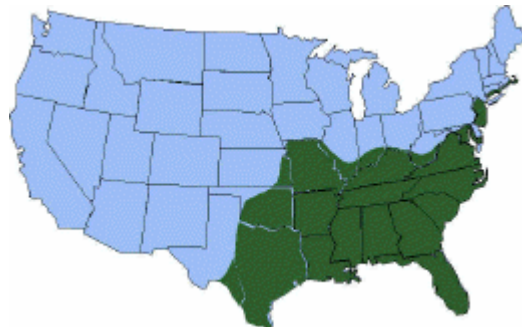
From Left: adult female, adult male, nymph, and larvae Deer Tick (cm scale)



Distribution of Pacific Deer Tick (dark green)



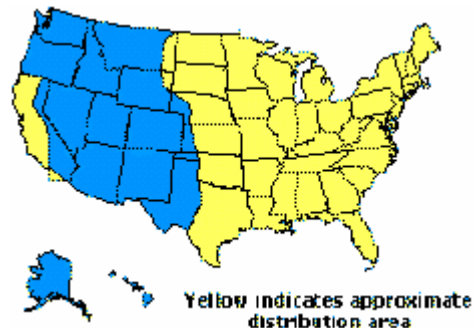
Lone Star Tick



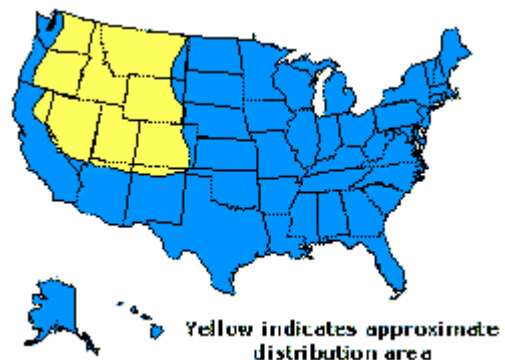
Distribution of Lone Star Tick (Green)



Dog Tick



Rocky Mountain Wood Tick



Illnesses and Signs & Symptoms

There are six notifiable tick-borne pathogens that cause human illness in the United States. These pathogens may be transmitted during a tick bite – normally hours after attachment. The illnesses, presented in approximate order of most common to least, include:

- Lyme (bacteria)
- RMSF (bacteria)
- Ehrlichiosis (bacteria)
- STARI (Southern Tick-Associated Rash Illness) (bacteria)
- Tularemia (Rabbit Fever) (bacteria)
- Babesia (protozoan parasite)

Symptoms will vary based on the illness, and may develop in infected individuals typically between 3 and 30 days after transmission. Some infected individuals will not become ill or may develop only mild symptoms. These illnesses present with some or all of the following signs & symptoms: fever, headache, muscle aches, stiff neck, joint aches, nausea, vomiting, abdominal pain, diarrhea, malaise, weakness, small solid, ring-like, or spotted rashes. The bite site may be red, swollen, or develop ulceration or lesions. A variety of long-term symptoms may result when untreated, including debilitating effects and death.

Poison Oak, Ivy and Sumac

Poison oak, ivy and sumac plants are the single most common cause of allergic skin reactions in the United States. They are caused by contact with urushiol (you-ROO-shee-ol), which is found in the sap of the plants. It is colorless or pale yellow oil that oozes from any cut or crushed part of the plant, including the roots, stems and leaves. The oil is active year round. Reaction to Poison Oak, Ivy, and Sumac ranges from no reaction to a severe “rhus” dermatitis. Rhus is the class of poisonous plants which includes poison oak, poison ivy, poison sumac, mango, and other urushiol containing plants. 3 of 4 people will develop dermatitis on contact with urushiol.

Contact with urushiol can occur in three ways: direct, indirect and airborne particles. Direct contact is touching the sap of the toxic plant, while indirect contact involves touching something which has urushiol on it, such as personal protective equipment (PPE), clothes, boots, field equipment, or any items that have come in contact with the plant (including your hands). Airborne urushiol particles, such as burning plants or spray from a weed whacker, may also contact the skin or be inhaled, causing internal inflammation.

The rash caused by urushiol can affect almost any part of the body, especially where the skin is thin, such as the face. The rash does not spread, although it may seem to when it breaks out in new areas. Actually, what happens is the urushiol absorbs more slowly into thicker skin, such as found on the forearms, legs and trunk.

Identification

Poison Oak

Poison oak shrubs are usually 12" to 30" high, or a tree-climbing vine, with triple leaflets and short, smooth hair underneath. A project site in Portland had 8' tall poison oak bushes. Early berries are fuzzy and white; later, dun-colored. Plants are red and dark green in Spring and Summer, with yellowing leaves anytime especially in dry areas. Leaves may achieve bright reds

in Fall, but the plant loses its (yellowed, then brown) leaves in Winter, leaving toxic stems. All parts of the plant remain toxic throughout the seasons.

Poison Ivy

Poison ivy plants are frequently found around lakes and streams in the Midwestern and the Eastern parts of the United States and are commonly found growing along trails and roadsides. Poison ivy grows as a woody, ropelike vine that can grow along fences or up trees, a trailing shrub on the ground, or a free-standing shrub. It normally has three leaflets (groups of leaves all on the same small stem coming off the larger main stem), but may vary from groups of three to nine. Poison ivy leaves are green in the summer and red in the fall with yellow or green flowers and white berries.

Poison Sumac

Poison sumac plants grow in boggy areas, especially in the Southeastern United States. Typically, poison sumac grows as a rangy shrub up to 15 feet tall. The plants are found to have seven to 13 smooth-edged leaflets and can have glossy pale yellow or cream-colored berries.

Primary contamination from poison oak, ivy or sumac, results from contact with bruised or broken plant parts that release "toxicodendrol", an oily resin containing the toxic chemical "urushiol".



Poison Ivy



Poison Sumac



Poison Oak

Exposure

Contamination with poison oak, ivy or sumac can happen through several pathways. These include

- Direct skin contact with any part of the plant.
- Contact with clothing that has been contaminated
- Contact from removing shoes that have been contaminated. (your shoes are coated with oil)
- Sitting in a vehicle that has become contaminated
- Contact with any objects or tools that have become contaminated.

Exposure to poison oak, ivy or sumac often becomes an OSHA recordable illness. The dermatitis is so severe that many people seek medical care and get prescription cortisone creams or steroid shots to reduce the suffering caused by the itch. If exposed, refer to the CH2M HILL HSE&Q Injury and Illness Reporting brochure for proper action to take if contaminated.

Best Work Practices

If you must work on a site that has been identified to potentially contain poison oak, ivy or sumac, the following precautions are necessary:



Identify plants containing urushiol – The best way to prevent exposure is to recognize the plant and avoid working in areas where poison oak, ivy or sumac is present.



If you must work in areas with urushiol containing plants, contact your project manager and health and safety manager to determine the best procedures to prevent contamination.



Do not drive vehicles onto the site where it will come into contact with poison oak, ivy or sumac. Vehicles which need to work in the area, such as drill rigs or heavy equipment must be washed and decontaminated as soon as possible after leaving the site.



All tools used in the area, including those used to cut back the plants, surveying instruments used in the area, air monitoring equipment or other test apparatus must be decontaminated before they are placed back into the site vehicle. If on-site decontamination is not possible, use plastic to wrap any tools or equipment until they can be decontaminated. If working on or near the ground surface, place plastic on the ground to cover the grass and foliage.



Personal protective equipment (PPE), including tyvek coveralls, gloves, and boot covers must be worn. PPE and plastic used to cover the ground must be placed into separate plastic bags and sealed if they are not disposed immediately into a trash receptacle.



Shower as soon as possible to remove any potential contamination. Any body part with suspected or actual exposure should be washed with “Tecnu” or other product designed for removing urushiol. If you do not have Tecnu wash with cold water. Do not take a bath, as the oils can form an invisible film on top of the water and contaminate your entire body upon exiting the bath.








Zanfel™ may also be used to treat exposed areas that are experiencing signs and symptoms of poison oak, ivy or sumac contamination. The CH2M HILL warehouses carry Zanfel™ products, which must be carried in First Aid Kits as deemed appropriate. Refer to the Zanfel™ information guide below for specific product and contact information.



Use products such as IvyBlock™ to prevent poison oak, ivy and sumac contamination. IvyBlock™ is approved by the FDA to prevent the rash caused by poison oak, ivy and sumac.

If there is exposure use the following first aid procedures, or others you may find to alleviate the pain and itching.



Poison Oak, Ivy, and Sumac First Aid

<p>Are there any of these problems?</p> <ul style="list-style-type: none"> • Swelling in the throat, tongue and/or lips • A hard time breathing or swallowing • Weakness, dizziness • Bluish lips and mouth • Unconsciousness <p>NO</p>	<p>YES</p> <div>   </div> <p>Use emergency kit with adrenalin, if available, and Get Emergency Care.</p>
<p>Do you have any of these problems?</p> <ul style="list-style-type: none"> • Skin that is very bright red. • Pus. • Rash that has spread to the mouth, eyes or genitals. • Rash on large areas of the body or the face. <p>NO</p>	<p>YES</p> <div>   </div> <p>Give first aid before seeing doctor:</p> <ul style="list-style-type: none"> • Take a hot shower (only after rash develops), put the rash area in hot water or pour hot water over it. Make sure the water is not too hot to burn the skin. The hot water causes itching at first, but brings relief later. Do not use soap. • Take an over-the-counter antihistamine, such as Benadryl, as stated on the label. • For weeping blisters: • Mix 2 teaspoons of baking soda in 1 quarter (4 cups) of water. • Dip squares of gauze in this mixture. • Cover the blisters with the wet gauze for 10 minutes, four times a day. (Do not apply this to the eyes.)
<p>NO</p> 	

Urushiol Plant Facts

Urushiol Oil is Potent

- Only 1 nanogram (billionth of a gram) needed to cause rash
- Average is 100 nanograms for most people
- 1/4 ounce of urushiol is all that is needed to cause a rash in every person on earth
- 500 people could itch from the amount covering the head of a pin
- Specimens of urushiol several centuries old have found to cause dermatitis in sensitive people.
- 1 to 5 years is normal for urushiol oil to stay active on any surface including dead plants
- Derived from **urushi**, Japanese name for lacquer

Myth 	Fact 
Poison oak, ivy, and sumac are contagious	Rubbing the rashes won't spread poison ivy to other parts of your body (or to another person). You spread the rash only if urushiol oil -- the sticky, resinlike substance that causes the rash -- has been left on your hands.
You can catch poison ivy simply by being near the plants	Direct contact is needed to release urushiol oil . Stay away from forest fires, direct burning, or anything else that can cause the oil to become airborne such as a lawnmower, trimmer, etc.
Leaves of three, let them be	Poison sumac has 7 to 13 leaves on a branch, although poison ivy and oak have 3 leaves per cluster
Do not worry about dead plants	Urushiol oil stays active on any surface, including dead plants, for up to 5 years.
Breaking the blisters releases urushiol oil that can spread	Not true. But your wounds can become infected and you may make the scarring worse. In very extreme cases, excessive fluid may need to be withdrawn by a doctor.

New Cream to Treat Exposure to Poison Plants

Exposure to poison oak, ivy and sumac can be uncomfortable, and in some cases the rash can become so severe that medical care is required. A new product is available Zanafel™ (www.zanafel.com) that helps prevent blistering and itching from becoming severe. If you are working in an area with poison oak, ivy or sumac, you can obtain this cream by contacting your regional Safety Program Assistants (SPAs):

SWR: Julie Yeager/SAC

NER: Lynn Bong/MKE

NWR: Donita O'Brien/SEA

SER: Vanessa Wheelus/GNV

CNR: Donita O'Brien/SEA

Please remember, the cream does not replace preventative measures, including:

- Avoiding contact with poison oak, ivy and sumac.
- Wearing Tyvek coveralls and gloves to prevent contact.
- Washing with Tecnu® (or a similar product) after potential exposure.
- Washing clothing and decontaminating equipment with an oil-cutting detergent.

More information about Zanafel (from Zanafel):

Zanafel™ is an effective wash for urushiol-induced contact dermatitis. Urushiol is the toxin known to cause the itching and rash associated with poison oak, ivy, sumac, poisonwood, and related plants. Zanafel works by surrounding urushiol and bonding with it, thereby enabling it to be rinsed away. Unlike some products that require use within 10-20 minutes of contact or that required continued use until the rash is gone (which can take up to 5 weeks), Zanafel offers relief at any stages of the reaction and often with only one wash. Individuals with particularly severe reactions may require additional washes. Most individuals experience relief from the itching within 30 seconds of application. The rash will begin to subside within hours if the reaction is mild to moderate. Severe and systemic cases will still require medical attention. Severe cases are defined as breakouts that are present on more than 15-percent of the body, and new breakouts continue to develop after day 4.

BROWN RECLUSE SPIDER



Its size - Adult brown recluse spiders have a leg span about the size of a quarter. Their body is about $\frac{3}{8}$ inches long and about $\frac{3}{16}$ inches wide. Males are slightly smaller in body length than females, but males have proportionally longer legs. Both sexes are venomous

Recluse spiders have been known to inhabit most of the lower 48 states; however its typical range is shown on the attached map.

- If bitten stay calm, immediately apply ice to the bite and to try and collect the spider (said even a mangled part of the spider might help a professional with a diagnosis) and go to the ER.
- Shake out clothing and shoes before getting dressed.
- Inspect bedding and towels before use.
- Wear gloves when handling firewood, lumber, and rocks (be sure to inspect the gloves for spiders before putting them on).
- Remove bedskirts and storage boxes from underneath beds. Move the bed away from the wall.
- Exercise care when handling cardboard boxes (recluse spiders often are found in the space under folded cardboard flaps)



Attachment 11
Drug Testing Hospital Kit Notice

HOSPITAL KIT NOTICE

You are receiving this package because you are listed as a Project Manager and/or Superintendent/CM who is managing a CCI project or an INC project which requires drug testing. The items in the package, known as a 'hospital kit', are needed if there is a serious injury requiring medical care on your project.

It is your responsibility to make certain that this hospital kit is onsite at all times while construction is in progress.

For minor injuries - Hospital Kits are NOT required. After the injury is treated, the injured employee will be tested at the emergency care clinic or you can take the injured employee to the usual laboratory collection facility. Both the emergency care clinic and the laboratory collection facility already have drug testing kits and you will only be responsible to provide them with your normal Custody and Control Form (CCF) in order for the employee to be tested.

For more serious injuries that require hospital, ambulance, or paramedic care, we need to provide the collector with the 'hospital kit' in order for the drug test specimen to be properly collected. This package *contains everything that the medical provider will need* to collect the sample. It is critical that the 'hospital kit' accompanies all injured employee(s) to the hospital so they will get drug tested. If more than one employee is injured, you must send one kit for each employee that is to receive care at the hospital. After the kit is used, you must immediately contact Elaine Senecal/ORL to get a replacement kit. These kits must remain onsite and be available for emergencies at all times.

Location for CHI

Contact Elaine Senecal (407-423-0001 x240) for location nearest your project site location.

CH2M HILL Personnel also need on-line training:

http://www.int.ch2m.com/safety_counts/Training_Basic_Modules/Drug_desc.html

Attachment 12
Incident Report Form and
Root Cause Investigation Information

CH2MHILL

Incident Report Form (Hardcopy)

Fax completed form to:

425.462.5957

CH2M HILL Seattle Office

Attention: Corporate HS&E Department

Type of Incident (Select at least one)

- | | | |
|---|--|--|
| <input type="checkbox"/> Injury/Illness | <input type="checkbox"/> Property Damage | <input type="checkbox"/> Spill/Release |
| <input type="checkbox"/> Environmental/Permit Issue | <input type="checkbox"/> Near Miss | <input type="checkbox"/> Other |

General Information (Complete for all incident types)

Preparer's Name: _____ Preparer's Employee Number: _____
Date of Report: _____ Date of Incident: _____ Time of Incident: _____ am/pm

Type of Activity (Provide activity being performed that resulted in the incident)

- | | | |
|--|--|--|
| <input type="checkbox"/> Asbestos Work | <input type="checkbox"/> Excavation Trench-Non Haz | <input type="checkbox"/> Process Safety Management |
| <input type="checkbox"/> Confined Space Entry | <input type="checkbox"/> Facility Walk Through | <input type="checkbox"/> Tunneling |
| <input type="checkbox"/> Construction Mgmt- Haz Waste | <input type="checkbox"/> General Office Work | <input type="checkbox"/> Welding |
| <input type="checkbox"/> Construction Mgmt - Non-Haz Waste | <input type="checkbox"/> Keyboard Work | <input type="checkbox"/> Wetlands Survey |
| <input type="checkbox"/> Demolition | <input type="checkbox"/> Laboratory | <input type="checkbox"/> Working from Heights |
| <input type="checkbox"/> Drilling-Haz Waste | <input type="checkbox"/> Lead Abatement | <input type="checkbox"/> Working in Roadways |
| <input type="checkbox"/> Drilling-Non Haz Waste | <input type="checkbox"/> Motor Vehicle Operation | <input type="checkbox"/> WWTP Operation |
| <input type="checkbox"/> Drum Handling | <input type="checkbox"/> Moving Heavy Object | |
| <input type="checkbox"/> Electrical Work | <input type="checkbox"/> Other (Specify) _____ | |
| <input type="checkbox"/> Excavation Trench-Haz Waste | | |

Location of Incident (Select one)

- ☐ Company Premises (CH2M HILL Office: _____)
☐ Field (Project #: _____ Project/Site Name: _____ Client: _____)
☐ In Transit (Traveling from: _____ Traveling to: _____)
☐ At Home

Geographic Location of Incident (Select region where the incident occurred)

- | | | |
|------------------------------------|------------------------------------|---|
| <input type="checkbox"/> Northeast | <input type="checkbox"/> Southwest | <input type="checkbox"/> Asia Pacific |
| <input type="checkbox"/> Southeast | <input type="checkbox"/> Corporate | <input type="checkbox"/> Europe Middle East |
| <input type="checkbox"/> Northwest | <input type="checkbox"/> Canadian | <input type="checkbox"/> Latin America |

If a CH2M HILL subcontractor was involved in the incident, provide their company name and phone number: _____

Describe the Incident (Provide a brief description of the incident): _____

Injured Employee Data (Complete for Injury/Illness incidents only)

If CH2M HILL employee injured

Employee Name: _____ Employee Number: _____

If CH2M HILL Subcontractor employee injured

Employee Name: _____ Company: _____

Injury Type

- ☐ Allergic Reaction
- ☐ Amputation
- ☐ Asphyxia
- ☐ Bruise/Contusion/ Abrasion
- ☐ Burn (Chemical)
- ☐ Burn/Scald (Heat)
- ☐ Cancer
- ☐ Carpal Tunnel
- ☐ Concussion
- ☐ Cut/Laceration
- ☐ Dermatitis
- ☐ Dislocation

- ☐ Electric Shock
- ☐ Foreign Body in eye
- ☐ Fracture
- ☐ Freezing/Frost Bite
- ☐ Headache
- ☐ Hearing Loss
- ☐ Heat Exhaustion
- ☐ Hernia
- ☐ Infection
- ☐ Irritation to eye
- ☐ Ligament Damage

☐ Multiple (Specify) _____

- ☐ Muscle Spasms
- ☐ Other (Specify) _____

- ☐ Poisoning (Systemic)
- ☐ Puncture
- ☐ Radiation Effects
- ☐ Strain/Sprain
- ☐ Tendonitis
- ☐ Wrist Pain

Part of Body Injured

- ☐ Abdomen
- ☐ Ankle(s)
- ☐ Arms (Multiple)
- ☐ Back
- ☐ Blood
- ☐ Body System
- ☐ Buttocks
- ☐ Chest/Ribs
- ☐ Ear(s)
- ☐ Elbow(s)
- ☐ Eye(s)
- ☐ Face
- ☐ Finger(s)
- ☐ Foot/Feet

- ☐ Hand(s)
- ☐ Head
- ☐ Hip(s)
- ☐ Kidney
- ☐ Knee(s)
- ☐ Leg(s)
- ☐ Liver
- ☐ Lower (arms)
- ☐ Lower (legs)
- ☐ Lung
- ☐ Mind

☐ Multiple (Specify) _____

- ☐ Neck
- ☐ Nervous System
- ☐ Nose
- ☐ Other (Specify) _____

- ☐ Reproductive System
- ☐ Shoulder(s)
- ☐ Throat
- ☐ Toe(s)
- ☐ Upper Arm(s)
- ☐ Upper Leg(s)
- ☐ Wrist(s)

Nature of Injury

- ☐ Absorption
- ☐ Bite/Sting/Scratch
- ☐ Cardio-Vascular/Respiratory System Failure
- ☐ Caught In or Between
- ☐ Fall (From Elevation)
- ☐ Fall (Same Level)
- ☐ Ingestion

- ☐ Inhalation
- ☐ Lifting
- ☐ Mental Stress
- ☐ Motor Vehicle Accident
- ☐ Multiple (Specify) _____

☐ Other (Specify) _____

- ☐ Overexertion
- ☐ Repeated Motion/Pressure
- ☐ Rubbed/Abraded
- ☐ Shock
- ☐ Struck Against
- ☐ Struck By
- ☐ Work Place Violence

Initial Diagnosis/Treatment Date: _____

Type of Treatment

- ☐ Admission to hospital/medical facility
- ☐ Application of bandages
- ☐ Cold/Heat Compression/Multiple Treatment
- ☐ Cold/Heat Compression/One Treatment
- ☐ First Degree Burn Treatment
- ☐ Heat Therapy/Multiple treatment
- ☐ Multiple (Specify) _____

- ☐ Heat Therapy/One Treatment
- ☐ Non-Prescriptive medicine
- ☐ None
- ☐ Observation
- ☐ Other (Specify) _____

☐ Prescription- Multiple dose

- ☐ Prescription- Single dose
- ☐ Removal of foreign bodies
- ☐ Skin Removal
- ☐ Soaking therapy- Multiple Treatment
- ☐ Soaking Therapy- One Treatment
- ☐ Stitches/Sutures
- ☐ Tetanus
- ☐ Treatment for infection
- ☐ Treatment of 2nd /3rd degree burns
- ☐ Use of Antiseptics - multiple treatment
- ☐ Use of Antiseptics - single treatment
- ☐ Whirlpool bath therapy/multiple treatment
- ☐ Whirlpool therapy/single treatment
- ☐ X-rays negative
- ☐ X-rays positive/treatment of fracture

CH2MHILL

Number of days doctor required employee to be off work: _____

Number of days doctor restricted employee's work activity: _____

Equipment Malfunction : Yes ☐ No ☐

Activity was a Routine Task: Yes ☐ No ☐

Describe how you may have prevented this injury: _____

Physician Information

Name: _____

Address: _____

City: _____

Zip Code: _____

Phone: _____

Hospital Information

Name: _____

Address: _____

City: _____

Zip Code: _____

Phone: _____

Property Damage (Complete for Property Damage incidents only)

Property Damaged: _____ Property Owner: _____

Damage Description: _____

Estimated Amount: \$ _____

Spill or Release (Complete for Spill/Release incidents only)

Substance (attach MSDS): _____ Estimated Quantity: _____

Facility Name, Address, Phone No.: _____

Did the spill/release move off the property where work was performed?: _____

Spill/Release From: _____ Spill/Release To: _____

Environmental/Permit Issue (Complete for Environmental/Permit Issue incidents only)

Describe Environmental or Permit Issue: _____

Permit Type: _____

Permitted Level or Criteria (e.g., discharge limit): _____

Permit Name and Number (e.g., NPDES No. ST1234): _____

Substance and Estimated Quantity: _____

Duration of Permit Exceedence: _____

Verbal Notification (Complete for all incident types)(Provide names, dates and times)

CH2M HILL Personnel Notified: _____

Client Notified: _____

Witnesses (Complete for all incident types)

Witness Information (First Witness)

Name: _____

Employee Number (CH2M HILL): _____

Address: _____

City: _____

Zip Code: _____

Phone: _____

Address: _____

City: _____

Zip Code: _____

Phone : _____

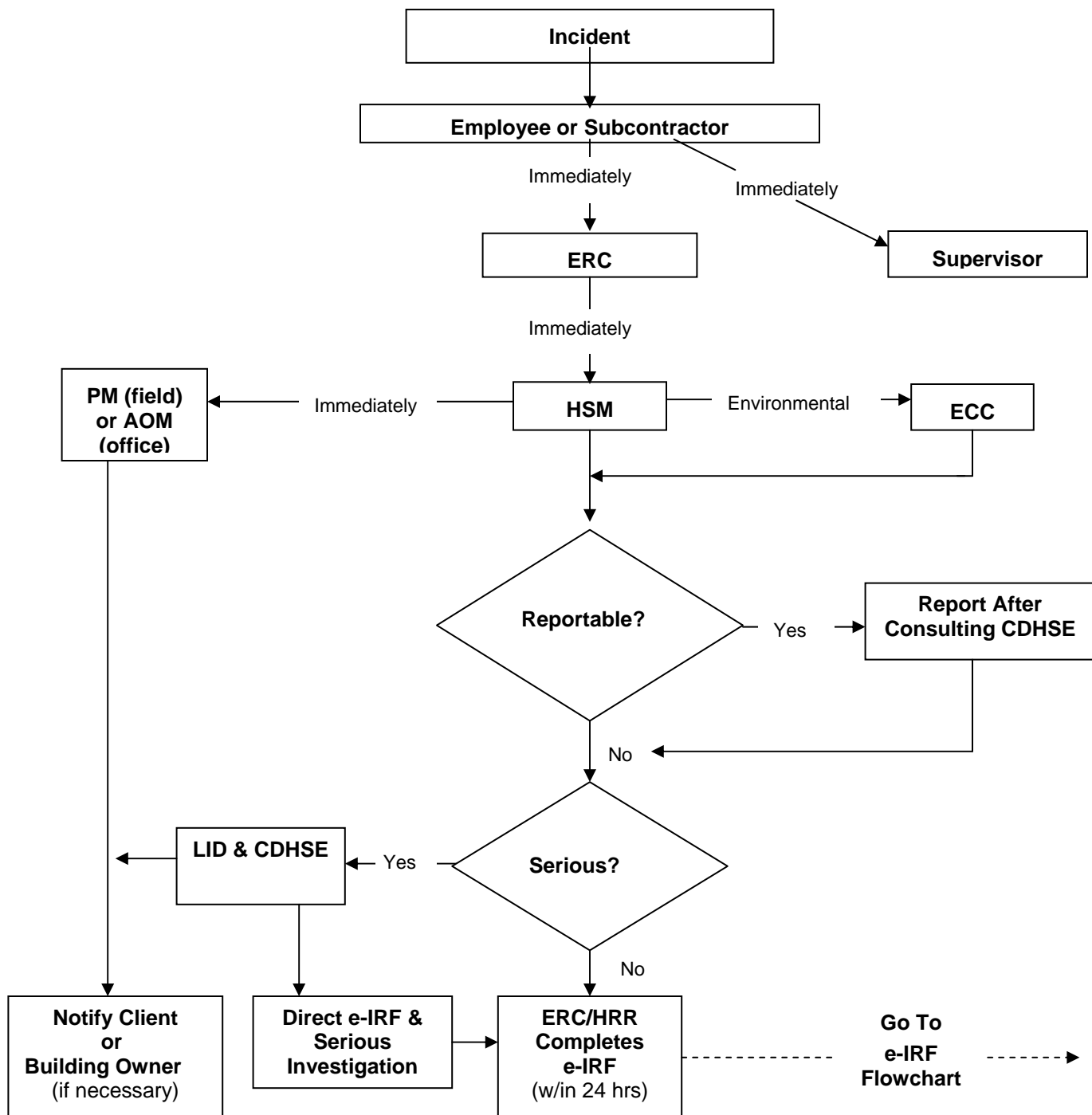
Additional Comments:

Witness Information (Second Witness)

Name: _____

Employee Number (CH2M HILL: _____

Incident Notification and Reporting Flowchart



CH2MHILL

Incident Reporting and Investigation Standard of Practice HSE-111

Investigation Guidelines

1.0 Introduction

This guideline is provided to assist in accessing, completing, and reviewing an incident investigation. It is important to remember the following when conducting an investigation:

- Gather relevant facts, focusing on fact finding, not fault finding.
- Draw conclusions, pitting facts together into a probable scenario.
- Determine incident root cause(s), which are basic causes on why an unsafe act/condition existed.
- Develop and implement solutions, matching all identified root causes with solutions.

2.0 Documentation

The following should be included in the IRF to document the incident.

Description

- Provide a description of the event and the sequence of events and actions that took place prior to the incident. Start with the incident event and work backwards in time through all of the preceding events that directly contributed to the incident. The information should identify why the event took place as well as who was involved, when and where the event took place, and what actions were taken.

Cause Analysis

Using the form and flowchart in Attachment 11-1, the root cause of the incident will be determined. This form must be retained in the project and/or regional HS&E files.

Immediate Causes – List the substandard actions or conditions that directly affected the incident.

The following are examples of immediate causes:

Substandard Actions: Operating equipment without authority; failure to warn; failure to secure; operating at improper speed; making safety device inoperable; using defective equipment; failing to use PPE; improper loading; improper lifting; improper position for task; under influence of alcohol or drugs; horseplay.

Substandard Conditions: Exposure to hazardous materials; exposure to extreme temperatures; improper lighting; improper ventilation; congestion; exposure to fire and explosive hazard; defective tools, equipment, or materials; exposure to extreme noise; poor ventilation; poor visibility; poor housekeeping.

Basic Causes – List the personal and job factors that caused the incident. The following are examples of basic causes:

Personal Factors: Capability; knowledge; skill; stress; motivation.

Job Factors: Abuse or misuse; engineering; maintenance; purchasing; supervision; tools and equipment; wear and tear; work standards.

Corrective Action Plan

Include all corrective actions taken or those that should be taken to prevent recurrence of the incident. Include the specific actions to be taken, the employer and personnel responsible for implementing the actions, and a time frame for completion. Be sure the corrective actions address the causes. For example, training may prevent recurrence of an incident caused by a lack of knowledge, but it may not help an incident caused by improper motivation.

The following are examples of management programs that may be used to control future incidents. These programs should be considered when determining specific corrective actions.

Management Programs: Accident/incident analysis; emergency preparedness; engineering controls; general promotion; group meetings; health control; hiring and placement; leadership and administration; management training; organizational rules; personal protective equipment; planned inspections; program audits; program controls; purchasing controls; task analysis and procedures; task observation

3.0 Attachments

Attachment 12-1 Root Cause Analysis Form and Flowchart



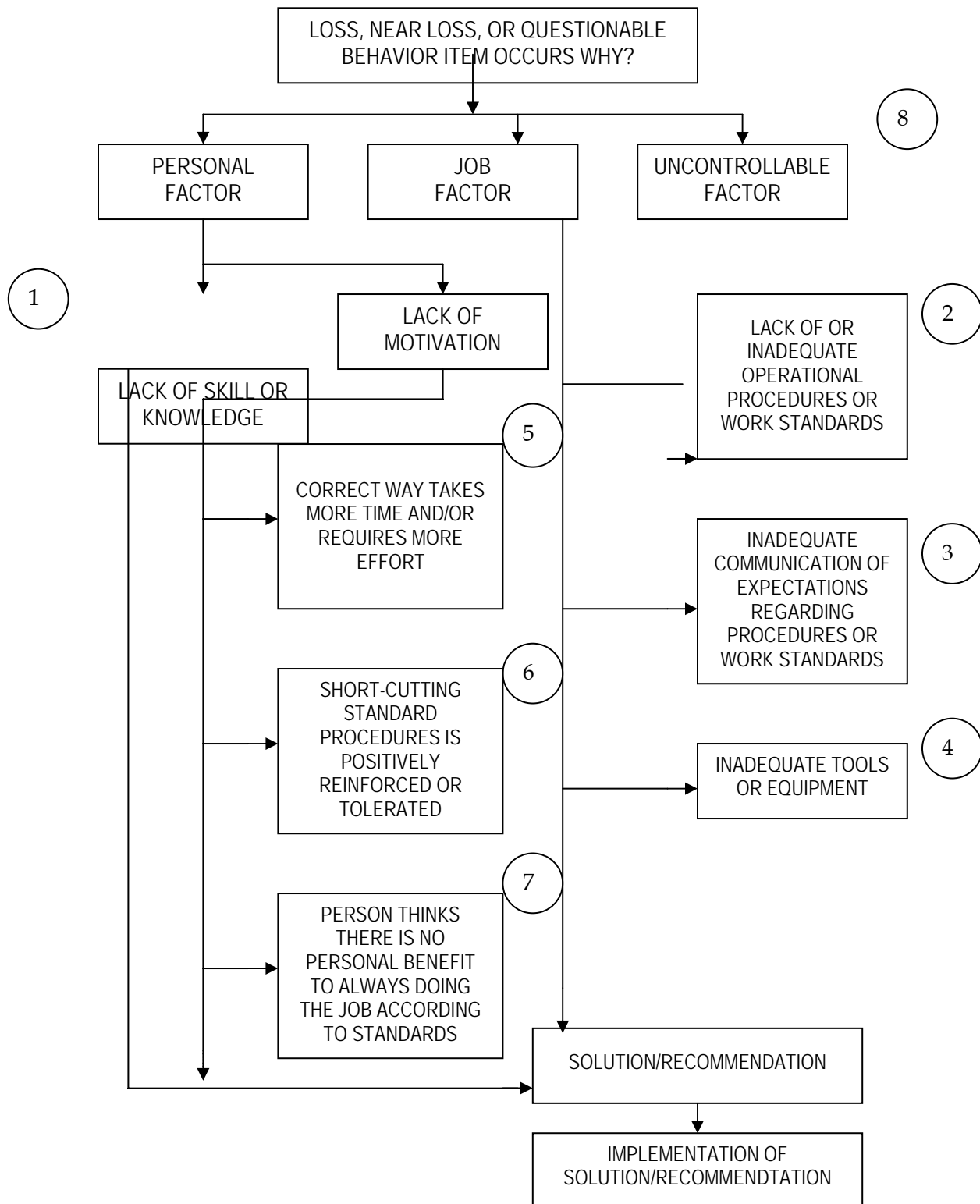
Incident Reporting and Investigation
Standard of Practice HSE-111
Attachment 12-1: Investigation Guidelines

Root Cause Analysis Form and Flowchart

Root Cause Analysis Form

Root Cause Analysis (RCA)							
<p>Root Cause Categories (RCC): Select the RCC numbered below that applies for the root cause (RC) and/or contributing factor (CF) in the first column, then describe the specific root cause and corrective actions in each column.</p> <ol style="list-style-type: none">1. Lack of skill or knowledge2. Lack of or inadequate operational procedures or work standards3. Inadequate communication of expectations regarding procedures or work standards4. Inadequate tools or equipment5. Correct way takes more time and/or requires more effort6. Short-cutting standard procedures is positively reinforced or tolerated7. Person thinks there is no personal benefit to always doing the job according to standards							
RCC #	Root Cause(s)	Corrective Actions	RC ¹	CF ²	Due Date	Completion Date	Date Verified
¹ RC = Root Cause; ² CF = Contributing Factors (check which applies)							
Investigation Team Members							
Name		Job Title			Date		
Results of Solution Verification and Validation							
Reviewed By							
Name		Job Title			Date		

Root Cause Analysis Flowchart



APPENDIX E

Sampling and Analysis Plan

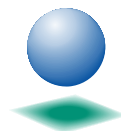
Sampling and Analysis Plan

Wastewater Treatment Solids Management Project

**International Paper Cell No. 2
Riegelwood, NC**

Prepared for
Honeywell International Inc.

Submitted by



CH2MHILL

May 2008

Contents

1. Introduction.....	1-1
2. Sampling Program.....	2-1
2.1 Post-Excavation Confirmation Soil Sampling	2-1
2.1.1 WWTS < 50 mg/kg	2-1
2.1.2 WWTS ≥ 50 mg/kg.....	2-1
2.1.3 Corrugated Discharge Pipe.....	2-2
2.2 Pre-Treatment Discharge Water Samples	2-3
2.3 WWTS Stockpile Sampling	2-3
2.4 Material Management Samples.....	2-4
2.5 General Field Operations	2-4
2.5.1 Sample Collection	2-4
2.5.2 Sample Management.....	2-4
2.5.3 Containers	2-5
2.5.4 Sample Preservation and Holding Times	2-6
2.5.5 Sample Handling, Packaging and Shipment.....	2-6
2.6 Field Activity Documentation and Logbook.....	2-8
2.6.1 Field Logbooks	2-8
2.6.2 Global Positioning System (GPS).....	2-9
2.6.3 Photographic Documentation	2-9
2.6.4 Sample Chain-of Custody	2-9
2.6.5 Field Custody Procedures	2-10
2.7 Instrument/Equipment Testing, Inspection, and Maintenance Requirements ..	2-10
2.8 Quality Control Sample Procedures.....	2-10
2.8.1 Field Quality Control Samples	2-10
2.8.2 Decontamination Procedures	2-11
2.8.3 Personnel Decontamination.....	2-11

Tables

1 Pre-treatment Effluent Monitoring Sampling Schedule	2-3
2 Sample Containers, Preservation, and Holding Times	2-6

Appendices

A Wastewater Sampling
B Wipe Sampling

Acronyms and Abbreviations

CERCLA	Comprehensive Environmental Response Compensation and Liability Act
EE/CA	Engineering Evaluation/Cost Analysis
FSP	Field Sampling Plan
GPS	Global Positioning System
IP	International Paper
mg/kg	milligram per kilogram
MS/MSD	matrix spike/matrix spike duplicate
OSWER	Office of Solid Waste and Emergency Response
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyls
PPE	personal protective equipment
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
SVOC	semivolatile organic compound
TAL	Target Analyte List
TCL	Target Compound List
TSCA	Toxic Substances Control Act
US EPA	U. S. Environmental Protection Agency
VOA	volatile organic analysis
VOC	volatile organic compound
WWTS	Wastewater Treatment Solids

1. Introduction

This Sampling and Analysis Plan (SAP) describes CH2M HILL's tasks and responsibilities for sampling and analysis activities associated with excavation, segregation, transportation, and storage of wastewater treatment solids (WWTS) located in Cell No. 2 of International Paper's (IP's) Riegelwood Mill North Bay Treatment Pond, located in Rieglewood, North Carolina.

Analytical results from samples collected from Cell No. 2 indicate the presence of Aroclor 1268 at concentrations exceeding 11 mg/kg. The US EPA has indicated the WWTS exceeding background concentrations are considered part of the Holtrachem site currently regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The North Carolina Division of Waste Management (DWM) has determined that WWTS with PCB concentrations <50 mg/kg can be disposed in Cell No. 1 in accordance with the Cell No. 1 Operations Manual (Industrial Landfill Facility Permit #24-02, February 2005). Honeywell will excavate the WWTS from Cell No. 2. WWTS containing concentrations of Aroclor 1268 <50 mg/kg will be transported to IP's Cell No. 1, which is constructed to Resource Conservation and Recovery Act (RCRA) criteria.

WWTS containing Aroclor 1268 concentrations of 50 mg/kg and greater will be managed by Honeywell on the Holtrachem site. Honeywell plans to temporarily contain these WWTS in an engineered stockpile located on the Holtrachem property pending implementation of a site-wide remedy.

CH2M HILL intends this document to be a site-specific guide for use by the field team while performing the project-required sampling and analysis. Any changes to the activities described in this SAP must be documented as an addendum to this SAP and approved by the CH2M HILL Project Manager and Project Chemist.

This Sampling and Analysis Plan (SAP) covers the following activities that will be performed during the project:

- Collection of post-excavation confirmation soil samples
- Collection of post-treatment water samples
- Collection of WWTS samples stored on Holtrachem property
- Collection of material management samples from overburden material located above WWTS with Aroclor 1268 concentrations ≥ 50 mg/kg.

The analytical requirements are discussed in detail in the Quality Assurance Project Plan (QAPP).

Any additional sampling effort that becomes necessary in the future will be addressed in an addendum to the SAP, QAPP, and other relevant documents specific to the project.

2. Sampling Program

2.1 Post-Excavation Confirmation Soil Sampling

The post-excavation confirmation sampling can be divided into three phases: post-excavation of the WWTS containing <50 mg/kg of Aroclor 1268, post-excavation of the WWTS containing ≥50 mg/kg of Aroclor 1268, and post-excavation after removal of the corrugated discharge pipe.

2.1.1 WWTS < 50 mg/kg

Upon completion of excavation activities, confirmation samples will be collected from the base of the excavation at each grid node. Samples will be collected from the top 12 inches. The samples will be sent to a North Carolina-certified laboratory for analysis of Aroclor 1268 by US EPA SW-846 Method 8082.

Due to personnel health and safety concerns, confirmation samples may be collected from the bucket of excavation equipment. The bucket will be decontaminated in accordance with the Engineering Evaluation/Cost Analysis (EE/CA) Field Sampling Plan (FSP) between sample locations to minimize the potential for cross-contamination. Sample material will be selected from a portion of the recovered material that is relatively undisturbed and not in contact with the excavation equipment.

2.1.2 WWTS ≥ 50 mg/kg

Post-excavation sampling will be performed to confirm that WWTS with PCB concentrations >11 mg/kg have been removed from Cell No. 2. The approximate extent of confirmation sampling within Cell No. 2 is the dashed area shown on **Figure 3-1**.

A 50 buffer area has been established around WWTS concentrations containing Aroclor 1268 concentrations ≥ 50 mg/kg. Excavation of material containing Aroclor 1268 concentrations ≥ 50 mg/kg will begin in the highest concentration areas and continue outward. Confirmation samples will be collected from the excavation sidewalls to confirm WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg have been removed. When confirmation samples indicate material containing Aroclor 1268 concentrations ≥ 50 mg/kg has been removed, the remaining buffer material will be excavated and transported to Cell No. 1.

Confirmation samples will be collected from the excavation using the following methods:

1. Overlay a square-based (maximum dimensions of 50 feet by 50 feet) grid system over the excavated area.
2. Divide the sampling grid into quadrants and mark out sampling points within the center of each quadrant.
3. Composite four discrete grab samples from the surface (0 to 6 inches below grade) in each quadrant of the removal area.

4. Collect sidewall samples from the elevation that corresponds to the highest PCB concentrations based on existing data. These samples will be collected as discrete grab samples.

Samples will be sent to a North Carolina-certified laboratory for analysis of Aroclor 1268 by US EPA SW-846 Method 8082.

If detected concentrations in the bottom confirmation soil samples exceed the cleanup goal, an additional 1-foot interval will be solidified and removed from the grid section and confirmation samples will be re-collected from the newly excavated area. In the event sidewall samples contain elevated concentrations of PCBs, the areal extent of the confirmation sampling will be extended by an appropriate distance based on the analytical results and the sidewall confirmation sampling repeated.

Bottom of excavation confirmation samples will be identified with a unique designation using the following protocol:

SB-B-QN-XY-C where:

SB = soil boring (all locations)

B = bottom

QN = quadrant number

XY = approximate depth interval below pre-excavation ground surface in feet

C = composite

Sidewall excavation confirmation samples will be identified with a unique designation using the following protocol:

SB-W-QN-XY-G where:

SB = soil boring (all locations)

W = sidewall

QN = quadrant number

XY = average depth interval below pre-excavation ground surface in feet

G = grab

Due to personnel health and safety concerns, confirmation samples may be collected from the bucket of excavation equipment. The bucket will be decontaminated in accordance with the SAP between sample locations to minimize the potential for cross-contamination. Sample material will be selected from a portion of the recovered material that is relatively undisturbed and not in contact with the excavation equipment.

2.1.3 Corrugated Discharge Pipe

Following removal of the pipe, soil samples will be collected from the sidewalls and floor of the piping trench to determine the residual concentrations of Aroclor 1268. Soil samples will be collected from the sidewalls and along the base of piping trench at intervals of 50 feet. The pipe sampling results will be compared with the cleanup goal of 11 mg/kg.

2.2 Pre-Treatment Discharge Water Samples

Water collected from WWTS dewatering activities will be treated using filtration methods before being discharged to the IP wastewater treatment system. Samples of the pre-treated water will be collected between the carbon units and at the discharge of the pre-treatment train (following the bag filters).

The sampling schedule is shown in **Table 1**.

TABLE 1
Pre-treatment Effluent Monitoring Sampling Schedule

Parameter	Method ^a	Removal of WWTS <50 mg/kg		Removal of WWTS ≥ 50 mg/kg	
		Sample Type	Min Frequency	Sample Type	Min Frequency
PCBs	EPA SW-846 Method 8082	G	1/week	G	1/day for first week, 1/week thereafter

G= Grab

MG = Multiple grab

^aFor parameters with multiple method options, any of the methods may be used with the following conditions:

The method chosen must meet the required Level of Quantitation (LOQ). Once a method is chosen, it must be used consistently throughout the duration of the project to maintain data comparability.

2.3 WWTS Stockpile Sampling

Composite samples will be collected from the engineered stockpile at a rate of one sample per 1,000 cubic yards of WWTS. With the exception of samples analyzed for volatile organic compounds (VOCs), grab samples will be collected from randomly selected truck loads and composited. The grab samples will be transferred to a clean stainless steel bowl for mixing prior to placement in the sample bottle. The composite sample will be sent to a NC-certified laboratory for analysis of semi-volatile organic compound (SVOCS), RCRA metals, pesticides, and dioxins. Samples collected for analysis of VOCs will be discrete grab samples from randomly selected truck loads.

Stockpile samples will be identified with a unique identification number using the following protocol:

ESP-#- where:

ESP = engineered stockpile

= unique sequential stockpile number

2.4 Material Management Samples

Overburden material removed from grid locations containing Aroclor 1268 concentrations ≥ 50 mg/kg will be removed and placed in stockpiles located within Cell No. 2. The stockpiles will be constructed within a bermed area lined with 10 mil polyethylene. A separate stockpile will be constructed for each grid section where Aroclor 1268 was detected at concentrations ≥ 50 mg/kg. Material management samples will be collected from each stockpile at a rate of 1 sample per 1,000 cubic yards of material and analyzed for Aroclor 1268 by US EPA SW-846 Method 8082. Based on the results of those samples, the overburden material will either be transported to Cell No. 1 or to the engineered stockpile.

2.5 Wipe Samples

In accordance with 40 CFR 761.79(b) and 761.79(c), any equipment, including excavation equipment, trucks, hand tools and non-disposable sampling equipment, coming into contact with sediment containing PCB concentrations ≥ 50 mg/kg will be decontaminated as described in the WWTS Removal Work Plan and the EE/CA FSP. Wipe samples will then be collected from the decontaminated equipment. Equipment will be considered appropriately decontaminated and may be removed from the site when wipe sample results are ≤ 10 $\mu\text{g}/100\text{ cm}^2$.

Wipe samples will be collected using a risk based approach. One wipe sample will be collected from each side or section of equipment that was in contact with soil containing PCB concentrations ≥ 50 mg/kg and composited into a single sample for analysis of Aroclor 1268 using EPA Method 8082. For example, for dump trucks, one wipe sample from each sidewall and bottom, totaling five single wipes, will be composited either in the field or by the laboratory for a single composited result. Decontamination and wipe sampling will be documented in the daily Quality Control Reports (QCRs) and/or Contractor Production Reports (CPRs). If sample results are greater than $10\text{ }\mu\text{g}/100\text{ cm}^2$, decontamination and wipe sampling will be repeated. Wipe Sampling SOPs are included in **Appendix B**.

2.6 General Field Operations

2.6.1 Sample Collection

Soil samples will be collected in accordance the Engineering Evaluation/Cost Analysis (EE/CA) SAP (Geosyntec 2004), effluent sampling procedures included in **Appendix A**, and wipe samples will be collected in accordance with **Appendix B**.

2.6.2 Sample Management

This section describes the procedures for sample handling, custody, and documentation required to ensure the integrity of all samples collected in support of the sampling effort.

Identification

Sample IDs will be in agreement with any project-developed sampling protocols. Each sample collected during the investigation will be given a unique identification code. Each unique sample identification code will consist of the following:

Date: An eight-number identification will be on every sample identifying the year, month, and day. For example, January 2, 2006, would be 20060102.

Sample location: See naming conventions outlined above.

QA/QC samples:

- Field duplicates will not be identified as such but will be numbered consecutively with other samples collected on the same day. A note will be made in the field logbook as to which sample is the field duplicate.
- Trip blanks will be identified with the date and “TB” designation and numbered consecutively with the other samples collected that day.
- Equipment blanks will be identified with the date and “EB” designation and numbered consecutively with the other samples collected that day. A note will be made in the field logbook as to the piece of equipment associated with the equipment blank.
- A sample collected for laboratory QC (such as a matrix spike sample) is considered to be a single sample, even though additional volume is provided to the laboratory. Consequently, all laboratory QC samples are assigned a single sample number and type identifier. Laboratory QC samples are not identified in the station location code but rather are called out on the chain-of-custody form in the *Samples to be used for laboratory QC* field and on the sample tag.

Examples:

- 20071206-ESP-1-C Composite sample collected on December 6, 2007, from Engineered Stockpile 1
- 20071206_TB The trip blank, sent on December 6, 2007

Each sampling label will be filled out with waterproof ink and will contain, at a minimum, the following information:

- Sample identification number
- Date/time of sample collection
- Sampler’s initials
- Required analyses
- Type of preservative

2.6.3 Containers

Table 2 summarizes the types of containers, sample quantities, and sample preservation required for each analysis. One additional soil sample volume will be provided when matrix spike and matrix spike duplicate samples are required. The laboratory will provide the sample containers, preservatives, shipping coolers, packing material, and absorbent necessary to properly collect and ship the samples to the laboratory. (The laboratory is responsible for the cost of shipping these materials to the site.) Sample bottles shall be preserved by the laboratory before shipment. Bottles will arrive onsite or a location designated by the laboratory task manager before scheduled sampling events.

TABLE 2

Sample Containers, Preservation, and Holding Times
WWTS Management Sampling and Analysis Plan

Analyte	Method	Container and Minimum Quantity	Preservation	Holding Time
Soil Samples				
Aroclor 1268	SW-846 8082	One 8-oz. glass	4°C	14 days to extraction/40 days from extraction to analysis.
Pre-Treatment Discharge Water Samples				
Aroclor 1268	SW-846 8082	Two 1-L amber glass	4°C	7 days to extraction, 40 days from extraction to analysis
Stockpiled WWTS Samples				
VOCs	SW-846 8260B	One 2-oz. glass jar OR 3 EnCore or equivalent samplers (Dependent upon sample matrix)	4°C	14 days to extraction/40 days from extraction to analysis. (If using EnCore or equivalent sampler, freeze, preserve or analyze samples within 48 hours of collection.)
SVOCs	SW-846 8270C	One 8-oz glass jar	4°C	14 days to extraction/40 days from extraction to analysis.
Pesticides	SW-846 8081A	One 8-oz. glass	4°C	14 days to extraction/40 days from extraction to analysis.
Metals	SW-846 6000 or 7000 series	One 4-oz. plastic	4°C	180 days, 28 days Hg
Dioxins	EPA Method 1613	One 4-oz. amber jar w/Teflon cap	4°C	1 year prior to extraction, 45 days from extraction to analysis

Sample containers shall be I-CHEM Series 200 type or equivalent. The laboratory shall follow the "Specifications and Guidance for Obtaining Contaminant-Free Sample Containers," USEPA Office of Solid Waste and Emergency Response (OSWER) Directive #9240.0-05 (rev. 6/90). The laboratory shall have available, if requested, information concerning the quality assurance/quality control (QA/QC) program for sample bottles and lot numbers for the supplied sample containers.

2.6.4 Sample Preservation and Holding Times

See **Table 2** for details on sample preservation.

2.6.5 Sample Handling, Packaging and Shipment

The following sections describe the procedures for sample handling, preservation, transportation, and storage. Sample chain-of-custody procedures are also described below.

Table 2 lists the required sample container, preservation, and holding times for the individual analytical methods and sample matrix. Sample containers will, with exception of zip-lock bags, be provided by the laboratory and prepared in accordance with *The Samplers Guide to the CLP Program* (USEPA, Draft Final June 2001). Sample containers will be purchased by the laboratory precleaned to requirements of the OSWER Directive 9240.05A.

Sample containers will be kept closed and in a cooler until used. As sample containers are filled they will be labeled as described above.

Sample Packaging.

Sample packaging and shipping procedures are designed to ensure that the samples will arrive at the laboratory, along with the chain of custody, intact. Samples will be packaged for shipment as outlined below:

- All sample containers will have the sample labels securely affixed to the container with clear packing tape.
- Caps on the sample containers will be checked to ensure they are properly sealed.
- Sample container caps will be wrapped with clear packing tape to prevent them from becoming loose.
- Chain-of-custody forms will be completed with required sampling information, and recorded information will match the sample labels.
- If the designated sampler relinquishes samples to other sampling or field crew member for packing or other purposes, the sampler will complete the chain of custody before the transfer.
- Appropriate personnel will sign and date chain-of-custody forms to document the sample custody transfer.
- The outside drain plug at the bottom of the cooler will be secured inside and out using duct tape.
- Sample containers will be protected in bubble wrap or other cushioning material. One to 2 inches of cushioning material will be placed at the bottom of the cooler.
- Sealed sample containers will be placed in the cooler.
- Ice will be double bagged with plastic zipper bags. Bags will be sealed and placed loosely in the cooler. Remaining space in the cooler will be filled with cushioning material.
- Chain-of-custody forms will be placed in a sealed plastic bag and taped to the inside of the cooler lid.
- The lid of the cooler will be closed, locked, and secured with strapping tape. Strapping tape will be wrapped around both ends of the cooler at least twice.
- The cooler will be marked on the outside with shipping address, return address, "Fragile" labels, and arrows indicating "This Side Up."
- Labels will be covered with clear plastic tape.
- A temperature blank will be placed in each cooler (temperature blanks are not required for geotechnical samples).
- Signed custody seals will be placed over opposite corners of the cooler lid.
- All coolers will be shipped or sent by courier with the samples to the analytical laboratory by express overnight service or courier service.

- All samples will be transported or shipped in a manner that protects integrity of the samples and safety of the handlers.
- Original chain-of-custody forms will accompany the shipment; copies will be retained by the sampler for sampling records.
- If samples are sent by common carrier, bills of lading will be used. Receipts or bills of lading will be retained as part of the permanent project documentation.
- Commercial carriers will not be required to sign off on chain-of-custody forms as long as the forms are sealed inside the sample cooler and custody seals remain intact.
- Packaging, marking, labeling, and shipping of samples will comply with the regulations promulgated by the U.S. Department of Transportation in the Code of Federal Regulations (49 CFR 171-177).

Disposable equipment and debris, such as health and safety equipment, plastic sheeting, sampling equipment, and other equipment or sampling debris that has come into contact with WWTS, will be collected in plastic trash bags and put in dumpsters for disposal.

Decontamination rinsate (tap and distilled water containing small amounts of solvent) will be placed in the pre-treatment holding tank for pre-treatment prior to discharge to the onsite treatment system.

Shipping Airbills. If samples are shipped, airbills will be retained to provide a record for sample shipment to the laboratory. Completed airbills will accompany shipped samples to the laboratory and will be forwarded along with data packages. Airbills will be kept as part of the data packages in the project files.

2.7 Field Activity Documentation and Logbook

2.7.1 Field Logbooks

Field logbook entries will be described in as much detail as possible so that persons going to the site could reconstruct a particular situation without reliance on memory. Modifications to field sampling protocols must be documented in the field logbook. The field team leader is responsible for ensuring that modifications to sampling protocols are documented in the field logbook.

Field logbooks will be bound field survey books or notebooks. Logbooks will be assigned to the field crew, but will be stored in a secure location when not in use. Project-specific document numbers will identify each logbook. The title page of each logbook will contain the following information:

- Person to whom the logbook is assigned
- Logbook number
- Project name
- Project start date
- Project end date

At the beginning of each entry, the date, start time, weather, names of all sampling team members present, level of personal protection being used, and the signature of the person making the entry will be documented. Names of visitors to the site, field sampling or investigation team personnel, and the purpose of their visit will also be recorded in the field logbook.

Measurements made and samples collected will be recorded. All entries will be made in ink, and no erasures will be allowed. If an incorrect entry is made, the information will be crossed out with a single strike mark and initialed. Blank pages will be noted as being intentionally blank. Whenever a sample is collected or a measurement made, a detailed description of the location of the station will be recorded. The number of all photographs taken also will be noted. All equipment used to make measurements will be identified, along with the date of calibration.

Samples will be collected following sampling procedures documented herein. Equipment used to collect samples will be noted, along with the time of sampling, sample description, depth at which the sample was collected, volume, and number of containers. Sample identification numbers will be assigned before collection. Field duplicate samples, which will receive an entirely separate sample identification number, will be noted under sample description.

Field personnel will provide comprehensive documentation covering all aspects of field sampling, field analysis, and sample chain of custody. This documentation constitutes a record that allows reconstruction of all field events to aid in the data review and interpretation process. All documents, records, and information relating to the performance of the field work will be retained in the project file.

2.7.2 Global Positioning System (GPS)

Sample locations will be recorded using a hand-held GPS unit. A sub-meter accurate unit will be used.

2.7.3 Photographic Documentation

Photographs will be taken to document field activities when required. Digital photographs will be downloaded from the camera to the project directory on the CH2M HILL server and stored in the project file. The information recorded in the field logbook will be transferred to a photographic log. The information which will be recorded includes:

- Name of personnel taking the picture
- Sequential number of the photograph
- Date and time photograph was taken
- Location and direction the photograph was taken
- Description of the photograph taken

2.7.4 Sample Chain-of Custody

Sample and data custody are necessary to provide relevant and defensible data. Custody is addressed during field sample collection, during data analyses in the laboratory, and through proper handling of project files. Persons will have custody of samples when

samples are in their physical possession, in their view after being in their possession, or in their physical possession and secured to prevent tampering. When samples are secured in a restricted area accessible only to authorized personnel, they will be deemed to be in the custody of such authorized personnel.

Chain-of-custody forms will provide the record of responsibility for sample collection, transport, and submittal to the laboratory. Field personnel designated as responsible for sample custody will fill out chain-of-custody forms at each sampling site, at a group of sampling sites, or at the end of each day of sampling. Original chain-of-custody forms will accompany samples to the laboratory, and copies will be forwarded to the project files.

2.7.5 Field Custody Procedures

Chain-of-custody forms will be required for all samples. The sample processing team will initiate chain-of-custody forms. Chain-of-custody forms will contain the sample's unique identification number, sample date and time, sample description, sample type, preservation (if any), and analyses required. Original chain-of-custody forms, signed by the field team, will accompany the samples to the laboratory. A copy of relinquished chain-of-custody forms will be retained with the field documentation. Chain-of-custody forms will remain with the samples at all times. Samples and signed chain-of-custody forms will remain in the possession of the field team until samples are delivered to the express carrier (such as Federal Express), or hand delivered to the laboratory, or placed in secure storage.

2.8 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Field equipment testing, inspection, and maintenance will be in accordance with the manufacturers' requirements. Laboratory equipment testing, inspection, and maintenance will be in accordance with the laboratory's quality assurance plans located in the QAPP. The QAPP discusses the maintenance, schedule, process, and criteria for verifying that all analytical equipment is operating in an accurate and precise manner.

2.9 Quality Control Sample Procedures

The contracted analytical laboratory will have a QC program to assess the reliability and validity of the analyses being performed. The purpose and creation of QC samples are discussed and summarized below.

2.9.1 Field Quality Control Samples

Field QC samples will be collected to assess the accuracy and precision of the analytical results. All sample handling procedures will be in accordance to those specified in this SAP and in the QAPP.

Trip Blanks. Trip blanks are used to monitor for contaminants introduced in the field, during shipment or in the laboratory. The trip blank will consist of a VOA vial filled and shipped by the laboratory with laboratory reagent grade water. The trip blank will remain

unopened. The trip blank will be identified in the chain of custody and labeled appropriately, and shipped one per cooler containing VOC samples to the laboratory.

Field Duplicates. Field duplicates are used to monitor the precision of the field sampling procedures and the variability of sample data. The field duplicate requires re-collection of a sample using the same techniques for collection as the first sample. Field duplicates should be collected 1 for every 10 samples, and should be sent blind to the laboratory.

Equipment Blanks. Equipment blanks (rinsate blank or field blank) are used to monitor cleanliness of the sampling equipment and the effectiveness of the decontamination procedures. The equipment blank will be a volume of deionized water that is passed through a decontaminated piece of equipment, or a clean piece if disposables such as dedicated tubing are used. One blank should be collected for every 20 samples.

Matrix Spike/Matrix Spike Duplicates. MS/MSDs will be used to assess the effects of sample matrix interference on the precision and accuracy of analyte recovery. MS/MSD pairs will be analyzed at a frequency of 1 pair for every 20 samples. MS/MSDs shall be collected and analyzed for the same parameters, as applicable, as the native samples.

Field Blanks. A field blank consists of a sample prepared in the field that will be used to evaluate the potential for contamination of a sample by a source not associated with the sample being collected. Organic-free water is taken to the field in sealed containers or generated onsite, and poured into the appropriate sample containers at pre-designated locations at the site. One field blank per source water will be collected during each sampling event. The field blank will be analyzed for the same parameters as are corresponding samples.

2.9.2 Decontamination Procedures

When practicable, disposable equipment will be used for sampling. When equipment is reused, the decontamination procedures presented in the EE/CA Field Sampling Plan (Geosyntec, 2004) will be followed for the Holtrachem site.

Investigation-derived waste includes personal protective equipment (PPE), residual samples, rinse water, and rinse solvents. PPE will be disposed of as solid waste in plastic trash bags and put in dumpsters for disposal.

Decontamination rinsate (tap and distilled water containing small amounts of solvent) will be placed in the pre-treatment holding tank for pre-treatment prior to discharge to the onsite treatment system.

2.9.3 Personnel Decontamination

The decontamination procedures presented in the Holtrachem EE/CA Field Sampling Plan will be followed.

APPENDIX A

Wastewater Sampling

SECTION 9 WASTEWATER SAMPLING

SECTION OBJECTIVE:

- To provide guidance for the proper collection of wastewater samples.

9.1 Introduction

The variety of conditions at different sampling locations require that considerable judgment be exercised regarding the methodologies and procedures for the collection of representative samples of wastewater. Each sampling location warrants attention commensurate with its complexity. There are, however, basic rules and precautions generally applicable to sample collection. Acceptable procedures are generally those outlined in the NPDES Compliance Inspection Manual (1). Some important considerations for obtaining a representative wastewater sample include:

- The sample should be collected where the wastewater is well mixed. Therefore, the sample should be collected near the center of the flow channel, at approximately 40 to 60 percent of the water depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Skimming the water surface or dragging the channel bottom should be avoided. However, allowances should be made for fluctuations in water depth due to flow variations.
- In sampling from wide conduits, cross-sectional sampling should be considered. Rhodamine WT dye (See Section 15.7 for references) may be used as an aid in determining the most representative sampling locations.
- If manual compositing is employed, the individual sample portions must be thoroughly mixed before pouring the individual aliquots into the composite container. For manual composite sampling, the individual sample aliquots should be preserved at the time of sample collection (2).
- When collecting samples or installing sampling equipment, field investigators should always wear a new pair of the appropriate protective gloves (disposable latex gloves, rubber gloves, etc.) to prevent contamination of the sample and reduce exposure to hazardous substances.

9.2 Site Selection

Where applicable, wastewater samples should be collected at the location specified in the NPDES permit (if the source has a permit). In some instances the sampling location specified in the permit, or the location chosen by the permittee, may not be acceptable for the collection of a representative wastewater sample. In such instances, the investigator is not limited by permit specifications and may collect a sample at a more representative location. When a conflict exists between the permittee and the regulatory agency regarding the most representative sampling location, both sites should be sampled, and the reason for the conflict should be noted in the field notes and the inspection or study report. Recommendations and reasons for a change in sampling locations should be given to the appropriate permitting authority.

9.2.1 Influent

Influent wastewaters are preferably sampled at locations of highly turbulent flow in order to ensure good mixing; however, in many instances the most desirable location is not accessible. Preferable influent wastewater sampling locations include: 1) the upflow siphon following a comminutor (in absence of grit chamber); 2) the upflow distribution box following pumping from main plant wet well; 3) aerated grit chamber; 4) flume throat; 5) pump wet well when the pump is operating; or 6) downstream of preliminary screening. When possible, influent samples should be collected upstream from sidestream returns.

9.2.2 Effluent

Effluent samples should be collected at the site specified in the permit, or if no site is specified in the permit, at the most representative site downstream from all entering wastewater streams prior to discharge into the receiving waters. If a conflict exists between the permittee and inspector regarding the source being sampled or the location of the most representative site, follow the procedures previously described under "Site Selection".

9.2.3 Pond and Lagoon Sampling

Generally, composite effluent wastewater samples should be collected from ponds and lagoons. Even if the ponds or lagoons have long retention times, composite sampling is necessary because of the tendency of ponds and lagoons to have flow paths that short circuit which changes the design detention time.

9.3 Sample Types

For NPDES sampling, two types of sampling techniques are used: grab and composite. For these procedures, the NPDES permit specifies the appropriate sample type. A complete description of all NPDES sampling procedures and techniques is presented in the NPDES Compliance Inspection Manual (1).

9.3.1 Grab Samples

Grab samples consist of either a single discrete sample or individual samples collected over a period of time not to exceed 15 minutes. The grab sample should be representative of the wastewater conditions at the time of sample collection. The sample volume depends on the type and number of analyses to be performed.

9.3.2 Composite Samples

Composite samples are collected over time, either by continuous sampling or by mixing discrete samples. A composite sample represents the average wastewater characteristics during the compositing period. Various methods for compositing are available and are based on either time or flow proportioning. The choice of a flow proportional or time composite sampling scheme depends on the permit requirements, variability of the wastewater flow or concentration of pollutants, equipment availability, and sampling location. The investigator must know each of these criteria before a sampling program can be initiated. Generally, a time composite is acceptable. However in enforcement cases where strict adherence to permit requirements are necessary or if an investigator knows or suspects that there is significant variability in the wastewater flow, a flow proportional sample is preferable .

A time composite sample consists of equal volume discrete sample aliquots collected at constant time intervals into one container. A time composite sample can be collected either manually or with an automatic sampler.

A flow proportional composite sample can be collected using one of two methods. One method consists of collecting a constant sample volume at varying time intervals proportional to the wastewater flow. For the other method, the sample is collected by varying the volume of each individual aliquot proportional to the flow, while maintaining a constant time interval between the aliquots. Prior to collecting flow proportional samples, the facility's flow measuring system should be examined for proper installation and accuracy (see Section 18). If the facility's primary flow measuring device does not meet standard conditions (see Section 18), or is in an unsafe or inaccessible location, then the investigator should collect time composite samples. If the flow measurement system is acceptable, samples should be collected using the appropriate flow proportioning methods.

Flow proportional samples can be collected with an automatic sampler and a compatible flow measuring device, with a flow chart and an automatic sampler capable of collecting discrete samples, or manually by compositing individual grab samples by volume versus flow chart readings.

9.4 Use of Automatic Samplers

9.4.1 Introduction

Automatic samplers may be used to collect composite or grab samples when several aliquots are to be collected at frequent intervals or when a continuous sample is required. For composite sampling applications, the automatic samplers may be used to collect time composite or flow proportional samples. In the flow proportional mode, the samplers are activated and paced by a compatible flow meter. Flow proportional samples can also be collected using an automatic sampler equipped with multiple containers and manually compositing the individual sample portions proportional to the flow (1).

Automatic samplers must meet the following requirements:

- Sampling equipment must be properly cleaned to avoid cross-contamination which could result from prior use (see Appendix B for cleaning procedures).
- No plastic or metal parts of the sampler shall come in contact with the water or wastewater stream when parameters to be analyzed could be impacted by these materials.
- The automatic sampler must be capable of providing adequate refrigeration during the sampling period. This can be accomplished in the field by using ice.
- The automatic sampler must be able to collect a large enough sample for all parameter analyses.
- The individual sample aliquot must be at least 100 mls.
- The automatic sampler should be capable of providing a lift of at least 20 feet and the sample volume should be adjustable since the volume is a function of the pumping head.
- The pumping velocity must be at least 2 ft/sec to transport solids and not allow solids to settle.
- The intake line leading to the pump must be purged before each sample is collected.
- The minimum inside diameter of the intake line should be 1/4 inch.
- An adequate power source should be available to operate the sampler for the time required to complete the project. Facility electrical outlets may be used if available.

- Facility automatic samplers should only be used if 1) field conditions do not allow for the installation of EPA sampling equipment, and 2) the facility sampling equipment meets all of the requirements of this SOP.

Specific operating instructions, capabilities, capacities, and other pertinent information for automatic samplers are included in the respective operating manuals.

9.4.2 Conventional Sampling (Inorganic Parameters)

Conventional sampling includes all inorganic parameters (e.g., BOD₅, TSS, COD, nutrients) that can be collected using an automatic sampler.

New tubing (Silastic®, or equal, in the pump and either Teflon® or Tygon®, or equal, in the sample train) will be used for each sampler installation.

Installation procedures include cutting the proper length of tubing, positioning it in the wastewater stream, and sampler programming. Protective gloves should be worn to reduce exposure and to maintain the integrity of the sample.

For a time composite sample, the sampler should be programmed to collect at least 100-milliliter aliquots at a frequency that provides a representative sample and enough sample volume to conduct all required analyses.

For a flow proportional sample, the sampler should be programmed to collect a minimum of 100 milliliters for each sample aliquot with the interval predetermined based on the flow of the monitored stream.

At the end of the compositing period, the sample collected should be properly mixed and transferred into the respective containers, followed by immediate preservation, if required. For routine inspections, the permittee should be offered a split sample.

9.4.3 Metals

When an automatic sampler is used for collecting samples for metals analyses, the entire sampler collection system should be rinsed with organic/analyte free water, and an equipment blank should be collected. Approximately one-half gallon of rinse water should be pumped through the sample tubing into the composite container and discarded. Nitric acid must be added to the metals blank container for proper preservation. The sampler may then be positioned in the appropriate location and the sampler program initiated.

If the sampler tubing is attached to a metal conduit pipe, the sampler intake tubing should be carefully installed upstream and away from the conduit to prevent metals contamination. This can be accomplished by clamping the tubing upstream of the conduit using laboratory clamps and wrapping the submerged portion of conduit pipe with a protective barrier (e.g., duct tape).

9.4.4 Extractable Organic Compounds, Pesticides, and PCBs

When an automatic sampler is used for collecting samples for the analyses of extractable organic compounds, pesticides, and/or PCBs, the installation procedures include cutting the proper length of new Teflon® tubing, rinsing of the entire sampler collection system with organic/analyte free water, and collection of appropriate blanks for organic compounds analysis. For the organic/analyte free water rinse, approximately one-half gallons is initially pumped into the composite sample container and discarded. An additional one and one-half gallons (approximate) are then pumped into the composite sample container for distribution into the appropriate blank container. Finally the collection tubing should be positioned in the wastewater stream and the sampler programmed and initiated.

9.4.5 Automatic Sampler Security

Field investigators should take whatever steps are necessary to prevent tampering with EPA equipment. A lock or custody seal may be placed on the sampler to detect tampering. However, this does not prevent tampering with the sample collection tubing. If necessary, seals may be placed on the sampling pole and tubing line to further reduce tampering possibilities.

9.4.6 Automatic Sampler Maintenance, Calibration, and Quality Control

To ensure proper operation of automatic samplers, and thus the collection of representative samples, the following maintenance and calibration procedures should be used and any deviations should be documented in the field log book.

Prior to being used, the sampler operation should be checked to ensure proper operation by Field Equipment Center personnel. This includes operation (forward, reverse, automatic) of at least one purge-pump-purge cycle; checking desiccant and replacing if necessary; checking the 12-volt batteries to be used with the sampler; and repairing any item if necessary.

During each field trip, prior to initiating the automatic sampler, the rinse and purge-pump-purge cycle shall be checked at least once. The pumping volume should be checked at least twice using a graduated cylinder or other calibrated container prior to initiating the sampler. For flow proportional sampling, the flow meter that activates the sampler should be checked to insure that it operates properly.

Upon returning from a field trip, the structural integrity of the sampler should be examined and repaired, if necessary. The desiccant will be checked and replaced if appropriate. The operation (forward, reverse, automatic, etc.) will be checked and required repairs will be made and documented. The sampler will then be cleaned as outlined in Appendix B.

The automatic sampler should be checked against the manufacturer's specifications and documented whenever one or more of the sampler functions appears to be operating improperly.

9.5 Manual Sampling

Manual sampling is normally used for collecting grab samples and/or for immediate in-situ field analyses. However, it can also be used in lieu of automatic equipment over extended periods of time for composite sampling, especially when it is necessary to evaluate unusual waste stream conditions.

The best method to manually collect a sample is to use the actual sample container which will be used to transport the sample to the laboratory. This eliminates the possibility of contaminating the sample with intermediate collection containers. If the water or wastewater stream cannot be physically reached by the sampling personnel or it is not safe to reach for the sample, an intermediate collection container may be used, from which the sample can be redistributed to other containers. If this is done, however, the container used to collect the sample must be properly cleaned (Appendix B) and must be made of a material that meets the requirements of the parameter(s) being investigated. Samples for oil and grease, bacteria, phenols, volatile organic compounds, and sulfides analyses must always be collected directly into the sample container.

In some cases it may be best to use a pump, either power or hand operated, to withdraw a sample from the water or wastewater stream. If a pump is used, it is imperative that all components of the pump that come in contact with the sample are properly cleaned (Appendix B) to ensure the integrity of the sample.

In general, samples are manually collected by first selecting a location in the wastestream that is well mixed (Section 9.1) then dipping the container in the water or wastewater stream so the mouth of the container faces upstream. The container should not be overfilled if preservatives are present in the container.

9.6 Special Sample Collection Procedures

9.6.1 Organic Compounds and Metals

Trace organic compounds and metals detection limits are usually in the parts per billion or parts per trillion range, so extreme care must be exercised to ensure sample integrity.

All containers, composite bottles, tubing, etc, used for sample collection for trace organic compounds and metals analyses should be prepared as described in Appendix B.

When possible, the sample should be collected directly into the appropriate sample container. If the material to be sampled cannot be physically reached, an intermediate collection device may be used. This should be a Teflon®, glass, or stainless steel vessel on a pole or rope or Teflon® tubing via a peristaltic type pump and a Teflon® vacuum container attachment which converts a sample container into a vacuum container. The device which is used should be cleaned as described in Appendix B.

9.6.2 Bacteriological

Samples for bacteriological analyses must always be collected directly into the prepared glass or plastic sample container. The sample container should be kept unopened until it is to be filled. When the cap is removed, care should be taken not to contaminate the cap or the inside of the bottle. The bottle should be held near the base and filled to within about one inch of the top without rinsing and recapped immediately. During sample collection, the sample container should be plunged with the neck partially below the surface and slightly upward. The mouth should be directed against the current. Appendix A lists preservation procedures and holding times.

When the sample container must be lowered into the waste stream, either because of safety or impracticality (manhole, slippery effluent area, etc.), care must be taken to avoid contamination.

9.6.3 Immiscible Liquids/Oil and Grease

Oil and grease may be present in wastewater as a surface film, an emulsion, a solution, or as a combination of these forms. Since it is very difficult to collect a representative sample for oil and grease analysis, the inspector must carefully evaluate the location of the sampling location. The most desirable sampling location is the area of greatest mixing. Quiescent areas should be avoided. The sample container should be plunged into the wastewater using a swooping motion with the mouth facing upstream. Care should be taken to ensure that the bottle does not over fill during sample collection.

Because losses of oil and grease will occur on sampling equipment, an automatic sampler should not be used to collect samples for oil and grease analysis. Individual portions collected at prescribed time intervals must be analyzed separately to obtain the average concentrations over an extended period.

9.6.4 Volatile Organic Compounds

Samples to be analyzed for volatile organic compounds (VOCs) should be collected in 40-ml septum vials with screw caps with a Teflon® lined silicone disk in the cap to prevent contamination of the sample by the cap. The disks should be placed in the caps (Teflon® side to be in contact with the sample) in the laboratory prior to the beginning of the sampling program.

When sampling for VOCs, triplicate samples should always be collected from each location. The investigator should determine if the water to be sampled contains chlorine. If the water contains no chlorine, three pre-preserved 40-ml vials should be filled with the sample. The samples may be held for up to 14 days before analysis. When preservation is not feasible, samples can be held up to 7 days before analysis.

If the water contains chlorine, fill an 8-ounce sampling container with 2 drops of a 25% ascorbic acid solution and the water sample. Cap and mix thoroughly but gently by swirling to eliminate residual chlorine. Transfer the sample to three pre-preserved 40-ml vials (see Appendix A). The ascorbic acid and preservative must be added in this order and in two separate steps.

The 40-ml vials should be completely filled to prevent volatilization, and extreme caution should be exercised when filling each vial to prevent any turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure using a new 40-ml vial.

9.7 Special Process Control Samples and Tests

During diagnostic evaluations, process control tests may be conducted to evaluate and troubleshoot the performance of the biological treatment processes of a municipal or industrial wastewater treatment facility. The EPA Activated Sludge Process Control Testing handbook is the standard reference for activated sludge process control testing (3). The manual includes a complete description of the step-by-step procedures for each test and the interpretation of the results. The six basic activated sludge process control tests are:

- Sludge settleability (settrometer).
- Centrifuge spins.
- Aeration basin DO profiles.
- Oxygen uptake rate (OUR) measurements.
- Mixed liquor microscopic examinations.
- Sludge blanket depth (SBD) measurements.

Additional references are available that provide a more comprehensive evaluation of the methods used to conduct a diagnostic evaluation (4, 5, 7, and 8.). Completion of the Sacramento Operation of Wastewater Treatment Plants course is highly recommended for all personnel prior to serving as the project leader on a Diagnostic Evaluation (6).

9.8 Supplementary Data Collection

While conducting wastewater sampling, the following information will also be obtained (if applicable):

- Field measurements -- pH, dissolved oxygen, conductivity, and temperature (see Section 16 for standard field analytical techniques).
- Flows associated with the samples collected -- continuous flows with composite samples and instantaneous flows with grab samples (Section 18).
- Diagrams and/or written descriptions of the wastewater treatment systems (if available).
- Photographs of pertinent wastewater associated equipment, such as flow measuring devices, treatment units, etc. (keep photolog as specified in section 3.2).
- Process control information on the wastewater treatment process (if applicable).
- Completion of applicable forms required during specific investigations.

All observations, measurements, diagrams, etc., will be entered in bound field logbooks or attached thereto (where applicable as specified in Section 3.5).

9.9 Sample Preservation

All sample collection and preservation procedures should comply with the requirements outlined in 40 CFR, Part 136.3 (e), Table 11 (9).

9.10 References

1. NPDES Compliance Inspection Manual, United States Environmental Protection Agency, September 1994.
2. Code of Federal Regulations, 40 CFR, Part 136.3, Table II, (latest issue).
3. US-EPA, "Activated Sludge Process Control Testing", ESD, Water Compliance Unit, Athens, GA., October 2000.
4. US-EPA, "Process Control Manual: Aerobic Biological Treatment Facilities MD-14", EPA 430/09-77-006, Office of Water, Washington, D.C., 1977.
5. Metcalf and Eddy, Inc., "Wastewater Engineering: Treatment, Disposal, Reuse", McGraw-Hill Book Co., New York, NY, 1991.
6. California State University - Sacramento, "Operation of Wastewater Treatment Plants - Volumes I, II, III", Sacramento, California.
7. "Operation Of Municipal Wastewater Treatment Plants", Manual Of Practice No.11, Fifth Edition, Water Environment Federation 1996.
8. "Design Of Municipal Wastewater Treatment Plants", Manual Of Practice No. 8, Fourth Edition, Water Environment Federation and ASCE, 1998.
9. 40 CFR, Part 136 (e), Table 11.

APPENDIX B

Wipe Sampling

Determining the surface concentration of PCBs

This guideline provides information on determining the concentration of PCBs on the surface of equipment.

Background

PCB is the common term used to describe the chemical Polychlorinated Biphenyl. PCBs can harm our health and, if they contaminate the environment, can stay there for many years. PCBs range in appearance from colourless oily liquids to more viscous darker fluids, or resins ranging from yellow through to black, depending on the chlorine content. Imports of PCBs to Australia have been banned since 1986.

The major use of PCBs in the electrical industry has been as an insulating fluid inside transformers and capacitors. Transformers and capacitors range in size from very large transformers used by electrical supply businesses and heavy industries containing several thousand litres of PCBs, to small capacitors used in farming equipment and on commercial premises, which may only contain several millilitres of PCBs.

Definitions

PCB material is “scheduled” if:

- the concentration of PCBs in the material is at least 50 mg/kg; and
- the material contains at least 50g of PCBs.

PCB material is “concentrated” if:

- the concentration of PCBs in the material is at least 100,000 mg/kg; and
- the material contains at least 50g of PCBs.

Non-scheduled PCB material means any material which contains PCBs at levels below the threshold concentration (50 mg/kg) or threshold quantity (50g) and above the concentration level considered as PCB-free (2 mg/kg).

Material is “PCB-free” if it is not PCB material.

Equipment is “PCB-free” if:

- there is no PCB material in the equipment other than on the surface area of the PCB contaminated metal in the equipment; and
- the PCB contaminated metal in the equipment does not have a coverage of PCBs on its surface area of more than 1 mg/m².

How to determine the surface concentration of PCBs

In order that equipment can be disposed of or recycled as “PCB-free”, the amount of PCB retained on the surface of any equipment after removal of oil and draining must be less than 1 mg/m² for non-porous material. If this limit is exceeded, the solid materials must be treated to reduce the concentration below this limit so that the material can be regarded as “PCB-free”.

Determining the surface concentration of PCBs

The amount of PCB retained in porous material or on non-porous contaminated metal can be directly measured using solvent extraction or the wipe test, respectively. It can also be directly estimated for equipment that has contained transformer mineral oil by applying retention factors to the results of the original concentration of PCB in the oil phase.

All PCB testing must be carried out by a NATA (National Association of Testing Authorities) laboratory accredited for PCB testing.

Direct measurement

Suitably qualified personnel should conduct the following tests.

Non-porous material (wipe test)

A wipe test may be performed on non-porous components, such as:

- bare copper leads;
- tank steel;
- structural/frame members;
- bushings; and
- fins (internal).

To determine PCB surface concentration on core laminations, a section of the core must be dismantled and the amount of material determined by a wipe test or by repeated solvent washing. It is not sufficient to test the outer layers only.

1. Prepare absorbent material (cotton wool or gauze pads) by solvent (soxhlet) extraction to remove any interfering compounds.
2. Choose a suitable high purity solvent such as hexane, heptane or isooctane that is free from interferences for Gas Chromatography/Electron Capture Detector (GC/ECD) analysis.
3. Prepare a clean solvent-washed glass sample jar to collect solvent washings and swabs. The sample jar must have a solvent-resistant lid, preferably metal or PTFE lined.
4. Measure the area of solid material to be sampled and mark boundaries with pencil or chalk. An area of at least 100 square centimetres (10cm x 10cm) is required.
5. Hold a portion of the absorbent material in clean metal laboratory tongs or a nitrile-gloved hand. Soak a portion of the absorbent material in the chosen solvent and swab the measured area. Use horizontal and vertical strokes to ensure adequate surface coverage. Rinse the absorbent with a minimum of solvent into the sample jar.
6. Repeat the swabbing and rinsing process, replacing the absorbent as necessary, until no trace of oil remains in the sample area.
7. Place used swabs in the sample jar and seal. Label the jar and consign it to a NATA accredited laboratory for analysis.
8. Analyse the recovered solvent for PCB content and calculate the surface concentration as mg PCB/m².

Determining the surface concentration of PCBs

Porous material

1. Select a sample of porous material for testing. Approximately five to 10 grams are required. If the porous material has been taken from equipment/plant that has been solvent washed, then porous material not directly in contact with the solvent must be selected (e.g. between conductor turns).
2. Extract the PCB via a soxhlet and analyse for PCB content.
3. Express the result as mg PCB per kg of porous material (i.e. ppm).

Direct estimation

The amount of PCB retained on surfaces and in porous material may also be determined by the use of retention factors or limits. These factors relate the amount of PCB in the bulk oil to the amount of PCB expected to be retained in the various components of the electrical equipment after draining for a preset time.

The retention factors will vary for different equipment components e.g. non-porous metal components, core laminations, cellulosic materials, and paper wrapped or covered materials. The retention factors will also be influenced by the preparation method of equipment (e.g. drainage process and time).

Industry may assess the retention characteristics of particular types of equipment and provide the results of assessment to the Environmental Protection Agency for consideration of the proposed retention factors for the equipment type.

Supporting information

Environmental Protection Agency, 2006. Managing PCBs.

Environmental Protection Agency, 2006. Identifying equipment containing PCBs.

Further information

For further supporting information, visit the EPA website at www.epa.qld.gov.au.

Disclaimer:

While this document has been prepared with care it contains general information and does not profess to offer legal, professional or commercial advice. The Queensland Government accepts no liability for any external decisions or actions taken on the basis of this document. Persons external to the Environmental Protection Agency should satisfy themselves independently and by consulting their own professional advisors before embarking on any proposed course of action.

Approved By

Signed
Signature

10 November 2006
Date

Dean Ellwood
Director, Integrated Assessment Branch
Environmental Protection Agency

Enquiries:
Ecoaccess Customer Service Unit
Ph. **1300 368 326**
Fax. (07) 3115 9600

APPENDIX F

Quality Assurance Project Plan

Quality Assurance Project Plan

Wastewater Treatment Solids Management Project

**International Paper Cell No. 2
Riegelwood, NC**

Prepared for
Honeywell International Inc.

Submitted by



May 2008

Contents

Introduction.....	1-1
Sampling Procedures	2-1
2.1 Sampling Design	2-1
2.2 Sampling Method Requirements	2-1
2.3 Field Quality Control Samples	2-1
2.3.1 Field Duplicate Samples	2-1
2.3.2 Equipment Blanks	2-1
2.3.3 Trip Blanks	2-1
2.3.4 Matrix Spike / Matrix Spike Duplicate	2-2
2.3.5 Field Blanks	2-2
2.4 Sample Documentation and Tracking	2-2
Sample Handling and Custody.....	3-1
3.1 Containers and Preservatives.....	3-1
3.2 Chain of Custody	3-1
3.3 Laboratory Responsibilities	3-3
3.4 Sample Packaging and Transport.....	3-4
Data Quality Objectives and Quality Assurance Program.....	4-1
4.1 Precision, Accuracy, Representativeness, Completeness, and Comparability	4-1
4.1.6 Precision.....	4-1
4.1.7 Accuracy	4-1
4.1.8 Representativeness.....	4-2
4.1.9 Completeness	4-3
4.1.10 Comparability	4-3
4.2 Method Detection Limits, Reporting Limits, and Instrument Calibration Requirements.....	4-3
4.2.11 Method Detection Limits.....	4-3
4.2.12 Reporting Limits.....	4-4
4.2.13 Instrument Calibration	4-5
4.3 Elements of Quality Control.....	4-7
4.3.14 Quality Control Analyses/Parameters Originated by the Laboratory	4-8
4.3.15 Quality Control Samples Originated by the Field Team	4-9
4.4 Additional Quality Control Requirements.....	4-9
4.4.16 Holding Time	4-9
4.4.17 Confirmation.....	4-10
4.4.18 Cleanup Procedures to Minimize Matrix Effects	4-10
4.4.19 Sample Dilution.....	4-10
4.4.20 Standard Materials and Other Supplies and Consumables	4-10
4.4.21 Manual Integration.....	4-10
4.4.22 Laboratory Quality Assurance Program.....	4-11
4.5 Reporting Limits and Analytical Requirements	4-12
Calibration Procedures and Frequency	5-1
5.1 Field Calibration Procedures.....	5-1

5.2 Laboratory Calibration Procedures	5-1
Data Reduction, Validation, and Reporting.....	6-1
6.1 Laboratory Data Management	6-1
6.1.23 Hardcopy Deliverables	6-1
6.2 Electronic Deliverables	6-3
6.3 Data Validation and Verification	6-3
Performance Evaluations	7-1
7.1 Performance Evaluations	7-1
7.2 External Audits	7-1
7.3 Internal Audits	7-1
Preventive Maintenance.....	8-1
8.1 Maintenance Responsibilities	8-1
8.2 Maintenance Schedules	8-1
Data Assessment.....	9-1
Corrective Action.....	10-1
Quality Assurance Reports	11-1
Data Management	12-1
12.1 Archiving	12-1
12.2 Data Flow and Transfer.....	12-1
12.3 Record Keeping	12-1
References	13-1

Tables

Table 3-1 Sample Containers, Preservation, and Holding Times.....	3-2
Table 4-1 Data Quality Objectives	4-2
Table 4-2 Analytical and Preparation Methodologies	4-12
Table 4-3 Soil Reporting Limit Objectives for Pesticides by SW846 8081A	4-12
Table 4-4 Soil Reporting Limit Objectives for Volatiles by SW846 8260B	4-13
Table 4-5 Soil Reporting Limit Objectives for Semivolatiles, SW846 8270C	4-14
Table 4-6 Soil Reporting Limit Objectives for Metals by SW846 6000 or 7000 Series	4-15
Table 4-7 Soil Reporting Limit Objectives for Dioxins by EPA Method 1613	4-16
Table 4-8 Pre-Treatment Effluent Water Reporting Limit Objectives for Aroclors by EPA 8082	4-16
Table 4-9 Accuracy and Precision Limits for PCB Aroclors by SW846 8082	4-16
Table 4-10 Accuracy and Precision Limits for Volatiles by SW846 8260B	4-17
Table 4-11 Accuracy and Precision Limits for TCL Semivolatiles, SW846 8270C and EPA 625.....	4-19
Table 4-12 Accuracy and Precision Limits for Metals by SW846 6000, 7000 Series	4-21
Table 4-13 Accuracy and Precision Limits for Pesticides by SW846 8081A.....	4-22
Table 4-14 Calibration and QC Requirements for Metals by SW846 6000 or 7000 Series	4-23
Table 4-15 Calibration and QC Requirements for Mercury by SW846 7471A	4-24
Table 4-16 Calibration and QC Requirements for Pesticides and Aroclors by SW846 8081A, SW846 8082	4-25
Table 4-17 Calibration and QC Requirements for Volatiles by SW846 8260B.....	4-26
Table 4-18 Calibration and QC Requirements for Semivolatiles by SW846 8270C	4-27

Table 6-1	Flagging Conventions for Organic Methods.....	6-5
Table 6-2	Flagging Conventions for Inorganic Methods.....	6-9
Table 6-3	Qualifier Flag Definitions	6-13

Acronyms and Abbreviations

°C	degrees Celsius
AB	ambient blank
ARAR	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
CLP	Contract Laboratory Program
DQO	Data Quality Objective
EB	equipment blank
EE/CA	Engineering Evaluation/Cost Analysis
FD	field duplicate
FSP	Field Sampling Plan
ICP	inductively-coupled plasma
IJC	International Joint Commission
LCL	lower control limit
LCS	laboratory control sample
MDL	method detection limit
mL	milliliter
MS/MSD	matrix spike and matrix spike duplicate
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RL	limit of quantification
RPD	relative percent difference
RSD	relative standard deviation
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
TAL	Target Analyte List
TB	trip blank
TCL	Target Compound List
UCL	upper control limit
USEPA	United States Environmental Protection Agency
VOA	volatile organic analysis
VOC	volatile organic compound

SECTION 1

Introduction

This Quality Assurance Project Plan (QAPP) was prepared to present the project-specific quality assurance/quality control (QA/QC) requirements for excavation, segregation, transportation, and storage of wastewater treatment solids (WWTS) located in Cell No. 2 of International Paper's (IP) North Bay Treatment Pond of the Riegelwood Mill. Analytical results from samples collected from IP's Cell No. 2 indicate the presence of Aroclor 1268 at concentrations >11 mg/kg. The United States Environmental Protection Agency (US EPA) has indicated WWTS exceeding background concentrations are considered part of the Holtrachem site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The North Carolina Division of Waste Management (DWM) has determined that WWTS with PCB concentrations <50 mg/kg can be disposed in Cell No. 1 in accordance with the Cell No. 1 Operations Manual (Industrial Landfill Facility Permit #24-02, February 2005). Honeywell will excavate the WWTS from Cell No. 2. WWTS containing concentrations of Aroclor 1268 <50 mg/kg will be transported to IP's Cell No. 1, which is constructed to Resource Conservation and Recovery Act (RCRA) criteria.

WWTS containing Aroclor 1268 concentrations of 50 mg/kg and greater will be managed by Honeywell on the Holtrachem site. Honeywell plans to temporarily contain these WWTS in an engineered stockpile located on the Holtrachem property pending implementation of a site-wide remedy.

The QAPP will address the data collection effort associated with removal of the WWTS. Confirmation samples will be collected at the completion of excavation activities. The discharge water from the pre-treatment facility will also be sampled and analyzed for Aroclor 1268 during removal of the WWTS.

The sampling program for the above media is discussed in the Sampling and Analysis Plan (SAP).

The QAPP presents the QA/QC requirements designed to ensure that environmental data collected for the site are of the appropriate quality to achieve the project objectives. The SAP discusses the specific protocols for sampling, sample handling and storage, and field quality control. The QAPP specifies the requirements for laboratory analyses, data handling, data evaluation and assessment performance evaluations, chain-of-custody requirements, corrective actions, preventive maintenance of equipment, and additional information regarding sample handling and storage and field quality control.

The elements included in this QAPP are consistent with those specified in the US EPA *Requirements for Quality Assurance Project Plans*, EPA QA/R-5, March 2001. The QAPP has the following objectives:

- Ensure that data collection and measurement procedures are standardized among all participants.

- Monitor the performance of the various measurement systems being used in the program to maintain control and provide rapid feedback, so that corrective measures, if needed, can be taken before the data quality is compromised.
- Periodically assess the performance of these measurement systems and their components.
- Verify that reported data are sufficiently complete, comparable, representative, and accurate, so that they are suitable for their intended use.

This QAPP supplements the SAP and other project-specific documents. If the project objectives change during the project, supplementary information and requirements will be documented by either updating this QAPP, project memorandum or an equivalent document.

Sampling Procedures

2.1 Sampling Design

The sampling design is a function of the medium sampled, information about the sampling site, the type of data to be collected, and how the data are to be used. The specific protocols for sampling, equipment decontamination, and field quality control are discussed in the Engineering Evaluation/Cost Analysis (EE/CA) Field Sampling Plan (FSP).

2.2 Sampling Method Requirements

The SAP discusses the sampling methods.

2.3 Field Quality Control Samples

Quality control samples will be collected to monitor accuracy, precision, and the presence of field contamination for analytical methods to be performed in the offsite laboratory. The frequency of collection of the quality control samples is outlined below.

2.3.1 Field Duplicate Samples

A field duplicate (FD) is an independent sample collected as close as possible to the original sample – from the same source and under identical conditions – and is used to document sampling and analytical precision. Field duplicates will be collected at a rate of one duplicate per 10 samples. The sampling locations for FD samples will be recorded in the field logbook. Duplicate samples will be collected simultaneously or in immediate succession to original samples, using identical recovery techniques, and treated identically during storage, transportation, and analysis.

2.3.2 Equipment Blanks

Equipment rinsate blanks (EBs) are collected to evaluate field sampling and decontamination procedures by pouring deionized water over the decontaminated equipment. EBs will be collected for soil samples only when non-dedicated sampling equipment is used and will be collected at a rate of 1 per piece of equipment per day. The EBs will be analyzed in the offsite laboratory for the same parameters specified for the corresponding matrix.

2.3.3 Trip Blanks

Trip blanks (TBs) are used to monitor for contamination during sample shipping and handling, and for cross-contamination through VOC migration among the collected samples. They are prepared in the laboratory by pouring American Society for Testing and Materials (ASTM) Type II or deionized water into the sample container. They are then sealed, transported to the field, remain sealed while VOC samples are taken, and transported back to

the laboratory in the same cooler as the VOC samples. One TB will be placed in each cooler that contains soil VOC samples shipped from the field to the laboratory.

2.3.4 Matrix Spike / Matrix Spike Duplicate

A matrix spike and matrix spike duplicate (MS/MSD) are a duplicate pair of samples – collected along with an investigatory sample to which the laboratory adds a spike containing the analytes of concern at known concentrations to assess the effect of the sample matrix on the extraction and analysis method.

For every 20 field samples of soil collected from each site, one location will have sample volume collected in duplicate for each analysis required and designated on the chain-of-custody form as an MS/MSD. MS/MSD samples may involve obtaining an independent pair of samples collected as close as possible to the original (parent) sample, from the same source under identical conditions, or prepared by the laboratory as part of its QA program and sub-sampled from an investigatory sample. MS/MSDs will be collected at a frequency of one MS/MSD per 20 samples.

Independent MS/MSD samples will be collected simultaneously or in immediate succession, using identical sampling techniques as those used for the parent sample. They will be treated in an identical manner as the parent sample during storage, transportation, and analysis. The sampling locations for the MS/MSD will be documented in the field logbook.

2.3.5 Field Blanks

A field blank consists of a sample prepared in the field that will be used to evaluate the potential for contamination of a sample by a source not associated with the sample being collected. Organic-free water is taken to the field in sealed containers or generated onsite, and poured into the appropriate sample containers at pre-designated locations at the site. One field blank per source water will be collected during each sampling event. The field blank will be analyzed for the same parameters as are corresponding samples.

2.4 Sample Documentation and Tracking

Sample containers should be received from the laboratory pre-labeled with preservative. The sample identification nomenclature and date and time of sampling are entered on the label immediately after collection. The labels must be secured using clear tape to maintain the identification of each sample.

Vital information regarding the collection of each sample will be recorded in a field logbook. A separate logbook will be used for this site. It will be bound with consecutively-numbered pages. All entries will be written legibly in black ink and signed and dated by the individual making the entries. Factual and objective language will be used. All entries will be complete and accurate enough to allow reconstruction of each field activity. The types of information to be recorded during collection are specified in the SAP.

Sample Handling and Custody

3.1 Containers and Preservatives

Laboratories will provide the required sample containers for all environmental and associated quality control samples. All containers will be certified free of the analytes of concern for this project. No sample containers will be reused. The contracted laboratory will add preservatives, if required, prior to shipping the sample containers to the field. The laboratory, upon receipt of the samples, will verify the adequacy of preservation and will add additional preservative, if necessary. The containers, minimum sample quantities, required preservatives, and maximum holding times for many parameters are listed in Table 3-1.

3.2 Chain of Custody

Collecting data of known quality begins at the point of sample collection. Legally defensible data are generated by adhering to proven evidentiary procedures. These procedures are outlined in the following sections and must be followed to preserve and ensure the integrity of all samples from the time of collection through analysis. Sample custody records must be maintained both in the field and in the subcontractor laboratory. A sample is considered to be in someone's custody if it is either in his or her physical possession or view, locked up, or kept in a secured and restricted area. Until shipment, sample custody will be the responsibility of the sampling team leader.

Chain-of-custody records document sample collection and shipment to the laboratory. A chain-of-custody form will be completed for each sampling event. The original copy will be provided to the laboratory with the sample shipping cooler, and a copy will be retained in the field documentation files. The chain-of-custody form will identify the contents of each shipment and maintain the custodial integrity of the samples. All chain-of-custody forms will be signed and dated by the responsible sampling team personnel. The "relinquished by" box will be signed by the responsible sampling team personnel, and the date, time, and airbill number will be noted on the chain-of-custody form. The laboratory will return the executed copy of the chain-of-custody with the hardcopy report.

The shipping coolers containing the samples will be sealed with a custody seal any time the coolers are not in an individual's possession or view before shipping. All custody seals will be signed and dated by the responsible sampling team personnel.

TABLE 3-1
Sample Containers, Preservation, and Holding Times
WWTs Management Quality Assurance Project Plan

Analyte	Method	Container and Minimum Quantity	Preservation	Holding Time
Soil Samples				
Aroclor 1268	SW-846 8082	One 8-oz. glass	4°C	14 days to extraction/40 days from extraction to analysis.
Discharge Water Samples				
Aroclor 1268	SW-846 8082	Two 1-L amber glass	4°C	7 days to extraction, 40 days from extraction to analysis
Wipe Samples				
Aroclor 1268	SW-846 8082	250-mL glass jar	4°C	7 days to extraction, 40 days from extraction to analysis
Stockpiled WWTs Samples				
VOCs	SW-846 8260B	One 2-oz. glass jar OR 3 EnCore or equivalent samplers (Dependent upon sample matrix)	4°C	14 days to extraction/40 days from extraction to analysis. (If using EnCore or equivalent sampler, freeze, preserve or analyze samples within 48 hours of collection.)
SVOCs	SW-846 8270C	One 8-oz glass jar	4°C	14 days to extraction/40 days from extraction to analysis.
Pesticides	SW-846 8081A	One 8-oz. glass	4°C	14 days to extraction/40 days from extraction to analysis.
Metals	SW-846 6000 or 7000 series	One 4-oz. plastic	4°C	180 days, 28 days Hg
Dioxins	EPA Method 1613	One 4-oz. amber jar w/Teflon cap	4°C	1 year prior to extraction, 45 days from extraction to analysis

At a minimum, the chain-of-custody form must contain:

- Site name
- Project manager, project chemist, and data manager names, and telephone and fax numbers
- Unique sample identification
- Date and time of sample collection
- Source of sample (including name, location, sample type, and matrix)
- Number of containers
- Designation of MS/MSD
- Preservative used
- Analyses required
- Name of sampler
- Custody transfer signatures and dates and times of sample transfer from the field to transporters and to the laboratories
- Bill of lading or transporter tracking number (if applicable)
- Turnaround time

- Lab name, address, and contact information
- Any special instructions

Erroneous entries on chain-of-custody records will be corrected by drawing a line through the error and entering the corrected information. The person performing the correction will date and initial each change made on the chain-of-custody form.

3.3 Laboratory Responsibilities

Once the samples reach the laboratory, they will be checked against information on the chain-of-custody form for anomalies. The condition, temperature, and appropriate preservation of samples will be checked and documented on the chain-of-custody form. Checking an aliquot of the sample using pH paper is an acceptable procedure (precautions must be taken to avoid contamination of the sample). Samples requiring VOC analyses should not undergo preservation verification until the time of analysis. The occurrence of any anomalies in the received samples and their resolution will be documented in laboratory records. All sample information will then be entered into a tracking system, and unique analytical sample identifiers will be assigned. A copy of this information will be reviewed by the laboratory for accuracy. Sample holding time tracking begins with the collection of samples and continues until the analysis is complete. **Samples not preserved or analyzed in accordance with the requirements in this QAPP will be resampled.** Laboratory analyses will be documented on the chain-of-custody form. Procedures ensuring internal laboratory chain of custody will also be implemented and documented by the laboratory. Ideally, sample custody will be maintained using an internal custody system that requires samples to be kept in a secured and restricted area when not in use and to be checked out and checked back in by the analysts who use the samples. Internal custody records must be maintained by the laboratory as part of the documentation file for each sample. Specific instructions concerning the analysis specified for each sample will be communicated to the analysts. Analytical batches will be created, and laboratory quality control samples will be introduced into each batch.

While samples are stored in the laboratory, they will be stored in limited-access, temperature-controlled areas. Refrigerators, coolers, and freezers will be monitored for temperature 7 days a week. Acceptance criterion for the temperatures of the refrigerators and coolers is $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Acceptance criterion for the temperatures of the freezers will be less than 0°C . All of the cold-storage areas will be monitored by thermometers that have been calibrated with a NIST-traceable thermometer. As indicated by the findings of the calibration, correction factors will be applied to each thermometer. Records that include acceptance criteria will be maintained. Samples for VOC determination will be stored separately from other samples, standards, and sample extracts. Samples will be stored after analysis until disposed of in accordance with applicable local, state, and federal regulations. Disposal records will be maintained by the laboratory.

Along with sample receipt documentation, the following information will be documented on sample receipt forms by the sample custodian:

- Date samples received
- CH2M HILL sample identification number
- Laboratory sample identification number

- Analytical tests requested for the sample batch
- Sample matrix
- Number of samples in the batch
- Container description and location in the laboratory
- Verification of sample preservation

3.4 Sample Packaging and Transport

The following sections contain guidelines for sample packaging and transport that may be superseded, amended, or replaced in an addendum to this QAPP. Sample packaging and shipping procedures are designed to ensure that the samples will arrive at the laboratory, along with the chain of custody, intact. Samples will be packaged for shipment as outlined below:

- All sample containers will have the sample labels securely affixed to the container with clear packing tape.
- Caps on the sample containers will be checked to ensure they are properly sealed.
- Sample container caps will be wrapped with clear packing tape to prevent them from becoming loose.
- Chain-of-custody forms will be completed with required sampling information, and recorded information will match the sample labels.
- If the designated sampler relinquishes samples to other sampling or field crew member for packing or other purposes, the sampler will complete the chain of custody before the transfer.
- Appropriate personnel will sign and date chain-of-custody forms to document the sample custody transfer.
- The outside drain plug at the bottom of the cooler will be secured inside and out using duct tape.
- Sample containers will be protected in bubble wrap or other cushioning material. One to 2 inches of cushioning material will be placed at the bottom of the cooler.
- Sealed sample containers will be placed in the cooler.
- Ice will be double bagged with plastic zipper bags. Bags will be sealed and placed loosely in the cooler. Remaining space in the cooler will be filled with cushioning material.
- Chain-of-custody forms will be placed in a sealed plastic bag and taped to the inside of the cooler lid.
- The lid of the cooler will be closed, locked, and secured with strapping tape. Strapping tape will be wrapped around both ends of the cooler at least twice.
- The cooler will be marked on the outside with shipping address, return address, "Fragile" labels, and arrows indicating "This Side Up."
- Labels will be covered with clear plastic tape.

- A temperature blank will be placed in each cooler (temperature blanks are not required for geotechnical samples).
- Signed custody seals will be placed over opposite corners of the cooler lid.
- All coolers will be shipped or sent by courier with the samples to the analytical laboratory by express overnight service or courier service.
- All samples will be transported or shipped in a manner that protects integrity of the samples and safety of the handlers.
- Original chain-of-custody forms will accompany the shipment; copies will be retained by the sampler for sampling records.
- If samples are sent by common carrier, bills of lading will be used. Receipts or bills of lading will be retained as part of the permanent project documentation.
- Commercial carriers will not be required to sign off on chain-of-custody forms as long as the forms are sealed inside the sample cooler and custody seals remain intact.
- Packaging, marking, labeling, and shipping of samples will comply with the regulations promulgated by the U.S. Department of Transportation in the Code of Federal Regulations (49 CFR 171-177).

Disposable equipment and debris, such as health and safety equipment, plastic sheeting, sampling equipment, and other equipment or sampling debris that has come into contact with WWTS, will be collected in plastic trash bags and put in dumpsters for disposal.

Decontamination rinsate (tap and distilled water containing small amounts of solvent) will be placed in the pre-treatment holding tank for pre-treatment prior to discharge to the onsite treatment system.

Shipping Airbills. If samples are shipped, airbills will be retained to provide a record for sample shipment to the laboratory. Completed airbills will accompany shipped samples to the laboratory and will be forwarded along with data packages. Airbills will be kept as part of the data packages in the project files.

SECTION 4

Data Quality Objectives and Quality Assurance Program

The data quality objectives (DQOs) for the project were established based upon the US EPA's *Guidance on Systematic Planning using the Data Quality Objectives Process* (EPA QA/G-4, November 2006) and are specified in Table 4-1. They are the basis for the design of the data collection plan and, as such, these DQOs specify the type, quality, and quantity of data to be collected and how the data are to be used to make the appropriate decisions for the project. The DQOs were developed through a seven-step process, each step of which derives valuable criteria that were used to establish the final data collection design. The first five steps identify mostly qualitative criteria, such as what problem has initiated the project and what decision is needed to resolve it. These steps also define the type of data to be collected, where and when the data will be collected, and a decision rule that defines how the decision will be made. The sixth step defines quantitative criteria, expressed as limits on decision errors that can be tolerated by the decision maker. The final step is the development of the data collection design using the criteria developed in the previous six steps. The final output of the process is a data collection design that meets the qualitative and quantitative needs of the project.

4.1 Precision, Accuracy, Representativeness, Completeness, and Comparability

Data quality will be evaluated based on their precision, accuracy, representativeness, completeness, and comparability.

4.1.6 Precision

Precision is a measure of reproducibility of analytical results. It can be defined as the degree of mutual agreement among individual measurements obtained under similar conditions. Total precision is a function of the variability associated with both sampling and analysis. Precision will be evaluated as the relative percent difference (RPD) between field duplicate sample results, laboratory sample duplicates, or between the MS and MSD results. Field duplicates will comprise 10 percent of the sampling effort. MS/MSD samples will be field-designated at a 5 percent frequency. These frequencies are subject to change as the data are continually evaluated for the impact of matrix effects.

4.1.7 Accuracy

Accuracy is the degree of agreement between a measured value and the "true" or expected value. It represents an estimate of total error from a single measurement, including either systematic error, or bias, and random error that may reflect variability due to imprecision. Accuracy is evaluated in terms of percent recoveries determined from results of MS/MSD and laboratory control sample (LCS) analyses.

TABLE 4-1

Data Quality Objectives

WWTS Management, Quality Assurance Project Plan

Step 1: Statement of Problem	<p>Wastewater from the neighboring LCP-Holtrachem (Holtrachem) facility was formerly discharged to IP's wastewater treatment system for treatment of process water generated during chlorine production. Analytical results from samples collected from Cell No. 2 indicate the presence of Aroclor 1268 at concentrations exceeding the Toxic Substances Control Act (TSCA) bulk remediation disposal limits.</p> <p>The project consists of construction of a engineered stockpile on the Holtrachem site, removing WWTS from Cell No.2, placing WWTS containing Aroclor 1268 concentrations <50 mg/kg in Cell No. 1, and transporting WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg to the engineered stockpile.</p>
Step 2: Identify the Decision	Confirmation samples will provide information to determine the disposal/storage location of the excavated WWTS and to confirm WWTS containing Aroclor 1268 concentrations above the clean-up level have been removed. Pre-treatment effluent samples will confirm water containing Aroclor 1268 is not discharged to the IP waste water treatment system above specified limits.
Step 3: Inputs to Decisions	<p>Material Management samples will provide information to determine the disposal/storage location of the excavated WWTS and to confirm WWTS containing Aroclor 1268 concentrations above the clean-up level have been removed.</p> <p>Pre-treatment effluent water samples will be collected and analyzed to assess compliance with the IP waste water treatment system.</p> <p>An offsite laboratory will be contracted by Honeywell to analyze the samples. The subcontracted laboratory will use the appropriate analytical methods to reach the project specific analytical requirements.</p>
Step 4: Study Boundaries	<p>Landfill Cell No. 2 is located in the northern portion of International Paper's Riegelwood Mill, Riegelwood, North Carolina, approximately 150 feet from the Cape Fear River. Cell No. 2 was part of the overall wastewater lagoon system for the mill until it was isolated by the earthen berms. Cell No. 2 is approximately 13 acres.</p> <p>A 16-inch diameter corrugated steel discharge pipe, running from the Holtrachem property to Landfill Cell No. 2 will also be removed. The exact location of the pipe will be determined using utility location techniques. The length of the pipe from the border of the Holtrachem property to Landfill Cell No. 2 is anticipated to be approximately 350 feet.</p> <p>There is approximately 12 feet of vertical relief across the Landfill Cell No. 2 area. Topography across the cell generally slopes to the south and east, towards local low lying areas.</p>
Step 5: Decision Rules	<p>Confirmation samples must meet the clean-up criteria of the Action Memorandum issued by US EPA (Cleanup goal specified in the Action Memo of 11 mg/kg).</p> <p>The parameter list and required reporting limits appear in Section 4 of this QAPP.</p> <p>The pre-treatment effluent samples must contain less than 3 mg/L of Aroclor 1268. This level is specified in 40 CFR 761.</p>
Step 6: Limits of Decision Errors	The probability of sampling and measurement errors at any site under investigation necessitates the development of sampling guidelines and the collection of quality control samples. Field errors are minimized by having each member of the field team follow the same SOPs for sampling. QC samples are used to verify the data's accuracy and precision. When a QC sample is outside of the established control limits, the data will be qualified and field corrective action implemented when applicable (such as when field duplicates are outside established control limits).
Step 7: Optimize the Sampling Design	The sampling design objective is to assess the degree and effectiveness of contaminant removal, and water treatment.

4.1.8 Representativeness

Representativeness is the degree to which sample data accurately reflect the characteristics of a population of samples. It is achieved through a well-designed sampling program and by using standardized sampling strategies and techniques and analytical procedures. Factors that

can affect representativeness include site homogeneity, sample homogeneity at a single point, and available information around which the sampling program is designed. Using multiple methods to measure an analyte can also result in nonrepresentativeness of sample data.

4.1.9 Completeness

Completeness is the amount of valid measurements compared to the total amount generated. It will be determined for each method, matrix, and analyte combination. The completeness goals of each project are optimized to meet the DQOs. The goals for this program are 95 percent.

4.1.10 Comparability

Comparability is the confidence with which one data set can be compared to another. It is achieved by maintaining standard techniques and procedures for collecting and analyzing samples and reporting the analytical results in standard units. Results of performance evaluation samples and systems audits will provide additional information for assessing comparability of data among participating subcontractor laboratories.

4.2 Method Detection Limits, Reporting Limits, and Instrument Calibration Requirements

The requirements specified in this section are the minimum that must be met for the specified methods.

4.2.11 Method Detection Limits

The method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero. Each participating laboratory will establish the MDL for each method, matrix, and analyte for each instrument that will be used to analyze samples. The MDLs initially will be calculated before analyzing samples and will be recalculated at least once every 12 months.

1. Estimate the MDL using one of the following:
 - a. The concentration value that corresponds to an instrument signal/noise ratio in the range of 2.5 to 5
 - b. The concentration equivalent of three times the standard deviation of replicate measurement of the analyte in reagent water
 - c. The region of the standard curve where there is a significant change in sensitivity (i.e., a break in the slope of the standard curve)
2. Prepare (i.e., extract, digest) and analyze seven samples of a matrix spike (ASTM Type II water for aqueous methods, Ottawa sand for soil methods, glass beads of 1 millimeter diameter or smaller for metals) containing the analyte of interest at a concentration three to five times the estimated MDL.
3. Determine the variance (S^2) for each analyte as follows:

$$S^2 = \frac{1}{n-1} \left[\sum_{i=1}^n (x_i - \bar{x})^2 \right] \quad (1)$$

where:

x_i = the i th measurement of the variable x .

\bar{x} = the average value of x .

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n x_i \quad (2)$$

4. Find the standard deviation for each analyte as follows:

$$s = (S^2)^{1/2} \quad (3)$$

5. Find the MDL for each analyte as follows:

$$\text{MDL} = 3.14(s) \quad (4)$$

Note: 3.14 is the one-sided t-statistic at the 99 percent confidence level appropriate for calculating the MDL using seven samples.

6. If the spike level used in Step 2 is more than 10 times the calculated MDL, repeat the process using a smaller spiking level.

4.2.12 Reporting Limits

Reporting limits will be greater than two times the laboratory calculated MDL. Reporting limits used by the laboratory should not be greater than the quantification limit objectives listed in Tables 4-3 through 4-18.

When calibrating instruments, a standard at a concentration equal to or less than the reporting limit must be included. Reporting requirements are listed below:

1. When analysis is preceded by sample preparation, such as digestion or extraction, analytes at concentrations equal to or greater than the laboratory's MDL, but less than the reporting limit will be flagged as estimated with a "J" qualifier and reported. Analytes that are not detected at or above the laboratory's MDL will be reported as not detected at the MDL and flagged "U."
2. When sample preparation is not employed, the analytical results will be reported as described above in item 1, except that the instrument detection limit (IDL) will be substituted for the MDL.

Reporting limits and sample results will be reported to two significant figures if less than 10 and to three significant figures if 10 or greater. Reporting limits will be reported on a dry-weight basis for soil samples. All quality control sample results will be reported to three significant figures.

4.2.13 Instrument Calibration

Laboratory instruments will be calibrated by qualified personnel before sample analysis, according to the procedures specified in each method. Calibration will be verified at method-specified intervals throughout the analysis sequence. The frequency and acceptance criteria for calibration are specified for each analytical method, with supplemental requirements defined below for organic methodologies. When multi-point calibration is specified, the concentrations of the calibration standards should bracket those expected in the samples. Samples will be diluted, if necessary, to bring analyte responses to within the calibration range. Data that exceed the calibration range cannot be reported by the laboratory. The initial calibration curve will be verified as accurate with a standard purchased or prepared from an independent second source. The initial calibration verification involves the analysis of a standard containing all the target analytes, typically in the middle of the calibration range, each time the initial calibration is performed. Quantitation based on extrapolation is not allowed.

4.2.13.1 Initial Calibration Models for the Determination of Organic Compounds

Organic methodologies often provide multiple options for initial calibration curve fits and associated acceptance criteria for use. The following sections specify “good laboratory practices” that will be employed by the laboratory. The hierarchy that the laboratory will use when selecting the calibration curve fit for use in quantitation of sample results is outlined below.

Calibration Techniques

- Verify that correct instrument operating conditions and routine maintenance as specified in the method and laboratory SOPs are employed. Document all maintenance activities in a laboratory notebook for troubleshooting and scheduling of future routine, periodic maintenance.
- Ensure that the instrument is free of contamination prior to calibration. Do NOT perform any blank subtraction.
- Perform the entire initial calibration before sample analyses. The calibration standards must be analyzed in a sequential order from the lowest to highest concentration. If **one** calibration standard fails to meet criteria, it may be reanalyzed at the end of the calibration sequence. Justification for removing a calibration point from the curve fit selected includes such items as improper purge, injection failure, spiking error, or other obvious failures. The failure of multiple standards suggests an instrument problem or operator error and corrective action is required.
- Only the lowest calibration point or the highest calibration point can be removed from the calibration curve without justification. If the lowest standard is removed, the reporting limit for that compound increases to the level of the next lowest calibration standard. Approval to elevate reporting limits greater than the project-specific objectives **MUST** be approved by the project chemist. If the highest standard is removed, the linear range is shortened for that compound.

- The lowest standard in the calibration curve must be at or below the required reporting limit.
- The other standard concentrations must define the working range of the instrument or the expected range of concentrations found in the samples.
- Either external or internal calibration can be employed for methods not involving mass spectrometry detectors. Internal calibration must be used when a mass spectrometry detector is employed.
- A minimum of five calibration points must be used for the calibration curve for gas chromatography/mass spectrometry and gas chromatography methods.
- Most compounds tend to be linear, and a linear approach will be favored when linearity is suggested by the calibration data. Nonlinear calibration will be considered only when a linear approach cannot be applied. Before using a nonlinear calibration approach, the Project Chemist must be notified and provide approval. It is not acceptable to use an alternate calibration procedure when a compound fails to perform in the usual manner. When this occurs, it is indicative of instrument problem or operator error.
- If a nonlinear calibration curve fit is employed, a minimum of six calibration levels must be used for second-order (quadratic) curves, and a third-order polynomial requires a minimum of seven calibration levels.
- When more than five levels of standards are analyzed in anticipation of using second- or third-order calibration curves, all calibration points **MUST** be used regardless of the calibration option employed. The highest or lowest calibration point may be excluded to narrow the calibration range and meet the requirements for a specific calibration option. Otherwise, unjustified exclusion of calibration data is expressly forbidden.
- If the initial calibration of a given analyte exhibits a relative standard deviation (RSD) greater than 20 percent, but the average RSD for all analytes is less than 20 percent, a list of those analytes that exceeded the criteria will be provided in the laboratory report. For analyses conducted under this QAPP, compounds outside these criteria and the actual values of the RSD will be listed in the case narrative.

Calibration Options.

The following section outlines the acceptable calibration options and the hierarchy that the laboratory should use when selecting a specific option. The choice of calibration option may also be based on previous experience or a prior knowledge of detector response.

- **Linear calibration using average calibration or response factors.** Calibration factors for external calibrations or response factors for internal calibrations must have an RSD not exceeding 20 percent or 15 percent, respectively, to be used for quantitation. A minimum response factor of 0.05 for most target analytes and 0.01 for the least-responsive target analytes must be achieved to ensure detectability.
- **Linear calibration using a linear regression equation ($y=mx+b$).** The correlation coefficient must equal 0.995 or better. The line should **NOT** be forced through the origin.

The equation and a plot of the linear regression must be included in the raw data generated by the laboratory, and made available in the data package upon request.

- **Nonlinear calibration.** This model may be a second-order or third-order polynomial. The model must be continuous without a break in the function and should NOT be forced through the origin. The coefficient of determination of the nonlinear regression must be 0.99 or better. The equation and a plot of the nonlinear regression must be included in the raw data generated by the laboratory, and made available in the data package upon request.

Continuing Calibration Verification

Periodic verification of the initial calibration is essential in generating analytical data of known quality. The continuing calibration verification analyses ensure that the instrument has not been adversely affected by the sample matrix or other instrument failures that would increase or decrease the sensitivity or accuracy of the method. The laboratory will perform continuing calibration for all methods according to the specific requirements in the method and laboratory SOPs.

Method SW8000B allows the use of the average of all analytes' percent-drift or recovery to meet the continuing calibration requirements for the method, but is NOT allowed by the QAPP. The use of this calibration verification approach must be approved by the Project Chemist.

4.3 Elements of Quality Control

Laboratory quality control checks indicate the state of control that prevailed at the time of sample analysis. Quality control checks that involve field samples, such as matrix, surrogate spikes, and field duplicates, also indicate the presence of matrix effects. Field-originated blanks provide a way to monitor for potential contamination to which field samples are subjected. This QAPP specifies requirements for method blanks, LCSs, surrogate spikes, and MS/MSDs that laboratories participating in the data collection effort must follow.

A laboratory quality control batch is defined as a method blank, LCS, MS/MSD, or a sample duplicate, depending on the method and 20 or fewer environmental samples of similar matrix that are extracted or analyzed together. For gas chromatography/mass spectrometry volatile analyses, a method blank, LCS, and MS/MSD must be analyzed in each 12-hour time period. The number of environmental samples allowed in the laboratory quality control batch is defined by the remaining time in the method-prescribed 12-hour time period divided by the analytical run time. Each preparation or analytical batch will be identified in such a way as to be able to associate environmental samples with the appropriate laboratory quality control samples.

4.3.14 Quality Control Analyses/Parameters Originated by the Laboratory

4.3.14.1 Method Blank

Blanks are used to monitor each preparation or analytical batch for contamination from glassware, reagents, and other potential sources within the laboratory. A method blank is an analyte-free matrix (laboratory reagent water for aqueous samples or Ottawa sand, sodium sulfate, or glass beads (metals) for soil samples) to which all reagents are added in the same amount or proportions as are added to the samples. It is processed through the entire sample preparation and analytical procedures along with the samples in the batch. There will be at least one method blank per preparation or analytical batch. If a target analyte is found at a concentration that exceeds the reporting limit, corrective action must be performed to identify and eliminate the contamination source. All associated samples must be reprepared and reanalyzed after the contamination source has been eliminated. No analytical data may be corrected for the concentration found in the blank.

4.3.14.2 Laboratory Control Sample

The LCS will consist of an analyte-free matrix such as laboratory reagent water for aqueous samples or Ottawa sand, sodium sulfate, or glass beads (metals) for soil samples spiked with known amounts of analytes that come from a source different than that used for calibration standards. Target analytes specified in the QAPP will be spiked into the LCS. The spike levels will be less than or equal to the mid-point of the calibration range. If LCS results are outside the specified control limits, corrective action must be taken, including sample re-preparation and reanalysis, if appropriate. If more than one LCS is analyzed in a preparation or analytical batch, the results of all LCSs must be reported. Any LCS recovery outside quality control limits may affect the accuracy for the entire batch and requires corrective action.

4.3.14.3 Surrogates

Surrogates are organic analytes that behave similarly to the analytes of interest but are not expected to occur naturally in the samples. They are spiked into the standards, samples, and quality control samples prior to sample preparation. Recoveries of surrogates are used to indicate accuracy, method performance, and extraction efficiency. If surrogate recoveries are outside the specified control limits, corrective action must be taken, including sample re-preparation and reanalysis, if appropriate.

4.3.14.4 Matrix Spike/Matrix Spike Duplicate

A sample matrix fortified with known quantities of specific compounds is called a matrix spike. It is subjected to the same preparation and analytical procedures as the native sample. Target analytes specified in the QAPP are spiked into the sample. Matrix spike recoveries are used to evaluate the effect of the sample matrix on the recovery of the analytes of interest. An MSD is a second fortified sample matrix. The RPD between the results of the duplicate matrix spikes measures the precision of sample results. Only project-specific samples designated on the chain-of-custody form will be spiked. The spike levels will be less than or equal to the mid-point of the calibration range.

4.3.14.5 Internal Standards

Some methods require the use of internal standards to compensate for losses during injection or purging or losses due to viscosity. Internal standards are compounds that have similar properties as the analytes of interest but are not expected to occur naturally in the samples. A measured amount of the internal standard is added to the standards, samples, and quality control samples following preparation. When the internal standard results are outside the control limits, corrective action must be taken, including sample reanalysis, if appropriate.

4.3.14.6 Laboratory Duplicate

A sample duplicate selected by the laboratory is called a laboratory duplicate. It is subjected to the same preparation and analytical procedures as the native sample. The RPD between the results of the native sample and laboratory duplicate measures the precision of sample results. The data collected may also yield information regarding whether the sample matrix is heterogeneous.

4.3.14.7 Interference Check Samples

The interference check samples are used in inductively coupled plasma (ICP) analyses to verify background and inter-element correction factors. They consist of two solutions: A and B. Solution A contains the interfering analytes, and Solution B contains both the analytes of interest and the interfering analytes. Both solutions are analyzed at the beginning and at the end of each analytical sequence. When the interference check samples results are outside the control limits, corrective action must be taken, including sample reanalysis, if appropriate.

4.3.14.8 Retention Time Windows

Retention time windows for gas chromatographic analyses must be established by replicate injections of the calibration standard over multiple days, as described in SW846 8000B, analytical method, or appropriate laboratory SOP. The absolute retention time of the calibration verification standard at the start of each analytical sequence will be used as the centerline of the window. For an analyte to be reported as positive, its elution time must be within the retention time window.

4.3.15 Quality Control Samples Originated by the Field Team

Section 2 specifies the type and frequency of quality control samples that are originated by the field team.

4.4 Additional Quality Control Requirements

4.4.16 Holding Time

The holding time requirements specified in this QAPP must be met. For methods requiring both sample preparation and analysis, the preparation holding time will be calculated from the time of sampling to the completion of preparation. The analysis holding time will be calculated from the time of completion of preparation to the time of completion of the analysis, including any required dilutions, confirmation analysis, and re-analysis. For methods requiring analysis

only, the holding time is calculated from the time of sampling to completion of the analysis, including any required dilutions, confirmation analysis, and re-analysis.

The holding times are listed in Table 3-1.

4.4.17 Confirmation

Confirmation analysis must be carried out as specified for specific methods when the result is at or above the reporting limit. The result designated as the primary result will be reported. All calibration and quality control requirements must be met when confirmation analysis is carried out.

4.4.18 Cleanup Procedures to Minimize Matrix Effects

To maintain the lowest possible reporting limits, appropriate cleanup procedures will be employed when it is indicated by the method to remove or minimize matrix interference. Methods and materials for sample cleanup include, but are not limited to, gel permeation chromatography, silica gel, alumina, florisil, mercury (sulfur removal), sulfuric acid, and acid/base partitioning. Method blanks, MS/MSDs, and LCSs must be subjected to the same cleanup procedures performed on the samples to monitor the efficiencies of these procedures.

4.4.19 Sample Dilution

Dilution of a sample results in elevated reporting limits and ultimately affects the usability of data related to potential actions at the sampling site. It is important to minimize dilutions and maintain the lowest possible reporting limits. When dilutions are necessary because of high concentrations of target analytes, lesser dilutions should also be reported to fully characterize the sample for each analyte. The level of the lesser dilution will be such that it will provide the lowest possible reporting limits without having a lasting deleterious effect on the analytical instrumentation.

When a sample exhibits characteristics of matrix interference that are identified through analytical measurement or visual observation, appropriate cleanup procedure(s) must be proven ineffective or inappropriate before proceeding with dilution and analysis.

4.4.20 Standard Materials and Other Supplies and Consumables

Standard materials must be of known high purity and traceable to an approved source. Pure standards must not exceed the manufacturer's expiration date or 1 year following receipt, whichever comes first. Solutions prepared by the laboratory from the pure standards must be used within the expiration date specified in the laboratory's SOP.

All other supplies and consumables must be inspected prior to use to ensure that they meet the requirements specified in the appropriate SOP. The laboratory's inventory and storage system should ensure their use within the manufacturer's expiration date and that the supplies are stored under proper conditions.

4.4.21 Manual Integration

The laboratory is required to provide all analysts performing methods that rely on interpretation of chromatographic data with training on appropriate software or manual

integration practices. The laboratory also will make every effort to minimize the use of manual integration of data. If manual integration is needed to correct a software auto-integration error, the manual integration will be clearly identified in the instrument data. Before- and after-enlargements of the region of the chromatogram where the manual integration was performed will be provided on an appropriate scale to allow an independent reviewer to evaluate the need and quality of the manual integration. The analyst will also document the reason for the manual integration on the chromatogram along with the date and his/her initials. The laboratory manager or designee will approve the manual integration by dating and initialing the chromatogram.

4.4.22 Laboratory Quality Assurance Program

The laboratory will maintain a Quality Assurance Manual or equivalent document. The Quality Assurance Manual will define the laboratory's internal QA/QC procedures, including:

- Quality assurance policies, objectives, and requirements
- Organization and personnel
- Document control
- SOPs (analytical methods and administrative)
- Data generation
- Software verification
- Quality assurance
- Quality control
- Nonconformance/corrective action procedures
- Data review

4.4.22.1 Laboratory SOPs

The laboratory will provide and maintain SOPs for all analytical methods and laboratory operations. The format for SOPs will generally conform to the following references:

- *Test Methods for Evaluating Solid Waste, Physical and Chemical Methods, SW-846, 3rd Edition, Update III, Section 1* (US EPA 1996)
- *Good Laboratory Practices in Principles and Guidance to Regulations for Ensuring Data Integrity in Automated Laboratory Operations* (US EPA 1995)

All SOPs must have a unique identification number that is traceable to previous revisions of the same document.

4.4.22.2 Demonstration of Capability

Laboratory quality assurance personnel will maintain records documenting the ability of each analyst to perform applicable method protocols. Documentation will include annual checks for each method and analyst. In addition, internal, blind performance evaluation samples for each method and matrix, demonstrating overall laboratory performance, must be submitted annually. The laboratory may receive additional blind performance evaluation samples in conjunction with this program.

4.5 Reporting Limits and Analytical Requirements

Tables 4-2 through 4-8 contain lists of target analytes, methods to be used, and the reporting limit objectives specific to this project. The laboratory will adhere to the requirements specified in these tables. The reporting limits included herein reflect quantifiable levels that are attainable with a specified degree of confidence using the specified methods. Where multiple method options are offered in the tables, the laboratory must choose a method that will achieve the reporting limit objective for the analyte. Once a method is chosen, it must be used throughout the duration of the project to maintain data comparability. Any subsequent change in method must be approved by the Project Chemist.

The accuracy and precision limits are listed in Table 4-9 through 4-13. Calibration and quality control requirements are specified in Tables 4-14 through 4-18.

TABLE 4-2
Analytical and Preparation Methodologies
WWTS Management, Quality Assurance Project Plan

Analysis	Preparation Method	Analytical Method
Soil Samples		
Aroclor 1268	SW-846 3540C/3550B	SW-846 8082
Discharge Water Samples		
Aroclor 1268	Per Analytical Method	SW-846 8082
Wipe Samples		
Aroclor 1268	Per Analytical Method	SW-846 8082
Stockpiled WWTS Samples		
VOCs	Per Analytical Method	SW-846 8260
SVOCs	Per Analytical Method	SW-846 8270
Pesticides	Per Analytical Method	SW-846 8081A
Metals	Per Analytical Method	SW-846 6000 or 7000 series
Dioxins	Per Analytical Method	EPA Method 1613

TABLE 4-3
Soil Reporting Limit Objectives for Pesticides by SW846 8081A
WWTS Management, Quality Assurance Project Plan

Analyte	RL (µg/kg)
Aldrin	1.7
α-BHC	1.7
β-BHC	1.7
δ-BHC	1.7
γ-BHC	1.7
α-Chlordane	1.7
γ-Chlordane	1.7
Chlordane	3.3

TABLE 4-3
Soil Reporting Limit Objectives for Pesticides by SW846 8081A
WWTs Management, Quality Assurance Project Plan

Analyte	RL (µg/kg)
4,4'-DDD	1.7
4,4'-DDE	1.7
4,4'-DDT	1.7
Dieldrin	1.7
Endosulfan I	1.7
Endosulfan II	1.7
Endosulfan sulfate	1.7
Endrin	1.7
Endrin aldehyde	1.7
Endrin ketone	1.7
Heptachlor	1.7
Heptachlor epoxide	1.7
Isodrin	1.7

µg/kg = micrograms per kilogram

TABLE 4-4
Soil Reporting Limit Objectives for Volatiles by SW846 8260B
WWTs Management, Quality Assurance Project Plan

Analyte	RL (µg/kg)
Acetone	10
Benzene	5
Bromodichloromethane	5
Bromoform	5
Bromomethane	10
2-butanone	20
Carbon disulfide	5
Carbon tetrachloride	5
Chlorobenzene	5
Chloroethane	10
Chloroform	5
Chloromethane	10
Cyclohexane	10
Dibromochloromethane	5
1,2-dibromo-3-chloropropane	10
1,2-dibromoethane	5
1,2-dichlorobenzene	5
1,3-dichlorobenzene	5
1,4-dichlorobenzene	5
Dichlorodifluoromethane	10
trans-1,2-dichloroethene	5
1,2-dichloropropane	5
cis-1,3-dichloropropene	5
trans-1,3-dichloropropene	5
Ethylbenzene	5
2-hexanone	20
Isopropylbenzene	5
Methyl acetate	10
Methylene chloride	5
Methylcyclohexane	10
4-methyl-2-pentanone	20
Methyl tert-butyl ether	20
Styrene	5
1,1,2,2-tetrachloroethane	5
Tetrachloroethene	5
Toluene	5
1,2,4-trichlorobenzene	5
1,1,1-trichloroethane	5
1,1,2-trichloroethane	5
Trichloroethene	5

TABLE 4-4
Soil Reporting Limit Objectives for Volatiles by SW846 8260B
WWTS Management, Quality Assurance Project Plan

Analyte		RL (µg/kg)	
1,1-dichloroethane	5	Trichlorofluoromethane	10
1,2-dichloroethane	5	1,1,2-trichloro-1,2,2-trifluoroethane	5
1,1-dichloroethene	5	Vinyl chloride	10
cis-1,2-dichloroethene	5	Xylenes (total)	5

TABLE 4-5
Soil Reporting Limit Objectives for Semivolatiles, SW846 8270C
WWTS Management, Quality Assurance Project Plan

Analyte	RL (µg/kg)	Analyte	RL (µg/kg)
Acenaphthene	330	2,4-dinitrophenol	1600
Acenaphthylene	330	2,4-dinitrotoluene	330
Acetophenone	330	2,6-dinitrotoluene	330
Anthracene	330	bis(2-ethylhexyl)phthalate	330
Atrazine	330	Fluoroanthene	330
Benzaldehyde	330	Fluorene	330
Benzo(a)anthracene	330	Hexachlorobenzene	330
Benzo(a)pyrene	330	Hexachlorobutadiene	330
Benzo(b)fluoranthene	330	Hexachlorocyclopentadiene	1600
Benzo(g,h,i)perylene	330	Hexachloroethane	330
Benzo(k)fluoranthene	330	Ideno(1,2,3-cd)pyrene	330
1,1'-Biphenyl	330	Isophorone	330
4-bromophenyl ether	330	2-methylnaphthalene	330
Butylbenzylphthalate	330	2-methylphenol	330
di-n-butylphthalate	330	4-methylphenol	330
Caprolactam	330	Naphthalene	330
Carbazole	330	2-nitroaniline	1600
4-chloroaniline	330	3-nitroaniline	1600
bis(2-chloroethoxy)methane	330	4-nitroaniline	1600
bis(2-chloroethyl)ether	330	Nitrobenzene	330
bis(2-chloroisopropyl)ether	330	2-nitrophenol	330
4-chloro-3-methylphenol	330	4-nitrophenol	1600
2-chloronaphthalene	330	n-nitroso-di-n-propylamine	330
2-chlorophenol	330	n-nitrosodiphenylamine	330

TABLE 4-5
Soil Reporting Limit Objectives for Semivolatiles, SW846 8270C
WWTS Management, Quality Assurance Project Plan

Analyte	RL (µg/kg)	Analyte	RL (µg/kg)
4-chlorophenyl phenyl ether	330	di-n-octylphthalate	330
Chrysene	330	Pentachlorophenol	670
Dibenzo(a,h)anthracene	330	Phenanthrene	330
Dibenzofuran	330	Phenol	330
3,3'-dichlorobenzidine	1600	Pyrene	330
2,4-dichlorophenol	330	2,4,5-trichlorophenol	330
Diethyl phthalate	330	2,4,6-trichlorophenol	330
4,6-dinitro-2-methylphenol	1600		

TABLE 4-6
Soil Reporting Limit Objectives for Metals by SW846 6000 or 7000 Series
WWTS Management, Quality Assurance Project Plan

Analyte	RL (µg/kg)
Aluminum	20000
Antimony	6000
Arsenic	1000
Barium	20000
Beryllium	500
Cadmium	500
Chromium	1000
Cobalt	5000
Copper	2500
Iron	10000
Lead	500
Manganese	1500
Mercury	100
Nickel	4000
Selenium	1000
Silver	1000
Thallium	1000
Vanadium	5000
Zinc	2000

TABLE 4-7
Soil Reporting Limit Objectives for Dioxins by EPA Method 1613
WWTS Management, Quality Assurance Project Plan

Analyte	RL (ng/kg)
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	5
1,2,3,4,7,8-HxCDD	5
1,2,3,6,7,8-HxCDD	5
1,2,3,7,8,9-HxCDD	5
1,2,3,4,6,7,8-HpCDD	5
OCDD	10
2,3,7,8-TCDF	1
1,2,3,7,8-PeCDF	5
2,3,4,7,8-PeCDF	5
1,2,3,4,7,8-HxCDF	5
1,2,3,6,7,8-HxCDF	5
2,3,4,6,7,8-HxCDF	5
1,2,3,7,8,9-HxCDF	5
1,2,3,4,6,7,8-HpCDF	5
1,2,3,4,6,7,8,9-HpCDF	5
OCDF	10

TABLE 4-8
Pre-Treatment Effluent Water Reporting Limit Objectives for Aroclors by EPA 8082
WWTS Management, Quality Assurance Project Plan

Analyte	RL (µg/L)
Aroclor-1268	0.5

TABLE 4-9
Accuracy and Precision Limits for PCB Aroclors by SW846 8082
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Soil (% R)	MS/MSD Accuracy Soil (% R)	Precision Soil (% RPD)
Aroclor-1268	76-128	51-142	19	75-137	39-160	29

TABLE 4-10
Accuracy and Precision Limits for Volatiles by SW846 8260B
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Soil (% R)	MS/MSD Accuracy Soil (% R)	Precision Soil (% RPD)
Acetone	39-162	32-166	20	18-170	10-184	34
Benzene	77-121	52-136	10	81-116	54-132	15
Bromodichloromethane	82-125	79-128	12	83-123	56-139	16
Bromoform	68-130	62-134	11	74-127	52-134	20
Bromomethane	57-141	56-141	15	60-134	10-141	31
2-Butanone	48-148	47-147	15	37-159	24-168	30
Carbon disulfide	53-134	54-129	15	52-138	32-143	20
Carbon tetrachloride	74-139	64-148	14	72-134	40-149	16
Chlorobenzene	80-117	76-120	10	83-115	50-136	19
Chloroethane	64-139	57-144	17	61-138	12-139	29
Chloroform	79-122	74-127	12	79-121	57-135	15
Chloromethane	56-152	53-142	20	57-139	41-138	22
Cyclohexane	59-127	51-148	15	50-141	28-153	21
1,2-Dibromo-3- chloropropane	70-131	69-134	13	70-129	48-142	22
Dibromochloromethane	78-124	77-128	9	80-127	57-139	18
1,2-Dibromoethane	79-122	77-124	10	85-122	58-138	18
1,2-Dichlorobenzene	79-116	76-119	10	80-117	39-144	23
1,3-Dichlorobenzene	78-116	75-119	12	79-117	37-146	23
1,4-Dichlorobenzene	76-118	73-118	11	77-114	38-139	24
Dichlorodifluoromethane	42-184	53-157	19	47-162	32-151	20
1,1-Dichloroethane	76-122	71-128	13	77-123	56-135	15
1,2-Dichloroethane	70-136	67-140	13	77-129	58-137	15
1,1-Dichloroethene	69-127	61-135	12	68-130	43-144	18
cis-1,2-Dichloroethene	75-119	70-128	10	77-122	54-139	15
trans-1,2-Dichloroethene	73-122	69-126	11	74-125	48-139	16
1,2-Dichloropropane	80-119	76-123	11	81-119	60-131	15
cis-1,3-Dichloropropene	79-120	74-123	11	83-119	51-137	16
trans-1,3-Dichloropropene	78-125	73-127	12	81-123	50-140	17
Ethylbenzene	80-121	52-140	11	81-118	44-142	20

TABLE 4-10
Accuracy and Precision Limits for Volatiles by SW846 8260B
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Soil (% R)	MS/MSD Accuracy Soil (% R)	Precision Soil (% RPD)
2-Hexanone	52-147	51-144	16	44-155	27-161	27
Isopropylbenzene	75-130	65-133	11	75-127	36-152	23
Methyl Acetate	52-144	45-137	16	58-146	41-172	27
Methylcyclohexane	71-127	56-140	15	61-132	23-156	24
Methyl Tert Butyl Ether	73-127	42-148	13	76-129	57-141	17
4-Methyl-2-pentanone	58-145	54-145	20	66-141	51-141	22
Methylene chloride	76-119	73-124	10	77-123	56-137	17
Styrene	81-124	74-131	9	85-121	43-148	22
1,1,2,2-Tetrachloroethane	74-120	72-121	11	75-125	51-137	24
Tetrachloroethene	65-135	66-129	11	67-132	33-167	29
Toluene	79-122	51-142	11	82-118	47-140	17
1,2,4-Trichlorobenzene	73-123	68-126	10	68-127	27-159	27
1,1,1-Trichloroethane	78-131	69-140	14	74-129	48-142	16
1,1,2-Trichloroethane	83-118	81-121	10	82-120	60-134	17
Trichloroethene	80-122	68-133	11	80-119	45-145	17
Trichlorofluoromethane	70-159	59-159	17	66-143	38-141	19
Vinyl chloride	64-144	52-145	17	62-139	42-142	18
Xylene (total)	81-120	63-127	10	82-119	43-144	21
Surrogates						
1,2-Dichloroethane-d ₄	69-131			62-131		
4-Bromofluorobenzene	80-121			67-137		
Dibromofluoromethane	79-121			70-122		
Toluene-d ₈	76-119			76-119		

TABLE 4-11
Accuracy and Precision Limits for TCL Semivolatiles, SW846 8270C and EPA 625
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Soil (% R)	MS/MSD Accuracy Soil (% R)	Precision Soil (% RPD)
2-Chlorophenol	50-108	31-120	25	63-106	45-103	18
4-Chloro-3-methylphenol	55-116	39-129	22	63-113	49-113	19
2,4-Dichlorophenol	55-115	37-123	28	62-108	44-112	18
2,4-Dinitrophenol	33-130	10-141	28	32-127	10-116	38
4,6-Dinitro-o-cresol	51-125	23-137	26	48-125	10-123	39
2-Methylphenol	36-101	24-118	34	56-109	42-105	20
4-Methylphenol	29-96	17-124	30	45-110	40-110	26
2-Nitrophenol	52-120	35-124	27	57-111	28-110	24
4-Nitrophenol	10-74	10-116	33	40-131	20-137	31
Pentachlorophenol	35-124	33-143	23	41-121	26-123	24
Phenol	10-64	10-103	30	56-113	43-106	21
2,4,5-Trichlorophenol	57-118	41-127	25	61-113	47-111	19
2,4,6-Trichlorophenol	59-117	40-126	22	65-111	50-113	19
Acenaphthene	58-109	38-118	27	62-103	31-120	27
Acenaphthylene	50-107	35-109	28	57-99	37-104	23
Acetophenone	56-115	28-130	29	53-99	30-104	21
Anthracene	65-113	56-117	20	67-111	41-119	28
Atrazine	17-158	10-163	23	20-154	10-164	23
Benzaldehyde	10-205	10-191	32	64-111	37-125	31
Benzo(a)anthracene	63-114	57-117	20	65-113	37-124	29
Benzo(a)pyrene	63-117	57-119	22	61-118	25-147	33
Benzo(b)fluoranthene	60-121	53-119	26	54-122	10-135	38
Benzo(g,h,i)perylene	58-125	35-135	27	59-121	25-142	31
Benzo(k)fluoranthene	60-123	47-132	27	65-113	48-115	20
4-Bromophenyl-phenyl ether	62-117	51-120	22	63-121	32-148	22
Butyl benzyl phthalate	63-123	54-131	22	62-104	39-113	22
1,1'-Biphenyl	58-110	35-119	27	10-185	10-199	40
2-Chloronaphthalene	58-110	36-119	28	63-104	45-105	19
4-Chloroaniline	38-116	12-113	29	24-92	10-94	31
Carbazole	68-122	59-127	22	67-121	37-136	26
Caprolactam	10-49	10-115	39	47-129	24-136	31
Chrysene	65-114	58-117	21	64-112	36-124	29

TABLE 4-11

Accuracy and Precision Limits for TCL Semivolatiles, SW846 8270C and EPA 625
 WWTs Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Soil (% R)	MS/MSD Accuracy Soil (% R)	Precision Soil (% RPD)
bis(2-Chloroethoxy)methane	57-119	35-126	30	59-112	40-112	21
bis(2-Chloroethyl)ether	53-116	31-124	28	56-108	37-105	25
Bis(2-Chloroisopropyl)ether	56-113	34-120	29	60-105	36-108	22
4-Chlorophenol phenyl ether	61-114	44-119	24	64-109	48-110	19
2,4-Dinitrotoluene	62-122	45-129	23	63-119	30-126	25
2,6-Dinitrotoluene	63-122	46-129	25	66-116	42-117	24
3,3'-Dichlorobenzidine	43-129	10-140	37	35-116	10-111	39
Dibenzo(a,h)anthracene	60-126	45-130	24	58-122	14-133	30
Dibenzofuran	62-114	43-121	25	66-108	37-125	29
di-n-Butylphthalate	67-122	62-123	22	66-120	47-122	21
di-n-Octylphthalate	60-139	48-155	24	61-137	27-168	29
Diethylphthalate	60-123	50-127	24	64-117	50-113	20
bis(2-Ethylhexyl)phthalate	61-124	55-133	24	60-123	29-151	25
Fluoranthene	64-117	58-119	21	65-114	28-133	35
Fluorene	61-114	45-120	24	65-108	39-119	32
Hexachlorobenzene	62-116	53-118	21	63-114	49-111	19
Hexachlorobutadiene	50-118	33-124	29	57-114	37-114	21
Hexachlorocyclopentadiene	24-114	10-113	37	21-114	10-95	42
Hexachloroethane	50-106	30-114	29	58-102	19-105	26
Indeno(1,2,3-cd)pyrene	58-124	39-133	25	56-121	13-130	35
Isophorone	51-111	33-116	26	53-103	36-103	20
2-Methylnaphthalene	55-108	35-117	28	57-105	30-120	26
2-Nitroaniline	57-128	39-133	28	58-122	39-122	23
3-Nitroaniline	48-128	17-135	25	42-116	27-107	30
4-Nitroaniline	51-131	28-137	30	48-131	20-123	35
Naphthalene	53-106	27-124	26	57-100	29-113	28
Nitrobenzene	55-110	33-122	27	57-104	31-112	21
n-Nitroso-di-n-dipropylamine	54-123	30-131	28	55-114	36-114	22
n-Nitrosodiphenylamine	62-119	47-126	23	65-117	35-136	22
Phenanthrene	63-111	52-118	19	65-108	29-129	39
Pyrene	61-113	49-124	22	62-112	20-148	40

TABLE 4-11
Accuracy and Precision Limits for TCL Semivolatiles, SW846 8270C and EPA 625
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Soil (% R)	MS/MSD Accuracy Soil (% R)	Precision Soil (% RPD)
Surrogates						
2,4,6-Tribromophenol	43-126			33-122		
2-Fluorobiphenyl	32-120			38-110		
2-Fluorophenol	14-81			34-111		
Nitrobenzene-d5	28-125			29-114		
Phenol-d5	10-64			34-111		
Terphenyl-d14	42-125			32-136		

TABLE 4-12
Accuracy and Precision Limits for Metals by SW846 6000, 7000 Series
WWTS Management Quality Assurance Project Plan

Analytes	LCS Accuracy Water (% R)	LCS Accuracy Soil (% R)	MS/MSD Water/Soil Accuracy (% R.)	Precision Water/Soil (% RPD)
Aluminum	80-120	75-125	75-125	20
Antimony	80-120	75-125	75-125	20
Arsenic	80-120	75-125	75-125	20
Barium	80-120	75-125	75-125	20
Beryllium	80-120	75-125	75-125	20
Cadmium	80-120	75-125	75-125	20
Chromium	80-120	75-125	75-125	20
Cobalt	80-120	75-125	75-125	20
Copper	80-120	75-125	75-125	20
Iron	80-120	75-125	75-125	20
Lead	80-120	75-125	75-125	20
Manganese	80-120	75-125	75-125	20
Mercury	80-120	75-125	75-125	20
Nickel	80-120	75-125	75-125	20
Selenium	80-120	75-125	75-125	20

TABLE 4-12
Accuracy and Precision Limits for Metals by SW846 6000, 7000 Series
WWTS Management Quality Assurance Project Plan

Analytes	LCS Accuracy Water (% R)	LCS Accuracy Soil (% R)	MS/MSD Water/Soil Accuracy (% R.)	Precision Water/Soil (% RPD)
Silver	80-120	75-125	75-125	20
Thallium	80-120	75-125	75-125	20
Vanadium	80-120	75-125	75-125	20
Zinc	80-120	75-125	75-125	20

Note: Spike recovery limits do not apply when the sample concentration exceeds the spike added concentration by a factor of 4 or more.

Precision limit for laboratory duplicates is $\pm 20\%$ if duplicate values are $\geq 5x$ RL; limit is \pm RL if one of the values is $<5x$ RL; no limit if both values are $<5x$ RL. For soils limits are $\pm 35\%$ RPD and $\pm 2x$ RL.

TABLE 4-13
Accuracy and Precision Limits for Pesticides by SW846 8081A
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Sediment (% R)	MS/MSD Accuracy Sediment (% R)	Precision Sediment (% RPD)
Aldrin	71-133	72-121	13	68-157	26-166	32
α -BHC	83-137	67-145	20	71-161	24-172	36
β -BHC	80-130	82-130	23	71-150	16-174	41
γ -BHC	82-138	50-150	14	71-158	26-168	38
δ -BHC	80-144	71-150	11	56-166	10-175	42
α -Chlordane	83-139	74-144	16	71-153	21-177	34
γ -Chlordane	85-140	82-128	12	74-153	24-173	38
Dieldrin	87-147	87-138	14	74-160	20-181	41
4,4'-DDD	85-146	89-136	13	74-160	22-186	36
4,4'-DDE	83-140	74-135	13	73-160	19-192	42
4,4'-DDT	82-154	81-145	15	68-164	18-200	44
Endrin	84-143	88-137	12	69-158	26-175	36
Endosulfan sulfate	82-158	94-153	12	67-158	10-175	46
Endrin aldehyde	83-139	61-152	12	45-138	10-141	46
Endosulfan-I	82-137	80-128	12	72-153	24-167	38
Endosulfan-II	85-139	85-136	14	72-155	13-175	40

TABLE 4-13
Accuracy and Precision Limits for Pesticides by SW846 8081A
WWTS Management Quality Assurance Project Plan

Analyte	LCS Accuracy Water (% R)	MS/MSD Accuracy Water (% R)	Precision Water (% RPD)	LCS Accuracy Sediment (% R)	MS/MSD Accuracy Sediment (% R)	Precision Sediment (% RPD)
Heptachlor	80-134	77-127	17	72-157	32-169	36
Heptachlor epoxide	84-138	83-129	25	71-155	25-169	34
Toxaphene	50-150	50-150	10	99-104	50-150	10

TABLE 4-14
Calibration and QC Requirements for Metals by SW846 6000 or 7000 Series
WWTS Management, Quality Assurance Project Plan

QC Check	Frequency	Criteria	Corrective Action
Initial calibration (a blank and at least one standard for ICP; a blank and at least three standards for non-ICP)	Before initial sample analysis, every 24 hours, whenever modifications are made to the analytical system, or when continuing calibration verification fails	If more than one standard is used, correlation coefficient must be > 0.995	N/A
Initial calibration verification	Immediately following each initial calibration	All analytes within $\pm 10\%$ ($\pm 5\%$ for method 200.7) of expected value	Correct problem and repeat initial calibration.
Calibration blank	After every calibration verification (initial calibration verification and continuing calibration verification)	No analytes detected at or above the reporting limit	Correct the problem, then reanalyze previous 10 samples.
Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within $\pm 10\%$ of expected value	Recalibrate and reanalyze all samples since the last acceptable continuing calibration verification
Method Blank	At least one per analytical batch	No analytes detected at or above the reporting limit	Correct the problem and re- prep and reanalyze all associated samples
Interference check standard (ICP only)	At the start and end of each analytical sequence or twice during an 8-hour period, whichever is more frequent	All analytes within $\pm 20\%$ of expected value	Correct the problem, recalibrate, reanalyze ICS and all affected samples.
MS/MSD	One set per 20 project-specific samples	All analytes within limits specified in Accuracy and Precision table	None
LCS	At least one per analytical batch	All analytes within limits specified in Accuracy and Precision table	Correct the problem, and re- prep and reanalyze the LCS and all samples in the analytical batch.
Dilution test	Each new sample matrix	Result from 1:5 dilution must be within $\pm 10\%$ of the undiluted sample result (applies only if undiluted sample result is at least 25 times the reporting limit)	Perform post-digestion spike addition.

TABLE 4-14

Calibration and QC Requirements for Metals by SW846 6000 or 7000 Series

WWTS Management, Quality Assurance Project Plan

QC Check	Frequency	Criteria	Corrective Action
Low-level calibration check standard (ICP only)	Once per analytical batch, prior to sample analysis	All analytes within $\pm 50\%$ of expected value	Correct problem then reanalyze the low level check standard and all samples in the analytical batch
Linear Range Calibration check standard (ICP only)	Once per quarter	All analytes within $\pm 10\%$ of expected value	Correct problem then reanalyze or re-set linear range
Post-digestion spike addition	When dilution test fails	Recovery within 75 to 125% of expected value	None

TABLE 4-15

Calibration and QC Requirements for Mercury by SW846 7471A

WWTS Management, Quality Assurance Project Plan

QC Check	Frequency	Criteria	Corrective Action
Multi-point initial calibration (a blank and at least five standards)	Before initial sample analysis, every 24 hours, whenever modifications are made to the analytical system, or when continuing calibration verification fails	Correlation coefficient of linear regression is ≥ 0.995	Correct the problem and repeat the initial calibration.
Second-source calibration verification	Immediately following each initial calibration	All analytes within $\pm 20\%$ - of expected value	Correct the problem and repeat initial calibration.
Calibration blank	After every calibration verification (initial calibration verification and continuing calibration verification)	No analytes detected at or above the reporting limit	Correct the problem, then reanalyze previous 10 samples.
Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within $\pm 20\%$ - of expected value	Recalibrate and reanalyze all samples since the last acceptable continuing calibration verification
Method Blank	At least one per analytical batch	No analytes detected at or above the reporting limit	Correct the problem and re-prepare and reanalyze all associated samples
MS/MSD	One set per 20 project-specific samples	All analytes within limits specified in Accuracy and Precision table	None
LCS	At least one per analytical batch	All analytes within limits specified in Accuracy and Precision table	Correct the problem, and re-prepare and reanalyze the LCS and all samples in the analytical batch
Dilution test	Each new sample matrix	Result from 1:5 dilution must be within $\pm 10\%$ of the undiluted sample result (applies only if undiluted sample result is at least 25 times the reporting limit)	Perform recovery test
Recovery test	When dilution test fails	Recovery within 85 to 115% of expected value	Analyze all samples by MSA

TABLE 4-16

Calibration and QC Requirements for Pesticides and Aroclors by SW846 8081A, SW846 8082
WWTS Management, Quality Assurance Project Plan

QC Check	Frequency	Criteria	Corrective Action
Multi-point initial calibration (minimum five points) for single-response pesticides; single-point calibration for Toxaphene and Chlordane; multi-point calibration for Aroclors 1016 and 1260 only, but include mid-point standard for all other Aroclors for pattern recognition; if a specific Aroclor is found in any sample, quantitation for that Aroclor must be done using 5-point calibration.	Prior to sample analysis, or when calibration verification fails	To use average RRF for quantitation of any analyte, % RSD must be $\leq 20\%$ ($\leq 10\%$ for method 608); otherwise use calibration curve with coefficient of correlation or determination ≥ 0.99 .	Correct the problem and repeat the initial calibration.
Second-source calibration verification – pesticides and Aroclors 1016 and 1260 (or Aroclors identified in samples)	Once for each multi-point initial calibration	All analytes within $\pm 15\%$ of expected value	Correct the problem, then recalibrate and reanalyze all samples since the last acceptable continuing calibration verification.
Continuing calibration verification – pesticides and Aroclors 1016 and 1260 (or Aroclors identified in samples)	At the start of each analytical sequence, after every 12 hours or 10 samples, whichever is more frequent, and at the end of the sequence	All analytes within $\pm 15\%$ of expected value	Correct the problem, then recalibrate and reanalyze all samples since the last acceptable continuing calibration verification.
Endrin/DDT breakdown check (Not applicable when analyzing for Aroclors/PCBs only)	At start of each 12-hour period	Breakdown of either Endrin or DDT $\leq 15\%$	Evaluate injector port and take corrective action; re-calibrate and reanalyze affected samples if necessary
Method Blank	At least one per analytical batch	No analytes detected at or above the reporting limit	Correct the problem and re-prepare and reanalyze all associated samples
Surrogate spike	Every standard, sample, method blank, MS/MSD, and LCS	At least one of the surrogates in samples, method blank, MS/MSD, and LCS within limits specified in corresponding Accuracy and Precision table	Correct the problem and reanalyze (re-prepare if necessary).
MS/MSD	One set per 20 project-specific samples	Within limits specified in corresponding Accuracy and Precision table	None
LCS	At least one per analytical batch	Within limits specified in corresponding Accuracy and Precision table	Correct the problem, and re-prepare and reanalyze the LCS and all samples in the analytical batch.
Second column confirmation	All samples with results above the reporting limit objectives must be confirmed within the holding time.	Confirmation to be done using second column of dissimilar phase and retention characteristics (or GC/MS if sample concentration is sufficiently high). All calibration and QC acceptance criteria specified for primary analysis must be met in the confirmation analysis.	Failure to perform confirmation will result in potential re-sampling and analysis at no cost to the project.

TABLE 4-17
Calibration and QC Requirements for Volatiles by SW846 8260B
WWTS Management, Quality Assurance Project Plan

QC Check	Frequency	Criteria	Corrective Action
BFB Tuning	Prior to initial calibration and calibration verification (every 12 hours)	Refer to criteria listed in the method	Retune instrument and verify
Multi-point initial calibration (minimum five points)	Prior to sample analysis, or when calibration verification fails	SPCCs average RF $\geq 0.30^a$ and %RSD for RFs for CCCs $\leq 30\%$ and one option below: Option 1: Mean %RSD for all analytes $\leq 15\%$ with no individual analyte RSD $> 30\%$, if using average RRFs Option 2: Least squares regression $r \geq 0.990$	Correct the problem and repeat the initial calibration.
Second-source calibration verification	Once for each multi-point initial calibration	All analytes within $\pm 25\%$ of expected value	Correct the problem and repeat initial calibration.
Continuing calibration verification	At the start of each analytical sequence, after every 12 hours or 10 samples, whichever is more frequent, and at the end of the sequence	SPCCs average RF $\geq 0.30^c$ and %D for RFs for CCCs $\leq 20\%$ All other analytes within $\pm 20\%$ of expected value.	Correct the problem, then recalibrate and reanalyze all samples since the last acceptable continuing calibration verification.
Retention time window calculated for each analyte	Each analyte	Relative retention time of each analyte within ± 0.06 relative retention time units of the continuing calibration verification	Not applicable (used for identification of analyte)
Internal Standards	Each sample and QC sample, method blank, MS/MSD and LCS	Retention time within ± 30 seconds from retention time of the daily continuing calibration verification standard. EICP area within -50% to $+100\%$ of the daily continuing calibration verification standard	Inspect mass spectrometer and GC for malfunctions; reanalyze all affected samples
Method Blank	At least one per analytical batch	No analytes detected at or above the reporting limit	Correct the problem, then re-prepare and reanalyze all associated samples
Surrogate spike	Every standard, sample, method blank, MS/MSD and LCS	All surrogates in samples, method blank and LCS within limits specified in Accuracy and Precision table	Correct the problem and reanalyze (re-prepare if necessary).
MS/MSD	One set per 20 project-specific samples	Within limits specified in Accuracy and Precision table	None
LCS	At least one per analytical batch	Within limits specified in Table 17	Correct the problem, then re-prepare and reanalyze the LCS and all samples in the analytical batch.

^aSPCC average RRF ≥ 0.10 for bromoform, chloromethane, 1,1-dichloroethane.

TABLE 4-18
Calibration and QC Requirements for Semivolatiles by SW846 8270C
WWTS Management, Quality Assurance Project Plan

QC Check	Frequency	Criteria	Corrective Action
DFTPP Tuning	Prior to initial calibration and calibration verification (every 12 hours)	Refer to criteria listed in the method	Retune instrument and verify
Multi-point initial calibration (minimum five points)	Prior to sample analysis, or when calibration verification fails	SPCCs average RF ≥ 0.050 and %RSD for RFs for CCCs $\leq 30\%$ and one option below: Option 1: Mean %RSD for all analytes $\leq 15\%$ with no individual analyte RSD $> 30\%$, if using average RRFs Option 2: Least squares regression $r \geq 0.990$	Correct the problem and repeat the initial calibration.
Second-source calibration verification	Once for each multi-point initial calibration	All analytes within $\pm 25\%$ of expected value	Correct the problem and repeat initial calibration.
Continuing calibration verification	At the start of each analytical sequence, after every 12 hours or 10 samples, whichever is more frequent, and at the end of the sequence	SPCCs average RF ≥ 0.050 and %D for RFs for CCCs $\leq 20\%$ All other analytes within $\pm 20\%$ of expected value.	Correct the problem, then recalibrate and reanalyze all samples since the last acceptable continuing calibration verification.
Retention time window calculated for each analyte	Each analyte	Relative retention time of each analyte within ± 0.06 relative retention time units of the continuing calibration verification	Not applicable (used for identification of analyte)
Internal Standards	Each sample and QC sample, method blank, MS/MSD and LCS	Retention time within ± 30 seconds from retention time of the daily continuing calibration verification standard. EICP area within -50% to $+100\%$ of the daily continuing calibration verification standard	Inspect mass spectrometer and GC for malfunctions; reanalyze all affected samples
Method Blank	At least one per analytical batch	No analytes detected at or above the reporting limit	Correct the problem, then re-prepare and reanalyze all associated samples
Surrogate spike	Every standard, sample, method blank, MS/MSD and LCS	At least two surrogates per fraction in samples, method blank and LCS within limits specified in Accuracy and Precision table	Correct the problem and reanalyze (re-prepare if necessary).
MS/MSD	One set per 20 project-specific samples	Within limits specified in Accuracy and Precision table	None
LCS	At least one per analytical batch	Within limits specified in Accuracy and Precision table	Correct the problem, then re-prepare and reanalyze the LCS and all samples in the analytical batch.

Calibration Procedures and Frequency

5.1 Field Calibration Procedures

Field equipment will be calibrated before the start of work and at the end of the sampling day. Any instrument drift from prior calibration will be recorded in the field notebook. Calibration will be in accordance with procedures and schedules outlined in the particular instrument's operations manual and the information included within the SAP.

Calibrated equipment will be uniquely identified by using either the manufacturer's serial number or other means. A label with the identification number and the date when the next calibration is due will be physically attached to the equipment. If this is not possible, records traceable to the equipment (e.g., showing the equipment identification) will be readily available for reference. In addition, the results of calibrations and records of repairs will be recorded in the logbook.

Scheduled periodic calibration of testing equipment does not relieve field personnel of the responsibility of using properly functioning equipment. If an individual suspects an equipment malfunction, the device will be removed from service, tagged so that it is not inadvertently used, and the appropriate personnel notified so that a recalibration can be performed or substitute equipment can be obtained.

Equipment that fails calibration or becomes inoperable during use will be removed from service and either segregated to prevent inadvertent use or tagged to indicate it is out of calibration. Such equipment will be repaired and satisfactorily recalibrated. Equipment that cannot be repaired will be replaced.

5.2 Laboratory Calibration Procedures

Qualified personnel will appropriately calibrate laboratory instruments prior to sample analysis. The requirements specified in each method will be followed. Only certified standards of known purity may be used for calibration. Calibration will be verified at specified intervals throughout the analysis. The frequency and acceptance criteria for calibration are specified for each analytical method in Tables 4-14 through 4-18. When multi-point calibration is specified, the concentrations of the calibration standards should bracket those expected in the samples. Samples must be diluted, if necessary, to bring analyte responses within the calibration range. The laboratory may only report those data that result from quantitation within the demonstrated working calibration range. Quantitation based on extrapolation is not acceptable.

Data Reduction, Validation, and Reporting

6.1 Laboratory Data Management

Data reduction will be performed manually or by using appropriate application software. Quantitation procedures specified for each method must be followed. If data reduction is performed manually, the documentation must include the formulas used. Any application software used for data reduction must have been verified previously by the laboratory for accuracy. Documentation of the software's verification must be maintained on file in the laboratory. All documentation of data reduction must allow recreation of the calculations.

All data will undergo at least three levels of review at the laboratory before release. The analyst performing the tests initially will review 100 percent of the data. After the analyst's review has been completed, 100 percent of the data will be reviewed independently by a senior analyst or by the section supervisor for accuracy; compliance with calibration, quality control requirements, and holding times; and completeness. Analyte identification and quantitation must be verified. Calibration and quality control results will be compared with the applicable control limits. Reporting limits will be reviewed to make sure they meet the project objectives. Results of multiple dilutions will be reviewed for consistency. Any discrepancies must be resolved and corrected. Laboratory qualifiers will be applied when there are nonconformances that potentially affect data usability. Qualifiers must be properly defined as part of the deliverables. All issues relevant to the quality of the data must be described in the case narrative. The laboratory quality control manager will review at least 10 percent of the data or deliverables generated for the program against the project-specific requirements. A final data review will be conducted by the laboratory manager or client service representative to ensure that all required analyses were performed on all samples and that all documentation is complete.

The laboratory will maintain the raw data and all other documentation associated with sample preparation and analysis in a manner that will allow easy retrieval and submittal to CH2M HILL when necessary. All data generated using gas chromatography/mass spectrometry must be maintained on a digital memory device and will be made available to CH2M HILL upon request. All documentation must be retained for a minimum of 10 years after data acquisition.

The primary responsibility for the implementation of these procedures within the laboratory will reside with the laboratory manager or equivalent. The laboratory manager will approve laboratory reports before transferring the information to CH2M HILL.

6.1.23 Hardcopy Deliverables

The hardcopy deliverables will consist of summary forms containing the information listed below in formats similar to those specified in the latest versions of the USEPA Contract Laboratory Program (CLP) Statements of Work for Organics and Inorganics Analyses are preferred (USEPA 1999, 2004). Raw data will not be submitted. However, the laboratory

must maintain raw data and all other required documentation associated with each data acquisition to allow re-creation of the sample preparation and analysis. They must be made available to CH2M HILL upon request for specific sample delivery groups. The deliverables will be organized in a format that easily enables identification and retrieval of data. Alternate reporting formats require approval from the project chemist.

- Cover letter complete with:
 - Title of report and unique laboratory report identification (Sample Delivery Group Number).
 - Project name and location.
 - Name and location of laboratory and second-site or subcontracted laboratory.
 - Client name and address.
 - Statement of authenticity and official signature and title of person authorizing report release.
- Table of contents.
- Summary of samples received that correlates field sample IDs with the laboratory IDs.
- Case narrative: a detailed case narrative for each analytical fraction that will include discussion of preparation and analytical problems and corrective action taken, holding time violations, and any other discrepancies that could potentially affect data quality
- Laboratory qualifier flags and definitions
- Completed chain-of-custody form and any sample receipt information
- Sample report form for each sample containing: field and laboratory IDs, date received, dates of preparation and analysis (also time of analysis if the holding time is less than or equal to 48 hours), preparation and analytical methods used, result for each analyte (dry-weight basis for soils) reported down to the MDL (or IDL as specified in Section 4 under "Reporting Limits"), percent solids for soils, dilution factor (provide both diluted and undiluted results when available), sample-specific reporting limit adjusted for sample size, dilution/concentration, sample-specific MDL (or IDL as specified in Section 4 under "Reporting Limits") adjusted for sample size, dilution/concentration, unit
- Method blank report form containing laboratory ID, dates of preparation and analysis, preparation and analytical methods used, result for each analyte reported down to the MDL (or IDL as specified in Section 4 under "Reporting Limits"), MDL (or IDL as specified in Section 4 under "Reporting Limits"), reporting limit, unit
- Surrogate recovery summary with percent recoveries and applicable control limits (for organics)
- LCS/LCSD summary with spike added, percent recoveries RPD, and applicable control limits
- MS/MSD summary with native concentrations, spiked sample concentrations, spike added, percent recoveries, RPDs (calculated based on concentration), and applicable control limits

- Post-spike summary with native concentrations, spiked sample concentrations, spike added, percent recoveries, and applicable control limits (if applicable, for inorganics)
- Laboratory duplicate summary with original and duplicate results and RPDs (for inorganics)
- Serial dilution summary (SW-846 6000 series and EPA 200 series only) with original and serial dilution results and percent differences
- Interference check standard summary report (ICP and ICP/MS) with solutions A and AB and recoveries
- Initial and continuing calibration blank summary report (ICP and ICP/MS)
- Method blank summary identifying each method blank and the samples associated with it
- Initial calibration summary report with concentration levels, individual and average response factors/relative response factors, and RSDs; regression equations, if used, and respective coefficients of correlation/determination
- Continuing calibration verification (CCV) summary report with individual response factors/relative response factors (both initial calibration averages and CCV), and percent differences or drifts (with signs, i.e., negative or positive)
- GC/MS tuning summary report with relative abundances and acceptance limits
- Internal standard summary report with areas and retention times
- Confirmation result summary for GC methods showing primary and confirmation results and RPDs between the results
- Analytical sequence log containing information to enable sample association with standards and blanks.
- Sample preparation log clearly identifying field and QC samples, sample sizes, and dilutions

6.2 Electronic Deliverables

Concurrent with the delivery of hardcopy deliverables within the time period specified in the laboratory purchase order from sample receipt, the laboratory will deliver an electronic spreadsheet containing results for all field samples, LCSs, MS/MSDs, surrogates, duplicates, and blanks.

All electronic data files will match the final hardcopy results.

6.3 Data Validation and Verification

The analytical results of the data collection effort will be validated by CH2M HILL. The review will include the information in the hardcopy deliverables, and will involve:

- verification that samples were analyzed for the methods requested,

- review of the data for outliers and anomalies,
- review of the laboratory case narrative for events in the laboratory that may have affected the accuracy or precision of the data,
- review of calibration and quality control indicator data, and
- A “reasonableness” review of the data.

The validation may be extended to include raw data for 10% of the data packages or as deemed necessary by the Project Chemist.

The validation approach will be similar to that used in the EPA Contract Laboratory Program for reviewing inorganic and organic data, and those outlined in the *USEPA Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review*, substituting the calibration and quality control requirements specified in this QAPP and the flagging criteria in Tables 6-1 to 6-2 of the document.

Qualifier flags, if required, will be applied to the electronic sample results. If multiple flags are required for a result, the most severe flag will be applied to the electronic result. The hierarchy of flags from the most severe to the least severe will be as follows: R, UJ, U, NJ, and J. The qualifier flags are defined in Table 6-3.

Personnel involved in data verification and validation will be independent of any data generation effort. The Project Chemist will be responsible for oversight of the process. It will be carried out when the data packages are received from the laboratory, and will be performed on an analytical batch basis.

Any significant data quality problems will be brought to the attention of the Project Chemist.

The final activity of the data validation process is to assess whether or not the data fulfilled the planned objectives for the project. The final results, as adjusted for the findings of any data validation/data evaluation, will be checked against the DQOs and summarized in a data quality evaluation (DQE) memorandum. The DQE will document the validation findings as well as document changes made to the data based upon the validation.

TABLE 6-1
Flagging Conventions for Organic Methods
WWTS Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Holding Time	Holding time exceeded for extraction or analysis by a factor of less than two	J positive results UJ nondetects	affected samples
	Holding time exceeded for extraction or analysis by a factor of two or more	J positive results R nondetects	
Temperature	Temperature exceedance >10C if received within 24 hr)	J positive results UJ nondetects	affected samples
	Temperature exceedance >6C if received > 24 hr)	J positive results UJ nondetects	
	Temperature exceedance >10C if received > 24 hr)	J positive results R nondetects	
Sample preservation (volatiles)	Sample preservation requirements not met If preservation not performed in the field, but performed in the laboratory upon receipt, no flagging is required	J positive results R nondetects	affected samples
Sample Integrity (volatiles)	Professional Judgment on sample condition Example: Bubbles in VOA vial used for analysis	J positive results/professional judgment R nondetects/professional judgment	affected samples
GC/MS Instrument Performance Check	Mass assignment in error and laboratory cannot reprocess data	R all results	all samples in batch
	Ion abundance criteria not met	R all results if critical ions involved, use judgment otherwise	all samples in batch
Initial Calibration GC/MS Methods	RRF <0.050	J positive results R nondetects	analyte in associated samples
	%RSD > 30% and no calibration curve used or linear calibration curve used and R < 0.990	J positive results UJ nondetects	analyte in associated samples
Initial Calibration GC Methods see Note 1.	%RSD > 20% and no calibration curve used or linear calibration curve used and R < 0.990	J positive results UJ nondetects	analyte in associated samples

TABLE 6-1
Flagging Conventions for Organic Methods
WWTS Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Continuing Calibration Verification GC/MS Methods	RRF <0.050	J positive results R nondetects	analyte in associated samples
(Continuing Calibration Verification and Second Source Calibration Verification) GC/MS Methods	% difference or % drift >25% with high recovery	J positive results UJ nondetects	analyte in associated samples
	% difference or % drift >25% with low recovery	J positive results UJ nondetects	analyte in associated samples
Continuing Calibration Verification and Second Source Calibration Verification GC Methods	% difference or % drift >15% with high recovery	J positive results UJ nondetects	analyte in associated samples
	% difference or % drift >15% with low recovery	J positive results UJ nondetects	analyte in associated samples
Laboratory Control Sample (LCS)	%R >UCL	J positive results	analyte in associated samples
	%R <LCL but $\geq 10\%$	J positive results UJ nondetects	analyte in associated samples
	%R <LCL but $\leq 10\%$	J positive results R nondetects	analyte in associated samples
Method Blank (MB) <RL	Convert blank to soil units if necessary, multiply highest blank value by 5 (by 10 for common lab contaminants, acetone, methylene chloride, MIBK, cyclohexane, phthalates)	U positive results < 5 x highest blank concentration (<10 x for common contaminants)	all associated samples in analytical batch
Equipment Blank (EB) <RL	Convert blank to soil units if necessary, multiply highest blank value by 5 (by 10 for common lab contaminants, acetone, methylene chloride, MIBK, cyclohexane, phthalates)	U positive results < 5 x highest blank concentration (<10 x for common contaminants)	all associated samples in sampling batch
Trip Blank (TB) <RL	Convert blank to soil units if necessary, multiply highest blank value by 5 (by 10 for common lab contaminants, acetone, methylene chloride, MIBK, cyclohexane, phthalates)	U positive results < 5 x highest blank concentration (<10 x for common contaminants)	all associated samples in same cooler

TABLE 6-1
Flagging Conventions for Organic Methods
WWTS Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Matrix Spike/Matrix Spike Dup (MS/MSD) does not apply if sample result is greater than four times the spike value	%R >UCL	J positive results	parent sample
	%R <LCL but $\geq 10\%$	J positive results UJ nondetects	parent sample
	%R <LCL but $\leq 10\%$	J positive results R nondetects	parent sample
	RPD >UCL	J positive results	parent sample
Surrogates - SW8260	%R >UCL	J positive results	affected sample
	%R <LCL but $\geq 10\%$	J positive results UJ nondetects	affected sample
	%R <LCL but $\leq 10\%$	J positive results R nondetects	affected sample
Surrogates - SW8270.	2 or more surrogates in same fraction with %R >UCL	J positive results	affected sample
	2 or more surrogates in same fraction with %R <LCL but $\geq 10\%$	J positive results UJ nondetects	affected sample
	2 or more surrogates in same fraction with %R <LCL but $\leq 10\%$	J positive results R nondetects	affected sample
Surrogates - GC Methods	%R >UCL	J positive results	affected sample
	%R <LCL but $\geq 10\%$	J positive results UJ nondetects	affected sample
	%R <LCL but $\leq 10\%$	J positive results R nondetects	affected sample
Internal Standards -50% to +100% recovery	Area > UCL	J positive results UJ nondetects	associated analytes in sample
	Area < LCL	J positive results UJ nondetects	associated analytes in sample

TABLE 6-1
Flagging Conventions for Organic Methods
WWTS Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Laboratory Duplicates $\pm 25\%$ precision	Both sample results >5 times RL and $RPD > UCL$	J positive results	Laboratory duplicate pair
	One or both samples <5 times RL and a difference between results of ± 2 times RL	J positive results UJ non detects	Laboratory duplicate pair
Field Duplicates $\pm 50\%$ precision for soil $\pm 30\%$ precision for aqueous	Both sample results >5 times RL and $RPD > UCL$	J positive results	Field duplicate pair
	One or both samples <5 times RL and a difference between results of ± 2 times RL for water and ± 3.5 times RL for soil	J positive results UJ non detects	Field duplicate pair
Confirmation $\pm 40\%$ RPD	$RPD > 40\%$ if lab reports higher of two results and co elution is suspected, reviewer can replace higher result with lower	NJ positive results	affected analytes in sample
	Confirmation analysis not performed	NJ positive results	affected analytes in sample

Initial calibration should be based on average response factors or a linear regression equation. Laboratories will need Project Chemist approval to use a nonlinear calibration curve.

TABLE 6-2
Flagging Conventions for Inorganic Methods
WWTs Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Holding Time	Holding time exceeded for digestion or analysis by a factor of less than two	J positive results UJ nondetects	affected samples
	Holding time exceeded for digestion or analysis by a factor of two or more	J positive results R nondetects	
Temperature (does not apply to metals)	Temperature exceedance >10C if received within 24 hr)	J positive results UJ nondetects	affected samples
	Temperature exceedance >6C if received > 24 hr)	J positive results UJ nondetects	
	Temperature exceedance >10C if received > 24 hr)	J positive results R nondetects	
Sample preservation	Sample preservation requirements not met if preservation not performed in the field, but performed in the laboratory upon receipt, no flagging is required	J positive results for all analytes	affected samples
		R nondetects for all analytes	
Initial Calibration (For multi-point only)	Correlation coefficient ≤ 0.995	J positive results	analyte in associated samples
		UJ nondetects	
Initial Calibration Verification (ICV)	%R >UCL	J positive results UJ nondetects	analyte in associated samples
	%R <LCL	J positive results UJ nondetects	analyte in associated samples
Continuing Calibration Verification (CCV)	%R >UCL	J positive results UJ nondetects	analyte in associated samples
	%R <LCL	J positive results UJ nondetects	analyte in associated samples

TABLE 6-2
Flagging Conventions for Inorganic Methods
WWTS Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Low-Level Calibration Check Standard	%R >UCL	J positive results <2xRL	analyte in associated samples
	%R <LCL	J positive results $\geq 2 \times \text{RL}$ R positive results <2xRL and nondetects	analyte in associated samples
Interference Check Sample (Metals by ICP only)	If Interference present and %R >UCL	J positive results	analyte in associated samples
	If interference is present and %R <LCL	J positive results UJ nondetects	analyte in associated samples
Laboratory Control Sample (LCS)	%R >UCL	J positive results	analyte in associated samples
	%R <LCL but $\geq 30\%$	J positive results UJ nondetects	analyte in associated samples
	%R <LCL but $\leq 30\%$	J positive results R nondetects	analyte in associated samples
Calibration Blank (ICB or CCB)	Convert positive blank concentration to soil units if necessary; multiply highest blank concentration by 5	U positive results < 5 x highest blank concentration	all associated samples in batch analyte in associated samples
	If the blank concentration is negative, and its absolute value is greater than the MDL, and >25% of sample result	J positive results UJ nondetects	analyte in associated samples
Method Blank	Convert positive blank concentration to soil units if necessary; multiply highest blank concentration by 5	U positive results < 5 x highest blank concentration	associated samples in analytical batch
	If the blank concentration is negative, and its absolute value is greater than the MDL, and >25% of sample result	J positive results UJ nondetects	associated samples in analytical batch

TABLE 6-2
Flagging Conventions for Inorganic Methods
WWTS Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Equipment Blank	Convert blank concentration to soil units if necessary; multiply highest blank concentration by 5	U positive results < 5 x highest blank concentration	associated samples in sampling batch
Field Blank (Mercury by EPA 1631)	Convert blank concentration to soil units if necessary; multiply highest blank concentration by 5	U positive results < 5 x highest blank concentration	associated samples in sampling batch
Bottle Blank (Mercury by EPA 1631)	Convert blank concentration to soil units if necessary; multiply highest blank concentration by 5	U positive results < 5 x highest blank concentration	samples in bottles from the contaminated lot
Matrix Spike/Matrix Spike Dup (MS/MSD)	%R >UCL	J positive results	parent sample
	%R <LCL but $\geq 30\%$	J positive results UJ nondetects	parent sample
	%R <LCL but $\leq 30\%$	J positive results R nondetects	parent sample
	RPD >UCL	J positive results	parent sample
Dilution Test	If concentration is >50 times the MDL and % difference is >UCL	J positive results UJ nondetects	All samples from same site as parent sample
Post-Digestion Spike	%R >UCL	J positive results	all samples in digestion batch
	%R <LCL but $\geq 30\%$	J positive results UJ nondetects	all samples in digestion batch
	%R <LCL but $\leq 30\%$	J positive results R nondetects	all samples in digestion batch

TABLE 6-2
 Flagging Conventions for Inorganic Methods
WWTs Management, Quality Assurance Project Plan

Quality Control Check	Evaluation	Flag	Samples Affected
Method of Standard Additions	$R < 0.995$	J positive results	analyte in sample
Laboratory Duplicates	Both sample results > 5 times RL and $RPD > UCL$	J positive results	Laboratory duplicate pair
	One or both samples < 5 times RL and a difference between results of ± 2 times RL for water and ± 3.5 times RL for soil	J positive results UJ non detects	Laboratory duplicate pair
Field Duplicates $\pm 50\%$ precision for solids $\pm 30\%$ precision for aqueous	Both sample results > 5 times RL and $RPD > UCL$	J positive results	Field duplicate pair
	One or both samples < 5 times RL and a difference between results of ± 2 times RL for water and ± 3.5 times RL for soil	J positive results UJ non detects	Field duplicate pair

TABLE 6-3
Qualifier Flag Definitions
WWTS Management, Quality Assurance Project Plan

Flag	Definition
J	Analyte was present but reported value may not be accurate or precise.
R	This result has been rejected.
U	This analyte was analyzed for but not detected at the specified detection limit.
UJ	The analyte was not detected above the detection limit objective. However, the reported detection limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
NJ	The analysis indicates the presence of an analyte that has been tentatively identified, and the associated numerical value represents its approximate concentration.

SECTION 7

Performance Evaluations

To assess sample and data collection procedures, performance evaluations will be conducted and will consist of technical systems audits and performance audits.

7.1 Performance Evaluations

Laboratories are required to participate in a performance evaluation program. Any method or analyte failure in a performance evaluation program that affects the certification status of the laboratory with the National Environmental Laboratory Accreditation Program must be immediately communicated to the program chemist.

7.2 External Audits

Announced and unannounced audits of the field operations and of the laboratories may be conducted during any stage of the project.

7.3 Internal Audits

Annual audits of the laboratory will be conducted by the laboratory's quality assurance officer. The audits will verify, at a minimum, that written SOPs are being followed; standards are traceable to certified sources; documentation is complete; data review is being performed effectively and is properly documented; and data reporting, including electronic and manual data transfer, is accurate and complete. All audit findings will be documented in quality assurance reports to laboratory management. Necessary corrective actions will be taken within a reasonable time. The quality assurance officer will verify that such actions are effective and complete and will document their implementation in an audit closeout report to laboratory management.

SECTION 8

Preventive Maintenance

The object of a preventive maintenance program is to promote the timely and effective completion of a measurement effort. The maintenance program will be designed to minimize the downtime of crucial sampling and analytical equipment from expected or unexpected component failure. In implementing this program, efforts will be focused on the following issues:

- Establishing maintenance responsibilities
- Establishing maintenance schedules for major or critical instrumentation and apparatus
- Establishing an adequate inventory of critical spare parts and equipment

8.1 Maintenance Responsibilities

Laboratory instrument maintenance is the responsibility of the participating laboratory. Generally, the laboratory manager or supervisor is responsible for the instruments in his or her work area. This responsible person will establish maintenance procedures and schedules for each instrument.

Maintenance responsibilities for field equipment are assigned to the field team leader for specific sampling tasks. However, the field team using the equipment is responsible for checking the status of the equipment before using it and reporting any problems encountered. The field team is also responsible for ensuring that critical spare parts are included as part of the field equipment checklist. Nonoperational field equipment will be removed from service and replacement equipment obtained. All field instruments will be properly protected against inclement weather during the field investigation.

8.2 Maintenance Schedules

The effectiveness of any maintenance program depends, to a large extent, on adherence to specific maintenance schedules for each piece of equipment. Other maintenance activities are conducted as needed. Manufacturers' recommendations should provide the primary basis for establishing maintenance schedules. Manufacturers' service contracts may be used for implementing scheduled maintenance.

An instrument logbook will be assigned for each analytical instrument. All maintenance activities will be documented in this logbook. For each instrument, the logbook should contain the following information:

- | | |
|--|--|
| • Date of service | • Replacement parts installed (if appropriate) |
| • Person performing service | • Date of next scheduled service |
| • Type of service performed and reason for service | • Any other useful information |

SECTION 9

Data Assessment

All data generated for this project will be evaluated according to the quality assurance acceptance criteria specified in Tables 4-14 through 4-18. Limitations on data usability will be assigned, if appropriate, as a result of the validation process described in Section 6.

Corrective Action

Corrective action may be required as a result of deviations from field or analytical procedures. Deficiencies identified in audits and data quality evaluations may also call for corrective action. All project personnel have the responsibility, as part of the normal work duties, to identify, report, and solicit approval of corrective actions for conditions adverse to data quality.

Tables 4-14 through 4-18 specify the corrective actions to be taken when deviations from calibration and quality control acceptance criteria occur. Field and laboratory staff may encounter conditions requiring immediate corrective action that are not covered in the SAP or QAPP. Those personnel will document conditions and the results of corrective actions in a field logbook or laboratory nonconformance report and communicate their actions as soon as feasible to the field team leader, laboratory supervisor, and if necessary, the project chemist, for immediate input. A mechanism must be established to allow for supervisory review or input for all deviations or deficiencies. A corrective action reporting system that requires immediate documentation of deviations or deficiencies and for supervisory review of the actions taken to correct them will be established. The corrective action report should include at least the following:

- Type of deviation or deficiency
- Date of occurrence
- Impact of deviation or deficiency, such as samples affected
- Corrective action taken
- Documentation that the process has been returned to control

The only time that a corrective action report may be waived is when a deviation or deficiency is immediately corrected and its impact is precluded; for example, an unacceptable initial calibration that is correctly calibrated before samples are analyzed.

Each corrective action report must be reviewed and approved by a person of authority, such as the field team leader or laboratory supervisor. The ultimate responsibility for the laboratory corrective action process is the quality control manager, who must ensure that proper documentation, approval, and closeout of all out-of-control or nonconformance events are performed. A nonconformance report will summarize each nonconformance condition. Corrective action reports that potentially affect data quality must be brought to the attention of the project chemist. Report disposition will be the responsibility of the project chemist. The project manager may be notified about a particular report at the project chemist's discretion. Copies of corrective action reports must be maintained in the laboratory or field project files.

SECTION 11

Quality Assurance Reports

The project chemist will submit a quality assurance report to the project manager at least quarterly or as requested by the project manager. The report will summarize the data validation and data assessment results. The results will be presented in a manner that enables decision-making. For example, temporal data may be more effectively presented if supplemented by a time plot. Any significant quality problems and recommended solutions will be included in the report. Limitations on data usability that were identified during data validation will be highlighted. The results of data assessment will be reconciled with the project objectives.

Data Management

A site-specific Data Management Plan will be developed before starting field work. The plan will outline the policies, procedures, and protocols to be followed to handle the environmental data generated. These protocols give data users simple procedures to rapidly access stored data; ensure consistency among all field activities; provide methods of data entry with known accuracy and efficiency; manage sample data using unique sample identification numbers; establish a sample inventory of new data collected and provide methods of sample inventory reconciliation; store and provide sample-specific attributes, including location identifiers, sample type and media, and sample date; and provide reporting and delivery formats to support data analysis and reduction.

12.1 Archiving

Hardcopy and electronic versions will be archived in project files and on electronic archive tapes for a period of five years upon completion of the project or as is stated in the Administrative Order on Consent (AOC).

12.2 Data Flow and Transfer

The data flow from the laboratory and field to the project staff and data users will be sufficiently documented to ensure that data are properly tracked, reviewed, and validated before use.

12.3 Record Keeping

In addition to the data management procedures outlined in Section 6 for analytical data, the laboratory will ensure that hardcopy records are maintained in a manner sufficient to re-create each analytical event. The laboratory will maintain the following minimum records:

- Raw data, including instrument printouts, bench worksheets, and chromatograms with compound identification and quantitation reports
- Laboratory-specific written SOPs for each analytical method and QA/QC function in place at the time of analysis of project samples

SECTION 13

References

United States Environmental Protection Agency (USEPA). 2004. *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*.

United States Environmental Protection Agency (USEPA). 2001. *Contract Laboratory Program National Functional Guidelines for Low Concentration Organic Data Review*.

United States Environmental Protection Agency (USEPA). 1999. *Contract Laboratory Program National Functional Guidelines for Organic Data Review*.

United States Environmental Protection Agency (USEPA). 1996. *Test Methods for Evaluating Solid Waste, Physical and Chemical Methods, SW-846, 3rd Edition, Update III, Section 1*.

United States Environmental Protection Agency (USEPA). 1995. *Good Laboratory Practices in Principles and Guidance to Regulations for Ensuring Data Integrity in Automated Laboratory Operations*.

QUALITY ASSURANCE PROJECT PLAN

Acme - Riegelwood - LCP Holtrachem
NC SH 87 (on State Road 1817)
Riegelwood, North Carolina

PHONE

Project Number: 365628

Project Manager (PM): Denis Ewing/ ATL.....678-530-4111

Quality Assurance Manager: Joe Hambrick/HOU.....381-308-0046

Preparation Date: February 11, 2008

APPROVALS

Project Manager:



4/30/08

(DATE)

Quality Assurance Manager:



05/01/08

(DATE)

APPENDIX G

Quality Control Plan

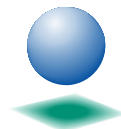
Quality Control Plan

Wastewater Treatment Solids Management Project

**International Paper Cell No. 2
Riegelwood, NC**

Prepared for
Honeywell International Inc.

Submitted by



CH2MHILL

May 2008

Contents

1.0	Introduction.....	1-1
1.1	Scope of Work	1-1
1.2	Site Description.....	1-1
1.3	Project Objectives and Scope	1-2
2.0	Organization and Responsibilities	2-1
2.1	Responsibility and Authority	2-1
2.1.1	Project Director – David Urann.....	2-1
2.1.2	Project Manager – Denis Ewing	2-2
2.1.3	Construction Manager – Robert Custance.....	2-3
2.1.4	Project QC Manager – Joe Hambrick.....	2-3
2.1.5	Subcontractors	2-4
2.2	Resolution of Conflicts.....	2-5
3.0	Inspection Activities	3-1
3.1	Inspections.....	3-1
3.2	Punch List Inspection.....	3-5
3.3	Pre-Final Inspection	3-5
3.4	Final Acceptance Inspection	3-6
4.0	Monitoring Tests and Observations	4-1
5.0	Sampling Requirements	5-1
6.0	Construction Quality Control Submittals	6-1
6.1	Submittal Review and Control	6-1
6.2	Honeywell Approval of Submittals.....	6-2
7.0	Change Control.....	7-1
7.1	Construction Changes.....	7-1
8.0	Noncompliance and Corrective Actions	8-1
8.1	Corrective Measure Plan	8-1
9.0	Quality Control Documentation.....	9-1
9.1	Daily Report	9-1
9.2	Field Documentation Operating Procedures.....	9-4
9.3	Site Preparation.....	9-4
9.4	Field Logbook	9-4

Tables

3-1	Project Inspection Activities by Task.....	3-2
9-1	Reporting and Field Documentation Required.....	9-2

Appendix A Project QC Forms

Submittal Register

Testing Plan and Log

Request for Information Form

Daily Report Form

Photo Log Template

Waste Tracking Log Template

Rework Items List

Acronyms and Abbreviations

AHA	Activity Hazard Analysis
ASTM	American Society for Testing and Materials
BMP	Best Management Practice
cy	cubic yards
QCP	Quality Control Plan
MSDS	Material Safety Data Sheet
NCDENR	North Carolina Department of Environment and Natural Resources
NIOSH	National Institute for Occupational Safety and Health
PPE	personal protective equipment
QA/QC	quality assurance/quality control
QCP	Quality Control Plan
RFI	Request for Information
SOW	Statement of Work
TO	Task Order
US EPA	U.S. Environmental Protection Agency
WWTS	Wastewater Treatment Solids

1.0 Introduction

CH2M HILL Constructors, Inc. (CH2M HILL) has prepared this site-specific Quality Control Plan (QCP) for excavation, segregation, transportation, and storage of wastewater treatment solids (WWTS) located in Cell No. 2 of International Paper's Riegelwood Mill North Bay Treatment Pond. The Riegelwood Mill is located in Riegelwood, Columbus County, North Carolina. This QCP has been prepared in accordance with provisions of the program Quality Management Plan (CH2M HILL, draft January 2007) and describes the quality systems and processes that will be implemented on the project. When this document references CH2M HILL, it should be construed to mean CH2M HILL and its subcontractors, as their respective trade may apply to the subject being discussed.

1.1 Scope of Work

The purpose of this QCP is to outline the quality control requirements applicable to completing the removal of WWTS within International Paper's (IP's) Cell No. 2. The removal action will include the following actions:

- Site mobilization and facilities installation
- Dewatering of Cell No. 2
- Engineered stockpile construction
- Mobilization and set-up of water treatment systems
- Removal of WWTS containing <50 milligrams per kilogram (mg/kg) Aroclor 1268 (approximately 93,500 cubic yards) and placement in IP's Cell No. 1
- Removal of WWTS containing ≥ 50 mg/kg Aroclor 1268 (approximately 6,500 cubic yards) and placement in an engineered stockpile
- Removal of the former discharge pipe and associated soil above 11 mg/kg Aroclor 1268
- Confirmation sampling
- Site restoration
- Decontamination and demobilization of personnel and equipment

1.2 Site Description

Landfill Cell No. 2 area is located in the northern portion of IP's Riegelwood Mill, approximately 150 feet from the Cape Fear River. The sludge and soils within Cell No. 2 are surrounded by an earthen berm that rises approximately 5 feet above the top of the cell surface. There is approximately 12 feet of vertical relief across the Landfill Cell No. 2 area. Topography across the cell generally slopes to the south and east, towards local low-lying

areas. Stormwater drains to the southeast corner of the cell and is periodically pumped to IP's existing wastewater treatment system (ARCADIS 2006a).

Cell No. 2 is located between Cell No. 1 and the Cape Fear River. The area drains to the southeast, where collected water is pumped to IP's wastewater treatment system. Cell No. 1 is a double-lined industrial landfill permitted for the disposal of wastewater sludges generated at the Mill. Cell No. 2 was part of the overall wastewater lagoon system for the Mill until it was isolated by the earthen berms. Process wastewater from the former Holtrachem facility was discharged into the lagoon system at the northwest corner of what is now Cell No. 2.

1.3 Project Objectives and Scope

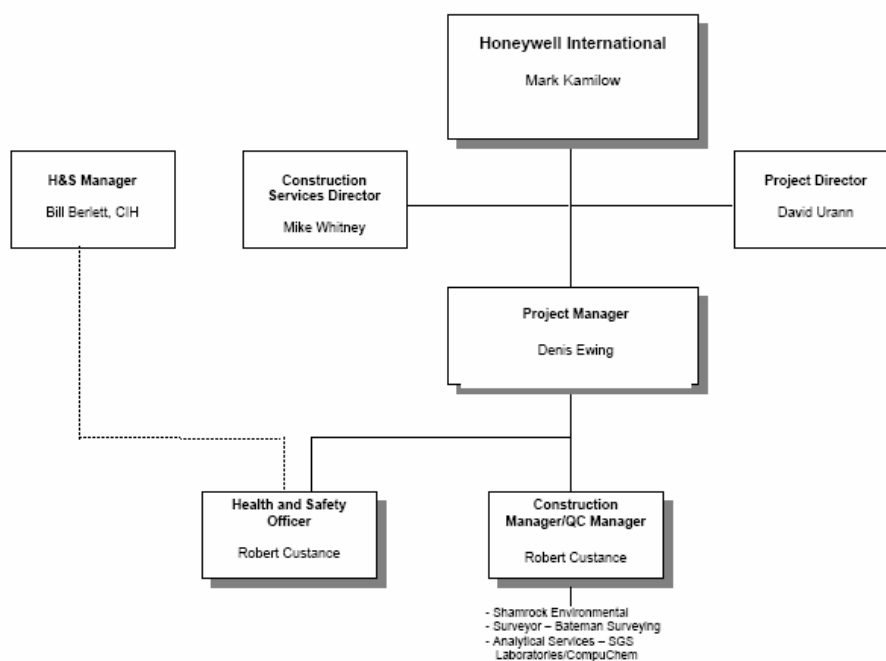
The Honeywell Construction Manager will approve all work plans and specified submittals prior to initiation of work. The project objectives are outlined in the Final Wastewater Treatment Solids Management Plan (CH2M HILL, 2008).

Specifically the QCP addresses the performance of the following activities:

- Construct the engineered stockpile including 40-mil HPDE liner installation.
- Dewater WWTS within Cell No. 2 using trenches and sump pumps in order to make the WWTS accessible and to assist in transportation and stockpiling.
- Remove approximately 93,500 in-place cubic yards (cy) of WWTS containing Aroclor 1268 concentrations <50 mg/kg and place in Cell No.1.
- Stabilize WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg using fly ash to make the WWTS stackable and transportable.
- Remove approximately 6,500 in-place cy of WWTS containing concentrations ≥ 50 mg/kg and place in the engineered stockpile.
- Remove the former discharge pipe and associated soils above 11 mg/kg Aroclor 1268.
- Perform site restoration and demobilization of all personnel, equipment, materials, and supplies utilized to complete the work.

2.0 Organization and Responsibilities

The overall responsibility for implementation and enforcement of the QCP is assigned to the Project Manager and Project Quality Control (QC) Manager. Designated qualified individuals will assume execution responsibility of this plan. These individuals include the Construction Manager, Project Engineer, or other project personnel. The Program QC Manager has quality assurance/quality control (QA/QC) responsibility for verification of the effectiveness of the program and project QC.



CH2MHILL

Project Organization Chart
LCP-Holtrachem Site

2.1 Responsibility and Authority

The responsibilities of the key members in the project organization are detailed below.

2.1.1 Project Director – David Urann

The Project Director directs the overall design and project management activities for all Honeywell projects. He provides principal support to the Project Manager on schedule, cost

control, organization development; and oversees the implementation of policy, strategy, and enforcement of quality, safety and project performance.

2.1.2 Project Manager – Denis Ewing

The primary responsibility of the Project Manager is the overall direction of the project and accountability for work activities undertaken as part of this project. As such, the Project Manager will provide the managerial administrative skills to ensure that resource allocations, planning, execution, and reporting meet contract and Task Order (TO) requirements. The global quality-related responsibilities of the Project Manager may include, but are not limited to, the following:

- Organizes project staff and assigns responsibilities
- Understands contract and scope of work for the specific project
- Ensures deliverables are completed and submitted, as required in the SOW
- Communicates to the project staff regarding client requirements and QA/QC practices
- Identifies, and provides documentation, and notifies the client and project team of changes in the scope of work, project documentation, and activities
- Supervises preparation and approval of project-specific procedures, work plans, and QA project plans
- Approves project design bases, design parameters, drawings, and reports
- Approves project construction methodologies
- Disseminates project-related information from the client such as design bases, input parameters, and drawings
- Serves as liaison for communications with the client and subcontractors
- Serves as liaison between the project staff and other internal groups
- Decides whether drawings require independent review
- Investigates nonconformance and implements corrective actions
- Evaluates the effect of nonconformance on the project and the appropriateness for reporting such items to the client, and providing appropriate documentation for reporting
- Determines that changes, revisions, and rework are subject to the same QC requirements as the original work
- Serves as final reviewer prior to release of project information
- Approves and signs outgoing correspondence

The Project Manager may assign a portion of these responsibilities to the Construction Manager, who will remain onsite throughout the project field activities.

2.1.3 Construction Manager – Robert Custance

The Construction Manager is responsible to the Project Manager for efficiently applying the resources of the project team to execute the construction work activities. In addition, the Construction Manager is responsible for the technical, personnel, construction methodology, quality, safety, and local client interface details of the project and the project team while mobilized to the site. The Construction Manager will assist the Project Manager to ensure that sufficient resource allocations to maintain project schedule and budget are available and provide daily feedback to the Project Manager on project progress, issues requiring resolution, and other project specific issues, as required. The quality-related responsibilities of the Construction Manager include, but are not limited to, the following:

- Notifies the Project Manager if the project cannot be completed with regard to quality, schedule, or cost
- Provides oversight and control of subcontractor services
- Serves as liaison for communications with project staff and subcontractors, as well as with the onsite Honeywell Construction Manager and the United States Environmental Protection Agency (US EPA) or North Carolina Department of Environment and Natural Resources (NCDENR) representatives
- Continuously monitors work progress, quality, safety, and adherence to authorized work scopes, budgets, and schedules
- Aids in the preparation of status reports and construction submittals
- Initiates corrective actions for non-conformance identified onsite
- Leads weekly status meetings
- Reviews the project work plans regularly
- Interfaces daily with the subcontractors
- Prepares and submits Requests for Information (RFIs) and routes them to the Project Manager and Project Engineer for review and approval

2.1.4 Project QC Manager – Joe Hambrick

The Project QC Manager is responsible for the execution of this project QCP and will communicate the onsite QC program policies, objectives and procedures to the project personnel and subcontractors during project meetings and informal discussions. Onsite technical personnel, who may include QC inspectors, engineers, chemists, hydrogeologists, and scientists, will assist the Project QC Manager in monitoring, controlling, and documenting the quality of the onsite construction and survey activities. Documentation related to the control of the quality of the project including analytical test results, inspections, material test results, and audits will be reviewed or prepared by the Project QC Manager. The Project QC Manager responsibilities include, but are not limited to, the following:

- QC inspections and testing of materials and workmanship

- Control testing
- Document control
- Review of Submittals
- Administering RFIs
- Completion inspection
- Records
- Audits and surveillance

The Project QC Manager will also coordinate with and assist the Honeywell Construction Manager in the performance of quality assurance audits and inspections.

The Project QC Manager has the authority to stop work on all or any project work activity due to nonconformance with the QCP. Onsite personnel will be encouraged to discuss concerns with the Project QC Manager and supporting technical personnel. In the event that the Project QC Manager is informed of and/or detects an incident of project nonconformance, the Project QC Manager will perform an initial investigation, evaluate the course of corrective action required, document the incident, and report the incident to the Project Manager and Construction Quality Manager. If the Project QC Manager is not satisfied with the resolution of the nonconformance, the Project QC Manager will contact the Construction Quality Manager.

2.1.5 Subcontractors

CH2M HILL assumes overall responsibility for conformance to the quality requirements for the subcontracted items and services. However, it is the role of each subcontractor to plan, manage, and accomplish the construction activities in accordance with the appropriate documentation.

Subcontractors are responsible directly to the Construction Manager for completion of the portion of project activities assigned, and to the Project QC Manager for QCP activities. Subcontractors will verify that construction and materials used to perform the activities associated with the remediation project, comply with the requirements of the Wastewater Treatment Solids Management Work Plan (CH2M HILL, 2008) and specifications. Subcontractors include those organizations supplying quality related items or services to the project.

Subcontractors Qualifications

Engineered Stockpile Construction, WWTS removal, segregation, and transportation. – Shamrock Environmental

Shamrock Environmental will construct the engineered stockpile, and will perform excavation, segregation, and transportation of WWTS within Cell No. 2. Materials, equipment, and work activities will be inspected and monitored by CH2M HILL staff.

WWTS containing Aroclor 1268 concentrations less than 50 mg/kg will be excavated and transported to Cell No.1. WWTS containing Aroclor 1268 concentrations ≥ 50 mg/kg will be stabilized in place using fly ash, excavated, and transported to the engineered stockpile.

Shamrock will also be responsible for performing the following general contractor services:

- Dewatering, excavation, stabilization and load-out of WWTS.
- Remove the former discharge pipe and associated soil above the cleanup level.
- Construction of the engineered stockpile
- Site restoration activities

Surveyor – Bateman Surveying

Bateman Surveying, a North Carolina licensed surveyor, will perform topographic surveys of Cell No. 2 before and after WWTS removal. During the pre-removal survey, the surveyor will reconstruct the sampling grid developed by ARCADIS during characterization activities.

Analytical Laboratory – SGS Laboratories/CompuChem

SGS Laboratories and CompuChem Labs, North Carolina certified laboratories, will be contracted to perform laboratory analysis.

2.2 Resolution of Conflicts

If the QC team detects a nonconforming item, the issue will be investigated by the Project QC Manager. If the Project QC Manager determines that additional corrective action is warranted, the Project QC Manager will document and review the issue with the Construction Manager and Project Manager. The Project QC Manager has the authority to stop work on any nonconforming activity. If satisfactory resolution cannot be achieved between the Project QC Manager and the Project Manager, it will be elevated to the Construction Quality Manager, and if necessary, to senior management (Program Manager, etc.). The Honeywell Construction Manager will be promptly notified of any nonconformance having significant impact on the project cost or schedule.

3.0 Inspection Activities

The Project QC Manager is responsible for performing inspection activities and documenting compliance with project requirements.

3.1 Inspections

The Project QC Manager's responsibilities include inspection of all equipment and materials prior to being accepted and installed at the site and daily review of all construction activities required to complete the scope of work as identified in the final approved project plans. The Project QC Manager will be assisted by the Construction Manager in performing inspections. Inspection activities for the project that will be performed by the Project QC Manager are identified in Table 3-1.

TABLE 3-1
Project Inspection Activities by Task

Task	Inspection
Mobilization/Site Setup	<ul style="list-style-type: none"> -Preconstruction meeting held with Honeywell and the subcontractors -Pre-construction and construction QC submittals to ensure they are approved -Qualifications of personnel to ensure they meet the specification and work plan requirements (certifications, licenses, etc.) -Materials and equipment received in working order and in compliance with work plans and specifications -Maintain log of materials and equipment received -Materials and equipment are stored in accordance with work plans and specifications -Permits -Record particulate monitor calibration results daily in field logbook -Construction Schedule rebaselined and maintained current -Traffic routes for compliance with work plan -Site security measures for compliance with work plan -Site work coordinated with any ongoing operations -Layout drawings for completeness and accuracy -Review staging areas for storage of wastes, recyclable materials, heavy equipment, and storage containers -Verify that equipment condition is acceptable and that features (such as backup alarms) function properly -Verify that personnel are properly trained and certified to perform the work -Ensure personnel have proper personal protective equipment (PPE) to perform the work -Ensure work areas and signage are properly established -Ensure that proper Material Safety Data Sheets (MSDSs) are available onsite -Ensure break and rest areas are established and set up -Ensure utilities are properly protected -Utility locates performed -Emergency points of contact, phone numbers, and hospital/emergency routes confirmed -Health and Safety measures taken (spill kits, first aid kits, blood borne pathogen kits, fire extinguishers, etc.) -Ensure stormwater erosion controls and other Best Management Practices (BMPs) are in place and functioning

TABLE 3-1
Project Inspection Activities by Task

Task	Inspection
Surveying	<ul style="list-style-type: none"> -Qualifications/License -Personnel Training Documentation -Key Measurements -Establish Temporary Bench Marks -Verification of Existing Monuments -Protection: Monuments and Control Points -Instrument Calibration and Accuracy -Horizontal and Vertical Control -Surveying Tolerances (horiz, vert, angles) -Reference to Applicable Plane Coordinates and Vertical Datum -Surveyor notes legibility, accuracy & completeness -Electronic and Hard Copy Data Deliverables -Stake Alignment & Spacing Intervals -Stake Flagging / Marking -As-builts, drawings, maps
Material Receiving	<ul style="list-style-type: none"> -Visual inspection of material upon arrival to the site for damages -Maintain log of deliveries (materials and equipment) and visitors -Check type and quantities of materials received against purchase order, shipping label, and confirmation lists. Note any incorrect quantities, incorrect type and models, and missing items -Visual inspection on the quality of the material if the material has manufacturer-specified grade or quality rating -Inspect and verify that the materials received were built or manufactured in accordance with manufacturer specifications and/or data -Inspect the temporary storage area provided by the construction subcontractor for material storage to ensure the materials are stored in a safe, secure, and manufacturer-specified environment prior to usage in construction

TABLE 3-1
Project Inspection Activities by Task

Task	Inspection
Dewater Cell No. 2 and Remove WWTS	<ul style="list-style-type: none"> --Review Activity Hazard Analyses (AHAs) and safety plan, conduct work area assessment during initial work activities, repeat if conditions change -Equipment inspected for integrity, appropriate for intended use, safety guards in place, no evidence of damage which might affect the performance or safe operation, documents results of inspections -Appropriate supplies on hand -Equipment set up, function tested, zero and calibration of measuring equipment in accordance with manufacturers specification -Verify benchmarks and control points -Material (debris, sediment, water, etc.) tracking logs maintained -Daily equipment inspection performed, results documented -Performed to Proper Lines, Grades, contours, elevation, and dimensions -Ensure 50-ft buffer area around WWTS containing Aroclor 1268 >50 mg/kg is not breached prior to confirmation sampling -Monitor water pre-treatment discharge during removal of WWTS containing >50 mg/kg Aroclor 1268; ensure concentration does not exceed 3 µg/L -Monitor and record approximate volumes placed in Cell No.1 and the engineered stockpile, respectively; report daily -Inspect the engineered stockpile weekly, document results -Ensure chemical analytical data received and communicated -Inspect equipment for safeguards, function test conveying equipment, inspect conveyor belts for tension, wear, and alignment; ensure secondary containment adequate
Engineered Stockpile Construction	<ul style="list-style-type: none"> -Inspect areas prior to liner deployment to ensure free from sharp objects or other debris -Reference Information -Management of Stockpiles -Proper Materials
Site Restoration	<ul style="list-style-type: none"> -Restoration Methods and Limits -Surface preparation -Damage (e.g. washout) Repair -Defective Material Rejection -Unused material properly stored
Waste Transport	<ul style="list-style-type: none"> -Qualifications/Experience -Proper Equipment -Inspect waste transport vehicles prior to acceptance for general cleanliness -Complete documentation -Appropriate registration and licensing -Manifest and measurement method -Waste tracking log completed
Waste Disposal	<ul style="list-style-type: none"> -Qualifications/Experience -Proper Equipment

TABLE 3-1
Project Inspection Activities by Task

Task	Inspection
	<ul style="list-style-type: none"> -Waste characterized through generator knowledge or sampling -Collect and process decontamination rinsate -Complete documentation -Appropriate registration and licensing -Manifest and measurement method -Waste tracking log completed
Demobilization/ Project Closeout	<ul style="list-style-type: none"> -Work areas to ensure all temporary facilities, equipment and materials are safely removed from the site -Work areas to ensure project housekeeping and cleaning -Completion inspection when work is substantially complete -Punch lists on outstanding items -Project housekeeping and final project cleaning -Final Inspections-all areas -Orderly Site Demobilization -Collation of Site Records & Documents -Records and Documentation Transfer to home office -P.O. Closeouts -Final Reports & Deliverables

As additional project-specific tasks are identified, this QCP will be amended to include inspections for those tasks.

3.2 Punch List Inspection

Punch List Inspections may occur near the completion of all work or any portion thereof established by a completion time agreed upon by CH2M HILL and Honeywell Construction Manager. The Project QC Manager will conduct an inspection of the work and develop a "punch list" of items that do not conform to the approved drawings and specifications. He will include in the punch list any remaining items on the "Rework Items List" which were not corrected prior to the Punch List Inspection. The punch list will include the estimated date by which the deficiencies will be corrected. A copy of the punch list will be provided to Honeywell. The Project QC Manager or staff will make follow-on inspections to ascertain that all deficiencies have been corrected. Once this is accomplished CH2M HILL will notify the Honeywell site representative that Cell No. 2 and the engineered stockpile are ready for the "Pre-Final Inspection."

3.3 Pre-Final Inspection

Honeywell will perform a pre-final inspection to verify that Cell No. 2, the engineered stockpile, or work area is complete and ready to be turned over. Honeywell should be sure to include Stakeholders of the property to conduct the Pre-Final Inspection. A "Pre-Final

Punch List" may be developed as a result of this inspection; if needed, Honeywell and CH2M HILL will review the Pre-Final Inspection Punch List for accuracy and completion. Each deficiency noted in the punch list will reference the applicable reference (specification paragraph, drawing number, etc.) that the deficiency stems from. The Project QC Manager will ensure that all items on this list are corrected prior to notifying Honeywell that a final inspection with the stakeholders can be scheduled. Any items noted on the "Pre-Final" inspection will be corrected in a timely manner and will be accomplished within the time slated for completion of the entire work, or any particular increment thereof if the project is divided into increments by separate completion dates.

3.4 Final Acceptance Inspection

The Project QC Manager, Project Manager, Construction Manager, other project management personnel, and Honeywell Construction Managers will be in attendance at this inspection. Other Honeywell personnel and Stakeholders may be in attendance. Honeywell, based upon results of the "Pre-Final" inspection, will formally schedule the final acceptance inspection. Scheduling should be coordinated with Honeywell at least 7 days prior to the final inspection. A Final Acceptance Inspection will be considered closed when: 1) confirmation that the WWTS removal has been completed, 2) the survey drawings and data verify the final volume of material removed, and 3) the work has been accepted by Honeywell and that acceptance has been documented and signed by all parties.

4.0 Monitoring Tests and Observations

The Project QC Manager is responsible for ensuring the subcontractor performs all testing required, as identified in the final approved work plans. Completion of field tests will be documented in the Testing Plan and Log (see Appendix A). The Project QC Manager will obtain all test results from the subcontractor, update the Testing Plan and Log at a minimum of once a week, and maintain the records onsite in the project files. A copy of the Testing Plan and Log will be submitted to the Construction Quality Manager at the end of each month.

As project-specific tasks are identified, the Testing Plan and Log will be amended to include monitoring tests and observations for those tasks. Specific monitoring requirements and observations are listed below.

Task	Monitoring Test / Observation	Frequency
Rainfall	Measure and record	Continuous
Illumination	Illumination standard – 0.2 foot-candle for residential area; 1 foot-candle for industrial area	3 per equally timed interval, non-daylight hours
Monitor Dust	Monitor during construction activity/less than 150 micrograms per cubic meter or less than 100 micrograms per cubic meter over concurrent upwind reading; whichever is greater	Continuous
Pre-treatment Effluent Discharge	Collect samples of pre-treatment effluent for analysis of Aroclor 1268 during removal of WWTS	Per the WWTS Work Plan
Post-excavation Confirmation Sampling	Collect samples for analysis of Aroclor 1268 along buffer sidewalls and at base of excavation after removal of WWTS	As required during excavation
Survey	Survey/verify WWTS volume removed, generate as-built map	Baseline and final
Treatability – stabilization	Optimize stabilization reagent rate	As needed
Waste Characterization	Sample stabilized WWTS for disposal options/SW-846 Methods	Collect one sample per 1,000 cubic yards
Removal interval thickness	Average interval thickness removed; verify only WWTS <50 mg/kg placed in Cell No. 1	Grid system will be used to monitor thickness and footprint

5.0 Sampling Requirements

Sampling will be required in conjunction with field tests as identified in the Testing Plan and Log. All sampling will be conducted in accordance with the final approved project plans. Samples will be collected in accordance with US EPA, NCDENR, National Institute for Occupational Safety and Health (NIOSH) methods and industry standards of practice.

As project-specific tasks are identified, this QCP will be amended to include sampling requirements for those tasks. Construction, geotechnical, physical, and other non-environmental sampling activities are summarized in the Testing Plan and Log (see Appendix A). Refer to the SAP for site-specific sampling protocols.

6.0 Construction Quality Control Submittals

Construction QC submittals are those submittals generated by either the Project QC Manager or the subcontractor during or immediately prior to construction to demonstrate compliance with the project plans. Submittal requirements for these projects are tabulated in the Submittal Register (Appendix A), in accordance with the requirements identified in the project plans.

The Project QC Manager will log and track all submittals on the Submittal Register. Specific responsibilities regarding submittals include:

- Coordinating all submittal actions
- Maintaining necessary submittal records in an organized manner
- Maintaining and tracking submittals in the Submittal Register
- Reviewing and certifying all submittals for compliance with the project plans, drawings, and specifications
- Approving all submittals except those designated to be approved by the Technical Lead (project plans Lead Engineer), Honeywell and/or Stakeholders
- Checking all material and equipment delivered to the project for compliance with the project plans, drawings, and specifications

Certain designated submittals require approval by authorities other than the Project QC Manager (such as the Project Manager, Technical Lead/Lead Engineer, or others). In such cases, the Project QC Manager forwards the submittal to the Project Manager or Project Engineer who routes the submittal to the appropriate approver.

The Construction Manager and Project QC Manager are responsible for coordinating the submittal transmittal and approval process and for following through to ensure that the process does not impact the project schedule.

6.1 Submittal Review and Control

CH2M HILL will control and schedule all submittals and document the process in the Submittal Register (Appendix A). The Project QC Manager is responsible for updating the Submittal Register at least weekly. He will forward a copy of the Submittal Register to the Project Manager and QC Program Manager at the end of each month of project work. Each submittal will be routed on a standard submittal form. Units of weights and measures used on all submittals will be consistent with those used in the project documents.

Each submittal will be reviewed for completeness and compliance with contract requirements by individuals qualified to perform the review of that specific item. The submittal reviewers and approvers will be designated prior to construction.

Prior to each submittal, the Project QC Manager will certify that the submittal is in compliance with the project plans and specifications. Submittals that do not comply with the requirements will be returned to the originator for correction and re-submittal. Substitutions or variations of specified requirements will be clearly noted. Certification of the approved submittals will be indicated by signing or initialing and dating the submittal form by the Project QC Manager. Submittals may include, but are not limited to, the following:

- Personnel qualifications (surveying, etc.)
- Product data
- Permits
- Samples
- Catalog cuts/pages
- Production, inspection, and test reports
- Material Certifications
- Progress reports, safety reports, manpower reports, etc.
- As-built or certified data
- Operation and maintenance manuals
- QC records and certifications
- Sample and test results
- QC reports
- Construction photographs
- Contract close-out documents

6.2 Honeywell Approval of Submittals

Submittals for items that are extremely critical or complex, or are considered an extension of the work plan, should be submitted for Honeywell approval. These submittals still require review for conformance and certification by the Project QC Manager. This includes instances where the approver requires knowledge of the design assumptions and calculations.

As project-specific tasks are identified, the Submittal Register (Appendix A) will be amended to include documentation requirements for those tasks.

7.0 Change Control

Changes to final designs, final project plans, field changes, and modifications to operating facilities are subject to design verification measures commensurate with those applied to the Final Design/Work Plan and draft project plans. The Project Manager approves work plan changes in consultation with the Technical Lead/Lead Engineer.

RFIs will be used to communicate and document clarifications and modifications requested by the subcontractor. The RFIs will be tracked and logged by the Project QC Manager to ensure that each RFI is fully addressed and that changes to the plans, drawings, and specifications are completely and accurately documented.

7.1 Construction Changes

Changes to materials, supplies, work approaches, and corrective action during the construction effort will be documented in an overall effort to support sound engineering judgment and cost effective project delivery. Changes during construction will be documented using the RFI process.

The RFI process involves either the subcontractor or the Project QC Manager identifying the situation in the field that requires change. When a change is identified by the subcontractor, the subcontractor reports the concern to the Project QC Manager. The Project QC Manager then prepares an internal memorandum (i.e., RFI) identifying the concern and forwards it to the Project Manager. The PM reviews and forwards to Honeywell. The RFI will contain the project number, an RFI Identification Number and a Title. This information is used for RFI tracking. The Project Manager forwards the RFI to the appropriate party who is then responsible to identify the appropriate design representative to evaluate the concern and prepare the appropriate response. The response should include a narrative explanation of the resolution and any drawings or specifications required to complete the work. The response is returned to the PM and forwarded to the Project QC Manager and Honeywell for field implementation. The RFIs are numbered sequentially for individual projects or task and filed at the job site, with the Project Manager and the design team.

Changes to construction drawings as a result of a RFI will be identified with a symbol in the border identifying the RFI identification number and title. The drawing should also be marked with a cloud, circle, etc., to distinguish the change from the original drawings. The sheet will then supercede the existing drawing in the drawing set.

Note that the RFI process is a field construction tool for documenting changed field conditions or other issues that may require a deviation from project requirements identified in the drawings and specifications of the project plans. The RFI is intended to obtain input and concurrence from the Lead Engineer responsible for the development of the project plans. Approval of the RFI by the Lead Engineer does not constitute approval for CH2M HILL or its subcontractors to perform work that is outside of the project scope or budget. In the event that issues identified in the RFI may require a change to the project

scope, schedule, or budget, this should be clearly conveyed in the RFI. In such instances, it is the responsibility of the Project Manager to work closely with the Contract Administrator to seek and obtain proper approval from the Honeywell contractual authority prior to implementing the change recommended in the RFI.

8.0 Noncompliance and Corrective Actions

The Project QC Manager will notify the subcontractor of any detected noncompliance with the foregoing requirements. The subcontractor will take immediate corrective action after receipt of such notice. Such notice, when delivered to the subcontractor at the work site, will be deemed sufficient notification. If the subcontractor fails or refuses to comply promptly, the Project QC Manager may issue an order stopping all or part of the work until satisfactory corrective action has been taken. Noncompliance notification or stop work orders will be documented in the Daily Report. Completion of corrective action will be noted on the Daily Report. Verification of the corrective action and its results will be performed by the Project QC Manager and documented in the Daily Report.

8.1 Corrective Measure Plan

Resolution of failing test results or noncompliance reports will be completed through a corrective measure plan. The corrective measure plan will be developed and documented by the Project QC Manager in conjunction with the Project Manager. The agreed-upon corrective measure plan will be implemented and documented by the Project QC Manager. Completion of the corrective measure plan is the responsibility of the Project QC Manager.

9.0 Quality Control Documentation

9.1 Daily Report

The Daily Report is an essential tool for recording and reporting the daily production, safety, and QC activities of the project. The Daily Report is the daily record of operations on the job site and must be kept current. These reports are the official record of work performance and compliance with project plans, drawings, and specifications. It is therefore critical that the reports are correct and timely.

The Project QC Manager is responsible for preparing the Daily Report and submitting these on a weekly basis to the Project Manager and the QC Program Manager. The Project QC Manager will obtain operational information from the Construction Manager. The Health and Safety Officer will provide information on the health and safety activities. The report also includes the reports from each subcontractor working on the site to address the following, at a minimum:

- Quality aspects of the project that is being performed by the subcontractor
- Scheduling and resource issues
- Site safety inspections and concerns
- Environmental concerns
- Job progress
- Control inspections
- Tests performed and their results
- Crafts, personnel, and equipment onsite
- Material received

The project team must review the Daily Reports for accuracy and completeness because oftentimes, they are used to prepare the final reports for the project. The Project Manager should review these reports and ensure the QC process is working on his/her project. The QC Program Manager should review these reports and ensure the QA/QC processes and systems are working on the program.

The Daily Report template is included in Appendix A. The following should be attached to the Daily Report:

- Tailgate Safety Meeting Minutes and Signatures
- Project Status Meeting Minutes
- Submittals
- Testing Plan and Log
- Permits
- Chain-of Custody records
- Waste disposal documentation

Implementation of the QCP is documented and reported to Honeywell using a series of reports, submittals, and deliverables. These deliverables, parties responsible for preparing them, frequency, and content are listed in Table 9-1.

TABLE 9-1
Reporting and Field Documentation Required

Report or Documentation Requirement	Completed By	Delivered To	Frequency	Report Description
Daily Report	Construction Manager and/or Project QC Manager	Project Manager	Daily To Construction Quality Manager weekly	Documents daily construction and QC activity A Daily Report Template is included in Appendix A.
Testing Plan and Log	Project QC Manager	Project Manager	As performed, attached to the last Daily Report submitted for each reporting period; To Construction Quality Manager weekly	Summarizes all testing activity conducted for the reporting period with test results (pass/fail) A Testing Plan and Log Template is included in Appendix A.
Project Status Meeting Minutes	Project QC Manager	Project Manager	Attached to the appropriate Daily Report To Construction Quality Manager weekly	Minutes of any project status meeting held. A Meeting Minutes Template is included in Appendix A.
Rework Items List	Project QC Manager	Project Manager	Monthly, attached to the last Daily Report submitted for each reporting period To Construction Quality Manager monthly	Documents re-work items not corrected on same day as discovery. Includes items identified by both CH2M HILL and Honeywell or Stakeholder(s). A Rework Items List Template is included in Appendix A.
Submittal Register	Project QC Manager	Project Manager	Maintained through life of project To Construction Quality Manager monthly	A part of Construction Quality Plan; Specific to the construction activity. A Submittal Register Template is included in Appendix A.

TABLE 9-1
Reporting and Field Documentation Required

Report or Documentation Requirement	Completed By	Delivered To	Frequency	Report Description
As-Built Records	Project QC Manager	Project Manager, Honeywell	Maintained in field through life of project; ensure to be complete and accurate by Field Engineer / Construction Quality Manager upon completion of field activities, included in Final Report	Requirements specified in Quality Control Plan; to be maintained at job site and inspected by Project QC Manager to ensure daily maintenance
Photographic Record	Project QC Manager	Project Manager	Maintained in field through life of project	Photographic record showing construction progress, special situations A Photo Log template is included in Appendix A.
RFIs	Project QC Manager	Project Manager, Lead Engineer	As required.	Standard form. Generated in the Field; routed to the office for approval. Log maintained in the field. An RFI form is included in Appendix A.
Waste Tracking Log	Project QC Manager	CH2M HILL Waste Coordinator and Construction Quality Manager	Monthly and maintained in field through life of project	Tracks waste on the project from generation to final disposition A template of the Waste Tracking Log is included in Appendix A.

Documentation that is generated by the QC system must be maintained in an orderly fashion. It is suggested that the Project QC Manager maintain a series of 3-ring binders for ready reference. These should be arranged by specification section, and tabbed to include the following items.

- Punch List inspections
- Pre-final and final inspection results
- Rework items lists
- Test results
- Contract modifications and RFIs arranged in numerical order
- Non-compliance notices and corrective actions

9.2 Field Documentation Operating Procedures

The objective of the field documentation operating procedures is to ensure that appropriate project information is documented in logbooks during construction. This documentation is important for communicating activities with other staff members and Honeywell.

QC observations, inspections, and records of general QC activities on a regular basis are as follows:

- Record daily progress and associated QA and QC sampling
- Record construction operations, sequence, staging, etc.
- Maintain waste disposal records
- Describe deviations from expected conditions, or unexpected problems and their resolution

9.3 Site Preparation

Site preparation is performed by the subcontractor but will be observed by the Project QC Manager with the following checks:

- Verify that the equipment delivered to the site is the equipment specified.
- Confirm that a clearance check is performed to locate and identify each pipeline for all known utilities.
- Monitor the condition of the access roads. Verify that the proper signs are installed, the roads are maintained, and the road can accommodate construction traffic.
- Observe arrival and testing of materials to be installed as they are delivered onsite.
- Inspect all delivered materials to verify there are no defects in workmanship.
- Monitor delivery, handling, and storage of materials per the specifications.
- Verify storage facilities are protective and secure to prevent damage to equipment and materials per specifications.
- Review manufacturer material certifications.

9.4 Field Logbook

The Project QC Manager will maintain a record of daily QC activities during construction in a field logbook. The field logbook will be available upon request for review. As an operating procedure for logbook entries, the following items will be recorded, at a minimum:

- Date, project name, and location
- Time that work starts every day
- Summary of weather conditions

- General description of work activities, size of work crew, and the equipment and personnel onsite
- Duration of lunch break
- Start time and duration of downtime resulting from equipment breakdown, weather, or plant emergencies, etc.
- Summaries of QC meetings and actions recommended to be performed
- QC testing equipment and personnel
- Identification of work locations
- Description of materials delivered to the site, including QC data provided by the suppliers
- Record of decisions made regarding defective work or corrective measures implemented, or both
- Field tests
- Sampling activities

The Project QC Manager will sign or initial the bottom of each page of the field log and date the entry in order to show that notes are being taken on a daily basis. A line-through will be placed on any portion of a logbook page that is unused.

In addition, the same information will be documented in the Daily Report.

Appendix A

Project QC Forms

- Submittal Register
- Testing Plan and Log
- Request for Information Form
- Daily Report Form
- Photo Log Template
- Waste Tracking Log Template
- Rework Items List

ITEM NO	DESCRIPTION OF SUBMITTAL	REFERENCE SPEC / DRAWING	SPEC / DRAWING PAGE NO	APPROVING REQUIREMENT (Approval (A) or Information (I))	SUBMITTAL FREQUENCY (Once, daily, weekly, etc.)	SUBMITTAL SCHEDULE	SUBMITTAL TYPE (Drop-Down List)	TRANSMITTAL NUMBER	SUBMITTAL NUMBER	DATE SUBMITTED TO APPROVER	APPROVING AUTHORITY NAME	TITLE / COMPANY OR AGENCY	STATUS (Drop-Down List)	DEFICIENCIES	DATE APPROVED	REMARKS
1	Work Plan	HON QMM		A	Once		H = Plans									
2	Health and Safety Plan (HASP)	MP-01 33 00	2	A	Once		H = Plans									
3	Daily Progress Reports	CQP	2	I	Daily		G = Administration such as Schedules, etc.									
4	Final As-Built of Post Excavation Cell No. 2	HON QMM	2	A	Once		G = Administration such as Schedules, etc.									
5	Topographic Survey Instrument Calibration Certificates	HON QMM	2	I	Once		G = Administration such as Schedules, etc.									
6	Field Notes, Computations and Survey Quantities	HON QMM	2	I	Upon Request		I = Reports									
7	Documentation Pertaining to Offsite Transport and Disposal	HON QMM	3	I	As Performed		G = Administration such as Schedules, etc.									
8	Construction Project Schedule	CQP	3	A	As Updated		G = Administration such as Schedules, etc.									
9	Wipe Sample Test Results	MP-35 20 23	1	I	As Performed		I = Reports									
10	Waste Disposal Records	WP	4	I	As Performed		G = Administration such as Schedules, etc.									
11	Transporter License	WP	4	I	Once		G = Administration such as Schedules, etc.									
12	Laboratory Certification	WP	QCP	I	Once		A = Test Results and/or Certificates									
13	Disposal Facility Permit	WP	2	I	Once		G = Administration such as Schedules, etc.									
14	Disposal Facility Weight Scale Calibration Logs	CQP	4	I	Once		A = Test Results and/or Certificates									

TESTING PLAN & LOG
Honeywell, WWTS Management, Riegelwood, NC

Reference	Test Required	Date Sampled	Sampled By	Tested By	Location of Test (on-site/off-site)	Frequency	Date Test Completed	Remarks

REQUEST FOR INFORMATION/CLARIFICATION**CH2MHILL****CONTRACT NO.****PROJECT No.****PROJECT TITLE & LOCATION:****BRIEF DESCRIPTION OF RFI:**

TO:	NAME	TITLE			
FROM:	NAME	TITLE			
Date Submitted:	RFI No		DC No		
Please Respond By:				Page:	of
REFERENCE					
DRAWING(S)/SPECS:					

1) DESCRIPTION OF EXISTING CONDITION AND/OR DEFICIENCY:

NAME	TITLE
PROJECT TEAM MEMBER SIGNATURE	DATE

2) RECOMMENDED SOLUTION:

NAME	TITLE	NAME	TITLE
PROJECT MANAGER APPROVAL SIGNATURE	DATE	PROJECT TEAM MEMBER SIGNATURE	DATE

3) RESPONSE/DISPOSITION:

NAME	NAME
LEAD ENGINEER SIGNATURE	PROJECT MANAGER SIGNATURE
DATE	DATE
RFC Required? Yes <input type="checkbox"/> No <input type="checkbox"/> Schedule Impact? Yes <input type="checkbox"/> No <input type="checkbox"/> Cost Impact? Yes <input type="checkbox"/> No <input type="checkbox"/>	

4) CTR RESPONSE/DISPOSITION CONCURRENCE:

NAME	NAME				
QC MANAGER SIGNATURE	AFCEE REP SIGNATURE				
DATE	DATE				
REVIEW DISTRIBUTION			FINAL DISTRIBUTION		
<input type="checkbox"/> Honeywell REP	<input type="checkbox"/> Honeywell Site Rep	<input type="checkbox"/> CH2M LEAD ENG	<input type="checkbox"/> Honeywell REP	<input type="checkbox"/> Honeywell Site Rep	<input type="checkbox"/> CH2M LEAD ENG
<input type="checkbox"/> Honeywell COR	<input type="checkbox"/> CH2M PM	<input type="checkbox"/> Other	<input type="checkbox"/> Honeywell COR	<input type="checkbox"/> CH2M PM	<input type="checkbox"/> Other
<input type="checkbox"/> KA	<input type="checkbox"/> CH2M PROJ ENG	<input type="checkbox"/>	<input type="checkbox"/> KA	<input type="checkbox"/> CH2M PROJ ENG	<input type="checkbox"/>



DAILY REPORT

SOP CQMM-017, Final, Rev 0

(ATTACH ADDITIONAL SHEETS IF NECESSARY)

CONTRACT NAME:				REPORT NO:			
CONTRACT NUMBER:				REPORT DATE:			
REVISION NUMBER:				REVISION DATE:			
TASK ORDER NUMBER:				PROJECT NAME / LOCATION:			
PROJECT NUMBER:				PROJECT DESCRIPTION:			
PROJECT MANAGER:				PROJECT QC MANAGER:			
CONSTRUCTION MANAGER:				SITE SAFETY MANAGER:			
AM WEATHER:		PM WEATHER:		MAX TEMP (F):		MIN TEMP (F):	
SUMMARY OF WORK PERFORMED TODAY							
HEALTH AND SAFETY REPORT							
SAFETY ACTIONS TAKEN TODAY/SAFETY INSPECTIONS CONDUCTED (Include Observations, Safety Violations, Corrective Instructions Given, Corrective Actions Taken, and Results of Safety Inspections Conducted:							
TAILGATE TOPICS:							
LOSS PREVENTION OBSERVATIONS:							
OPERATIONS / PRODUCTION REPORT							
WORK FORCE – CONTRACTOR AND SUBCONTRACTOR							
Company		Cumulative Total of Work Hours From Previous Report		Total Hours Today		Total Work Hours From Start of Construction	
CH2MHILL							
EQUIPMENT ON HAND							
Description of Equipment		Make/Model/Manufacturer		Equipment ID Number		Inspection Performed By	
COMMENTS (acceptance status, inspection findings, etc.):							
WORK AND/OR TESTS ACCOMPLISHED OR IN PROGRESS							
Performed Work / Test for Today:							
Planned Work / Test for Tomorrow:							

Planned Work / Test for Next Week:				
CHANGED CONDITIONS/DELAY/CONFLICTS ENCOUNTERED (List any conflicts with the project [i.e., scope of work and/or drawings], delays to the project attributable to site and weather conditions, etc.):				
VISITORS AND DISCUSSIONS:				
QUALITY CONTROL REPORT				
MATERIALS DELIVERED TO JOB SITE				
Quantity/Volume/ Weight	Description of Materials Received	Make/Model/Manufacturer	Material Lot Number	Inspection Performed By
COMMENTS (acceptance status, inspection findings, etc.):				
INSPECTIONS PERFORMED				
Task/Activity Inspected	Inspection Performed	Findings		
TESTS PERFORMED				
Task/Activity Tested	Test Performed	Test Results (Pass/Fail) - Criteria		
QUALITY ISSUES AND RESOLUTIONS:				
SUBMITTALS INSPECTION / REVIEW				
Submittal No.	Submittal Description	Specification/Plan Reference	Submittal Approved?	Comment/Reason/Action
			Yes <input type="checkbox"/> No <input type="checkbox"/>	
			Yes <input type="checkbox"/> No <input type="checkbox"/>	
			Yes <input type="checkbox"/> No <input type="checkbox"/>	
			Yes <input type="checkbox"/> No <input type="checkbox"/>	
REGULATORY COMPLIANCE REPORT				
PERMIT INSPECTIONS PERFORMED:				
WASTE ACCUMULATION/STOCKPILE AREA INSPECTION				
Inspection Performed By:		Signature of Inspector:		
Accumulation / Stockpile Area Inspected:				

No of Containers:		No of Tanks		No of Roll-Off Boxes:		No. of Drums	
Inspection Results:							
GENERAL COMMENTS							
General Comments~ (rework, directives, etc.):							
ATTACHMENTS							
List of Attachments: (examples, as applicable: submittals, meeting minutes, safety meeting minutes, COCs, weight tickets, manifests, profiles, rework item list, RFIs, DCNs, photographs, etc.):							
<p>NOTE: Write all entries legibly in ink. Line out all unused portions or designate as "not applicable". Preparer signs first and last name on each completed daily report. This form may be filled out electronically and signed electronically.</p>							
						PREPARER'S SIGNATURE	
						DATE	

PHOTOGRAPHS

Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	
Subject/Description:	
Photo Log No:	

Rework Items List

Contract Number:						
Contractor: CH2M HILL Constructors, Inc.						
Item Number	Date Identified	Description	Referenced Spec or Drawing	Action Performed	Resolution	Date Completed

APPENDIX H

Aroclor 1268 Toxicity Studies

Development of a neurotoxic equivalence scheme of relative potency for assessing the risk of PCB mixtures

Ted Simon ^{a,*}, Janice K. Britt ^b, Robert C. James ^b

^a Ted Simon, LLC, 4184 Johnston Road, Winston, GA 30187, USA

^b Center for Environmental and Human Toxicology, University of Florida, Gainesville, FL 32611

Received 1 February 2007

Available online 31 March 2007

Abstract

PCBs produce adverse effects in humans and animals by several modes of action. The first mode of action is binding of coplanar or mono-*ortho*-PCBs to the aryl hydrocarbon (Ah) receptor leading to effects associated with the activation of this receptor. The remaining PCB congeners do not activate this receptor and have different modes of action underlying their toxic effects. One mode of action that has been shown for di-*ortho*-substituted non-coplanar PCBs (PCB congeners with two or more chlorines in the *ortho*-positions) is the interference with intracellular signaling pathways dependent on Ca²⁺ homeostasis and the resulting cellular, organ-level and organismal effects. The *ortho*-substituted non-coplanar congeners produce other cellular or organ-level effects including changes in protein kinase C translocation, changes in cellular dopamine (DA) uptake, formation of reactive oxygen species, and thyroid effects. Here, we propose a scheme for developing relative potency estimates (REP) for the PCB congeners not considered in the TEF scheme used to assess the toxicity of coplanar and mono-*ortho*-PCBs and chlorinated dioxins and furans. Because a number of the modes of action listed here for the *ortho*-substituted non-coplanar PCB congeners have been implicated in the neurotoxic effects of these PCBs congeners, this relative potency scheme is referred to here as the Neurotoxic Equivalent (NEQ) scheme for estimating toxicity of PCB mixtures. The Neurotoxic Equivalent (NEQ) values are developed in a way similar in concept to the derivation of the well-known TEF congener values. Although this scheme is in its infancy and the set of NEQ values are limited by the current data, there are several compelling reasons for proposing such a scheme now. First, it should open discussions as to how different modes of action can be utilized to predict congener potency differences for the effects they produce. Second, consideration and evaluation of the ability of the proposed NEQ scheme to predict the toxicity of PCB mixtures will assist in the identification of the specific modes of action relevant to the effects produced by non-coplanar PCBs. If other modes of action are suggested and subsequently identified, then other schemes of relative potency could be developed specifically for those modes of action, distinct from either the TEF scheme or the NEQ scheme. Knowing these other modes of action and the relative toxicity of the various congeners would advance our understanding of PCB toxicology and thereby ultimately improve our ability to estimate the toxic potency of PCB mixtures for each identified mode of action. Third, a quantitative scheme for assessing the toxicity of the non-coplanar PCB congeners present in a mixture has the potential to improve significantly future risk assessments of PCB mixtures.

© 2007 Elsevier Inc. All rights reserved.

Keywords: Polychlorinated biphenyls; Neurotoxic equivalence; Relative potency; Aroclor; Calcium homeostasis; Toxicity equivalence factors

1. Introduction

Estimating the actual risks or hazards posed by a chemical mixture is a frequent problem faced by toxicologists,

risk assessors, risk managers and decision-makers. The development of appropriate toxicity criteria for chemical mixtures represents one of the primary challenges facing toxicologists and risk assessors today. Nowhere is this problem more frequently encountered than when dealing with exposure to polychlorinated biphenyls (PCBs). There exist 209 distinct PCB congeners. These synthetic chemicals were used commercially for decades before it was

* Corresponding author.

E-mail addresses: simonfam@dscga.com (T. Simon), jbritt@terra1.com (J.K. Britt), rjames@terra1.com (R.C. James).

recognized that their chemical stability resulted in their persistent and ubiquitous presence as environmental pollutants. Environmental mixtures of PCBs contain a variety of individual PCB congeners, each congener having its own characteristics regarding biological effects, chemistry and environmental fate. The persistent presence of these mixtures in the environment continues to challenge toxicologists because of the extrapolations required to assess the risks posed by these mixtures.

PCBs produce adverse effects in humans and animals by several modes of action. The best known mode of action involves the binding of a set of 12 coplanar and mono-*ortho*-PCB congeners to the aryl hydrocarbon (Ah) receptor. These congeners are often referred to as the dioxin-like (DL) PCB congeners because the TEF scheme developed for dioxins has also been applied to coplanar polychlorinated dibenzofuran and biphenyl congeners that, similar to 2,3,7,8-TCDD, bind to the Ah-receptor and activate various responses associated with this receptor. The remaining 197 PCB congeners fall into a second general category, and here are referred to as the non-dioxin like (NDL) PCB congeners. Within this group of NDL PCB congeners are a large number of non-coplanar PCB congeners containing two or more chlorines in the four available *ortho*-positions of the biphenyl nucleus. These di-*ortho*-congeners have little Ah-receptor affinity, and may, in fact, antagonize the activity of coplanar PCB congeners. At sufficient concentrations, the di-*ortho*-congeners may contribute to the toxicity of PCB mixtures by one or more different modes of action, as has been shown in other studies (e.g., see Kodavanti, 2005; Warren et al., 2004).

One mode of action that has become linked to certain di-*ortho*-PCB congeners is interference with intracellular signaling pathways that are dependent on Ca^{2+} homeostasis and the consequent cellular, organ-level and organismal effects. These non-coplanar congeners produce adverse effects including changes in protein kinase C translocation, changes in cellular dopamine (DA) uptake, and formation of reactive oxygen species. These endpoints may be related by similar cellular or biochemical mechanisms, or the endpoints may be separate but occur in parallel fashion and appear to be related on an organismal level. These cellular endpoints likely underlie the well known neurotoxic effects of PCBs (Bushnell et al., 2002; Levin et al., 1988; Rice, 1997; Arnold et al. 1993a,b; Barsotti et al., 1976; Barsotti and Van Miller, 1984; Bushnell et al., 2002; Freeman et al., 2000; Harris et al., 1993; Lillie et al., 1974; Tryphonas et al., 1986, 1989, 1991a,b).

The development of a relative potency scheme based on the endpoints mentioned above and the determination of whether this scheme could predict the NDL toxicity of different PCB congeners or mixtures could serve to clarify the relationship of these various cellular and biochemical effects in producing the toxic effects observed at the organismal level. For example, a similar approach recently indicated the carcinogenic potency of Aroclor

mixtures was driven by at least two different modes of action. Recognizing and accounting for both modes of action subsequently helped correct for the variability in mixture potency caused by the Ah-receptor-independent component and in turn better estimate the contribution being made by the Ah-receptor-mediated mode of action (Warren et al., 2004). Thus, the goal of this paper is to propose and develop an initial relative potency scheme for NDL congeners [referred to hereafter as the Neurotoxic Equivalent (NEQ) scheme] that can be tested and modified as new data become available. This should ultimately lead to a better understanding of the toxicity of individual PCB congeners, PCB mixtures, and the structural requirements for the NDL congeners that produce the neurotoxic effects of PCBs. If successful, this scheme would, in turn, pave the way for the development of other relative potency schemes to predict PCB congener toxicity occurring by other modes of action.

1.1. PCB mixture potency issues: degree of chlorination and its relationship to toxicity

PCBs are a group of synthetic organic compounds consisting of a biphenyl nucleus substituted with varying numbers of chlorine atoms. Groups of PCB congeners with the same number of chlorines are called PCB homologues; hence, monochlorobiphenyl (monoCB) and trichlorobiphenyl (triCB) are PCB homologues containing one and three chlorines, respectively.

Commercial PCB dielectric fluids were synthesized via a batch chlorination process with the goal of producing a mixture with a specified average weight percent of chlorine. The percentage of chlorine was controlled by the duration of the reaction (Sawhney, 1986). Commercial Aroclor mixtures are named for their weight percentage of chlorine. For example, Aroclor 1221 has 21% chlorine by weight, Aroclor 1254 has 54% chlorine and Aroclor 1268 has 68% chlorine. The exception is Aroclor 1016, which has 41% chlorine by weight. For thermodynamic reasons, during PCB synthesis, chlorine binding is favored at the *ortho*- and *para*-positions over binding in the *meta*-position. Not all 209 congeners would be expected in any commercial Aroclor mixture, and about 20 individual PCB congeners have never been found in any of the commercial PCB mixtures (Kimbrough, 1980; Anderson, 1991; Frame et al., 1996; Frame, 2001; Kodavanti et al., 2001).

The environmental fate of PCBs depends on their physical/chemical properties and these properties vary with the degree of chlorination. For example, there is an increase in the density, flash point, fire point, pour point, and distillation range (boiling point) with increasing chlorine content. Dielectric constant and water solubility vary inversely with the extent of chlorination (Hutzinger et al., 1974; Kimbrough, 1980; Cairns et al., 1986). Environmental PCB mixtures “weather” over time (Borja et al., 2005; Blankenship et al., 2005). This change occurs because variations exist in the degradation rates of different PCB congeners. These

rates depend on physical/chemical properties, such as vapor pressure, water solubility, octanol–water partition coefficient, and also the presence of biota that can enzymatically degrade PCBs. The largest difference in degradation rates exists between the lower-chlorinated and higher-chlorinated PCB congeners. However, enzymatic biodegradation rates may be significantly different within a PCB homologue group because of different patterns of chlorination of the various congeners (i.e., *ortho*-, *meta*- or *para*-). Changes in the congener composition of a PCB mixture can affect the toxicity of the mixture, and the weathering of commercial PCB mixtures has been recognized for some time as an uncertainty in risk assessment of environmental PCB mixtures.

Chlorination of the biphenyl nucleus thermodynamically favors adding chlorines first at the *ortho*- and *para*-positions. Hence, PCB mixtures in the middle range of chlorination (e.g., Aroclors 1242, 1248 and 1254) tend to contain both congeners that bind to the Ah-receptor as well as congeners with two or three *ortho*-substitutions that interfere with Ca^{2+} homeostasis. A lesser chlorinated mixture, such as Aroclor 1221, is likely to have neither as many PCB congeners with four chlorines attached in the *meta*-/*para*-positions of both rings (needed for Ah-binding) nor as many PCB congeners with two or three chlorines attached in the *ortho*-positions (needed for Ca^{2+} effects). A more heavily chlorinated mixture (e.g., Aroclors 1262 and 1268) will contain more congeners with four *ortho*-substitutions that possess both a lower Ah-binding affinity and also a lower ability to interfere with Ca^{2+} -dependent intracellular signaling pathways. Hence, one would expect PCB mixtures containing greater amounts of moderately chlorinated homologues (tetra-, penta-, and hexaCBs) to be more toxic than mixtures containing lesser amounts of these moderately chlorinated homologues regarding effects produced by both Ah-receptor binding and disruption of Ca^{2+} homeostasis.

The toxicity of individual PCB congeners and PCB mixtures depends on the degree of chlorination. Nebeker and Puglisi (1974) examined the endpoints of lethality and reproductive toxicity in the crustacean, *Daphnia magna*, and found that PCB mixtures in the middle of the range of chlorination (i.e., Aroclor 1248 and Aroclor 1254) were the most toxic, while mixtures at the extreme ends of the range of chlorination (Aroclor 1221 and Aroclor 1268) were less toxic. The difference in toxicity was about an order of magnitude. In GT1-7 cells derived from mouse hypothalamic neurons, Gore et al. (2002) showed that Aroclor 1221 and Aroclor 1254 had different effects on secretion of gonadotropin-releasing hormone and that Aroclor 1254 produced potentially neurotoxic effects whereas Aroclor 1221 did not. Aroclor 1248 produced cytotoxicity and apoptosis in primary cultures of rat cortical neurons to a greater extent than did Aroclor 1260 (Sanchez-Alonso et al., 2004). Moderately chlorinated Aroclors 1242, 1248 and 1254 produced a more severe effect on weight gain and thymic atrophy than did the less chlori-

nated Aroclor 1232 or the more chlorinated Aroclor 1260 (Harris et al., 1993). Aroclor 1254 was more potent than either Aroclor 1221 or Aroclor 1268 on the success rate of *in vitro* fertilization of mouse ova (Kholkute et al., 1994). In short, reduced toxicity at the extremes of average mixture chlorination has been observed in fish, birds, and mammals (Desaiah et al., 1972; Cutkomp et al., 1972; Lillie et al., 1974; Cecil et al., 1974; Harris et al., 1993; Kholkute et al., 1994).

Regarding individual PCB congeners, the pattern of chlorine substitution on the biphenyl nucleus has been shown to be a critical determinant of congener toxicity. The binding affinity of PCBs to the Ah-receptor is dependent on chlorines in the *meta*- and *para*-positions of both rings forming the biphenyl nucleus (i.e., at positions 3, 4, and 5), making 3,3',4,4'-tetrachlorobiphenyl (PCB-77), 3,3',4,4',5-pentachlorobiphenyl (PCB-126), and 3,3',4,4',5,5'-hexachlorobiphenyl (PCB-169) the three most potent dioxin-like congeners.

On the other hand, PCB congeners with two or three chlorine substitutions in the *ortho*-positions bind weakly or not at all to the Ah-receptor. Instead, these non-coplanar *ortho*-substituted congeners disrupt intracellular signaling pathways that are regulated and modulated by Ca^{2+} , such as those involving protein kinase C (PKC), inositol triphosphate (IP3) or arachidonic acid; PCB congeners with one or four *ortho*-substitutions interfere with Ca^{2+} homeostasis to a lesser extent (Kodavanti, 2004, 2005). The role of Ca^{2+} in the proper functioning of the nervous system is well known and the non-Ah-related modes of action likely underlie observed neurotoxic effects, as NDL-PCBs have been shown to produce these neurotoxic effects (Schantz et al., 1997; Kodavanti and Tilson, 2000; Kodavanti, 2005; Pessah et al., 2006). Thus, it is reasonable that an NDL mode of action can ultimately be used to develop a relative potency scheme capable of predicting the neurotoxic potential of these PCB congeners.

1.2. Determining mixture toxicity by relative potency estimates: the clear need for more than just the current TEF scheme for dioxin-like compounds

Relative potency (REP) schemes are used to predict the toxicity of mixtures. The best known example of a relative potency scheme is the set of Toxic Equivalence Factors (TEF) developed for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofuran congeners (PCDD/Fs) and dioxin-like PCBs (DL-PCBs) (Van den Berg et al., 1998, 2006; Haws et al., 2006). The dioxin TEF scheme has been adopted by the risk assessment community for assessing the risks and hazards posed by exposures to mixtures of PCDD/Fs and DL-PCBs (Finley et al., 2003; Haws et al., 2006; National Academy of Sciences, 2006).

Initially, the endpoints used to predict TEF values involved the binding affinity of each congener for the Ah-receptor and data obtained from *in vitro* receptor binding

and antagonism studies. In recent years, a more robust analysis of the relative potencies of dioxin-like compounds has begun to evolve as more endpoints are added and evaluated, including more relevant *in vivo* measurements of biological responses to dioxins (Van den Berg et al., 2006; Haws et al., 2006).

The TEF approach considers the impact of the presence of the 12 coplanar and mono-*ortho*-dioxin-like-PCBs and their contribution to the dioxin-like toxicity of a PCB mixture. One issue that the TEF scheme does not consider for a PCB mixture is the potential toxicity of the remaining 197 congeners. Filling this data gap for risk assessment of PCBs has become even more pressing since the release of the NAS review of EPA's dioxin reassessment (National Academy of Sciences, 2006). The lack of a scientifically credible cancer slope factor for dioxin and the absence of a reference dose for dioxin renders moot any risk assessment for PCBs dependent solely on their dioxin-like effects (USEPA, 2003; National Academy of Sciences, 2006). In fact, recent work by the National Toxicology Program and others (National Toxicology Program, 2004a,b,c,d; Maruyama and Aoki, 2006) suggests that dioxin-like effects of PCB mixtures may contribute a lesser proportion of the risk associated with these mixtures and, therefore, the risk associated with NDLE effects assumes greater importance. These new findings also emphasize the need for an assessment method for the NDLE PCB congeners.

The modes of action that have been of greatest interest for NDLE PCB congeners involve changes in Ca^{2+} homeostasis. Excellent reviews of the cellular/macromolecular aspects are available in Kodavanti (2004, 2005) and a review of the organismal and human biology aspects are provided in Rice (2000) and Schantz et al. (2003).

To summarize, environmental PCB mixtures consist of both coplanar and non-coplanar PCB congeners, and exposures occur to both types of congeners. A relative potency scheme for the non-coplanar *ortho*-substituted PCB congeners would enable risk assessors to adjust the toxicity estimate for a PCB mixture based on the amounts of *ortho*-substituted non-coplanar congeners present in the mixture. This adjustment method would predict the toxicity of a PCB mixture based on the amounts of the relevant PCB congeners in the mixture in the same way that the dioxin TEF scheme predicts DL toxicity based on the amounts of DL chemicals present in a mixture of PCDD/Fs/DL-PCBs (Haws et al., 2006; Van den Berg et al., 2006).

2. Methods and Results

As previously indicated, research on the effects of PCBs has recently been directed toward an elucidation of the cellular and biochemical effects contributing to a systems biology approach to understanding the organismal effects of PCBs (e.g., Henry, 2003). Such an approach is necessary because of the complex and interacting effects of PCBs on various physiological systems.

Here, the toxicity estimates of various Aroclor mixtures relative to that of Aroclor 1016 and Aroclor 1254 are developed by combining Neurotoxic Equivalence (NEQ) potency values obtained by consideration of REPs

from several sources as a measure of the potential for neurotoxic effects for each PCB congener. These congener-specific NEQ values can be used along with measurements of the composition of various Aroclor mixtures to estimate the relative neurotoxic potency of each mixture. Adjusted reference doses for various Aroclor mixtures are developed that include consideration of both DL and NDLE effects.

PCB homologue analysis is one of more economical (and hence more common) methods of PCB analysis used in environmental investigations. Hence, NEQ values representative of homologues would be much more useful for risk assessment than congener-specific values. Therefore, the congener-specific NEQ values are also used to estimate the neurotoxicity for PCB homologues for use in the risk assessment of weathered environmental PCB mixtures that possess different homologue compositions than the original Aroclor mixtures.

2.1. Estimates of neurotoxic potency of single PCB congeners

Similar to the earliest TEF schemes, *in vitro* effects were used to develop the NEQ scheme for individual congeners. Potency values for a range of cellular and biochemical effects reflective of potential neurotoxicity were assembled from the scientific literature for various PCB congeners.

2.1.1. Choice of *in vitro* measures of effect

The effects considered were [^3H]phorbol ester binding as a measure of PKC translocation in rat cerebellar granule cells, inhibition of microsomal and mitochondrial Ca^{2+} sequestration in rat cerebellum, reduction in dopamine content in PC-12 cells *in vitro*, and binding to the ryanodine receptor (RyR1) in rabbit skeletal muscle (Kodavanti et al., 1995, 1996; Shain et al., 1991; Pessah et al., 2006). The measures of potency were EC_{50} or EC_{2x} values measured *in vitro*. These studies provided five measures of potency for a relatively large range of PCB congeners (see Table 1).

Although the RyRs were obtained from skeletal muscle, ryanodine receptors are expressed in all tissues and rabbit skeletal muscle is a convenient source of this macromolecule (Wong and Pessah, 1996; Wong et al., 1997; Pessah et al., 2006). Ryanodine receptors from brain and skeletal muscle appear to be similar in their affinity for various PCB congeners (Wong et al., 1997). Ryanodine receptors are not only generally distributed in the brain and skeletal muscle, but also in the lung, kidney, liver, testis, and other tissues (Sorrentino, 1995) and are highly evolutionarily conserved (Rosen, 2003; Sorrentino et al., 2000). In the brain, RyRs play a role in the functioning of dendritic spines, neuroplasticity and spatial learning (Korkotian and Segal, 1999; Conti et al., 2004; Unni et al., 2004; Zhao et al., 2000). Therefore, consideration of the RyR-binding affinity of PCB congeners seemed an appropriate mode of action to include in the development of the proposed NEQ scheme.

Data on the effects of PCBs on respiratory bursting as a measure of reactive oxygen species (ROS) in human granulocytes (Voie and Fonnum, 1998; Voie et al., 1998, 2000) and data on binding to trans-thyretin (Chauhan et al., 2000) were not used because they were not reflective of potential neurotoxicity. Data on uptake of neurotransmitters by synaptosomes were considered, but not used, because the data were sparse (Mariussen et al., 1999, 2001, 2002, 2003).

2.1.2. Calculation of neurotoxic relative potency factors and neurotoxic equivalents

Table 1 shows the effect levels of the various congeners. For congeners with weak effects (i.e., a high EC_{50} value), the data were often censored and the reported limit was used as a surrogate value. For each of the individual effects (Table 1), a neurotoxic REP value was calculated for each congener as the ratio between the lowest concentration producing a given effect level (e.g., EC_{50} value) in the particular study and the concentration producing that same effect level; hence, the congener with the lowest effective concentration would have a neurotoxic REP value of 1 and those for the less potent congeners would range between 1 and 0 (Table 2).

Table 1
Potentially neurotoxic effect values of individual PCB congeners

PCB structure	IUPAC No.	Homologue	Kodavanti et al. (1995) ³ H Phorbol ester binding EC ₅₀ (μM)	Shain et al. (1991) DA release from—PC12 EC ₅₀ (μM)	Kodavanti et al. (1996)		Pessah et al. (2006) Binding to RyR1	
					Inhibition of microsomal Ca ²⁺ uptake EC ₅₀ (μM)	Inhibition of mitochondrial Ca ²⁺ uptake EC ₅₀ (μM)	EC _{2x} (μM)	EC ₅₀ (μM)
2-	1	mono		182				
3-	2	mono		>201				
4-	3	mono		>201				
2,2'-	4	di	43	64	8	9	2.18	5.61
2,3-	5	di		173				
2,3'-	6	di		173				
2,4-	7	di		200				
2,4'-	8	di						
2,5-	9	di		>201			4.09	0.98
2,6-	10	di		106				
3,3'-	11	di	60	195	12.5	13.1		
3,4-	12	di		169				
3,4'-	13	di		>201				
3,5-	14	di	74	>201	17.2	22.3		
4,4'-	15	di	NEO		NEO	NEO		
2,2',3-	16	tri						
2,2',4-	17	tri						
2,2',5-	18	tri		82			1.05	2.81
2,2',6-	19	tri	58		7	14.8		
2,3,3'-	20	tri						
2,3,4-	21	tri		>201				
2,3,4'-	22	tri						
2,3,5-	23	tri						
2,3,6-	24	tri		160			2.98	3.53
2,3',4-	25	tri		>201				
2,3',5-	26	tri		161			3.53	3.87
2,3',6-	27	tri					1.51	3.26
2,4,4'-	28	tri	>100	196	6.9	9.1		
2,4,5-	29	tri						
2,4,6-	30	tri		150			2.62	10.92
2,4',5-	31	tri		176				
2,4',6-	32	tri						
2',3,4-	33	tri		185				
2',3,5-	34	tri						
3,3',4-	35	tri						
3,3',5-	36	tri						
3,4,4'-	37	tri						
3,4,5-	38	tri						
3,4',5-	39	tri		>201				
2,2',3,3'-	40	tetra						
2,2',3,4-	41	tetra					1.51	2.58
2,2',3,4'-	42	tetra						
2,2',3,5-	43	tetra						
2,2',3,5'-	44	tetra		114				
2,2',3,6-	45	tetra						
2,2',3,6'-	46	tetra						
2,2',4,4'-	47	tetra	89	115	5.8	6.7		
2,2',4,5-	48	tetra						
2,2',4,5'-	49	tetra		97			1.82	2.17
2,2',4,6-	50	tetra	41	71	7.3	9.6		
2,2',4,6'-	51	tetra	50		2.4	9.1		
2,2',5,5'-	52	tetra	28	86	4.9	5.8	0.49	1.25
2,2',5,6'-	53	tetra	NEO					
2,2',6,6'-	54	tetra	NEO		NEO	NEO		
2,3,3',4-	55	tetra						
2,3,3',4'-	56	tetra						
2,3,3',5-	57	tetra						
2,3,3',5'-	58	tetra						
2,3,3',6-	59	tetra						
2,3,4,4'-	60	tetra						
2,3,4,5-	61	tetra						
2,3,4,6-	62	tetra						
2,3,4',5-	63	tetra						
2,3,4',6-	64	tetra						
2,3,5,6-	65	tetra						
2,3',4,4'-	66	tetra					2.38	3.1

Table 1 (continued)

PCB structure	IUPAC No.	Homologue	Kodavanti et al. (1995) ³ H Phorbol ester binding EC ₅₀ (μM)	Shain et al. (1991) DA release from—PC12 EC ₅₀ (μM)	Kodavanti et al. (1996)		Pessah et al. (2006) Binding to RyR1	
					Inhibition of microsomal Ca ²⁺ uptake EC ₅₀ (μM)	Inhibition of mitochondrial Ca ²⁺ uptake EC ₅₀ (μM)	EC _{2x} (μM)	EC ₅₀ (μM)
2,3',4,5-	67	tetra						
2,3',4,5'-	68	tetra						
2,3',4,6-	69	tetra		78				
2,3',4',5-	70	tetra					3.1	2.2
2,3',4',6-	71	tetra						
2,3',5,5'-	72	tetra						
2,3',5',6-	73	tetra						
2,4,4',5-	74	tetra						
2,4,4',6-	75	tetra		118			Inactive	Inactive
2',3,4,5-	76	tetra						
3,3',4,4'-	77	tetra	NEO		NEO	NEO		
3,3',4,5-	78	tetra						
3,3',4,5'-	79	tetra						
3,3',5,5'-	80	tetra	72		>100	>100		
3,4,4',5-	81	tetra						
2,2',3,3',4-	82	penta						
2,2',3,3',5-	83	penta						
2,2',3,3',6-	84	penta					0.42	1.8
2,2',3,4,4'-	85	penta						
2,2',3,4,5-	86	penta						
2,2',3,4,5'-	87	penta						
2,2',3,4,6-	88	penta						
2,2',3,4,6'-	89	penta						
2,2',3,4',5-	90	penta						
2,2',3,4',6-	91	penta						
2,2',3,5,5'-	92	penta						
2,2',3,5,6-	93	penta						
2,2',3,5,6'-	94	penta						
2,2',3,5',6-	95	penta					0.22	0.49
2,2',3,6,6'-	96	penta					0.44	0.77
2,2',3',4,5-	97	penta						
2,2',3',4,6-	98	penta						
2,2',4,4',5-	99	penta						
2,2',4,4',6-	100	penta		158				
2,2',4,5,5'-	101	penta					0.86	1.9
2,2',4,5,6'-	102	penta						
2,2',4,5',6-	103	penta		157				
2,2',4,6,6'-	104	penta	38	93	5.5	4.7		
2,3,3',4,4'-	105	penta	95		5.3	6.6		
2,3,3',4,5-	106	penta						
2,3,3',4',5-	107	penta						
2,3,3',4,5'-	108	penta						
2,3,3',4,6-	109	penta						
2,3,3',4',6-	110	penta					1.13	1.7
2,3,3',5,5'-	111	penta					4.83	ASL
2,3,3',5,6-	112	penta						
2,3,3',5',6-	113	penta						
2,3,4,4',5-	114	penta						
2,3,4,4',6-	115	penta						
2,3,4,5,6-	116	penta						
2,3,4',5,6-	117	penta						
2,3',4,4',5-	118	penta	>100		6.6	9.1		
2,3',4,4',6-	119	penta						
2,3',4,5,5'-	120	penta						
2,3',4,5',6-	121	penta						
2',3,3',4,5-	122	penta						
2',3,4,4',5-	123	penta					Inactive	Inactive
2',3,4,5,5'-	124	penta						
2',3,4,5,6'-	125	penta						
3,3',4,4',5-	126	penta	NEO		>100	>100	Inactive	Inactive
3,3',4,5,5'-	127	penta	NEO					
2,2',3,3',4,4'-	128	hexa	>100		4.9	11		
2,2',3,3',4,5-	129	hexa						
2,2',3,3',4,5'-	130	hexa						
2,2',3,3',4,6-	131	hexa						
2,2',3,3',4,6'-	132	hexa					0.91	1.8
2,2',3,3',5,5'-	133	hexa	>100		5.1	15.2		
2,2',3,3',5,6-	134	hexa						
2,2',3,3',5,6'-	135	hexa						

(continued on next page)

Table 1 (continued)

PCB structure	IUPAC No.	Homologue	Kodavanti et al. (1995) ³ H Phorbol ester binding EC ₅₀ (μM)	Shain et al. (1991) DA release from—PC12 EC ₅₀ (μM)	Kodavanti et al. (1996)		Pessah et al. (2006) Binding to RyR1	
					Inhibition of microsomal Ca ²⁺ uptake EC ₅₀ (μM)	Inhibition of mitochondrial Ca ²⁺ uptake EC ₅₀ (μM)	EC _{2x} (μM)	EC ₅₀ (μM)
2,2',3,3',6,6'-	136	hexa	58		6.3	9.9	0.23	0.48
2,2',3,4,4',5'-	137	hexa						
2,2',3,4,4',5'-	138	hexa					2.61	4.3
2,2',3,4,4',6'-	139	hexa						
2,2',3,4,4',6'-	140	hexa						
2,2',3,4,5,5'-	141	hexa						
2,2',3,4,5,6'-	142	hexa						
2,2',3,4,5,6'-	143	hexa						
2,2',3,4,5',6'-	144	hexa						
2,2',3,4',6,6'-	145	hexa						
2,2',3,4',5,5'-	146	hexa						
2,2',3,4',5,6'-	147	hexa						
2,2',3,4',5,6'-	148	hexa						
2,2',3,4',5',6'-	149	hexa					0.33	0.7
2,2',3,4',5,6'-	150	hexa						
2,2',3,5,5',6'-	151	hexa					0.5	1.54
2,2',3,5,6,6'-	152	hexa						
2,2',4,4',5,5'-	153	hexa	>100				1.21	2.86
2,2',4,4',5,6'-	154	hexa						
2,2',4,4',6,6'-	155	hexa		156				
2,3,3',4,4',5'-	156	hexa	>100		5.4	7.3		
2,3,3',4,4',5'-	157	hexa					Inactive	Inactive
2,3,3',4,4',6'-	158	hexa						
2,3,3',4,5,5'-	159	hexa					1.95	>25
2,3,3',4,5,6'-	160	hexa						
2,3,3',4,5',6'-	161	hexa						
2,3,3',4',5,5'-	162	hexa						
2,3,3',4',5,6'-	163	hexa					1.44	1.92
2,3,3',4',5',6'-	164	hexa						
2,3,3',5,5',6'-	165	hexa						
2,3,4,4',5,6'-	166	hexa						
2,3',4,4',5,5'-	167	hexa						
2,3',4,4',5',6'-	168	hexa						
3,3',4,4',5,5'-	169	hexa	NEO		NEO	NEO		
2,2',3,3',4,4',5'-	170	hepta					0.73	1.51
2,2',3,3',4,4',6'-	171	hepta		134				
2,2',3,3',4,5,5'-	172	hepta						
2,2',3,3',4,5,6'-	173	hepta						
2,2',3,3',4,5,6'-	174	hepta						
2,2',3,3',4,5',6'-	175	hepta						
2,2',3,3',4,6,6'-	176	hepta					0.38	0.82
2,2',3,3',4',5,6'-	177	hepta						
2,2',3,3',5,5',6'-	178	hepta						
2,2',3,3',5,6,6'-	179	hepta						
2,2',3,4,4',5,5'-	180	hepta	NEO		4.8	6.6	0.96	2.62
2,2',3,4,4',5,6'-	181	hepta		>201				
2,2',3,4,4',5,6'-	182	hepta						
2,2',3,4,4',5',6'-	183	hepta					0.55	1.31
2,2',3,4,4',6,6'-	184	hepta						
2,2',3,4,5,5',6'-	185	hepta						
2,2',3,4,5,6,6'-	186	hepta						
2,2',3,4',5,5',6'-	187	hepta					0.58	1.83
2,2',3,4',5,6,6'-	188	hepta						
2,3,3',4,4',5,5'-	189	hepta						
2,3,3',4,4',5,6'-	190	hepta						
2,3,3',4,4',5',6'-	191	hepta						
2,3,3',4,5,5',6'-	192	hepta						
2,3,3',4',5,5',6'-	193	hepta						
2,2',3,3',4,4',5,5'-	194	octa						
2,2',3,3',4,4',5,6'-	195	octa						
2,2',3,3',4,4',5,6'-	196	octa						
2,2',3,3',4,4',6,6'-	197	octa						
2,2',3,3',4,5,5',6'-	198	octa						
2,2',3,3',4,5,5',6'-	199	octa						
2,2',3,3',4,5,6,6'-	200	octa						
2,2',3,3',4,5',6,6'-	201	octa						

Table 1 (continued)

PCB structure	IUPAC No.	Homologue	Kodavanti et al. (1995)	Shain et al. (1991)	Kodavanti et al. (1996)		Pessah et al. (2006)	
			³ H Phorbol ester binding EC ₅₀ (μM)	DA release from—PC12 EC ₅₀ (μM)	Inhibition of microsomal Ca ²⁺ uptake EC ₅₀ (μM)	Inhibition of mitochondrial Ca ²⁺ uptake EC ₅₀ (μM)	EC _{2x} (μM)	EC ₅₀ (μM)
2,2',3,3',5,5',6,6'-	202	octa						
2,2',3,4,4',5,5',6-	203	octa						
2,2',3,4,4',5,6,6'-	204	octa						
2,3,3',4,4',5,5',6-	205	octa						
2,2',3,3',4,4',5,5',6-	206	nona						
2,2',3,3',4,4',5,6,6'-	207	nona						
2,2',3,3',4,5,5',6,6'-	208	nona						
2,2',3,3',4,4',5,5',6,6'-	209	deca						

The shading of the table is to enable ease of reading across the columns. Abbreviations: NEO, no effect observed; ASL, above solubility limit.

When two or more laboratory-based REP values were available, Neurotoxic Equivalent (NEQ) values were calculated as an average of REP values from the existing studies (Table 3). When no laboratory-based REP value was available, either a statistical estimate of the neurotoxic REP developed from PKC translocation data using an empirical Bayes technique (Svensgaard et al., 1997) or a surrogate value based on a structurally similar congener was considered. When only a single laboratory value was available, either that laboratory-based value or the empirical Bayes estimate was considered as the NEQ value.

For those congeners with a single laboratory result, the choice between the empirical Bayes estimate and the laboratory result value was based on the level of chlorination. For those congeners without a laboratory result, the choice of an empirical Bayes estimate or a value from a structurally similar congener was similarly based on the level of chlorination. For di-CBs, tri-CBs, and hepta-CBs, the lower of the two values was chosen; for the more toxic tetra-CBs, penta-CBs, and hexa-CBs, the higher of the two REP values was chosen. The rightmost column of Table 3 indicates the choice for each congener. Mono-CBs, octa-CBs, nona-CBs and deca-CB were assumed to have NEQ values of zero. Not all the congeners are represented; only for those congeners comprising at least 1% of an Aroclor mixture was an NEQ value developed. The authors recognize and remind the reader that the NEQ values in Table 3 are preliminary and will undoubtedly be altered as more data become available.

This distinction between neurotoxic relative potency estimates and Neurotoxic Equivalents is similar to the distinction between DL REP values from individual studies and TEQ values selected from the dataset of REP values (Haws et al., 2006; Van den Berg et al., 1998, 2006). The PCB congeners with the three highest NEQ values are 2,2',5,6'-tetraCB (PCB-53, NEQ = 1.0), 2,2',3,4',6-pentaCB (PCB-95, NEQ = 0.991) and 2,3,3',4',6-pentaCB (PCB-110, NEQ = 0.971). Hence, the NEQ scheme represents the neurotoxicity of a given PCB congener relative to PCB-53 in the same fashion that the dioxin TEQ scheme represents Ah-receptor-related toxicity relative to 2,3,7,8-TCDD.

2.1.3. Determination of neurotoxic potency for PCB homologues

Because homologue analysis is one of more economical (and hence more common) methods of chemical analysis for PCBs used in environmental investigations, NEQ values representative of homologues rather than single congeners would be more useful for risk assessment.

Table 4 shows the congener compositions of various Aroclor mixtures. These percent compositions are averages of data available in Anderson (1991), Frame et al. (1996, 2001) and Kodavanti et al. (2001). Within each homologue group, the average percentage of each detected congener in the mixtures Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260, Aroclor 1262, and Aroclor 1268 was

multiplied by its NEQ value. The total NEQ content within each homologue group is a measure of that group's neurotoxic potential. These homologue-specific NEQ values are shown in Table 5.

2.2. Comparison of the effects of single congeners and mixtures to the NEQ predictions

Tan et al. (2004) examined the effects of single PCB congeners on membrane integrity and consequent viability in acutely dissociated rat cerebellar granule cells. The efficacy of the congeners was PCB-52 > PCB-47 > PCB-28 (NEQs = 0.699, 0.497 and 0.298, respectively). These neurotoxic potency relationships are predicted by the NEQ values in Table 3. In addition, PCB-77, PCB-80 and PCB-81 (NEQs = 0.0, 0.13, and 0.13 respectively) were without effect, also consistent with the values in Table 3. Seegal et al. (1990a,b) examined dose dependent changes of dopamine content in PC-12 cells and primate brain and found that PCB-52 > PCB-47 > PCB-28, as would be predicted by their NEQ values.

The use of the NEQ values in this paper can also be validated by comparison with laboratory findings of the effects of PCB mixtures. Kodavanti (2005) provides actual measures of relative potency for the Aroclors 1016, 1254 and 1260 of 0.394, 0.500 and 0.280, respectively. In the NEQ scheme proposed here, the sum of the NEQ values for these three Aroclor mixtures are 0.282, 0.354 and 0.207, respectively. While at first glance it may appear as though our numbers are different, in actuality the relative potencies of the three mixtures, as derived by the NEQ scheme match those reported by Kodavanti very well. This is shown in Table 6 where we have normalized the NEQ predictions for a value of 0.500 for Aroclor 1254. When this is done the relative mixture potencies Aroclor 1016 and 1260 are essentially these same as those reported in Kodavanti (2005) using PKC translocation as the sole endpoint.

2.3. Determination of the relative neurotoxic potency of Aroclor mixtures

Table 4 shows the congener compositions of various Aroclor mixtures. These percent compositions are averages of data available in Anderson (1991), Frame et al. (1996, 2001), and Kodavanti et al. (2001). Ideally, values for neurotoxic REPs would be available for all congeners found in all PCB mixtures. Currently, more than 50 congeners are supported by a single REP value only or the empirical Bayes estimate (Svensgaard et al., 1997). Hence, this paper reflects the current state of knowledge and it is clear from a comparison of Tables 1–3 that additional work needs to be conducted to obtain NEQ values for as yet untested congeners.

To obtain estimates of the relative potency of the various Aroclor mixtures, the composition values for each congener (Table 4) were multiplied by the NEQ value (Table 3) for each congener. The sum of these products

Table 2

Neurotoxic REP values for individual congeners calculated from the data in Table 1

PCB structure	IUPAC No.	CB	Kodavanti et al. (1995) ³ H Phorbol ester binding	Shain et al. (1991) DA release from PC12 cells	Kodavanti et al. (1996)		Pessah et al. (2006) Ryanodine binding
					Microsomal Ca ²⁺ release	Mitochondrial Ca ²⁺ release	
2-	1	mono		0.352			
3-	2	mono		0.000			
4-	3	mono		0.000			
2,2'-	4	di	0.651	1.000	0.300	0.522	0.101
2,3-	5	di		0.370			
2,3'-	6	di		0.370			
2,4-	7	di		0.320			
2,4'-	8	di					
2,5-	9	di		0.000			0.054
2,6-	10	di		0.604			
3,3'-	11	di	0.467	0.328	0.192	0.359	
3,4-	12	di		0.379			
3,4'-	13	di		0.000			
3,5-	14	di	0.378	0.000	0.140	0.211	
4,4'-	15	di	0.000		0.000	0.000	
2,2',3-	16	tri					
2,2',4-	17	tri					
2,2',5-	18	tri		0.780			0.210
2,2',6-	19	tri	0.483		0.343	0.318	
2,3,3'-	20	tri					
2,3,4-	21	tri		0.000			
2,3,4'-	22	tri					
2,3,5-	23	tri					
2,3,6-	24	tri		0.400			0.074
2,3',4-	25	tri		0.000			
2,3',5-	26	tri		0.398			0.062
2,3',6-	27	tri					0.146
2,4,4'-	28	tri	0.000	0.327	0.348	0.516	
2,4,5-	29	tri					
2,4,6-	30	tri		0.427			0.084
2,4',5-	31	tri		0.364			
2,4',6-	32	tri					
2',3,4-	33	tri		0.346			
2',3,5-	34	tri					
3,3',4-	35	tri					
3,3',5-	36	tri					
3,4,4'-	37	tri					
3,4,5-	38	tri					
3,4',5-	39	tri		0.000			
2,2',3,3'-	40	tetra					
2,2',3,4-	41	tetra					0.146
2,2',3,4'-	42	tetra					
2,2',3,5-	43	tetra					
2,2',3,5'-	44	tetra		0.561			
2,2',3,6-	45	tetra					
2,2',3,6'-	46	tetra					
2,2',4,4'-	47	tetra	0.315	0.557	0.414	0.701	
2,2',4,5-	48	tetra					
2,2',4,5'-	49	tetra		0.660			0.121
2,2',4,6-	50	tetra	0.683	0.901	0.329	0.490	
2,2',4,6'-	51	tetra	0.560		1.000	0.516	
2,2',5,5'-	52	tetra	1.000	0.744	0.490	0.810	0.449
2,2',5,6'-	53	tetra	0.000				
2,2',6,6'-	54	tetra	0.000		0.000	0.000	
2,3,3',4-	55	tetra					
2,3,3',4'-	56	tetra					
2,3,3',5-	57	tetra					
2,3,3',5'-	58	tetra					
2,3,3',6-	59	tetra					
2,3,4,4'-	60	tetra					
2,3,4,5-	61	tetra					
2,3,4,6-	62	tetra					

Table 2 (continued)

PCB structure	IUPAC No.	CB	Kodavanti et al. (1995) ³ H Phorbol ester binding	Shain et al. (1991) DA release from PC12 cells	Kodavanti et al. (1996)		Pessah et al. (2006) Ryanodine binding
					Microsomal Ca ²⁺ release	Mitochondrial Ca ²⁺ release	
2,3,4',5-	63	tetra					
2,3,4',6-	64	tetra					
2,3,5,6-	65	tetra					
2,3',4,4'-	66	tetra					0.092
2,3',4,5-	67	tetra					
2,3',4,5'-	68	tetra					
2,3',4,6-	69	tetra		0.821			
2,3',4',5-	70	tetra					0.071
2,3',4',6-	71	tetra					
2,3',5,5'-	72	tetra					
2,3',5',6-	73	tetra					
2,4,4',5-	74	tetra					
2,4,4',6-	75	tetra		0.542			0.000
2',3,4,5-	76	tetra					
3,3',4,4'-	77	tetra	0.000		0.000	0.000	
3,3',4,5-	78	tetra					
3,3',4,5'-	79	tetra					
3,3',5,5'-	80	tetra	0.389		0.000	0.000	
3,4,4',5-	81	tetra					
2,2',3,3',4-	82	penta					
2,2',3,3',5-	83	penta					
2,2',3,3',6-	84	penta					0.524
2,2',3,4,4'-	85	penta					
2,2',3,4,5-	86	penta					
2,2',3,4,5'-	87	penta					
2,2',3,4,6-	88	penta					
2,2',3,4,6'-	89	penta					
2,2',3,4',5-	90	penta					
2,2',3,4',6-	91	penta					
2,2',3,5,5'-	92	penta					
2,2',3,5,6-	93	penta					
2,2',3,5,6'-	94	penta					
2,2',3,5',6-	95	penta					1.000
2,2',3,6,6'-	96	penta					0.500
2,2',3',4,5-	97	penta					
2,2',3',4,6-	98	penta					
2,2',4,4',5-	99	penta					
2,2',4,4',6-	100	penta		0.405			
2,2',4,5,5'-	101	penta					0.256
2,2',4,5,6'-	102	penta					
2,2',4,5',6-	103	penta		0.408			
2,2',4,6,6'-	104	penta	0.737	0.688	0.436	1.000	
2,3,3',4,4'-	105	penta	0.295		0.453	0.712	
2,3,3',4,5-	106	penta					
2,3,3',4',5-	107	penta					
2,3,3',4,5'-	108	penta					
2,3,3',4,6-	109	penta					
2,3,3',4',6-	110	penta					0.195
2,3,3',5,5'-	111	penta					0.046
2,3,3',5,6-	112	penta					
2,3,3',5',6-	113	penta					
2,3,4,4',5-	114	penta					
2,3,4,4',6-	115	penta					
2,3,4,5,6-	116	penta					
2,3,4',5,6-	117	penta					
2,3',4,4',5-	118	penta	0.000		0.364	0.516	
2,3',4,4',6-	119	penta					
2,3',4,5,5'-	120	penta					
2,3',4,5',6-	121	penta					
2',3,3',4,5-	122	penta					
2',3,4,4',5-	123	penta					0.000
2',3,4,5,5'-	124	penta					
2',3,4,5,6'-	125	penta					
3,3',4,4',5-	126	penta	0.000		0.000	0.000	0.000

(continued on next page)

Table 2 (continued)

PCB structure	IUPAC No.	CB	Kodavanti et al. (1995) ³ H Phorbol ester binding	Shain et al. (1991) DA release from PC12 cells	Kodavanti et al. (1996)		Pessah et al. (2006) Ryanodine binding
					Microsomal Ca ²⁺ release	Mitochondrial Ca ²⁺ release	
3,3',4,5,5'-	127	penta	0.000				
2,2',3,3',4,4'-	128	hexa	0.000		0.490	0.427	
2,2',3,3',4,5-	129	hexa					
2,2',3,3',4,5'-	130	hexa					
2,2',3,3',4,6-	131	hexa					
2,2',3,3',4,6'-	132	hexa					0.242
2,2',3,3',5,5'-	133	hexa	0.000		0.471	0.309	
2,2',3,3',5,6-	134	hexa					
2,2',3,3',5,6'-	135	hexa					
2,2',3,3',6,6'-	136	hexa	0.483		0.381	0.475	0.957
2,2',3,4,4',5-	137	hexa					
2,2',3,4,4',5'-	138	hexa					0.084
2,2',3,4,4',6-	139	hexa					
2,2',3,4,4',6'-	140	hexa					
2,2',3,4,5,5'-	141	hexa					
2,2',3,4,5,6-	142	hexa					
2,2',3,4,5,6'-	143	hexa					
2,2',3,4,5',6-	144	hexa					
2,2',3,4',6,6'-	145	hexa					
2,2',3,4',5,5'-	146	hexa					
2,2',3,4',5,6-	147	hexa					
2,2',3,4',5,6'-	148	hexa					
2,2',3,4',5',6-	149	hexa					0.667
2,2',3,4',5,6'-	148	hexa					
2,2',3,5,5',6-	151	hexa					0.440
2,2',3,5,6,6'-	152	hexa					
2,2',4,4',5,5'-	153	hexa	0.000				0.182
2,2',4,4',5,6'-	154	hexa					
2,2',4,4',6,6'-	155	hexa		0.410			
2,3,3',4,4',5-	156	hexa	0.000		0.444	0.644	
2,3,3',4,4',5'-	157	hexa					0.000
2,3,3',4,4',6-	158	hexa					
2,3,3',4,5,5'-	159	hexa					0.113
2,3,3',4,5,6-	160	hexa					
2,3,3',4,5',6-	161	hexa					
2,3,3',4',5,5'-	162	hexa					
2,3,3',4',5,6-	163	hexa					0.153
2,3,3',4',5',6-	164	hexa					
2,3,3',5,5',6-	165	hexa					
2,3,4,4',5,6-	166	hexa					
2,3',4,4',5,5'-	167	hexa					
2,3',4,4',5',6-	168	hexa					
3,3',4,4',5,5'-	169	hexa	0.000		0.000	0.000	
2,2',3,3',4,4',5-	170	hepta					0.301
2,2',3,3',4,4',6-	171	hepta		0.478			
2,2',3,3',4,5,5'-	172	hepta					
2,2',3,3',4,5,6-	173	hepta					
2,2',3,3',4,5,6'-	174	hepta					
2,2',3,3',4,5',6-	175	hepta					
2,2',3,3',4,6,6'-	176	hepta					0.579
2,2',3,3',4',5,6-	177	hepta					
2,2',3,3',5,5',6,-	178	hepta					
2,2',3,3',5,6,6'-	179	hepta					
2,2',3,4,4',5,5'-	180	hepta	0.000		0.500	0.712	0.229
2,2',3,4,4',5,6-	181	hepta		0.000			
2,2',3,4,4',5,6'-	182	hepta					
2,2',3,4,4',5',6-	183	hepta					0.400
2,2',3,4,4',6,6'-	184	hepta					
2,2',3,4,5,5',6-	185	hepta					
2,2',3,4,5,6,6'-	186	hepta					
2,2',3,4',5,5',6-	187	hepta					0.379

PCB188 through PCB209 were not included in the table because no effect data from these congeners is available. Also, these heavily chlorinated congeners are generally possess low or no efficacy regarding neurotoxic effects. Shading is used to facilitate reading across the columns.

Table 3

Average and surrogate NEQ values used to obtain relative toxicity estimates of the Aroclor mixtures

IUPAC No.	PCB structure	CB	Neurotoxic equivalent value (average of REPs)	No. of individual REP values supporting NEQ	Rationale and source for surrogate
4	2,2'-	di	0.515	5	Shain et al. (1991) Value lower than regression estimate
5	2,3'-	di	0.370	1	
6	2,3'-	di	0.370	1	
9	2,5'-	di	0.027	2	Shain et al. (1991) Value lower than regression estimate
10	2,6'-	di	0.480	1	
11	3,3'-	di	0.336	4	Svensgaard et al., 1997 regression estimate, value lower than Shain et al., 1991
13	3,4'-	di	0.053	1	
14	3,5'-	di	0.182	4	
15	4,4'-	di	0.000	3	
16	2,2',3'-	tri	0.495	0	Svensgaard et al. (1997), sole non-zero estimate
17	2,2',4'-	tri	0.495	0	
18	2,2',5'-	tri	0.495	2	PCB18 based on structural similarity and lower than Svensgaard et al. (1997) value
19	2,2',6'-	tri	0.381	3	
21	2,3,4'-	tri	0.000	1	PCB18 based on structural similarity and lower than Svensgaard et al. (1997) value
22	2,3,4'-	tri	0.416	0	
23	2,3,5'-	tri	0.230	0	Shain et al. (1991) lower than regression estimate
24	2,3,6'-	tri	0.237	2	
25	2,3',4'-	tri	0.195	1	Svensgaard et al. (1997), sole estimate
26	2,3',5'-	tri	0.230	2	
27	2,3',6'-	tri	0.240	1	PCB26 based on structural similarity and lower than Svensgaard et al. (1997) value
28	2,4,4'-	tri	0.298	4	
30	2,4,6'-	tri	0.255	2	Pessah et al. (2006) lower than regression estimate of Svensgaard et al. (1997)
31	2,4',5'-	tri	0.195	1	
32	2,4',6'-	tri	0.255	0	Svensgaard et al., 1997 regression estimate, value lower than Shain et al., 1991
33	2',3,4'-	tri	0.350	1	
37	3,4,4'-	tri	0.083	0	PCB30 based on structural similarity and lower than Svensgaard et al (1997) estimate
40	2,2',3,3'-	tetra	0.757	0	
41	2,2',3,4'-	tetra	0.769	1	Shain et al. (1991), value equal to regression estimate of Svensgaard et al. (1997)
42	2,2',3,4'-	tetra	0.797	0	
44	2,2',3,5'-	tetra	0.794	1	Svensgaard et al. (1997), sole estimate
45	2,2',3,6'-	tetra	0.891	0	
47	2,2',4,4'-	tetra	0.497	4	Svensgaard et al. (1997) sole estimate
48	2,2',4,5'-	tetra	0.807	0	
49	2,2',4,5'-	tetra	0.390	2	Svensgaard et al. (1997) sole estimate
50	2,2',4,6'-	tetra	0.601	4	
51	2,2',4,6'-	tetra	0.692	3	Svensgaard et al. (1997) sole estimate
52	2,2',5,5'-	tetra	0.699	5	
53	2,2',5,6'-	tetra	1.000	1	Svensgaard et al. (1997) estimate higher than that of Pessah et al. (2006)
54	2,2',6,6'-	tetra	0.000	3	
60	2,3,4,4'-	tetra	0.206	0	Svensgaard et al. (1997) sole estimate
64	2,3,4',6'-	tetra	0.378	0	
66	2,3',4,4'-	tetra	0.208	1	Svensgaard et al. (1997), sole estimate
68	2,3',4,5'-	tetra	0.209	0	
70	2,3',4',5'-	tetra	0.208	1	Svensgaard et al. (1997), estimate higher than that of Pessah et al. (2006)
74	2,4,4',5'-	tetra	0.208	0	
75	2,4,4',6'-	tetra	0.271	2	Svensgaard et al. (1997), sole estimate
77	3,3',4,4'-	tetra	0.000	3	

(continued on next page)

Table 3 (continued)

IUPAC No.	PCB structure	CB	Neurotoxic equivalent value (average of REPs)	No. of individual REP values supporting NEQ	Rationale and source for surrogate
80	3,3',5,5'-	tetra	0.130	3	
81	3,4,4',5-	tetra	0.130	0	Svensgaard et al. (1997), sole estimate
82	2,2',3,3',4-	penta	0.798	0	Svensgaard et al. (1997), sole estimate
86	2,2',3,4,5-	penta	0.687	0	Svensgaard et al. (1997), sole estimate
87	2,2',3,4,5'-	penta	0.508	0	Svensgaard et al. (1997), sole estimate
90	2,2',3,4',5-	penta	0.511	0	Svensgaard et al. (1997), sole estimate
91	2,2',3,4',6-	penta	0.991	0	Svensgaard et al. (1997), sole estimate
92	2,2',3,5,5'-	penta	0.506	0	Svensgaard et al. (1997), sole estimate
95	2,2',3,5',6-	penta	0.991	1	Svensgaard et al. (1997), value equal to that of Pessah et al. (2006)
97	2,2',3',4,5-	penta	0.508	0	Svensgaard et al. (1997), sole estimate
99	2,2',4,4',5-	penta	0.225	0	Svensgaard et al. (1997), sole estimate
104	2,2',4,6,6'-	penta	0.715	4	
105	2,3,3',4,4'-	penta	0.487	3	
110	2,3,3',4',6-	penta	0.971	1	Svensgaard et al. (1997), estimate higher than that of Pessah et al. (2006)
118	2,3',4,4',5-	penta	0.293	3	
126	3,3',4,4',5-	penta	0.000	4	
127	3,3',4,5,5'	penta	0.063	1	Svensgaard et al. (1997) estimate higher than that of Kodavanti et al. (1995)
128	2,2',3,3',4,4'-	hexa	0.306	3	
132	2,2',3,3',4,6'-	hexa	0.242	1	Pessah et al. (2006) value higher than regression estimate of Svensgaard et al. (1997)
133	2,2',3,3',5,5'-	hexa	0.260	3	
135	2,2',3,3',5,6'-	hexa	0.188	0	Svensgaard et al. (1997), sole estimate
136	2,2',3,3',6,6'-	hexa	0.574	4	
138	2,2',3,4,4',5'-	hexa	0.115	1	Svensgaard et al. (1997), estimate higher than that of Pessah et al. (2006)
141	2,2',3,4,5,5'-	hexa	0.115	0	Svensgaard et al. (1997), sole estimate
146	2,2',3,4',5,5'-	hexa	0.146	0	Svensgaard et al. (1997), sole estimate
149	2,2',3,4',5',6-	hexa	0.667	1	Pessah et al. (2006) value higher than regression estimate of Svensgaard et al. (2006)
151	2,2',3,5,5',6-	hexa	0.440	1	Pessah et al. (2006) value higher than regression estimate of Svensgaard et al. (2006)
153	2,2',4,4',5,5'-	hexa	0.091	2	
156	2,3,3',4,4',5-	hexa	0.363	3	
169	3,3',4,4',5,5'-	hexa	0.000	3	
170	2,2',3,3',4,4',5-	hepta	0.025	1	Svensgaard et al. (1997), estimate lower than that of Pessah et al. (2006)
171	2,2',3,3',4,4',6-	hepta	0.188	1	Svensgaard et al. (1997), estimate lower than that of Shain et al. (1991)
174	2,2',3,3',4,5,6'-	hepta	0.188	0	Svensgaard et al. (1997), sole estimate
177	2,2',3,3',4',5,6-	hepta	0.188	0	Svensgaard et al. (1997), sole estimate
178	2,2',3,3',5,5',6,-	hepta	0.188	0	Svensgaard et al. (1997), sole estimate
179	2,2',3,3',5,6,6'-	hepta	0.132	0	Svensgaard et al. (1997), sole estimate
180	2,2',3,4,4',5,5'-	hepta	0.360	4	
183	2,2',3,4,4',5',6-	hepta	0.188	1	Svensgaard et al. (1997), estimate lower than that of Pessah et al. (2006)
187	2,2',3,4',5,5',6-	hepta	0.188	1	Svensgaard et al. (1997), estimate lower than that of Pessah et al. (2006)
190	2,3,3',4,4',5,6-	hepta	0.018	0	Svensgaard et al. (1997), sole estimate

for each Aroclor mixture in the mixture NEQ and represents a measure of neurotoxicity relative to PCB-53, the most potent neurotoxic congener in the present scheme.

Table 7 shows the neurotoxic potencies, TEQ and adjusted RfDs relative to Aroclor 1254 (USEPA, 1996a). For Aroclor 1254, the mixture NEQ value is 0.354; hence, each mg of Aroclor 1254 would contain 0.354 mg Neurotoxic Equivalents. If one considers NEQ-related effects only, the RfD value for Aroclor 1254 expressed as NEQ would be $0.354 \times 2E-05$ mg/kg-day or $7E-06$ mg NEQ/kg-day or $7E-06$ mg PCB-53 equivalents/kg-day. However, because Aroclor 1254 contains over 4 ppm DL TEQ, TEQ related effects were also considered as a

possible contributor to the neurotoxicity of this mixture (Kodavanti et al., 2001; Rushneck et al., 2004). Hence, NEQ and TEQ for the various mixtures relative to Aroclor 1254 were determined (columns 4 and 5 of Table 7). The geometric mean of the relative TEQ and NEQ concentrations in the mixtures was used to adjust the RfD value. This procedure acknowledges the fact that TEQ present in the mixture may contribute to some neurotoxic effects observed (Agrawal et al., 1981; Tilson et al., 1990; Eriksson, 1988; Eriksson et al., 1991; Chou et al., 1979). Expressing the RfD of the mixtures as a combination of NEQ and TEQ does not permit the value to be expressed in terms of PCB-53 alone.

Table 4
Congener composition of aroclor mixtures

PCB structure	IUPAC No.	CB	A1016 (%)	A1221 (%)	A1232 (%)	A1242 (%)	A1248 (%)	A1254 (%)	A1260 (%)	A1262 (%)	A1268 (%)
Biphenyl				2.95	2.38						
2-	1	mono		33.25	15.82						
3-	2	mono		2.01	1.02						
4-	3	mono		19.07	9.09						
2,2'-	4	di	1.91	3.59	2.01	1.46					
2,3-	5	di	3.26	2.88	1.98	1.60					
2,3'-	6	di	1.07	2.00	1.13						
2,4-	7	di	1.14	1.45							
2,4'-	8	di	1.59	8.40	6.55	3.95					
2,5-	9	di	4.47	2.14	1.37						
2,6-	10	di	2.09	4.06	2.48	1.90					
3,3'-	11	di									
3,4-	12	di									
3,4'-	13	di		1.22							
3,5-	14	di									
4,4'-	15	di	2.46	2.45	3.11	2.42					
2,2',3-	16	tri	1.39		1.69	3.19	1.21				
2,2',4-	17	tri	5.51		2.52	3.02	1.03				
2,2',5-	18	tri	3.45		2.84	7.21	3.06				
2,2',6-	19	tri									
2,3,3'-	20	tri	3.48		1.05	1.52	1.12				
2,3,4-	21	tri	1.99								
2,3,4'-	22	tri	7.95		2.03	3.42	2.02				
2,3,5-	23	tri									
2,3,6-	24	tri									
2,3',4-	25	tri	1.09								
2,3',5-	26	tri	1.21		1.06	1.57					
2,3',6-	27	tri	4.95								
2,4,4'-	28	tri	5.57		3.71	6.77	5.08				
2,4,5-	29	tri									
2,4,6-	30	tri	1.19								
2,4',5-	31	tri	2.70		2.70	5.20	3.61				
2,4',6-	32	tri	4.24			1.17					
2',3,4-	33	tri	1.90		2.11	4.04	2.01				
2',3,5-	34	tri									
3,3',4-	35	tri									
3,3',5-	36	tri									
3,4,4'-	37	tri				1.44					
3,4,5-	38	tri									
3,4',5-	39	tri									
2,2',3,3'-	40	tetra					1.15				
2,2',3,4-	41	tetra	1.15			1.19	1.24				
2,2',3,4'-	42	tetra	1.53		1.17	1.98	2.64				
2,2',3,5-	43	tetra									
2,2',3,5'-	44	tetra	1.93		1.70	3.00	4.29	2.08			
2,2',3,6-	45	tetra	1.20				1.02				
2,2',3,6'-	46	tetra									
2,2',4,4'-	47	tetra					2.59				
2,2',4,5-	48	tetra				1.32					
2,2',4,5'-	49	tetra	1.49		1.35	2.33	3.54	1.28			
2,2',4,6-	50	tetra									
2,2',4,6'-	51	tetra									
2,2',5,5'-	52	tetra	2.72		2.08	3.62	5.75	3.98			
2,2',5,6'-	53	tetra	1.57			1.45	1.22				
2,2',6,6'-	54	tetra									
2,3,3',4-	55	tetra									
2,3,3',4'-	56	tetra									
2,3,3',5-	57	tetra									
2,3,3',5'-	58	tetra									
2,3,3',6-	59	tetra									
2,3,4,4'-	60	tetra	2.27			1.13	2.12				
2,3,4,5-	61	tetra									
2,3,4,6-	62	tetra									
2,3,4',5-	63	tetra									
2,3,4',6-	64	tetra	1.15		1.27	2.32	3.44				

(continued on next page)

PCB structure	IUPAC No.	CB	A1016 (%)	A1221 (%)	A1232 (%)	A1242 (%)	A1248 (%)	A1254 (%)	A1260 (%)	A1262 (%)	A1268 (%)
2,3,5,6-	65	tetra									
2,3',4,4'-	66	tetra			1.37	2.52	5.41	5.52			
2,3',4,5-	67	tetra									
2,3',4,5'-	68	tetra	1.68								
2,3',4,6-	69	tetra									
2,3',4',5-	70	tetra			1.66	3.02	5.45	3.74			
2,3',4',6-	71	tetra									
2,3',5,5'-	72	tetra									
2,3',5',6-	73	tetra									
2,4,4',5-	74	tetra	2.65		1.09	1.77	3.66	1.19			
2,4,4',6-	75	tetra									
2',3,4,5-	76	tetra									
3,3',4,4'-	77	tetra						1.79			
3,3',4,5-	78	tetra									
3,3',4,5'-	79	tetra									
3,3',5,5'-	80	tetra									
3,4,4',5-	81	tetra									
2,2',3,3',4-	82	penta						1.60			
2,2',3,3',5-	83	penta									
2,2',3,3',6-	84	penta					1.08	1.68			
2,2',3,4,4'-	85	penta									
2,2',3,4,5-	86	penta									
2,2',3,4,5'-	87	penta					2.11	3.15			
2,2',3,4,6-	88	penta									
2,2',3,4,6'-	89	penta									
2,2',3,4',5-	90	penta						4.19	1.16		
2,2',3,4',6-	91	penta						1.34			
2,2',3,5,5'-	92	penta						2.01			
2,2',3,5,6-	93	penta									
2,2',3,5,6'-	94	penta									
2,2',3,5',6-	95	penta				1.37	4.61	1.37	1.34		
2,2',3,6,6'-	96	penta									
2,2',3',4,5-	97	penta						1.73			
2,2',3',4,6-	98	penta									
2,2',4,4',5-	99	penta					1.38	2.97			
2,2',4,4',6-	100	penta									
2,2',4,5,5'-	101	penta									
2,2',4,5,6'-	102	penta									
2,2',4,5',6-	103	penta									
2,2',4,6,6'-	104	penta									
2,3,3',4,4'-	105	penta					1.31	5.46			
2,3,3',4,5-	106	penta									
2,3,3',4',5-	107	penta									
2,3,3',4,5'-	108	penta									
2,3,3',4,6-	109	penta									
2,3,3',4',6-	110	penta					1.82	7.37	1.35		
2,3,3',5,5'-	111	penta									
2,3,3',5,6-	112	penta									
2,3,3',5',6-	113	penta									
2,3,4,4',5-	114	penta									
2,3,4,4',6-	115	penta									
2,3,4,5,6-	116	penta									
2,3,4',5,6-	117	penta									
2,3',4,4',5-	118	penta					2.11	10.60			
2,3',4,4',6-	119	penta									

Table 4 (continued)

PCB structure	IUPAC No.	CB	A1016 (%)	A1221 (%)	A1232 (%)	A1242 (%)	A1248 (%)	A1254 (%)	A1260 (%)	A1262 (%)	A1268 (%)
2,2',3,3',4,4'-	128	hexa									
2,2',3,3',4,5-	129	hexa									
2,2',3,3',4,5'-	130	hexa									
2,2',3,3',4,6-	131	hexa									
2,2',3,3',4,6'-	132	hexa						3.14	3.91	1.89	
2,2',3,3',5,5'-	133	hexa									
2,2',3,3',5,6-	134	hexa						1.14	1.78	1.30	
2,2',3,3',5,6'-	135	hexa							1.71	1.18	
2,2',3,3',6,6'-	136	hexa									
2,2',3,4,4',5-	137	hexa									
2,2',3,4,4',5'-	138	hexa						3.61	8.10	4.14	
2,2',3,4,4',6-	139	hexa									
2,2',3,4,4',6'-	140	hexa									
2,2',3,4,5,5'-	141	hexa						1.04	2.09	1.16	
2,2',3,4,5,6-	142	hexa									
2,2',3,4,5,6'-	143	hexa									
2,2',3,4,5',6-	144	hexa									
2,2',3,4',6,6'-	145	hexa									
2,2',3,4',5,5'-	146	hexa							1.18		
2,2',3,4',5,6-	147	hexa									
2,2',3,4',5,6'-	148	hexa									
2,2',3,4',5',6-	149	hexa						2.95	7.80	5.96	
2,2',3,4',5,6'-	150	hexa									
2,2',3,5,5',6-	151	hexa							3.40	3.37	
2,2',3,5,6,6'-	152	hexa									
2,2',4,4',5,5'-	153	hexa						3.72	8.14	6.60	
2,2',4,4',5,6'-	154	hexa									
2,2',4,4',6,6'-	155	hexa									
2,3,3',4,4',5-	156	hexa						1.85			
2,3,3',4,4',5'-	157	hexa									
2,3,3',4,4',6-	158	hexa									
2,3,3',4,5,5'-	159	hexa									
2,3,3',4,5,6-	160	hexa									
2,3,3',4,5',6-	161	hexa									
2,3,3',4',5,5'-	162	hexa									
2,3,3',4',5,6-	163	hexa									
2,3,3',4',5',6-	164	hexa									
2,3,3',5,5',6-	165	hexa									
2,3,4,4',5,6-	166	hexa									
2,3',4,4',5,5'-	167	hexa									
2,3',4,4',5',6-	168	hexa									
3,3',4,4',5,5'-	169	hexa									
2,2',3,3',4,4',5-	170	hepta							2.90	2.30	
2,2',3,3',4,4',6-	171	hepta							1.16	1.03	2.78
2,2',3,3',4,5,5'-	172	hepta									
2,2',3,3',4,5,6-	173	hepta									
2,2',3,3',4,5,6'-	174	hepta						1.50	4.14	5.44	
2,2',3,3',4,5',6-	175	hepta									
2,2',3,3',4,6,6'-	176	hepta									
2,2',3,3',4',5,6-	177	hepta							2.54	2.79	
2,2',3,3',5,5',6,-	178	hepta								1.30	
2,2',3,3',5,6,6'-	179	hepta							1.91	1.82	
2,2',3,4,4',5,5'-	180	hepta							8.91	12.70	1.14
2,2',3,4,4',5,6-	181	hepta									
2,2',3,4,4',5,6'-	182	hepta									
2,2',3,4,4',5',6-	183	hepta							2.58	2.88	
2,2',3,4,4',6,6'-	184	hepta									
2,2',3,4,5,5',6-	185	hepta									
2,2',3,4,5,6,6'-	186	hepta									
2,2',3,4',5,5',6-	187	hepta							4.51	7.60	3.79
2,2',3,4',5,6,6'-	188	hepta									
2,3,3',4,4',5,5'-	189	hepta									
2,3,3',4,4',5,6-	190	hepta							1.64	1.47	
2,3,3',4,4',5',6-	191	hepta									

(continued on next page)

Table 4 (continued)

PCB structure	IUPAC No.	CB	A1016 (%)	A1221 (%)	A1232 (%)	A1242 (%)	A1248 (%)	A1254 (%)	A1260 (%)	A1262 (%)	A1268 (%)
2,3,3',4,5,5',6-	192	hepta									
2,3,3',4',5,5',6-	193	hepta									
2,2',3,3',4,4',5,5'-	194	octa							1.80	3.85	3.19
2,2',3,3',4,4',5,6-	195	octa								1.12	6.12
2,2',3,3',4,4',5,6'-	196	octa								1.52	5.67
2,2',3,3',4,4',6,6'-	197	octa									
2,2',3,3',4,5,5',6-	198	octa									
2,2',3,3',4,5,5',6'-	199	octa								2.80	
2,2',3,3',4,5,6,6'-	200	octa									1.46
2,2',3,3',4,5',6,6'-	201	octa						1.36	3.05		14.92
2,2',3,3',5,5',6,6'-	202	octa							1.04		2.78
2,2',3,4,4',5,5',6-	203	octa						1.56	3.70		5.67
2,2',3,4,4',5,6,6'-	204	octa									
2,3,3',4,4',5,5',6-	205	octa									
2,2',3,3',4,4',5,5',6-	206	nona								1.66	28.70
2,2',3,3',4,4',5,6,6'-	207	nona									2.47
2,2',3,3',4,5,5',6,6'-	208	nona									6.12
2,2',3,3',4,4',5,5',6,6'-	209	deca									8.12

Only those congeners comprising >1% of the mixtures are shown. Shading is used to facilitate reading across the columns.

Table 5
NEQ values representing PCB homologues

Homologue	NEQ (mg/mg homologue)
DiCB	0.184
TriCB	0.284
TetraCB	0.383
PentaCB	0.541
HexaCB	0.31
HeptaCB	0.205

See text for details of calculation.

Table 6
Values for relative potency (Kodavanti, 2005) and normalized neurotoxic equivalents for three Aroclor mixtures

PCB mixture	Relative potency from Kodavanti et al. (1995, 1996) and Kodavanti (2005)	Neurotoxic equivalent normalized to 0.500
Aroclor 1016	0.394	0.387
Aroclor 1254	0.500	0.500
Aroclor 1260	0.280	0.292

Table 7
Neurotoxic potency of Aroclor mixtures and adjusted RfDs relative to Aroclor 1254

Mixture	Dioxin-like TEQ (mg/kg Aroclor)	NEQ (mg/mg Aroclor)	TEQ relative to Aroclor 1254	NEQ relative to Aroclor 1254	Geometric Mean of relative TEQ and relative NEQ	Adjusted RfD (mg PCB/kg-day)
Aroclor 1016	0.07	0.282	0.016	0.797	0.114	2.E–04
Aroclor 1221	0.037	0.057	0.009	0.161	0.037	5.E–04
Aroclor 1232	2.57	0.16	0.600	0.452	0.521	4.E–05
Aroclor 1242	4.03	0.304	0.942	0.859	0.899	2.E–05
Aroclor 1248	10.37	0.363	2.423	1.025	1.576	1.E–05
Aroclor 1254	4.28	0.354	1.000	1.000	1.000	2.E–05
Aroclor 1260	0.54	0.207	0.127	0.585	0.272	7.E–05
Aroclor 1262	0.48	0.169	0.112	0.477	0.231	9.E–05
Aroclor 1268	0.27	0.016	0.064	0.045	0.053	4.E–04

Table 8 shows a similar analysis using Aroclor 1016 as the basis for adjusting the RfD values of the other mixtures (USEPA, 1996b). Because Aroclor 1016 contains only tiny amounts of TEQ, adjusting RfDs for other Aroclor mixtures that contain much greater amounts of TEQ would bias the adjusted RfD specific for neurotoxicity toward the TEQ contribution. RfD values for all the Aroclors expressed in terms of total PCBs relative to that for Aroclor 1016 are shown in the seventh and eighth columns of Table 8. The seventh column (shaded) shows the adjusted RfD values based on the geometric mean of the relative concentrations of NEQ and TEQ. The eighth column shows the adjusted RfD values based on NEQ only. Hence, mixture specific RfDs derived on the basis of Aroclor 1016 use their respective NEQ values only. This approach provides results that are much more consistent with those obtained using Aroclor 1254 as the adjustment mixture.

2.3.1. Consistency in the predicted RfD values

The relative potency ratios between the various Aroclor mixtures do indeed seem to be well predicted by their relative NEQ concentrations when adjusted to Aroclor 1016 and by the geometric mean of the relative NEQ and TEQ concentrations when adjusted to Aroclor 1254. The largest difference in the adjusted RfD values is observed with Aroclor 1248, a 5-fold difference (1E–05 in Table 7 versus 5E–05 in Table 8). This difference is due mainly to the 2.5-fold larger amount of TEQ in Aroclor 1248

Table 8
Neurotoxic potency of Aroclor mixtures and adjusted RfDs relative to Aroclor 1016

Mixture	Dioxin-like TEQ (mg/kg Aroclor)	NEQ (mg/mg Aroclor)	TEQ relative to Aroclor 1016	NEQ relative to Aroclor 1016	Geometric mean of relative TEQ and relative NEQ	Adjusted RfD based on Geo. mean of NEQ and TEQ (mg/PCB/kg-day)	Adjusted RfD (mg PCB/kg-day)
Aroclor 1016	0.07	0.282	1	1	1	<i>7.E–05</i>	7.E–05
Aroclor 1221	0.037	0.057	0.529	0.202	0.327	<i>2.E–04</i>	3.E–04
Aroclor 1232	2.57	0.16	36.7	0.567	4.56	<i>2.E–05</i>	1.E–04
Aroclor 1242	4.03	0.304	57.6	1.08	7.88	<i>9.E–06</i>	6.E–05
Aroclor 1248	10.37	0.363	148.1	1.29	13.8	<i>5.E–06</i>	5.E–05
Aroclor 1254	4.28	0.354	61.1	1.26	8.76	<i>8.E–06</i>	6.E–05
Aroclor 1260	0.54	0.207	7.71	0.734	2.38	<i>3.E–05</i>	1.E–04
Aroclor 1262	0.48	0.169	6.86	0.599	2.03	<i>3.E–05</i>	1.E–04
Aroclor 1268	0.27	0.016	3.86	0.057	0.468	<i>2.E–04</i>	1.E–03

* Because the TEQ content of Aroclor 1016 was extremely low relative to the other mixtures, adjustment of the Aroclor 1016 RfD was based on the NEQ concentration only. This is shown by comparison of column 7 (italicized) and column 8 of Table 6 above.

compared to Aroclor 1254 and the 3.5-fold difference in the published reference doses for Aroclor 1016 and Aroclor 1254 (USEPA, 1996a,b). Note that the relative amounts of NEQ in Aroclor 1016, Aroclor 1248 and Aroclor 1254 are very similar (column 5 in Tables 7 and 8). Also note that the differences in the mixture RfD values for the Aroclor mixtures other than Aroclor 1248 are within a factor of 3.

In fact, there is striking consistency between the two sets of values, and this fact suggests that even though the NEQ scheme is new, it can make reasonable predictions of the relative toxicity of various PCB mixtures. The other interesting implication is that TEQ may make little difference. Adjusting the RfD values based on the RfD of Aroclor 1254 and using NEQ only gives values that are also within 3 fold of those based on Aroclor 1016. However, because extant laboratory studies suggest that TEQ may have an effect on neurotoxicity, TEQ were included when adjusting using Aroclor 1254 (Agrawal et al., 1981; Tilson et al., 1990; Eriksson, 1988; Eriksson et al., 1991; Chou et al., 1979).

2.4. Comparison of predicted mixture estimates with results of neurotoxicity and neurobehavioral assays

There is more than ample evidence that single PCB congeners and PCB mixtures affect the brain and nervous system via a Ca^{2+} -dependent mechanism (reviews in Kodavanti and Tilson, 2000; Kodavanti, 2004, 2005; see also Hong et al., 1998; Inglefield and Shafer, 2000; Bushnell et al., 2002; Basha et al., 2006).

Kodavanti et al. (2001) showed that two different lots of Aroclor 1254 contained different amounts of TEQ but had similar potency regarding intracellular Ca^{2+} buffering in rat cerebellar granule cells. Using the NEQ scheme and the composition of the two lots, the relative amounts of NEQ in each was about equal (360 mg/g for lot 124–191 versus 382 mg/g for lot 6024) whereas there was about 50- to 100-fold more TEQ in lot 6024. Measured mean IC_{50} values for microsomal Ca^{2+} buffering were 1.65 $\mu\text{g}/\text{ml}$ and 1.23 $\mu\text{g}/\text{ml}$ for lot 124–191 and lot 6024, respectively. Measured mean IC_{50} values for mitochondrial Ca^{2+} buffering were 1.78 $\mu\text{g}/\text{ml}$ and 1.47 $\mu\text{g}/\text{ml}$ for lot 124–191 and lot 6024, respectively. The similarity of these binding results between the two lots and the fact that lot 6024 is slightly more potent than lot 124–191 are predicted much more accurately by the NEQ scheme than the TEF scheme.

When measured by phorbol ester binding reflective of PKC translocation, the neurochemical potency of lot 124–191 was about 2.5-fold greater than lot 6024 (Kodavanti et al., 2001). At this point in time, it cannot be determined whether a 2.5 fold difference, when the NEQ values predict essentially the same potency, suggests that an additional mode of action may be involved with changes in PKC translocation produced by PCBs. However, this result is not predicted by the TEQ content of the mixtures and is still more closely predicted by the NEQ scheme. Should this small difference be ultimately shown to reflect that another mode of action is present, it only serves to support one of our reasons for proposing an

NEQ scheme now, i.e., to begin to determine which effects are predicted by the NEQ scheme and which effects have modes of action that require an additional REP scheme be developed.

Wong and Pessah (1996) reported that Aroclors 1242, 1254, and 1260 increased binding of radiolabeled ryanodine to its receptor site with high potency (EC_{50} values = 1.3, 1.4 and 1.3 μM , respectively) while Aroclors 1221, 1232, and 1268 show about 5–10 fold lower activity. These results are also predicted by the NEQ scheme – the NEQ concentrations in Aroclors 1242, 1254, and 1260 are up to 10-fold higher than the NEQ concentrations in Aroclors 1221, 1232, and 1268.

In a study of hyperactivity and impulsiveness in rats fed either Aroclor 1248 or contaminated fish from the Saint Lawrence River in Quebec, Berger et al. (2001) found comparable behavioral deficits in both groups relative to a control group. The deficits observed from Aroclor 1248 exposure were slightly but not significantly greater than from contaminated fish consumption. Using analytical PCB data from Canadian fish obtained in Quebec (LaFontaine et al., 2002), the total NEQ for these fish was determined to be 0.309 mg NEQ/mg mixture and for Aroclor 1248 is 0.363 mg NEQ/mg Aroclor, consistent with the results of Berger et al. (2001).

3. Discussion

In recent years, research on the effects of PCBs has been directed toward an elucidation of the cellular and biochemical effects that contribute to a systems biology type of approach to the total organismal effects of PCBs (e.g., Rochfort, 2005; Kell, 2006). USEPA's Cancer Guidelines and the recent interim policy on the use of genomics in risk assessment also endorse such a systems biology approach (USEPA, 2004a,b,c, 2005). The NEQ scheme for predicting the neurotoxicity of PCB congeners and mixtures developed in this paper is consistent with such a systems biology approach.

There are at least two modes of action of PCB toxicity. At present, environmental regulatory agencies have methods to use TEQ present in PCB mixtures to predict toxicity but do not have a method to predict the toxicity of the NDL congeners. The NEQ scheme shows great consistency with results from *in vitro* studies (Basha et al., 2006; Eriksson 1988; Eriksson et al., 1991; Gore et al., 2002; Hong et al., 1998; Inglefield and Shafer, 2000; Kholkute et al., 1994; Kodavanti et al., 1995, 1996, 2001; Mariussen

et al., 1999, 2001, 2002, 2003; Pessah et al., 2006; Sanchez-Alonso et al., 2004; Seegal et al., 1990a,b; Tan et al., 2004; Wong and Pessah, 1996; Wong et al., 1997) and from whole animal experiments (Agrawal et al., 1981; Arnold et al., 1993a,b; Barsotti et al., 1976; Barsotti and Van Miller, 1984; Bushnell et al., 2002; Chou et al., 1979; Freeman et al., 2000; Harris et al., 1993; Kodavanti and Tilson, 2000; Levin et al., 1988; Lillie et al., 1974; Rice, 1997; Schantz et al., 1989, 1991, 1997; Tryphonas et al., 1989, 1991a,b). The NEQ scheme also predicted the relative potency of an environmental PCB mixture such as a fish compared with a commercial mixture (Berger et al., 2001). Because of the current, apparent consistency of the approach, regulatory agencies may in time adopt the NEQ scheme (or some variant) as an additional method of addressing noncancer effects of environmental PCB mixtures.

The scheme set forth here builds upon and extends the pioneering work of Svensgaard et al. (1997) and Tilson and Kodavanti (1997). At the present time, data on a larger number of endpoints are available and were used to support the NEQ scheme, although the concept of this scheme is not new.

Similar to the TEQ scheme for DL compounds, the underlying assumption of the NEQ scheme is that differences in congener potency measured *in vitro* reflect the congener potency differences at the organismal level. Others have suggested that noncancer effects like low birth weight, neurodevelopmental effects, and immunological changes may be related to disturbances in Ca^{2+} homeostasis (Kodavanti, 2004, 2005; Wong and Pessah, 1996). However, changes in Ca^{2+} homeostasis is only one in a range of effects observed *in vitro* (e.g., Voie and Fonnum, 1998; Voie et al., 1998, 2000; Chauhan et al., 2000). The exact relationship between the range of *in vitro* effects and organism-level effects remains to be determined; however, as more whole animal and *in vitro* studies are conducted, the predictive power of the NEQ scheme can be evaluated further, as well as the need for additional equivalence schemes based on other modes of action.

We recognize that the NEQ scheme is new and untested. This infant scheme will no doubt be improved by additional data and more sophisticated application of the scheme. One such sophisticated application might be the consideration of whole animal effects and pharmacokinetics. For example, some PCB congeners preferentially accumulate in brain tissues (Kodavanti et al., 1998; Saghir et al., 2000; Kania-Korwel et al., 2005). However, a comparison of the *in vivo* effects of various PCB congeners and mixtures and the NEQ scheme reveals that, even without consideration of pharmacokinetics, this scheme is remarkably consistent with *in vivo* data (e.g., Harris et al., 1993; Berger et al., 2001). Ideally, the NEQ scheme could be used in conjunction with physiologically-based pharmacokinetic models to estimate the potential effects of neurotoxic PCBs on the brain and on other specific tissues. In such a case, it would be preferable to apply the

NEQ values to tissue concentrations than to administered doses or environmental concentrations, similar to the recent caution regarding application of TEFs for DL compounds (Van den Berg et al., 2006). We also recognize that the NEQ scheme is likely applicable to chemicals structurally related to PCBs, such as polybrominated diphenyl ethers (PBDEs). Indeed, EC_{50} values are available for a number of PBDEs and DDT (Kodavanti, 2005) and these could be included in the NEQ scheme in much the same way that the dioxin TEQ scheme includes coplanar PCBs.

Ideally, we would wish to compare results of neurobehavioral assays in whole animals treated with various PCB mixtures. Then the NEQ totals for the body burden mixtures could be determined using the NEQ values for individual congeners (Table 3). Development of toxicity criterion could then be based on a measure of exposure and threshold effect such as an ED_{10} developed as a benchmark dose.

Unfortunately, the extant studies on whole animals do not provide sufficient detail for this comparison to be made. Bushnell et al. (2002) performed a behavioral dose–response study in rats but used Aroclor 1254 as the only toxicant. Levin et al. (1988) found deficits in delayed spatial alternation in monkeys exposed to Aroclor 1016 and Aroclor 1254 *in utero* and for four months after birth. Schantz et al. (1989) observed effects in a two-choice discrimination reversal learning test in monkeys whose mothers had been given either Aroclor 1016 or Aroclor 1248 for 7 months prior to breeding. Rice (1997) exposed monkeys from birth until 20 weeks of age to a mixture of PCB congeners typically found in human breast milk. These monkey studies found neurobehavioral deficits, but because of the lack of a range of doses and the use of different exposure patterns, the monkey studies are difficult to compare in a quantitative fashion. Nonetheless, both the dose–response and the effects of Aroclor 1016 and Aroclor 1254 appear to be quite similar in a number of studies (Arnold et al., 1993a,b; Barsotti et al., 1976; Barsotti and Van Miller, 1984; Bushnell et al., 2002; Freeman et al., 2000; Harris et al., 1993; Levin et al., 1988; Lillie et al., 1974; Tryphonas et al., 1986, 1989, 1991a,b). It is interesting to note that this similarity is predicted by the NEQ scheme proposed here, but not by the TEF scheme.

We also recognize that weathering within a homologue group may produce a different congener composition than the Aroclor mixture averages used here to obtain the homologue-specific NEQ-values (Table 4 and Table 5). In some specific instances, there may be a need to develop different homologue-specific NEQ values than those in Table 5. The NEQ scheme presented here is sufficiently flexible to accommodate these changes and the homologue-specific NEQ values may change as more becomes known about weathering of PCB mixtures in the environment.

We recognize that the data in Tables 1–3 are far from complete, and that more data are needed to implement a full NEQ scheme. The assumptions for choosing surrogate values or depending on the empirical Bayes statistical

estimate in cases where no data were available in Table 3 reflect a transparent, albeit speculative and arbitrary, decision process. Undoubtedly, the recommended NEQ values will change as more data become available. Despite any limitations of the data currently available, however, as shown in Section 2 of this paper, there is presently a strong consistency between the predictions of the NEQ scheme and the potency of PCB congeners and mixtures measured both *in vivo* and *in vitro*. This in turn suggests that the proposed NEQ scheme is a reasonable approach to consider, refine, and continue to test.

Deriving an NEQ scheme acceptable for the regulatory community would enable the consideration of changes in the NDL composition of environmental PCB mixtures rather than limiting the focus to changes in coplanar congener composition only (e.g., see Blankenship et al., 2005; Borja et al., 2005). The NEQ scheme can be applied to both commercial Aroclor mixtures having different chlorine compositions as well as environmentally weathered PCB mixtures. Using the homologue-specific NEQ values enables risk assessors to use cost-effective homologue analysis rather than the much more expensive congener analysis. Assessment of the neurotoxic potential of PCBs is all the more important, since there is currently no credible regulatory toxicity criterion for DL chemicals (National Academy of Sciences, 2006).

Given the increasing importance of the neurotoxic endpoint in future risk assessments, the authors of this paper encourage other researchers to expand both the number of congeners examined as well as the number of endpoints being studied. Increasing the robustness of the available database would allow the use of the approach adopted here to characterize the NEQ point estimates more fully and to develop probability distributions of the NEQ values (e.g., Finley et al., 2003; Haws et al., 2006; Staskal et al., 2006; Van den Berg et al., 2006). Probability distributions will also enable the use of a consistent percentile or point of departure for future NEQ point estimates. Additional supporting data might also help determine whether additional modes of actions, with different organism-level endpoints and separate congener equivalence schemes, are needed.

The Neurotoxic Equivalence (NEQ) scheme indicates that the Aroclors 1221, 1260, 1262, and 1268 are less toxic than Aroclor 1254 or Aroclor 1016. This prediction is similar to predictions that could be made using the dioxin TEF scheme. Hence, more data and analysis will be needed to understand and separate potentially neurotoxic effects based solely on Ah-binding and those based on the effects used to develop the NEQ scheme.

Although in its infancy, the NEQ scheme will enable scientists and risk assessors to determine the potential for neurotoxic outcomes or other endpoints to be predicted for different mixtures. Where the prediction is consistent with observed changes at the whole animal level, such data would suggest the mechanisms for those toxic effects are likely an extension of the effects used to generate the NEQ scheme. In cases where the predictions are not consis-

tent with observed effects, then other modes of action may be operative and other mechanisms should be studied. Using the NEQ scheme in this manner should eventually indicate which toxic effects of the NDL congeners can be predicted by this scheme and thus enable the use of this scheme for assessing the risks for those endpoints produced by the NDL congeners in a particular mixture. The remaining congeners for which the TEQ and the NEQ predictions do not apply could be identified and then become a future area of study.

We believe this proposed NEQ scheme will likely produce three beneficial outcomes. First, we expect the proposal of this NEQ scheme to foster open discussion as to how different modes of action can be utilized to predict congener potency differences for the various effects they produce. Second, we expect that evaluation and scrutiny of the ability of proposed NEQ scheme to predict the toxicity of PCB mixtures will assist in the identification of other specific modes of action underlying the effects produced by PCBs. Third, we anticipate that providing a quantitative scheme to begin assessing the toxicity of the non-coplanar PCB congeners present in a mixture will significantly improve future risk assessments of PCB mixtures and provide a better understanding of the associated uncertainties.

Acknowledgments

This work was partially funded by Honeywell International, Inc. and the SouthWire Company. The authors have researched the toxicology and risk assessment issues of PCBs and dioxins for many years and have provided consultations to various private and public sector clients regarding toxicology, risk assessment and the interpretation of scientific information. One of the authors (RCJ) has been an expert witness for Honeywell. However, the conceptualization and interpretation of the analyses contained in this paper and conclusions offered here are those of the authors alone.

References

- Agrawal, A.K., Tilson, H.A., Bondy, S.C., 1981. 3,4,3',4'-Tetrachlorobiphenyl given to mice prenatally produces long-term decreases in striatal dopamine and receptor binding sites in the caudate nucleus. *Toxicol. Lett.* 7, 417–424.
- Anderson, J.W., 1991. Determination of congeners of polychlorinated biphenyls in reference materials. *J. High. Res. Chromatogr.* 14, 369–372.
- Arnold, D.L., Bryce, F., Karpinski, K., Mes, J., Fernie, S., Tryphonas, H., Truelove, J., McGuire, P.F., Burns, D., Tanner, J.R., Stapley, R., Zawidzka, Z.Z., Basford, D., 1993a. Toxicological consequences of Aroclor 1254 ingestion by female rhesus (*Macaca mulatta*) monkeys. Part 1B. Prebreeding phase: clinical and analytical laboratory findings. *Food Chem. Toxicol.* 31 (11), 811–824.
- Arnold, D.L., Bryce, F., Stapley, R., McGuire, P.F., Burns, D., Tanner, J.R., Karpinski, K., 1993b. Toxicological consequences of Aroclor 1254 ingestion by female rhesus (*Macaca mulatta*) monkeys. Part 1A. Prebreeding phase: Clinical health findings. *Food Chem. Toxicol.* 31 (11), 799–810.

- Barsotti, D.A., Marlar, R.J., Allen, J.R., 1976. Reproductive dysfunction in rhesus monkeys exposed to low levels of polychlorinated biphenyls (Aroclor 1248). *Food Cosmet. Toxicol.* 14, 99.
- Barsotti, D.A., Van Miller, J.P., 1984. Accumulation of a commercial polychlorinated biphenyl mixture (Aroclor 1016) in adult Rhesus Monkeys and their nursing infants. *Toxicology* 30, 31–44.
- Basha, M.R., Braddy, N.S., Zawia, N.H., Kodavanti, P.R.S., 2006. Ontogenetic alterations in prototypical transcription factors in the rat cerebellum and hippocampus following perinatal exposure to a commercial PCB mixture. *Neurotoxicology* 27, 118–124.
- Berger, D.F., Lombardo, J.P., Jeffers, P.M., Hunt, A.E., Bush, B., Casey, A., Quimby, F., 2001. Hyperactivity and impulsiveness in rats fed diets supplemented with either Aroclor 1248 or PCB-contaminated St. Lawrence river fish. *Behav. Brain Res.* 126, 1–11.
- Blankenship, A.L., Zwiernik, M.J., Coady, K.K., Kay, D.P., Newsted, J.L., Bradley, P.W., Neigh, A.M., Giesy, J.P., 2005. Differential accumulation of PCB congeners in the terrestrial food web of the Kalamazoo River Superfund Site, Michigan, USA. *Environ. Sci. Technol.* 39 (16), 5954–5963.
- Borja, J., Taleon, D.M., Aurenesia, J., Gallardo, S., 2005. Polychlorinated biphenyls and their degradation. *Process Biochem.* 40, 1999–2013.
- Bushnell, P.J., Moser, V.C., MacPhail, R.C., Oshiro, W.M., Derr-Yellin, E.C., Phillips, P.M., Kodavanti, P.R.S., 2002. Neurobehavioral assessments of rats perinatally exposed to a commercial mixture of polychlorinated biphenyls. *Toxicol. Sci.* 68, 109–120.
- Cairns, T., Doose, G.M., Froberg, J.E., Jacobson, R.A., Siegmund, E.G., 1986. Analytical chemistry of PCBs. In: Waid, J.S. et al. (Eds.), . In: *PCBs and the Environment*, vol. 1. CRC Press Inc., Boca Raton, FL, p. 1.
- Cecil, H.C., Bitman, J., Lillie, R.J., Fries, G.F., Verrett, J., 1974. Embryotoxic and teratogenic effects in unhatched fertile eggs from hens fed polychlorinated biphenyls (PCBs). *Bull. Environ. Contam. Toxicol.* 11, 489–495.
- Chauhan, K.R., Kodavanti, P.R.S., McKinney, J.D., 2000. Assessing the role of *ortho*-substitution on polychlorinated biphenyl binding to transthyretin, a thyroxine transport protein. *Toxicol. Appl. Pharmacol.* 162, 10–21.
- Chou, S.M., Miike, T., Payne, W.M., Davis, G.J., 1979. Neuropathology of ‘spinning syndrome’ induced by prenatal intoxication with a PCB in mice. *Ann. New York Acad. Sci.* 320, 373–395.
- Conti, R., Tan, Y.P., Llano, I., 2004. Action potential-evoked and ryanodine-sensitive spontaneous Ca^{2+} transients at the presynaptic terminal of a developing CNS inhibitory synapse. *J. Neurosci.* 24, 6946–6957.
- Cutkomp, L.K., Desai, D., Koch, R.B., 1972. The *in-vitro* sensitivity of fish brain ATPases to organochlorine acaricides. *Life Sci. II Biochem. Gen. Mol. Biol.* 11 (23), 1123–1133.
- Desai, D., Cutkomp, L.K., Yap, H.H., Koch, R.B., 1972. Inhibition of oligomycin-sensitive and insensitive magnesium adenosine triphosphatase activity in fish by polychlorinated biphenyls. *Biochem. Pharmacol.* 21, 857–865.
- Eriksson, P., 1988. Effects of 3,3',4,4'-tetrachlorobiphenyl in the brain of the neonatal mouse. *Toxicology* 49, 43–48.
- Eriksson, P., Lundkvist, U., Fredriksson, A., 1991. Neonatal exposure to 3,3',4,4'-tetrachlorobiphenyl: changes in spontaneous behaviour and cholinergic muscarinic receptors in the adult mouse. *Toxicology* 69, 27–34.
- Finley, B.L., Connor, K.T., Scott, P.K., 2003. The use of toxic equivalency factor distributions in probabilistic risk assessments for dioxins, furans, and PCBs. *J. Toxicol. Environ. Health A* 66, 533–550.
- Frame, G.M., Wagner, R.E., Carnahan, J.C., Brown, J.F., May, R.J., Smullen, L.A., Bedard, D.L., 1996. Comprehensive, quantitative, congener-specific analyses of eight Aroclors and complete Pcb congener assignments on Db-I capillary Gc columns. *Chemosphere* 33 (4), 603–623.
- Frame, G.M., 2001. The current state-of-the-art of comprehensive, quantitative, congener-specific PCB analysis, and what we now know about the distributions of individual congeners in commercial Aroclor mixtures. In: Robertson, L.W., Hansen, L.G. (Eds.), *PCBs: Recent Advances in Environmental Toxicology and Health Effects*. The University Press of Kentucky, Lexington.
- Freeman, G.B., Lordo, R.A., Singer, A.W., Peters, A.C., Neal, B.H., McConnell, E.E., Mayes, B.A., 2000. An assessment of neurotoxicity of Aroclors 1016, 1242, 1254, and 1260 administered in diet to Sprague–Dawley rats for one year. *Toxicol. Sci.* 53, 377–391.
- Gore, A.C., Wu, T.J., Oung, T., Lee, J.B., Woller, M.J., 2002. A novel mechanism for endocrine-disrupting effects of polychlorinated biphenyls: direct effects on gonadotropin-releasing hormone neurones. *J. Endocrinol.* 14, 814–823.
- Harris, M., Zacharewski, T., Safe, S., 1993. Comparative potencies of Aroclors 1232, 1242, 1248, 1254, and 1260 in male Wistar rats—assessment of the toxic equivalency factor (TEF) approach for polychlorinated biphenyls (PCBs). *Fundam. Appl. Toxicol.* 20 (4), 456–463.
- Haws, L.C., Su, S.H., Harris, M., Devito, M.J., Walker, N.J., Farland, W.H., Finley, B., Birnbaum, L.S., 2006. Development of a refined database of mammalian relative potency estimates for dioxin-like compounds. *Toxicol. Sci.* 89 (1), 4–30.
- Henry, C.J., 2003. Evolution of toxicology for risk assessment. *Int. J. Toxicol.* 22, 3–7.
- Hong, S.J., Grover, C.A., Safe, S.H., Tiffany-Castiglione, E., Frye, G.D., 1998. Halogenated aromatic hydrocarbons suppress CA1 field excitatory postsynaptic potentials in rat hippocampal slices. *Toxicol. Appl. Pharmacol.* 148, 7–13.
- Hutzinger, O., Safe, S., Zitko, V., 1974. *The Chemistry of PCBs*. CRC Press, Cleveland, Ohio.
- Inglefield, J.R., Shafer, T.J., 2000. Perturbation by the PCB mixture Aroclor 1254 of GABAA receptor-mediated calcium and chloride responses during maturation in vitro of rat neocortical cells. *Toxicol. Appl. Pharmacol.* 164, 184–195.
- Kania-Korwel, I., Hornbuckle, K.C., Peck, A., Ludewig, G., Robertson, L.W., Sulkowski, W.W., Espandiani, P., Gairola, C.G., Lehmler, H.J., 2005. Congener-specific tissue distribution of Aroclor 1254 and a highly chlorinated environmental PCB mixture in rats. *Environ. Sci. Technol.* 39 (10), 3513–3520.
- Kell, D.B., 2006. Metabolomics, modelling and machine learning in systems biology—towards an understanding of the languages of cells. Delivered on 3 July 2005 at the 30th FEBS Congress and 9th IUBMB conference in Budapest. *FEBS J.* 273, 873–894.
- Kimbrough, R.D., 1980. Environmental pollution of air, water and soil. In: *Halogenated Biphenyls, Terphenyls, Naphthalenes, Dibenzodioxins and Related Products*. Elsevier/North-Holland Biomedical Press, New York, p. 77.
- Khokute, S.D., Rodriguez, J., Dukelow, W.R., 1994. Effects of polychlorinated biphenyls (PCBs) on in vitro fertilization in the mouse. *Reprod. Toxicol.* 8 (1), 69–73.
- Kodavanti, P.R., Ward, T.R., McKinney, J.D., Tilson, H.A., 1995. Increased [3H]phorbol ester binding in rat cerebellar granule cells by polychlorinated biphenyl mixtures and congeners: Structure–activity relationships. *Toxicol. Appl. Pharmacol.* 130, 140–148.
- Kodavanti, P.R.S., Ward, T.R., McKinney, J.D., Tilson, H.A., 1996. Inhibition of microsomal and mitochondrial Ca^{2+} sequestration in rat cerebellum by polychlorinated biphenyl mixtures and congeners: Structure–activity relationships. *Arch. Toxicol.* 70, 150–157.
- Kodavanti, P.R., Ward, T.R., Derr-Yellin, E.C., Mundy, W.R., Casey, A.C., Bush, B., Tilson, H.A., 1998. Congener-specific distribution of polychlorinated biphenyls in brain regions, blood, liver, and fat of adult rats following repeated exposure to Aroclor 1254. *Toxicol. Appl. Pharmacol.* 153 (2), 199–210.
- Kodavanti, P.R.S., Tilson, H.A., 2000. Neurochemical effects of environmental chemicals: in vitro and in vivo correlations on second messenger pathways. *Ann. N. Y. Acad. Sci.* 919, 97–105.
- Kodavanti, P.R.S., Kannan, N., Yamashita, N., Derr-Yellin, E.C., Ward, T.R., Burgin, D.C., Tilson, H.A., Birnbaum, L.S., 2001. Differential effects of two lots of Aroclor 1254: congener-specific analysis and neurochemical end points. *Environ. Health Perspect.* 109 (11), 1153–1161.

- Kodavanti, P.R.S., 2004. Intracellular signaling and developmental neurotoxicity. In: Zawia, N.H. (Ed.), *Molecular Neurotoxicology: Environmental Agents and Transduction-Coupling*. CRC Press, Boca Raton, FL, pp. 151–182.
- Kodavanti, P.R.S., 2005. Neurotoxicity of persistent organic pollutants: possible mode(s) of action and further considerations. *Dose Response* 3, 273–305.
- Korkotian, E., Segal, M., 1999. Release of calcium from stores alters the morphology of dendritic spines in cultured hippocampal neurons. *Proc. Natl. Acad. Sci. USA* 96, 12068–12072.
- Lafontaine, Y.D., Gilbert, N.L., Dumouchel, F., Brochu, C., Moore, S., Pelletier, E., Dumont, P., Branchaud, A., 2002. Is chemical contamination responsible for the decline of the copper redhorse (*Moxostoma hubbsi*), an endangered fish species, in Canada? *Sci. Tot. Environ.* 298, 25–44.
- Levin, E.D., Schantz, S.L., Bowman, R.E., 1988. Delayed spatial alternation deficits resulting from perinatal PCB exposure in monkeys. *Arch. Toxicol.* 62 (4), 267–273.
- Lillie, R.J., Cecil, H.C., Bitman, J., Fries, G.F., 1974. Differences in response of caged white leghorn layers to various polychlorinated biphenyls (PCBs) in the diet. *Poult. Sci.* 53 (2), 726–732.
- Mariussen, E., Mørch-Andersen, J., Fonnum, F., 1999. The effect of polychlorinated biphenyls on the uptake of dopamine and other neurotransmitters into rat brain synaptic vesicles. *Toxicol. Appl. Pharmacol.* 161, 274–282.
- Mariussen, E., Andersson, P.L., Tysklind, M., Fonnum, F., 2001. Effect of polychlorinated biphenyls on the uptake of dopamine into rat brain synaptic vesicles: a structure–activity study. *Toxicol. Appl. Pharmacol.* 175, 176–183.
- Mariussen, E., Myhre, O., Reistad, T., Fonnum, F., 2002. The polychlorinated biphenyl mixture aroclor 1254 induces death of rat cerebellar granule cells: the involvement of the *m*-methyl-*D*-aspartate receptor and reactive oxygen species. *Toxicol. Appl. Pharmacol.* 179, 137–144.
- Mariussen, E., Andersson, P.L., Olstrom, H., Voie, O.A., Fonnum, F., 2003. The effect of various substituents in ortho position of biphenyls on respiratory burst, intracellular calcium elevation in human granulocytes and uptake of dopamine into brain synaptic vesicles and synaptosomes. *Environ. Toxicol. Pharmacol.* 14, 43–50.
- Maruyama, W., Aoki, Y., 2006. Estimated cancer risk to humans using a bioassay and physiologically based pharmacokinetic model. *Toxicol. Appl. Pharmacol.* 214 (2), 198–199.
- National Academy of Sciences, 2006. Health Risks from Dioxin and Related Compounds Evaluation of the EPA Reassessment. At <http://www.nap.edu/catalog/11688.html>.
- National Toxicology Program. 2004a. Toxicology and Carcinogenesis Studies of a Mixture of 2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD) (CAS No. 1746-01-6), 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) (CAS No. 57117-31-4), and 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (CAS No. 57465-28-8) in Female Harlan Sprague–Dawley Rats (Gavage Studies) - DRAFT At <http://ntp-server.niehs.nih.gov/ntpweb/index.cfm?objectid=08481142-D3A0-C8AE-408773AC4B6D89C5>.
- National Toxicology Program. 2004b. Toxicology and Carcinogenesis Studies of 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) (CAS No. 35065-27-1) in Female Harlan Sprague–Dawley Rats (Gavage Studies). At <http://ntp-server.niehs.nih.gov/ntpweb/index.cfm?objectid=08481142-D3A0-C8AE-408773AC4B6D89C5>.
- National Toxicology Program. 2004c. Toxicology and Carcinogenesis Studies of a Binary Mixture of 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (CAS No. 57465-28-8) and 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) (CAS No. 35065-27-1) in Female Harlan Sprague–Dawley Rats (Gavage Studies). At <http://ntp-server.niehs.nih.gov/ntpweb/index.cfm?objectid=08481142-D3A0-C8AE-408773AC4B6D89C5>.
- National Toxicology Program. 2004d. Toxicology and Carcinogenesis Studies of a Binary Mixture of 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (CAS No. 57465-28-8) and 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) (CAS No. 31508-00-6) in Female Harlan Sprague–Dawley Rats (Gavage Studies) - DRAFT. At <http://ntp-server.niehs.nih.gov/ntpweb/index.cfm?objectid=08481142-D3A0-C8AE-408773AC4B6D89C5>.
- Nebeker, A.V., Puglisi, F.A., 1974. Effect of polychlorinated biphenyls (PCBs) on survival and reproduction of daphnia, gammarus, and tanytarsus. *Trans. Am. Fish. Soc.* 103, 722–728.
- Pessah, I.N., Hansen, L.G., Albertson, T.E., Garner, C.E., Ta, T.A., Do, Z., Kin, K.H., Wong, P.H., 2006. Structure–activity relationship for noncoplanar polychlorinated biphenyl congeners toward the ryanodine receptor-Ca²⁺ channel complex type 1 (RyR1). *Chem. Res. Toxicol.* 19, 92–101.
- Rice, D.C., 1997. Effects of postnatal exposure of monkeys to a PCB mixture on spatial discrimination reversal and DRL performance. *Neurotoxicol. Teratol.* 20 (4), 391–400.
- Rice, D.C., 2000. Parallels between attention deficit hyperactivity disorder and behavioral deficits produced by neurotoxic exposure in monkeys. *Environ. Health Perspect.* 108 (Suppl 3), 405–408, Review.
- Rochfort, S., 2005. Metabolomics reviewed: a new “omics” platform technology for systems biology and implications for natural products research. *J. Nat. Prod.* 68 (12), 1813–1820.
- Rosen, C.J., 2003. Insulin-like growth factor i and calcium balance: evolving concepts of an evolutionary process. *Endocrinology* 144 (11), 4679–4681.
- Rushneck, D.R., Beliveau, A., Fowler, B., Hamilton, C., Hoover, D., Kaye, K., Berg, M., Smith, T., Telliard, W.A., Roman, W.S., Ruder, E., Ryan, L., 2004. Concentrations of dioxin-like PCB congeners in unweathered aroclors by HRGC/HRMS using EPA method 1668A. *Chemosphere* 54, 9–87.
- Saghir, S.A., Hansen, L.G., Holmes, K.R., Kodavanti, P.R., 2000. Differential and non-uniform tissue and brain distribution of two distinct¹⁴ C-hexachlorobiphenyls in weanling rats. *Toxicol. Sci.* 54 (1), 60–70.
- Sanchez-Alonso, J.A., Lopez-Aparicio, P., Recio, M.N., Perez-Albarsanz, M.A., 2004. Polychlorinated biphenyl mixtures (Aroclors) induce apoptosis via Bcl-2, Bax and caspase-3 proteins in neuronal cell cultures. *Toxicol. Lett.* 153, 311–326.
- Sawhney, B.L. (1986). Chemistry and properties of PCBs in relation to environmental effects. In: Waid, J.S., et al. (Eds.), *PCBs and the Environment*. Boca Raton, FL, p. 47.
- Schantz, S.L., Levin, E.D., Bowman, R.E., Heironimus, M.P., Laughlin, N.K., 1989. Effects of perinatal PCB exposure on discrimination-reversal learning in monkeys. *Neurotoxicol. Teratol.* 11 (3), 243–250.
- Schantz, S.L., Levin, E.D., Bowman, R.E., 1991. Long-term neurobehavioral effects of perinatal polychlorinated biphenyl (PCB) exposure in monkeys. *Environ. Toxicol. Chem.* 10, 747–756.
- Schantz, S.L., Seo, B.W., Wong, P.W., Pessah, I.N., 1997. Long-term effects of developmental exposure to 2,2',3,3',5,5'-pentachlorobiphenyl (PCB 95) on locomotor activity, spatial learning and memory and brain ryanodine binding. *Neurotoxicology* 18 (2), 457–467.
- Schantz, S.L., Widholm, J.J., Rice, D.C., 2003. Effects of PCB exposure on neuropsychological function in children. *Environ. Health Perspect.* 111 (3), 357–376.
- Seegal, R.F., Bush, B., Shain, W., 1990a. Lightly chlorinated ortho-substituted PCB congeners decrease dopamine in nonhuman primate brain and in tissue culture. *Toxicol. Appl. Pharmacol.* 106, 136–144.
- Seegal, R.F., Brosch, K., Bush, B., Ritz, M., Shain, W., 1990b. Effects of Aroclor 1254 on dopamine and norepinephrine concentrations in pheochromocytoma (PC-12) cells. *Neurotoxicology* 10 (4), 757–764.
- Shain, W., Bush, B., Seegal, R., 1991. Neurotoxicity of polychlorinated biphenyls: structure–activity relationship of individual congeners. *Toxicol. Appl. Pharmacol.* 111, 33–42.
- Sorrentino, V., 1995. The ryanodine receptor family of intracellular calcium release channels. *Adv. Pharmacol.* 33, 67–90.
- Sorrentino, V., Barone, V., Rossi, D., 2000. Intracellular Ca²⁺ release channels in evolution. *Curr. Opin. Genet. Dev.* 10, 662–667.
- Staskal D.F., Unice K.M., Walker, N.J., DeVito, M.J., Birnbaum, L.S., Scott, P.K., Harris, M.A., Farland, W.H., Finley, B.L., Haws, L.C., 2006. An Alternative Method For Establishing TEFs For Dioxin-Like Compounds. Part 3. Development Of Weighted Distributions Of REPs For PCB 126 And 2,3,4,7,8-PeCDF. *Dioxin 2006*, Oslo.

- Svensgaard, D.J., Ward, T.R., Tilson, H.A., Kodavanti, P.R.S., 1997. Empirical modeling of an in vitro activity of polychlorinated biphenyl congeners and mixtures. *Environ. Health Perspect.* 105 (10), 1106–1115.
- Tan, Y., Chen, C.-H., Lawrence, D., Carpenter, D.O., 2004. Ortho-substituted pcbs kill cells by altering membrane structure. *Toxicol. Sci.* 80, 54–59.
- Tilson, H.A., Kodavanti, P.R., 1997. Neurochemical effects of polychlorinated biphenyls: An overview and identification of research needs. *Neurotoxicology* 18, 727–743.
- Tilson, H.A., Jacobson, J.L., Rogan, W.J., 1990. Polychlorinated biphenyls and the developing nervous system: cross species comparison. *Neurotoxicol. Teratol.* 12, 239–248.
- Tryphonas, L., Charbonneau, S., Tryphonas, H., Zawidzka, Z., Mes, J., Wong, J., Arnold, D.L., 1986. Comparative aspects of Aroclor 1254 toxicity in adult Cynomolgus Monkeys and Rhesus Monkeys: a pilot study. *Arch. Environ. Contam. Toxicol.* 15, 159–169.
- Tryphonas, H., Hayward, S., O'Grady, L., Loo, J.C.K., Arnold, D.L., Bryce, F., Zawidzka, Z.Z., 1989. Immunotoxicity studies on PCB (Aroclor 1254) in the adult rhesus (*Macaca mulatta*) monkey: preliminary report. *Int. J. Immunopharmacol.* 11, 199–206.
- Tryphonas, H., Luster, M.I., White, K.L., Naylor, P.H., et al., 1991a. Effects of PCB (Aroclor 1254) on non-specific immune parameters in rhesus (*Macaca mulatta*) monkeys. *Int. J. Immunopharmacol.* 13, 639–648.
- Tryphonas, H., Luster, M.I., Schiffman, G., Dawson, L.-L., Hodgen, M., Germolec, D., Hayward, S., Bryce, F., Loo, J.C., Mandy, F., Arnold, D.L., 1991b. Effect of chronic exposure of PCB (Aroclor 1254) on specific and nonspecific immune parameters in the rhesus (*Macaca mulatta*) monkey. *Fundam. Appl. Toxicol.* 16, 73–786.
- Unni, V.K., Zakharenko, S.S., Zablow, L., DeCostanzo, A.J., Siegelbaum, S.A., 2004. Calcium release from presynaptic ryanodine sensitive stores is required for long-term depression at hippocampal CA3-CA3 pyramidal neuron synapses. *J. Neurosci.* 24, 9612–9622.
- USEPA (1996a) IRIS. Aroclor 1254 (CASRN 11097-69-1), last revised 11/01/96 at <http://www.epa.gov/iris/subst/0389.htm>.
- USEPA (1996b) IRIS Aroclor 1016 (CASRN 12674-11-2), last revised 11/01/96 at <http://www.epa.gov/iris/subst/0462.htm>.
- USEPA, 2003 Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD) and Related Compounds. EPA/600/P-00/001Cb. December 2003 NAS Review Draft. at <http://www.epa.gov/ncea>.
- USEPA. (2004a) Memorandum from Paul Gilman. Interim Policy on Genomics. At <http://www.epa.gov/osa/spc/pdfs/igpmemo.pdf>.
- USEPA. (2004b) Interim Policy on Genomics. Science Policy Council at <http://www.epa.gov/osa/spc/pdfs/genomics.pdf>.
- USEPA. (2004c) Potential Implications of Genomics for Regulatory and Risk Assessment Applications at EPA. At <http://www.epa.gov/osa/genomics.htm>.
- USEPA. 2005. Guidelines for Carcinogen Risk Assessment and Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. EPA/630/P-03/001F.
- Van den Berg, M., Birnbaum, L., Bosveld, A.T.C., Brunstrom, B., Cook, P., Feeley, M., Giesy, J.P., Hanberg, A., Hasegawa, R., Kennedy, S.W., Kubiak, T., Larsen, J.C., van Leeuwen, F.X., Liem, A.K., Nolt, C., Peterson, R.E., Poellinger, L., Safe, S., Schrenk, D., et al., 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife (with Vos, 2000 comment and authors reply). *Environ. Health Perspect.* 106, 775–792.
- Van den Berg, M., Birnbaum, L.S., Denison, M., De Vito, M., Farland, W., Feeley, M., Fiedler, H., Hakansson, H., Hanberg, A., Haws, L., Rose, M., Safe, S., Schrenk, D., Tohyama, C., Tritscher, A., Tuomisto, J., Tysklind, M., Walker, N., Peterson, R.E., 2006. The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicol. Sci. Adv.* Access 93 (2), 223–241.
- Voie, O.A., Fonnum, F., 1998. Ortho substituted polychlorinated biphenyls elevate intracellular [Ca²⁺] in human granulocytes. *Environ. Toxicol. Pharmacol.* 5, 105–112.
- Voie, O.A., Wiik, P., Fonnum, F., 1998. Ortho-substituted polychlorinated biphenyls activate respiratory burst measured as luminol-amplified chemoluminescence in human granulocytes. *Toxicol. Appl. Pharmacol.* 150, 369–375.
- Voie, O.A., Tysklind, M., Andersson, P.L., Fonnum, F., 2000. Activation of respiratory burst in human granulocytes by polychlorinated biphenyls: A structure–activity study. *Toxicol. Appl. Pharmacol.* 167, 118–124.
- Warren, D.A., Kerger, B.D., Britt, J.K., James, R.C., 2004. Developments of an oral cancer slope factor for Aroclor 1268. *Regul. Toxicol. Pharmacol.* 40, 42–53.
- Wong, P.W., Pessah, I.N., 1996. Ortho-substituted polychlorinated biphenyls alter calcium regulation by a ryanodine receptor-mediated mechanism: structural specificity toward skeletal- and cardiac-type microsomal calcium release channels. *Mol. Pharmacol.* 49 (4), 740–751.
- Wong, P.W., Brackney, W.R., Pessah, I.N., 1997. Ortho-substituted polychlorinated biphenyls alter microsomal calcium transport by direct interaction with ryanodine receptors of mammalian brain. *J. Biol. Chem.* 272, 15145–15153.
- Zhao, W., Meiri, N., Xu, H., Cavallaro, S., Quattrone, A., Zhang, L., Alkon, D.L., 2000. Spatial learning induced changes in expression of the ryanodine type II receptor in the rat hippocampus. *FASEB J.* 14, 290–300.

Development of an oral cancer slope factor for Aroclor 1268

D. Alan Warren,^{a,*} Brent D. Kerger,^b Janice K. Britt,^a and Robert C. James^a

^a *TERRA, Inc., Tallahassee, FL, USA*

^b *HSRI, Inc., Tallahassee, FL, USA*

Received 1 January 2003

Available online 10 June 2004

Abstract

Rodent cancer bioassays indicate that substantial differences exist among PCB mixtures in terms of tumorigenic response, although no bioassay has been conducted with Aroclor 1268. The USEPA has used data from these studies to develop three sets of PCB cancer slope factors (CSFs) ranging from 0.07 to 2.0(mg/kg-day)⁻¹. Selection of the appropriate CSF for risk assessment purposes is largely a function of the exposure circumstances rather than the PCB mixture involved. Since the congener composition of Aroclor 1268 differs substantially from that of the predominant PCB mixture (Aroclor 1254) used to derive the CSFs, the validity of applying existing CSFs to Aroclor 1268 is questionable. We have therefore undertaken the task of developing cancer potency estimates specifically for Aroclor 1268. Potency estimation approaches for Aroclor 1268 were based in part on existing potency estimates for other PCB mixtures, coupled with the relative 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalents (TEQ) content and bioaccumulation potential of PCB mixtures. As such, both Ah-dependent and independent mechanisms of tumorigenesis were considered relevant. Both empirical evidence and mechanistic considerations indicate Aroclor 1268 is substantially less toxic and carcinogenic than the PCB mixtures that have been used by the USEPA to develop CSFs. The present analysis indicates that Aroclor 1268 is likely to be 1–2 orders of magnitude less potent than Aroclor 1254 in terms of potential tumorigenicity. Therefore, we suggest an upper-bound cancer potency factor of 0.27(mg/kg-day)⁻¹ for Aroclor 1268, a value that is 7- to 8-fold lower than the USEPA's current default, but nonetheless adequately conservative.

© 2004 Elsevier Inc. All rights reserved.

Keywords: Aroclor 1268; Polychlorinated biphenyls; Toxic equivalency factors; Toxic equivalents; Cancer slope factor; Risk assessment

1. Introduction

PCB mixtures have been tested for potential carcinogenicity in cancer bioassays in rats and mice, and a number of studies have tried to gain insight into PCB carcinogenicity in humans by examining causes of mortality among PCB exposed workers. Collectively, the data from humans are equivocal—some studies have found excesses of specific cancer types, but no cancer type is consistently elevated across studies. In some cases, increases in cancer incidence among PCB-exposed workers were not clearly related to the extent of PCB exposure and/or did not demonstrate appropriate la-

tency, making their association with PCBs tenuous. Reviews of these studies by both the USEPA and IARC have concluded that PCB mixtures are probably carcinogenic to humans, based on “sufficient” evidence of carcinogenicity in animals and “limited” or “inadequate, but suggestive” evidence in humans (IARC, 1987; USEPA, 1996).

The quantitative assessment of cancer risk from PCBs is based entirely upon data derived from laboratory animals, principally bioassays of PCBs in rats. Several commercial PCB mixtures have been tested for carcinogenicity from lifetime exposure, most recently examined in two reports (Brunner et al., 1996; Mayes et al., 1998) on the tumorigenicity of Aroclors 1016, 1242, 1254, and 1260 in rats. These authors demonstrated that Aroclor 1254 showed the peak potency for liver tumors while the other higher chlorinated (Aroclor 1260) and lower chlorinated mixtures (Aroclors 1242 and 1016)

* Corresponding author. Current address: University of South Carolina-Beaufort, 801 Carteret Street, Beaufort, SC 29907. Fax: 1-843-521-4197.

E-mail address: dwarren@gwm.sc.edu (D.A. Warren).

had lower potencies. Aroclor 1268 was not among the PCB mixtures tested, and no chronic bioassay data currently exist with which to directly obtain a cancer slope factor (CSF) for this commercial mixture. This is unfortunate given that rodent cancer bioassays indicate that there are substantial differences among PCB mixtures in terms of tumorigenic response that might be predicted based on differences in congener make-up. For example, Aroclor 1268 (like Aroclor 1260) is expected to have a lower content of the more potent tetra-, penta-, and hexachlorinated biphenyls (Anderson, 1991; Hutzinger et al., 1974), and accordingly a much lower TCDD toxic equivalents score compared to Aroclor 1254.

The current USEPA cancer slope factors (CSFs) for estimating potential cancer risk from PCBs are based largely on findings for the most potent mixture, Aroclor 1254 (IRIS, 2004). Since the congener composition of Aroclor 1268 is dramatically different from Aroclor 1254, we believe that extending the generic CSFs to this mixture would not be scientifically appropriate. Therefore, the objective of this study was to examine the relationship between PCB congener composition and tumorigenicity such that a CSF estimate for Aroclor 1268 could be derived.

2. Summary of the basis for USEPA'S PCB cancer potency estimates

Several studies examined tumor responses in mice and rats subjected to less-than-lifetime exposure to PCB mixtures ranging from 42 to 60% chlorine content (Ito et al., 1973; Ito et al., 1974; Kimbrough et al., 1972; Kimbrough and Linder, 1974; Kimura and Baba, 1973; Rao and Banerji, 1988). In general, these studies were negative or found an increase in pre-neoplastic lesions, but no increase in carcinomas. While less-than-lifetime

studies can offer useful information, lifetime exposure is usually regarded as necessary for adequate assessment of potential carcinogenicity and for development of quantitative cancer potency estimates. PCB mixtures of 42, 54, and 60% chlorine content have been tested in conventional rodent cancer bioassays with lifetime exposure, and the results of these bioassays are summarized in Table 1. All of the bioassays were conducted in rats, usually with both sexes. Collectively, the results show positive responses in females and negative responses in males with 42% chlorine PCB mixtures and positive responses in both males and females with 60% chlorine PCB mixtures. Two studies of Aroclor 1254 gave conflicting results, one was essentially negative in both males and females (NCI, 1978) and the other was negative in males but strongly positive in females (Brunner et al., 1996). The reason for this discrepancy is not clear, but may relate to differences in composition of the Aroclor 1254 material used in these studies or the rat strain in which these different batches of Aroclor mixtures were tested.

Potential differences in cancer potency among different commercial mixtures are illustrated by the study of Brunner et al. (1996). This is the only study to examine more than one commercial mixture, and in fact four mixtures were included in the analysis—Aroclors 1260, 1254, 1242, and 1016. Each commercial mixture was tested in both male and female rats. In its cancer dose-response assessment for PCBs, the USEPA fit data from this and other studies to derive the estimated dose associated with a 10% increased tumor incidence (ED10) for each commercial PCB mixture, as well as the 95% lower bound estimate of the ED10, termed the LED10 (USEPA, 1996). From these values, a linear extrapolation to the origin of a dose-response plot was used to derive a central estimate of the slope (from the ED10) and an upper-bound estimate of the slope (from the

Table 1
Summary of cancer bioassay results for commercial PCB mixtures

Mixture	Results (male animals)	Results (female animals)	Reference
42% chlorine			
Clophen A30	Negative	ND	Schaeffer et al. (1984)
Aroclor 1242	Negative	Positive	Brunner et al. (1996)
Aroclor 1016	Negative	Positive	Brunner et al. (1996)
54% chlorine			
Aroclor 1254	Negative	Negative	NCI (1978)
Aroclor 1254	Negative	Positive	Brunner et al. (1996)
60% chlorine			
Clophen A60	Positive	ND	Schaeffer et al. (1984)
Aroclor 1260	ND	Positive	Kimbrough et al. (1975)
Aroclor 1260	Positive	Positive	Norback and Weltman (1985)
Aroclor 1260	Positive	Positive	Brunner et al. (1996)

“Positive” indicates a statistically significant increase in hepatocellular adenomas or carcinomas compared with control at one or more PCB doses; “negative” indicates no significant increase at any dose. ND, not determined since animals of this gender were not included in the study. All studies were in rats and were conducted for approximately 2 years.

LED₁₀). For the purposes of converting the doses used in these studies to an equivalent human dose, the following expression was used:

$$\begin{aligned} \text{Human dose (mg/kg-day)} \\ &= \text{PCB dose (ppm in diet)} \times 0.05 \\ &\quad \times (\text{animal weight/70 kg human weight})^{1/4}. \end{aligned}$$

Table 2 summarizes the cancer potency estimates for each commercial PCB mixture in both male and female rats in the Brunner et al. (1996) study. Comparisons of these cancer potency estimates result in two observations: (1) cancer potencies for all Aroclors are substantially higher in female rats than male rats; and (2) for males, potency was directly measurable for only Aroclor 1260 (the potency estimates for the other Aroclors listed in Table 2 are “best guesses” that were based on the sensitivity of the study), suggesting that it was the most potent mixture in males; while in the female animals the differences in Aroclor potency are measurable and more substantial, and the potency is greatest at 54% chlorine content.

The USEPA has used data from Brunner et al. (1996) and other studies to develop three sets of PCB CSFs ranging from 0.04 to 2.0 (mg/kg-day)⁻¹. The PCB slope factor to be used in a particular situation is primarily a function of the exposure circumstances rather than the PCB mixture to which the individual is, or will be, exposed. According to USEPA guidance, most exposure situations for PCBs (e.g., exposure to PCB-contaminated soils) are viewed as falling under the category of “High Risk and Persistence,” where CSFs of 1.0 and 2.0 (mg/kg-day)⁻¹ are recommended as central and upper-bound values, respectively. These slope factors are taken from responses in female rats to Aroclors 1254 and 1260 and are considered to be the “highest observed potency” factors from animal studies (USEPA, 1996). The highest of the central tendency slope factor values (1.0 (mg/kg-day)⁻¹) is based on the ED₁₀ for the highest tumor incidence observed in the Brunner et al. (1996) study, i.e., that of female rats exposed to Aroclor 1254. The upper-bound CSF value derived from the LED₁₀ (2.0 (mg/kg-day)⁻¹) was selected to reflect the highest upper-bound slope factor derived in the Brunner et al.

(1996) study (again that of female rats exposed to Aroclor 1254), as well as the highest upper-bound slope factor that could be derived for female rats from any chronic study (i.e., based on Aroclor 1260 in the Norback and Weltman study).

The other two sets of central tendency and upper-bound CSF estimates adopted by the USEPA are representative of the lowest and intermediate values calculated for PCB mixtures other than Aroclor 1254 that were tested in the Brunner et al. (1996) study. The USEPA recommends that these two remaining sets of CSFs be applied in the following manner: In situations of “Low Risk and Persistence,” values of 0.3 and 0.4 (mg/kg-day)⁻¹ are to be used as the central and upper-bound slope factor values, respectively, as taken from the response of female rats to Aroclor 1242 (see Table 2). Examples where these values are recommended include ingestion of water-soluble congeners, inhalation of evaporated congeners, and dermal exposure (without correction for dermal bioavailability). The third category is described as “Lowest Risk and Persistence,” and is the only one that requires a characterization of the PCB congeners of the mixture. This category is defined as situations where >99.5% of the PCB congeners present in the PCB mixture has 4 or fewer chlorines. In this case, a value of 0.04 (mg/kg-day)⁻¹ is to be used as the central tendency CSF value, and 0.07 (mg/kg-day)⁻¹ as the upper-bound CSF. These two values are taken from the response of female rats to Aroclor 1016 in the Brunner et al. (1996) study (see Table 2).

3. Choosing a slope factor for Aroclor 1268

This approach of using the highest CSFs derived from animal studies to estimate PCB cancer risks is certainly conservative, but its validity in situations involving Aroclor 1268 contamination is questionable. There is reason to believe that congener composition is a critical determinant of the cancer potency of PCB mixtures, and that potency estimates from female animals exposed to PCB mixtures of 54% or even 60% chlorine content are not representative of the potencies of mixtures with substantially greater (or lesser) chlorination,

Table 2
Cancer slope factors for various PCB mixtures in male and female rats

PCB mixture	Cancer slope factor			
	Central estimate		Upper-bound estimate	
	Male	Female	Male	Female
Aroclor 1260	0.1	0.4	0.2	0.5
Aroclor 1254	0.06 ^a	1.2	0.1 ^a	1.5
Aroclor 1242	0.03 ^a	0.3	0.08 ^a	0.4
Aroclor 1016	0.02 ^a	0.04	0.04 ^a	0.07

Data from Brunner et al. (1996) as presented in USEPA (1996). Slope factors are in units of (mg/kg-day)⁻¹.

^a No significant increase in tumors; slope estimate based on the sensitivity of the study.

including Aroclor 1268. This conclusion is supported by the fact that in the recent USEPA re-evaluation, the upper-bound slope factors for PCB mixtures of approximately 42–60% chlorine content (Aroclor 1016 to Aroclor 1260) ranged between 0.07 and 2.2, i.e., the potency of the different mixtures varied 30-fold (USEPA, 1996).

Understanding the problem with using the USEPA default CSFs for Aroclor 1268 first requires recognition that male and female rats respond differently to PCBs. Data from the Brunner et al. (1996) study clearly suggest greater potency of PCBs in females as compared with males (see Table 2). This observation is acknowledged in the USEPA dose–response assessment, although its significance is downplayed somewhat:

The different responses for male and female rats (Brunner et al., 1996) suggest the possibility of developing different potency values for males and females. In view of the 91 percent response in male Wistar rats (Schaeffer et al., 1984), as well as the sensitivity of male mice (Ito et al., 1973; Kimbrough and Linder, 1974), it is premature to conclude that females are always more sensitive. (USEPA, 1996)

It should be recognized, however, that the reference in the above passage to the response in male Wistar rats in the Schaeffer et al. study has confused potency with efficacy. The fact that a strong response occurred in males is not the point—it is the dose at which this response occurred and how it compares with the dose required to produce an equal response in females that is important in assessing relative potency. Since Schaeffer and colleagues did not include females in their study, this study offers nothing to contradict the concept that PCBs are more potent in females. Similarly, the cited studies in mice (Ito et al., 1973 and Kimbrough and Linder, 1974) used only males, and no inferences on relative potency between the sexes are possible. There are two studies other than Brunner et al. (1996) that examined both male and female rats—the NCI bioassay of Aroclor 1254 (NCI, 1978) and the study of Aroclor 1260 by Norback and

Weltman (1985). The NCI study found little difference between the sexes, but noticeable differences are not expected in a study where the results were negative. In the study of Norback and Weltman (1985), however, where positive responses were seen in both male and female animals, the potency in females was approximately 10-fold higher than males (see Table 3-1 in USEPA, 1996). Thus, the data from which potency comparisons can be reasonably made are consistent in showing that greater potency is generally observed in female rats.

Recent analyses of data developed in the Brunner et al. (1996) study suggest that there are two mechanisms of PCB hepatocarcinogenesis, one that results from Ah-receptor mediated effects and predominates in female animals, and a second mechanism that is predominant in male animals (Brown et al., 1997, 2001). The principal evidence for this lies in the fact that the tumorigenic potency of PCBs in female rats is strongly predicted by the total 2,3,7,8-TCDD toxic equivalents (TEQ) of the PCB mixture, while potency in males appears to be unrelated to the mixture TEQ.

Aroclor 1268 contains only small percentages of the toxic tetra-, penta-, and hexachlorobiphenyl congeners (Table 3), and its TEQ value is much lower than that of Aroclors 1242, 1254, and 1260 (Tables 4 and 5). Consequently, it is reasonable to expect that Aroclor 1268's cancer potency will be much less than the potencies of these other mixtures in the more sensitive female animals. Even though an empirical cancer potency estimate for Aroclor 1268 does not yet exist, a cancer potency estimate for this mixture in female rats can nonetheless be projected based on the apparent relationship between TEQ and cancer potency demonstrated by the Brunner et al. (1996) study. That is, using the TEQ–cancer potency relationship evident in the Brunner et al. (1996) study, a cancer potency estimate can be derived corresponding to the TEQ value for Aroclor 1268. Two approaches are possible, each with slightly different mechanistic assumptions.

Table 3
Weight percentage of PCB congeners in Aroclor mixtures

Biphenyl	Aroclor 1221*	Aroclor 1232*	Aroclor 1016	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 1268
Monochloro	47.88	22.27	1.31	0.95	0	0	0	0
Dichloro	35.94	21.19	19.40	15.15	2.03	0.49	0.10	0
Trichloro	6.52	23.47	45.36	36.53	24.9	1.31	0.27	0
Tetrachloro	1.69	23.37	32.82	36.07	51.36	26.81	4.39	0.51
Pentachloro	0.65	4.78	1.16	8.73	18.45	44.32	10.56	2.75
Hexachloro	1.09	0.61	0	1.11	2.07	21.85	40.68	2.08
Heptachloro	0.43	0.50	0	0.79	1.48	4.68	33.37	8.32
Octachloro	0.06	0.12	0	0.28	0.45	0.54	9.40	40.93
Nonachloro	0	0.02	0	0.03	0.06	0.03	1.21	37.29
Decachloro	0.01	0.01	0.01	0	0	0.02	0.02	8.12

Source: Anderson (1991).

*Aroclors 1221 and 1232 contain 5.92 and 4.77% unsubstituted biphenyls, respectively.

Table 4

Toxic equivalents ($\mu\text{g/g}$) for non-ortho and mono-ortho coplanar PCBs in Aroclor mixtures based on AHH induction^a

IUPAC No.	Aroclor 1221	Aroclor 1016	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
81	—	—	0.001	0.0018	0.002	0.0015	0.0002	0.0001	0.0001
77	0.2	0.22	3.2	7.2	8.1	4.2	0.57	0.3	0.35
123	0.0003	0.0001	0.0024	0.006	0.016	0.052	0.011	0.0088	0.0002
118	0.0005	0.0004	0.01	0.02	0.066	0.23	0.032	0.013	0.0015
114	0.0006	—	0.015	0.03	0.11	0.39	0.003	0.0043	0.0011
105	0.075	0.068	2.7	5.9	19.8	75.9	0.49	0.84	0.26
126	—	—	3.6	11.6	40	100	9.6	12.8	2
167	0.0001	0.0003	0.0003	0.0004	0.002	0.013	0.011	0.002	0.0001
156	0.0012	—	0.007	0.01	0.026	0.38	0.14	0.034	0.0011
157	—	—	0.006	0.01	0.022	0.39	0.027	0.013	0.0086
169	—	—	—	—	—	—	—	—	—
189	—	—	0.0001	—	0.0002	0.0021	0.009	0.0036	0.00004
Total	0.28	0.29	9.5	24.8	68.1	182	10.9	14	2.6

^a Reproduced from Table 3 of Hong et al. (1993).

Table 5

Toxic equivalents ($\mu\text{g/g}$) for non-ortho and mono-ortho coplanar PCBs in Aroclor mixtures based on reevaluated WHO TEFs as published by van den Berg et al. (1998)^a

IUPAC No.	Aroclor 1221	Aroclor 1016	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
81	—	—	—	—	—	—	—	—	0.0009
77	0.0074	0.0082	0.12	0.267	0.3	0.155	0.021	0.011	0.013
123	0.0012	0.003	0.01	0.024	0.065	0.217	0.044	0.0365	0.001
118	0.0064	0.0046	0.122	0.23	0.79	2.74	0.39	0.151	0.0182
114	0.003	0	0.08	0.175	0.58	2.075	0.015	0.0225	0.006
105	0.0068	0.0062	0.247	0.338	1.8	6.9	0.045	0.076	0.0234
126	0	0	0.9	2.9	10	25	2.4	3.2	0.5
167	0.00014	0.00043	0.00042	0.00061	0.003	0.018	0.0156	0.00284	0.00019
156	0.013	0	0.075	0.121	0.28	4.18	1.565	0.363	0.012
157	0	0	0.021	0.038	0.0825	1.44	0.1	0.047	0.032
169	0	0	0	0	0	0	0	0	0
189	0	0	0.0009	0	0.0018	0.025	0.106	0.042	0.0005
Total	0.04	0.02	1.58	4.09	13.9	42.75	4.70	3.95	0.61

^a Source of TEFs is van den Berg et al. (1998). Toxic equivalents were calculated using the mean concentration of coplanar PCBs in Aroclor mixtures as published in Table 2 of Hong et al. (1993).

3.1. Prediction of an Aroclor 1268 slope factor assuming an Ah-receptor-dependent mechanism in female rats

The first approach assumes that tumorigenicity in the more responsive female rats is largely, if not completely, an Ah-receptor-dependent phenomenon, and that cancer potency is directly proportional to the TEQ content of the PCB mixture. The data from which an Aroclor 1268 CSF can be extrapolated are shown in Table 6. This table contains the central and upper-bound CSF values derived by the USEPA for Aroclors 1016, 1242, 1254, and 1260 using data from female rats in the Brunner et al. (1996) study. It also lists the TEQ values for these mixtures based on congener analysis of the test materials as reported by Mayes et al. (1998). To extrapolate a cancer potency estimate for Aroclor 1268 from these data, a TEQ value for Aroclor 1268 is required. Two relatively recent and complete TEQ analyses for various PCB mixtures were selected that can be used to obtain this value. Hong et al. (1993) not only

published mean concentrations of coplanar PCBs in nine Aroclor mixtures, including 1268, but also computed TEQs for these nine mixtures (Table 4). The World Health Organization (WHO) International TEFs (I-TEFs) reported by van den Berg et al. (1998) are presented in Table 5. While the absolute TEQ values for specific Aroclor mixtures differed between these analyses, the relative rankings of the TEQs within each study for various Aroclors were nearly identical. As a result, the two analyses, despite their differences, provided a relatively consistent view of the comparative TEQ content of various PCB mixtures. For example, both analyses found the TEQ content of Aroclor 1268 to be only 1.43% that of Aroclor 1254. This percentage (1.43%), when applied to the TEQ content of the Aroclor 1254 mixture used in the Brunner et al. (1996) study (i.e., 47.6 $\mu\text{g/g}$, as shown in Table 6), resulted in a corresponding Aroclor 1268 TEQ of 0.68 $\mu\text{g/g}$ (i.e., $0.0143 \times 47.6 = 0.68$). In other words, had Aroclor 1268 been included in the Brunner et al. (1996) study, it is

Table 6

Predicted cancer slope factors for Aroclor 1268 based on the Brunner et al. (1996) data^a

PCB mixture	Mixture TEQ ^b (μg/g) Mayes et al. (1998)	Cancer slope factor (mg/kg-day) ⁻¹		Predicted cancer slope factor for Aroclor 1268 ^c	
		Central estimate	Upper bound	Based on central tendency	Based on upper bound
Aroclor 1260	7.2	0.4	0.5	0.038	0.047
Aroclor 1254	47.6	1.2	1.5	0.017	0.021
Aroclor 1242	7.8	0.3	0.4	0.026	0.035
Aroclor 1016	0.11	0.04	0.07	0.247	0.433
Average ± SD including Aroclor 1016 (SD as percentage of mean)				0.082 ± 0.110 (134%)	0.134 ± 0.200 (149%)
Average ± SD excluding Aroclor 1016 (SD as percentage of mean)				0.027 ± 0.011 (39%)	0.034 ± 0.013 (38%)

^a Cancer slope values are central tendency and upper-bound estimates from female rats only using the study by Brunner et al. (1996) as derived by USEPA (1996).

^b The TEQ values listed in this column are those reported for the Brunner et al. (1996) study in the recent publication of this experiment by Mayes et al. (1998).

^c The total TEQ for Aroclor 1268 was 1.43% (Hong et al., 1993; van den Berg et al., 1998) that for Aroclor 1254. Using this percentage (i.e., 1.43%) and the total TEQ of 47.6 μg/g for Aroclor 1254, the projected TEQ for Aroclor 1268 would be 0.68. Predicted CSFs for Aroclor 1268 were arrived at using the formula: $[(0.68 \div \text{mixture TEQ from Mayes et al. (1998)}) \times \text{CSF for the mixture}]$.

estimated that it would have had a TEQ value of about 0.68 μg/g.

This estimated TEQ of 0.68 μg/g for Aroclor 1268 is 70-fold less than that of Aroclor 1254, approximately 10-fold less than the TEQs for Aroclors 1242 and 1260, and about 6-fold larger than the 0.11 μg/g TEQ for Aroclor 1016. Using these TEQ relationships, the USEPA-derived CSFs for the Aroclor mixtures in the Brunner et al. (1996) study were adjusted assuming a linear relationship between TEQ and CSF to derive predicted CSFs for Aroclor 1268. The results, both in terms of central tendency and upper-bound estimates, are shown in Table 6. The Aroclor 1268 CSFs based on extrapolation from the three different Aroclor mixtures with the highest TEQ contents (Aroclors 1242, 1254, and 1260) were remarkably similar. When averaged across these three Aroclors, they yielded central tendency and upper-bound Aroclor 1268 CSFs of 0.027 ± 0.011 and 0.034 ± 0.013 (mg/kg-day)⁻¹, respectively. The degree of variance indicated by the standard deviation as a percentage of these mean values is quite low (38–39%). These Aroclor 1268 CSF estimates are 37- and 59-fold lower than the default USEPA slope factors for PCB mixtures of 1.0 and 2.0 (mg/kg-day)⁻¹, more accurately reflecting the fact that Aroclor 1268 is so heavily chlorinated that it is likely to have little Ah-receptor activity.

Table 6 also illustrates that inclusion of the data for Aroclor 1016 in such an analysis leads to apparently anomalous and highly variable slope factor estimates. The combination of its comparatively low TEQ content and lower CSFs than the remaining mixtures tested by Brunner et al. (1996) leads to calculated Aroclor 1268 slope factors that are 1–2 orders of magnitude higher than the respective central tendency and upper-bound estimates for the three higher TEQ mixtures. Moreover,

the variance introduced by including Aroclor 1016 data leads to standard deviations that are 134–149% of the mean. These observations support the contention that the weaker cancer potency of Aroclor 1016 does not correlate well with TEQ as does the higher potency of the more chlorinated Aroclors. This suggests that the weakly positive tumor response of female rats to Aroclor 1016 may be explained by non-Ah receptor mechanisms.

As indicated above (Tables 4 and 5), different analyses yield different estimates of the TEQ values for specific PCB mixtures. For the extrapolations described above, the Aroclor TEQ values of Mayes et al. (1998) were used because they are based on the congener composition of the specific test materials used in the Brunner et al. (1996) study. However, other sets of TEQ values for these mixtures could be substituted with little effect on the extrapolated Aroclor 1268 CSF. This is illustrated in Table 7, in which TEQs for Aroclors 1260, 1254, and 1242 taken from Hong et al. (1993) and van den Berg et al. (1998) were used instead of TEQs from Mayes et al. (1998) in the extrapolation of CSFs (central tendency and upper-bound) for Aroclor 1268. The results based on Hong et al. (1993) and van den Berg et al. (1998) indicate that although the absolute TEQ values for individual Aroclor mixtures may differ markedly, the extrapolated Aroclor 1268 CSFs based on the three Aroclors with higher TEQ values (Aroclors 1242, 1254, and 1260, without 1016 data) are comparable to those developed using the TEQs of Mayes et al. (1998). This is because, as discussed above, the relationships among mixture TEQ values within a given study are relatively consistent, even though the absolute values for a given Aroclor mixture may vary between studies. Inclusion of Aroclor 1016 in the Table 7 analyses once again resulted in much higher and apparently anomalous slope factor estimates.

Table 7
Predicted cancer slope factors for Aroclor 1268 based on other TEF analyses

PCB mixture	Mixture TEQ ($\mu\text{g/g}$)		Cancer slope factor (mg/kg-day) ⁻¹		Predicted slope factor for Aroclor 1268 TEF Source: Hong et al. (1993)		Predicted slope factor for Aroclor 1268 TEF Source: van den Berg et al. (1998)	
	Hong et al. (1993)	van den Berg et al. (1998)	Central tendency	Upper bound	Based on central tendency	Based on upper-bound	Based on central tendency	Based on upper-bound
Aroclor 1260	10.9	4.70	0.4	0.5	0.095	0.119	0.052	0.065
Aroclor 1254	182	42.75	1.2	1.5	0.017	0.021	0.017	0.021
Aroclor 1242	24.8	4.09	0.3	0.4	0.031	0.042	0.045	0.060
Aroclor 1016	0.29	0.02	0.04	0.07	0.359	0.628	1.22	2.14
CSF for Aroclor 1268 including data for Aroclor 1016	Average \pm SD (SD as percentage of mean)				0.123 \pm 0.159 (129%)	0.203 \pm 0.287 (141%)	0.334 \pm 0.591 (177%)	0.572 \pm 1.046 (183%)
CSF for Aroclor 1268 excluding data for Aroclor 1016	Average \pm SD (SD as percentage of mean)				0.048 \pm 0.042 (88%)	0.061 \pm 0.052 (85%)	0.038 \pm 0.019 (50%)	0.049 \pm 0.024 (49%)

Cancer slope factors are central tendency and upper-bound estimates from female rats in the study by Brunner et al. (1996) as derived by USEPA (1996). The predicted Aroclor 1268 CSFs are based on Aroclor 1268 TEQs of 2.6 (Hong et al., 1993) and 0.61 (van den Berg et al., 1998) and equal [(Aroclor 1268 TEQ \div mixture TEQ) \times CSF for the mixture]. As TEQs reported by Ahlborg et al. (1994) are very similar to those of van den Berg et al. (1998), CSF derivation using TEQs reported by Ahlborg et al. is not shown.

3.2. Prediction of an Aroclor 1268 slope factor assuming that an Ah-receptor-independent mechanism exists in addition to an Ah-receptor-dependent mechanism

The second extrapolation approach, like the first, assumes a linear relationship between TEQ and cancer potency in female rats, but does not assume that the cancer potency of an Aroclor mixture becomes zero when its TEQ is zero. In essence, this second extrapolation approach assumes that two mechanisms of cancer induction exist in females (Brown et al., 2001), whereas the first extrapolation approach assumes that TEQ is the sole determinant of cancer potency. In this second approach to CSF estimation, the USEPA-derived CSFs for the PCB mixtures in the Brunner et al. (1996) study (Aroclors 1242, 1254, and 1260, with and without Aroclor 1016) were linearly regressed against their respective TEQs. The CSFs and TEQs used in this regression are those provided in Table 6. The resulting regression equations were then used to predict central tendency and upper-bound CSFs for Aroclor 1268 using a TEQ of 0.68 for this mixture, as discussed above. Regressing the central tendency CSFs for the female rat tumor responses to Aroclors 1242, 1254, and 1260 against their corresponding TEQs as reported by Mayes and co-workers resulted in a linear regression line with the equation: $y = 0.021x + 0.192$, where y is the central tendency CSF (dependent variable) and x is TEQ (independent variable). When the estimated TEQ for Aroclor 1268 of 0.68 is substituted into this equation, a central tendency CSF of $0.21 (\text{mg/kg-day})^{-1}$ is derived. This same process was used to predict an upper-bound CSF for Aroclor 1268 of $0.27 (\text{mg/kg-day})^{-1}$. As was done for the first extrapolation approach using com-

parative TEQ analysis, central and upper-bound CSFs for Aroclor 1268 based on TEQs published by Hong et al. (1993) and van den Berg et al. (1998) were also estimated and proved to be comparable to those estimated using the Mayes' data (data not shown). Table 8 presents the regression equations and the central and upper-bound CSFs that were estimated from the Mayes' data set (i.e., 0.21 and $0.27 (\text{mg/kg-day})^{-1}$ for central and upper-bound CSFs, respectively). Table 8 also shows the linear regression equations and slope factor estimates for Aroclor 1268 when the data for all four tested Aroclors (1016, 1242, 1254, and 1260) are included. In this case, inclusion of Aroclor 1016 data did not greatly skew the linear relationship observed across the three higher TEQ Aroclor mixtures. In fact, the correlation coefficients were consistently above 0.98 for each of the four regression lines presented in Table 8. However, inclusion of the Aroclor 1016 data leads to estimated Aroclor 1268 slope factors about 25–30% lower than those predicted using the higher TEQ Aroclor mixture data alone.

As can be seen by comparing the analyses in Tables 6 and 8 (exclusive of Aroclor 1016, the inclusion of which results in seemingly anomalous slope factor estimates), CSF estimates for Aroclor 1268 were different for the two extrapolation approaches, as the linear regression method yielded values 7- to 8-fold higher than those derived by assuming that the CSF was directly proportional to the mixture TEQ. In other words, when two cancer mechanisms are assumed to co-exist in females, that mechanism independent of the Ah-receptor contributes more to the value of the Aroclor 1268 CSF than does the mechanism mediated by the Ah-receptor. In fact, for Aroclors 1016, 1242, 1254, 1260, and 1268, the

Table 8

Predicted cancer slope factors for Aroclor 1268 based on linear regression analysis of Aroclor TEQ vs. slope factors

Aroclors included	Regression equation (central estimate)	Correlation coefficient (<i>r</i>)	Regression equation (upper-bound)	Correlation coefficient (<i>r</i>)	Central cancer slope factor	Upper-bound cancer slope factor
Only Aroclors 1242, 1254, and 1260	$y = 0.021x + 0.192$	0.993	$y = 0.026x + 0.254$	0.995	0.21	0.27
Aroclors 1016, 1242, 1254, and 1260	$y = 0.023x + 0.126$	0.987	$y = 0.028x + 0.175$	0.988	0.14	0.20

Linear regression equations describe best fit lines through data points consisting of central or upper-bound CSFs for female rat tumor responses to Aroclors 1242, 1254, and 1260, with or without Aroclor 1016, regressed against their respective mixture TEQs as cited in Brunner et al., 1996 and Mayes et al., 1998. In the above regression equations, *y* is the central or upper-bound CSF and *x* is the estimated Aroclor 1268 TEQ of 0.68. Cancer slope factors were obtained by simply substituting 0.68 for *x* in the regression equations and solving for *y*.

non-Ah-receptor mechanism is estimated to contribute 100%, 44–64%, 12–17%, 35–51%, and 88–94% of the upper-bound CSF value, respectively (the contribution of the non-Ah-receptor mechanism can be estimated by assigning a value of zero to *x* in the regression equations in Table 8). These percentages are roughly inversely related to the combined percentages of tetra-, penta-, and hexachlorobiphenyls found in these PCB mixtures (Aroclor 1016: 34%; Aroclor 1242: 45%; Aroclor 1254: 93%; Aroclor 1260: 56%; Aroclor 1268: 5%), an observation that also correlates with the abundance of the more potent ‘dioxin-like’ PCBs and PCDFs in these mixtures. The contribution of the Ah-receptor mediated mechanism to the CSF is, as would be predicted, maximal for the most potent Aroclor (i.e., Aroclor 1254) and minimal for the mixtures which are arguably the least potent based on TEQ content (i.e., Aroclors 1016 and 1268). Interestingly, using a rat liver tumor promotion model van der Plas et al. (2000) have calculated that 80% of the total liver tumor promoting capacity of Aroclor 1260 resides with its non-dioxin-like fraction. Given the high percentage contribution of the non-Ah-receptor mechanism to the potency of Aroclor 1268 in females, one might predict that the CSF for Aroclor 1268 in male rats, the sex for which cancer potency does not correlate with TEQ content, would be more comparable than that of the other Aroclors to the CSF for female rats. As shown in the next analysis, this non-Ah-receptor mediated response in male animals is quite

comparable to the response in females when both non-Ah-receptor and Ah-receptor mechanisms are assumed to co-exist.

3.3. Prediction of an Aroclor 1268 slope factor for male rats assuming a mechanism related to the bioaccumulation potential of PCB mixtures

Factors that dictate PCB potency for the mechanism of hepatocarcinogenesis predominant in male rats remain unidentified, but it appears unlikely at present that the mechanism involves the Ah-receptor. A possible Ah-receptor-independent mechanism operative in males is a hepatic response to the bioaccumulation of those PCB congeners most resistant to metabolic clearance. Indeed, Brown and colleagues (Silkworth et al., 1997) have speculated that the carcinogenic potency of a PCB mixture in male rats is a function of its bioaccumulation potential. If this is the case, then the cancer potency of Aroclor 1268 might be expected to be similar to (or perhaps slightly greater than) that of Aroclor 1260. To estimate Aroclor 1268 cancer potency based on male rat tumor responses, with the assumption that potency is a function of bioaccumulation potential, a regression approach was utilized. Similar to the regressions of CSF versus TEQ content in females, USEPA-derived cancer potency values for Aroclors 1016, 1242, 1254, and 1260 from the Brunner et al. (1996) study were used (USEPA, 1996). Unfortunately, there is no unambiguous parameter

Table 9

Predicted cancer slope factors for Aroclor 1268 based on linear regression analysis

Variables regressed	Regression equation	Correlation coefficient (<i>r</i>)	Cancer slope factor (mg/kg-day) ⁻¹
Upper-bound CSF vs. average No. of Cl atoms per biphenyl molecule	$y = 0.0430x - 0.0879$	0.946	0.27
Central tendency CSF vs. average No. of Cl atoms per biphenyl molecule	$y = 0.0239x - 0.0546$	0.994	0.14
Upper-bound CSF vs. percentage chlorine by weight	$y = 0.0066x - 0.2214$	0.904	0.23
Central tendency CSF vs. percentage chlorine by weight	$y = 0.0038x - 0.1336$	0.976	0.12

Linear regression equations describe best fit lines through data points consisting of central or upper-bound CSFs of Aroclors 1016, 1242, 1254, and 1260 (for male rats in Brunner et al., 1996) regressed against their respective average number of chlorine atoms per biphenyl molecule (estimated based on Table 3 to be 3.13, 3.43, 5.02, and 6.35 for Aroclors 1016, 1242, 1254, and 1260, respectively) or their respective percentages of chlorine by weight (1, 42, 54, and 60%, respectively). In the above regression equations, *y* is the central or upper-bound CSF and *x* is 8.31 (the average number of chlorine atoms per biphenyl molecule composing Aroclor 1268) or 68 (the percentage chlorine by weight of Aroclor 1268). Cancer slope factors were obtained by simply substituting 8.31 or 68 for *x* in the appropriate regression equations and solving for *y*.

for the bioaccumulation potential of all PCB mixtures and, as a result, two indirect indicators of bioaccumulation potential were used in the regressions—percentage chlorine content by weight and average number of chlorine atoms per molecule. These two indicators correlate with one another to some degree, but each has different implications with respect to congener distribution, bioaccumulation potential and mixture toxicity. The regression equations are summarized in Table 9.

From these regression equations, CSF estimates were derived for Aroclor 1268 based on its percentage chlorine content by weight and average number of chlorines per biphenyl molecule. As shown in Table 9, central tendency slope factor estimates for Aroclor 1268 based on the two regression lines were 0.14 and 0.12 (mg/kg-day)⁻¹, while upper-bound estimates were 0.27 and 0.23 (mg/kg-day)⁻¹. These values are quite similar to the CSF estimates for Aroclor 1268 derived from data on female rats using the linear regression approach when the value of x (i.e., the Ah-receptor mediated component) is set to zero (see Table 8). When this is done, the central tendency and upper-bound CSF estimates for female rats due to the non-Ah-receptor mediated component are estimated to be about 0.19 and 0.25 (mg/kg-day)⁻¹, respectively, based on the higher TEQ mixtures (exclusive of Aroclor 1016), and about 0.13 and 0.18 (mg/kg-day)⁻¹ based on all four Aroclor mixtures. The similarity in the CSFs derived for the non-Ah-receptor mediated component of both sexes suggests that the bioaccumulation mechanism thought to be operative in males may be the second mechanism observed to occur in female rats. If this is indeed the case, the results of chronic cancer bioassays of Aroclor 1268 would likely resemble the responses of male rats in the Brunner et al. (1996) study rather than the generally greater response of female rats.

The two indirect indicators of bioaccumulation potential (i.e., percentage chlorine content by weight and average number of chlorine atoms per molecule) were also regressed against empirical data describing the relative accumulation of total adipose PCBs in rats following treatment with Aroclors 1016, 1242, 1254, and 1260 (relative accumulation = 0.04, 0.05, 0.51, and 1,

respectively) (Silkworth et al., 1997). From the resulting linear regression equations, the relative accumulation of Aroclor 1268 was estimated to be 1.52 which represents the mean of the two estimates that were made using the two indirect indicators of bioaccumulation potential (i.e., 1.73 and 1.30). Regression equations were then derived for the prediction of central tendency and upper-bound CSFs based on bioaccumulation potential from which CSFs for Aroclor 1268 were estimated (see Table 10). These CSFs of 0.26 (upper-bound) and 0.14 (central tendency) are very similar to the respective average of the two values (averaging 0.25 and 0.13) predicted in Table 9 using indirect indicators of bioaccumulation potential rather than empirical data.

With regard to the above analyses based on bioaccumulation potential, it is noteworthy that only Aroclor 1260 was found to be carcinogenic for male rats in the Brunner et al. (1996) study, although cancer potency estimates for other Aroclor mixtures (Aroclors 1016, 1242, and 1254) were mathematically estimated by the USEPA based on the study's sensitivity. While Aroclor 1260 has greater chlorination and hence a greater bioaccumulation potential than the other Aroclors tested in the Brunner et al. (1996) study, other differences exist among the Aroclors that could also explain the observed differences in cancer potency. It is certainly possible for example, that the presence of certain individual PCB congeners may be necessary for carcinogenicity and that the pattern of chlorination is as important, if not more important, than the overall degree of chlorination. Despite the fact that a rigorous examination of the relationship between chlorination (or bioaccumulation) and cancer potency is precluded by the fact that only one of the four PCB mixtures in the Brunner et al. (1996) study was positive for carcinogenicity in males, if it is assumed that a bioaccumulation-related mechanism exists and is a function of chlorine content, available data predict central tendency and upper-bound CSFs for Aroclor 1268 in males of 0.12 to 0.14 and 0.23 to 0.27 (mg/kg-day)⁻¹, respectively (see Tables 9 and 10). These values are remarkably similar to the estimates for the “non-Ah-receptor mediated” cancer potency of PCBs in females when TEQs are set at zero. This in turn suggests that because Aroclor 1268 has a very low TEQ value, the

Table 10
Predicted cancer slope factors for Aroclor 1268 based on linear regression analysis

Variables regressed	Regression equation	Correlation coefficient (r)	Cancer slope factor (mg/kg-day) ⁻¹
Upper-bound CSF vs. relative bioaccumulation of total adipose PCBs	$y = 0.1419x + 0.0482$	0.951	0.26
Central CSF vs. relative bioaccumulation of total adipose PCBs	$y = 0.0783x + 0.0212$	0.994	0.14

Linear regression equations describe best fit lines through data points consisting of central or upper-bound CSFs of Aroclors 1016, 1242, 1254, and 1260 (for male rats in Brunner et al., 1996) regressed against the relative accumulation of total adipose PCBs for the respective Aroclor mixtures (Silkworth et al., 1997). In the above regression equations, y is the central or upper-bound CSF and x is the relative accumulation of total adipose PCBs. Cancer slope factors for Aroclor 1268 were obtained by simply substituting 1.52 (the estimated relative bioaccumulation potential of Aroclor 1268) for x in the appropriate regression equation and solving for y .

large sex difference observed with the more moderately chlorinated mixtures (i.e., Aroclors 1242, 1254, and 1260) would essentially be absent, much like that observed for Aroclor 1016, which has a similarly low TEQ content relative to the other mixtures assessed directly for cancer potency.

3.4. Estimation of the Ah-receptor mediated component in Aroclor 1268 after correcting for the contribution to potency made by the Ah-receptor-independent component

Because the carcinogenic potency of PCB mixtures in female animals is derived from two sources, i.e., Ah-receptor-dependent and Ah-receptor-independent mechanisms, the most representative estimate of the Ah-receptor-dependent contribution to Aroclor 1268's potency is made after correcting for the contribution made by the Ah-receptor-independent mechanism. This correction was not made in the calculations provided in Table 6 since the effect of the Ah-receptor-independent mechanism had not yet been estimated for either sex. The regression equations in Table 8 (with and without Aroclor 1016) indicate that the Ah-receptor-independent mechanism (which is probably linked to bioaccumulation) contributes 0.126–0.192 (central tendency) and 0.175–0.254 (upper-bound) (mg/kg-day)⁻¹ to the final CSF estimates for female rats when two mechanisms are assumed to co-exist. Subtracting the average of these central tendency (0.159 (mg/kg-day)⁻¹) and upper-bound (0.215 (mg/kg-day)⁻¹) contributions from the CSFs for each Aroclor before using them to predict a CSF for Aroclor 1268 should provide a more representative estimate of the Ah-receptor mediated cancer potency of Aroclor 1268. By repeating the calculations originally made in Table 6 after correcting for the non-Ah-receptor contribution, revised CSF estimates for Aroclor 1268 were derived (see Table 11). All of the

predicted CSFs for Aroclor 1268 in Table 11 were comparable to those derived in Table 6 for Aroclor 1268 based on the mixture TEQ and CSF of Aroclor 1254 (i.e., 0.017 and 0.021 (mg/kg-day)⁻¹ for central tendency and upper-bound, respectively). This result was anticipated as the total cancer potency for Aroclor 1254 was the least affected of all the Aroclors by the Ah-receptor-independent mechanism. On the other hand, subtracting the non-Ah-receptor contribution from the Aroclor 1016 CSFs led to negative slope factors for the Ah-receptor-dependent component, and hence corrected CSFs for Aroclor 1016 were not included in the Aroclor 1268 slope factor calculations. These findings further suggest that the low TEQ and low cancer potency of Aroclor 1016 may be best explained by non-Ah-receptor mechanisms or by the absence of any appreciable tumorigenic response in the rat studies of Brunner et al. (1996).

In summary, the original calculations made in Table 6 for the Ah-receptor-dependent fraction of the Aroclor CSF were inflated by the effect of a second, Ah-receptor-independent mechanism. This inflation had its greatest impact on the predicted Aroclor 1268 CSFs derived from Aroclors 1242 and 1260, two PCB mixtures for which this second mechanism appears to contribute about one-half of the observed potency. By correcting for the contribution of this second mechanism, a better estimate of the fraction of Aroclor 1268's cancer potency contributed by the Ah-receptor-dependent mechanism has been derived. This fraction is estimated to be about 0.02 (mg/kg-day)⁻¹ and is quite similar across all of the PCB mixtures in Table 11 (contrast this with the greater variability across predicted Aroclor 1268 CSFs in Table 6). Thus, we have a high degree of confidence in the mean predicted CSFs for Aroclor 1268 in Table 11 (0.017 and 0.020 (mg/kg-day)⁻¹) attributable to the Ah-receptor-dependent fraction of cancer potency.

Table 11
Predicted Ah-receptor-dependent cancer slope factors for Aroclor 1268 after correction for the Ah-receptor-independent mechanism(s)

PCB mixture	Mixture TEQ ^b Mayes et al. (1998)	Cancer slope factor ^a		Predicted cancer slope factor for Aroclor 1268 ^c	
		Corrected central tendency	Corrected upper-bound	Based on central tendency	Based on upper-bound
Aroclor 1260	7.2	0.241	0.285	0.023	0.027
Aroclor 1254	47.6	1.04	1.29	0.015	0.018
Aroclor 1242	7.8	0.141	0.185	0.012	0.016
Aroclor 1016	0.11	(Negative)	(Negative)	–	–
Average ± SD (without Aroclor 1016)				0.017 ± 0.005	0.020 ± 0.006
(SD as percentage of mean)				(33%)	(28%)

^a Corrected CSFs are in (mg/kg-day)⁻¹ and were derived by subtracting 0.159 or 0.215 (mg/kg-day)⁻¹ from those CSFs reported for female rats in USEPA (1996).

^b The TEQ values listed in this column are those reported for the Brunner et al. (1996) study in the recent publication of this experiment by Mayes et al. (1998).

^c The total TEQ for Aroclor 1268 was 1.43% (Hong et al., 1993; van den Berg et al., 1998) that for Aroclor 1254. Using this percentage (1.43%) and the total TEQ of 47.6 µg/g for Aroclor 1254 as measured in the Brunner et al. (1996) study (Mayes et al., 1998), the projected TEQ for Aroclor 1268 would be 0.68. Predicted CSFs for Aroclor 1268 were arrived at using the formula: [(0.68 ÷ mixture TEQ from Mayes et al. (1998)) × Corrected CSF for the mixture].

4. Summary and conclusions

The analyses presented in this report are consistent with the contemporary concept of two different mechanisms of PCB hepatocarcinogenesis in rats, one Ah-receptor-dependent and the other Ah-receptor independent (Brown et al., 2001). Data from Brunner et al. (1996) and other studies suggest that the Ah-receptor-dependent mechanism exists predominantly in female rats, and that at least a second mechanism, one that is Ah-receptor independent, is present in both male and female rats. The presence of an Ah-receptor-dependent mechanism in females would explain their generally greater sensitivity to PCB hepatocarcinogenesis compared with males, and the close correlation in females (but not males) between cancer potency and the TEQ content of the PCB mixture being tested (at least for the moderately chlorinated mixtures). Because of this high degree of correlation between cancer potency and TEQ content, it is expected that the subordinate, Ah-receptor-independent mechanism in females would be largely masked by the stronger response mediated by the Ah-receptor for the most commonly used commercial PCB mixtures, and would become apparent only in PCB mixtures with very low TEQ values (such as Aroclors 1016 and 1268). This would explain the positive y-axis intercept in regressions of CSFs versus TEQ values for females and the similarity of male and female CSFs for Aroclor 1268 when both are derived using linear regression analysis.

The coplanar tetra-, penta-, and hexa-chlorinated PCB congeners comprise a relatively small fraction of Aroclor 1268, corresponding to its low TEQ content compared to other heavily chlorinated Aroclors (e.g., 1260 and 1254) that exhibit much higher TEQ content. Accordingly, the more potent and sex-dependent (female rat) tumorigenic response reported for Aroclors 1254 and 1260 would not be expected for Aroclor 1268. Similarly, the lack of a substantial sex-dependent response would also be predicted when the chlorination of the Aroclor mixture is very limited, as it is with Aroclor 1016. For Aroclor 1016, its weak overall Ah-receptor mediated potency combined with the lower potential for its congeners to bioaccumulate would be predicted to produce a lower CSF that has little sex-dependence. This is in fact what was observed in the Brunner et al. (1996) study where the estimated upper-bound CSF for Aroclor 1016 was 0.07 in females and 0.04 in males (USEPA, 1996).

Several CSF estimation approaches for Aroclor 1268 have been examined in the present study. All of these estimation approaches make use of existing data on the cancer potency of other PCB mixtures, predominantly from the recent study by Brunner et al. (1996), coupled with differing assumptions regarding mechanism(s) of PCB hepatocarcinogenesis. All of the estimation approaches when applied to Aroclor 1268 yielded cancer

potency estimates that are nearly an order of magnitude or more below the current upper-bound USEPA default value of $2 \text{ (mg/kg-day)}^{-1}$. Estimates based solely on relative TEQ content, which recognize the dominant role of the Ah-receptor-dependent mechanism in female rats, are some 60- and 100-fold below the regulatory default values for the central tendency ($1.0 \text{ (mg/kg-day)}^{-1}$) and upper-bound slope factors ($2.0 \text{ (mg/kg-day)}^{-1}$), respectively (see averages in Table 11). If one assumes, as the data suggest, that the Ah-receptor-dependent mechanism in females is also accompanied by an Ah-receptor-independent mechanism, then the application of linear regression analysis yields CSFs roughly an order of magnitude higher than those estimated based on relative TEQ content alone (see Table 8 versus Table 11). The estimates of the Ah-receptor-independent contribution to cancer potency are similar for both sexes, and are based on the assumption that the chlorine content of a PCB mixture determines its degree of bioaccumulation, which in turn dictates the final cancer potency of the mixture.

Based on the use of comparative TEQ analysis for females and linear regression analysis for both sexes, it seems appropriate to conclude that an upper-bound Aroclor 1268 CSF should fall between 0.03 (67-fold lower than the default value of 2.0) and $0.27 \text{ (mg/kg-day)}^{-1}$ (7- to 8-fold lower than the default value of 2.0). We propose that an upper-bound CSF for Aroclor 1268 of $0.27 \text{ (mg/kg-day)}^{-1}$ is reasonable based on the available data. Although this CSF would represent about a 7- to 8-fold reduction relative to USEPA's default value, it is still believed to be a conservative estimate based on the animal data. It not only equals the highest upper-bound estimate calculated for male rats (see Table 9), but also equals the highest upper-bound estimate calculated for females assuming that Ah-receptor-dependent and independent cancer mechanisms co-exist (see Table 8).

Acknowledgments

The authors thank Dr. Stephen Roberts of the University of Florida for his helpful comments and constructive criticisms related to the article. This article was an outgrowth of a consulting effort by TERRA, Inc. It was written independently of the client, its content is the sole responsibility of the authors, and the effort was not compensated.

References

- Ahlborg, U.G., Becking, G.C., Birnbaum, L.S., et al., 1994. Toxic equivalency factors for dioxin-like PCBs. *Chemosphere* 28 (6), 1049–1067.

- Anderson, J.W., 1991. Determination of congeners of polychlorinated biphenyls in reference materials. *J. High Resolut. Chromatogr.* 14, 369–372.
- Brown, J.F., Fish, K.M., Silkworth, J.B., Mayes, B.A., 1997. Biochemical and histological precursors of liver tumors in PCB-dosed Sprague–Dawley rats. *Organohalogen Compounds* 34, 301–304.
- Brown, J.F., Fish, K.M., Mayes, B.A., Silkworth, J.B., Hamilton, S.B., Whysner, J., 2001. PCB effects on epigenetic carcinogenic processes. In: Roberston, L.W., Hansen, L.G. (Eds.), *Recent Advances in Environmental Toxicology and Health Effects*. The University Press of Kentucky, Lexington, KY, pp. 329–336.
- Brunner, M.J., Sullivan, T.M., Singer, A.W., et al., 1996. An assessment of the chronic toxicity and oncogenicity of Aroclor 1016, Aroclor 1242, Aroclor 1254, and Aroclor 1260 administered in diet to rats. Report to General Electric Company on Study Number SC920172. Batelle, Columbus, Ohio.
- Hong, C.S., Bush, B., Xiao, J., Qiao, H., 1993. Toxic potential of non-ortho and mono-ortho coplanar polychlorinated biphenyls in Aroclors, seals, and humans. *Arch. Environ. Contam. Toxicol.* 25 (1), 118–123.
- Hutzinger, O., Safe, S., Zitko, V. (Eds.), 1974. *The Chemistry of PCBs*. CRC Press, Boca Raton, FL.
- International Agency for Research on Cancer (IARC), 1987. Overall Evaluations of Carcinogenicity, An Updating of IARC Monographs Volumes I to 42. Supplement 7. Polychlorinated Biphenyls. World Health Organization, International Programme on Chemical Safety, IARC, Lyon, France.
- IRIS, 2004. USEPA Integrated Risk Information System on-line database for risk assessment toxicity criteria for polychlorinated biphenyls.
- Ito, N., Nagasaki, H., Arai, M., Makiura, S., Sugihara, S., Hirao, K., 1973. Histopathologic studies on liver tumorigenesis induced in mice by technical polychlorinated biphenyls and its promoting effects on liver tumors induced by benzene hexachloride. *J. Natl. Cancer Inst.* 51, 1637.
- Ito, N., Nagasaki, H., Makiura, S., Arai, M., 1974. Histopathological studies on liver tumorigenesis in rats treated with polychlorinated biphenyls. *Gann* 65, 545.
- Kimbrough, R.D., Linder, R.E., Gaines, T.B., 1972. Morphological changes in livers of rats fed polychlorinated biphenyls, light microscopy and ultrastructural. *Arch. Environ. Health* 25, 354.
- Kimbrough, R.D., Linder, R.E., 1974. Induction of adenofibrosis and hepatomas of the liver in Balb/cJ mice by polychlorinated biphenyls (Aroclor 1254). *J. Natl. Cancer Inst.* 53, 547.
- Kimbrough, R.D., Squire, R.A., Linder, R.E., et al., 1975. Induction of liver tumors in Sherman strain rats by polychlorinated biphenyl Aroclor 1260. *J. Natl. Cancer Inst.* 55, 1453.
- Kimura, N.T., Baba, T., 1973. Neoplastic changes in the rat liver induced by polychlorinated biphenyl. *Gann* 64, 105.
- Mayes, B.A., McConnell, E.E., Neal, B.H., et al., 1998. Comparative carcinogenicity in Sprague–Dawley rats of the polychlorinated biphenyl mixtures Aroclors 1016, 1242, 1254, and 1260. *Fundam. Appl. Toxicol.* 41 (1), 62–76.
- NCI, 1978. Bioassay of Aroclor 1254 for possible carcinogenicity. DHEW Publication No. (NIH) 78-838.
- Norback, D.H., Weltman, R.H., 1985. Polychlorinated biphenyl induction of hepatocellular carcinoma in the Sprague–Dawley rat. *Environ. Health Perspect.* 60, 97.
- Rao, C.V., Banerji, A.S., 1988. Induction of liver tumors in male Wistar rats by feeding polychlorinated biphenyls (Aroclor 1260). *Cancer Lett.* 39, 59.
- Schaeffer, E., Greim, H., Goessner, W., 1984. Pathology of chronic polychlorinated biphenyl (PCB) feeding in rats. *Toxicol. Appl. Pharmacol.* 75 (2), 278–288.
- Silkworth, J.B., Mayes, B.A., Fish, K.M., Brown, J.F., 1997. Tumor responses, PCB tissue concentrations and PCB hepatic binding in S–D rats fed Aroclors 1016, 1242, 1254, or 1260. In: Hites, R. (Ed.), *Dioxin 97, 17th International Symposium on Chlorinated Dioxins and Related Compounds*. Organohalogen Compounds. Risk Assessment, Toxicology, Endocrine Disruptors, Epidemiology, vol. 34. Indiana University, Indianapolis, IN, pp. 164–166.
- USEPA, 1996. PCBs, Cancer Dose–Response Assessment and Application to Environmental Mixtures. (EPA/600/P-96/001F). The National Center for Environmental Assessment, Office of Research and Development, Washington, DC.
- van den Berg, M., Birnbaum, L., Bosveld, A.T.C., et al., 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environ. Health Perspect.* 106 (12), 775–792.
- van der Plas, S.A., Sundberg, H., van den Berg, H., et al., 2000. Contribution of planar (0–1 ortho) and nonplanar (2–4 ortho) fractions of Aroclor 1260 to the induction of altered hepatic foci in female Sprague–Dawley rats. *Toxicol. Appl. Pharmacol.* 169, 255–268.

APPENDIX I

Soil Screening Level Calculations

$$C_{\text{soil}} = C_{\text{gw}} \left[K_s + \frac{(\theta_w + \theta_a H')}{\rho_b} \right] df$$

C_{soil} = soil conc. mg/kg

C_{gw} = ground water target conc = .0005 mg/L

df = dilution factor = 20

$K_s = K_{oc} f_{oc}$

$$\log K_{oc} = 1 \times \log K_{ow} - 0.21$$

$K_{ow} = 6.7$ (lowest value)

$$f_{oc} = 0.001$$

θ_w = water filled porosity = 0.3

θ_a = air filled porosity = 0.13

ρ_b = bulk density = 1.5

H' = Henry's Law coefficient = 0.205

$$\log K_{oc} = 1 \times 6.7 - .21 = 6.49$$

$$K_{oc} = 3,090,295$$

$$K_s = 3,090,295 \times 0.001 = 3090$$

$$C_{\text{soil}} = 0.0005 \left[3090 + \frac{(0.3 + 0.13 \times 0.205)}{1.5} \right] \times 20$$

$$C_{\text{soil}} = 30.9 \text{ mg/kg}$$



[Home](#) [Papers in Press](#) [Current](#) [Archive](#) [Subscribe](#) [Advertise](#) [Issue Alerts](#) [Search](#) [Help](#)

SETAC Journals Online Access Control

[Volume 17, Issue 12 \(December 1998\)](#)



The article you have requested is available via Journal Subscription, or Single Article Purchase:
[[Free Abstract](#)] [[Subscriber Login](#)] [[Purchase Article](#)]

Environmental Toxicology and Chemistry

Article: pp. 2463–2469 | [Abstract](#) | [PDF \(265K\)](#)

BIOTA–SEDIMENT ACCUMULATION AND TROPHIC TRANSFER FACTORS FOR EXTREMELY HYDROPHOBIC POLYCHLORINATED BIPHENYLS

Keith A. Maruya and Richard F. Lee

Skidaway Institute of Oceanography, 10 Ocean Science Circle, Savannah, Georgia 31411, USA

Polychlorinated biphenyls (PCBs) in fish, invertebrates, and sediment from a contaminated tidal creek system in coastal Georgia (USA) were traced to Aroclor 1268, a mixture of hepta through decachlorinated homologs ($\bar{X}_{Cl} = 8.5$) used at a former chlor/alkali plant adjacent to the study site. The base 10 logarithm of the octanol/water partition coefficient (K_{ow}) for the 15 most abundant Aroclor 1268 components in these samples ranged from 6.7 to >9. The composite mean biota–sediment accumulation factor (BSAF) for these congeners was 3.1, 0.81, and 0.28 for yearling striped mullet, spotted sea trout, and grass shrimp, respectively, species representing three trophic levels of the local food web. Individual congener BSAFs were negatively correlated ($p \leq 0.05$) with $\log K_{ow}$ for all three species. The composite mean trophic transfer factor (TTF_{lip}), defined as the ratio of lipid-normalized PCB concentrations in fish to grass shrimp, was higher for mullet (12) than for sea trout (2.9). Individual TTF_{lip} values were two to three times higher for Cl_7 and Cl_8 homologs that were substituted at all four *ortho* positions, suggesting a difference in PCB retention based on chlorine substitution patterns. The relative magnitude of BSAFs and TTF_{lip} values indicated that sediment-ingesting forage species like mullet efficiently accumulate PCBs and are an important link in the food web transfer of sediment-associated contaminants in this system. The negative linear relationships between BSAF and $\log K_{ow}$ established in this study are among the first to be reported in the field for extremely hydrophobic PCBs.

Keywords: Polychlorinated biphenyls, Aroclor 1268, Sediment quality, Bioaccumulation, Trophic transfer

Received: July 31, 1997; Accepted: April 15, 1998

DOI: 10.1897/1551-5028(1998)017<2463:BSAATT>2.3.CO;2

[http://www.setacjournals.org/perlserv/?request=get-document&doi=10.1897%2F1551-5028\(1998\)...](http://www.setacjournals.org/perlserv/?request=get-document&doi=10.1897%2F1551-5028(1998)...) 9/19/2007

Journal Subscription

If you are a journal subscriber, please use the login form on the right to retrieve the article.

To remain logged in, your browser must allow cookies. Use this link to [check](#).

Journal Subscribers

User Name:

Password:

Login

Need a Subscription?

[Subscribe Now!](#)

Purchase Single Article

To purchase access to this individual article, select "Purchase Article". If you have previously purchased access to this individual article and would like to re-visit it, Please [sign in and re-visit](#).

Single Article Access

Purchase Article

[top](#)

[Feedback](#) | [SETAC](#)

Published by SETAC and Allen Press Publishing Services.

[Copyright](#) © 2007 Society of Environmental Toxicology and Chemistry

[Terms and conditions](#)

Worksheet 1: Calculation of Effective Volubility (from Shiu, 1988; Feenstra, Mackay, & Cherry, 1991)

For a single-component DNAPL, the pure-phase volubility of the organic constituent can be used to estimate the theoretical upper-level concentration of organics in aquifers or for performing dissolution calculations. For DNAPLs comprised of a mixture of chemicals, however, the **effective volubility** concept should be employed:

$$S_i^e = X_i S_i$$

Where

S_i^e = the effective volubility (the theoretical upper-level dissolved-phase concentration of a constituent in ground water in equilibrium with a mixed DNAPL; in mg/l)

X_i = the mole fraction of component i in the DNAPL mixture (obtained from a lab analysis of a DNAPL sample or estimated from waste characterization data)

S_i = the pure-phase volubility of compound i in mg/l (usually obtained from literature sources)

For example, if a laboratory analysis indicates that the mole fraction of trichloroethylene (TCE) in DNAPL is 0.10, then the effective solubility would be 110 mg/l [pure phase solubility of TCE times mole fraction TCE: (1100 mg/l) * (0.10) = 110 mg/l]. Effective solubilities can be calculated for all components in a DNAPL mixture. Insoluble organics in the mixture (such as long-chained alkanes) will reduce the mole fraction and effective volubility of more soluble organics but will not contribute dissolved-phase organics to ground water. *Please note that this relationship is approximate and does not account for non-ideal behavior of mixtures, such as co-solvency, etc.*

Worksheet 2: Method for Assessing Residual NAPL Based on Organic Chemical Concentrations in Soil Samples (From Feenstra, Mackay, and Cherry, 1991)

To estimate if NAPLs are present, a partitioning calculation based on chemical and physical analyses of soil samples from **the saturated zone** (from cores, excavations, etc.) can be applied. This method tests the assumption that all of the organics in the subsurface are either dissolved in ground water or adsorbed to soil (assuming dissolved-phase sorption, not the presence of NAPL). By using the concentration of organics on the soil and the partitioning calculation, a theoretical pore-water concentration of organics in ground water is determined. If the theoretical pore-water concentration is greater than the estimated volubility of the organic constituent of interest, then NAPL may be present at the site. A worksheet for performing this calculation is presented below; see Feenstra, Mackay, and Cherry (1991) for the complete methodology.

Step 1: Calculate S_i^e , the effective volubility of organic constituent of interest.

See Worksheet 1, above.

Step 2: Determine **Koc**, the organic carbon-water partition coefficient from one of the following:

A) Literature sources (such as 22) or

B) From empirical relationships based on **Kow**, the octanol-water partition coefficient, which is also found in the literature (22). For example, **Koc** can be estimated from **Kow** using the following expression developed for polyaromatic hydrocarbons (8):

$$\text{Log Koc} = 1.0 * \text{Log Kow} - 0.21$$

Other empirical relationships between **Koc** and **Kow** are presented in refs. 4 and 15.

Step 3: Determine **foc**, the fraction of organic carbon on the soil, from a laboratory analysis of clean soils from the site. Values for **foc** typically range from 0.03 to 0.00017 mg/mg (4). Convert values reported in percent to mg/mg.

Step 4: Determine or estimate **pb**, the dry bulk density of the soil, from a soils analysis. Typical values range from 1.8 to 2.1 g/ml (kg/l). Determine or estimate **φw**, the water-filled porosity.

Step 5: Determine **Kd**, the partition (or distribution) coefficient between the pore water (ground water) and the soil solids:

$$Kd = Koc * foc$$

Step 6 Using **Ct**, the measured conc. of the organic compound in saturated soil in mg/kg, calculate the theoretical pore water conc. assuming no DNAPL (i.e., **Cw** in mg/l):

$$Cw = \frac{(Ct * pb)}{(Kd * pb + \phi w)}$$

Step 7 Compare **Cw** and S_i^e (from Step 1):

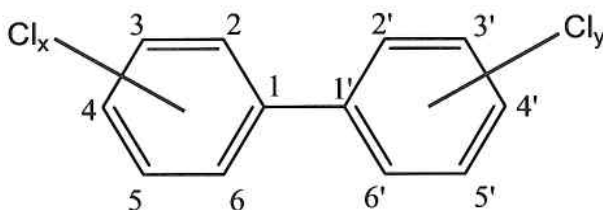
$Cw > S_i^e$ suggests possible **presence** of DNAPL

$Cw < S_i^e$ suggests possible **absence** of DNAPL

4. CHEMICAL AND PHYSICAL INFORMATION

4.1 CHEMICAL IDENTITY

PCBs are a class of chemical compounds in which 2–10 chlorine atoms are attached to the biphenyl molecule. Monochlorinated biphenyls (i.e., one chlorine atom attached to the biphenyl molecule) are often included when describing PCBs. The general chemical structure of chlorinated biphenyls is shown below.



It can be seen from the structure that a large number of chlorinated compounds are possible. The 209 possible compounds are called congeners. PCBs can also be categorized by degree of chlorination. The term “homolog” is used to refer to all PCBs with the same number of chlorines (e.g., trichlorobiphenyls). Homologs with different substitution patterns are referred to as isomers. For example, the dichlorophenyl homolog contains 12 isomers.

The numbering system for the PCBs is also shown above. Positions 2, 2', 6, and 6' are called ortho positions, positions 3, 3', 5, and 5' are called meta positions, and positions 4 and 4' are called para positions. The benzene rings can rotate around the bond connecting them; the two extreme configurations are planar (the two benzene rings in the same plane) and the nonplanar in which the benzene rings are at a 90° angle to each other. The degree of planarity is largely determined by the number of substitutions in the ortho positions. The replacement of hydrogen atoms in the ortho positions with larger chlorine atoms forces the benzene rings to rotate out of the planar configuration. The benzene rings of non-*ortho* substituted PCBs, as well as mono-*ortho* substituted PCBs, may assume a planar configuration and are referred to as planar or coplanar congeners; the benzene rings of other congeners cannot assume a planar or coplanar configuration and are referred to as non-planar congeners.

Monsanto Corporation, the major U.S. producer of PCBs from 1930 to 1977, marketed mixtures of PCBs under the trade name Aroclor. The Aroclors are identified by a four-digit numbering code in which the

4. CHEMICAL AND PHYSICAL INFORMATION

first two digits indicate the type of mixture and the last two digits indicate the approximate chlorine content by weight percent. Thus, Aroclor 1242 is a chlorinated biphenyl mixture of varying amounts of mono- through heptachlorinated homologs with an average chlorine content of 42%. The exception to this code is Aroclor 1016, which contains mono- through hexachlorinated homologs with an average chlorine content of 41% (Hutzinger et al. 1974).

The trade names of some commercial PCB mixtures manufactured in other countries are Clophen (Germany), Fenclor (Italy), Kanechlor (Japan), and Phenoclor (France) (De Voogt and Brinkman 1989). The composition of commercial Clophen A-60 and Phenoclor DP-6 is similar to Aroclor 1260; that of Kanechlor 500 is similar to Aroclor 1254. Fenclor contains 100% decachlorobiphenyl (De Voogt and Brinkman 1989). The chemical identity of the Aroclors is summarized in Table 4-1. The identity of the 209 PCB congeners is shown in Table 4-2. The congeners are arranged in ascending numerical order using a numbering system developed by Ballschmiter and Zell (1980) that follow the IUPAC rules of substituent characterization in biphenyls. The resulting PCB numbers, also referred to as congener, IUPAC, or BZ numbers, are widely used for identifying individual congeners.

4.2 PHYSICAL AND CHEMICAL PROPERTIES

Physical and chemical properties of the Aroclors are summarized in Table 4-3. An important property of PCBs is their general inertness; they resist both acids and alkalis and have thermal stability. This made them useful in a wide variety of applications, including dielectric fluids in transformers and capacitors, heat transfer fluids, and lubricants (Afghan and Chau 1989). In general, PCBs are relatively insoluble in water, and the solubility decreases with increased chlorination (see Table 4-3). PCBs are also freely soluble in nonpolar organic solvents and biological lipids (EPA 1980b). PCBs are combustible liquids, and the products of combustion may be more hazardous than the material itself. By-products of combustion include hydrogen chloride, polychlorinated dibenzodioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) (NFPA 1994).

The approximate weight percent of chlorobiphenyls in some commercial Aroclors is summarized in Table 4-4, and the congener composition of Aroclors is shown in Table 4-5. The congener composition of commercial PCBs may vary from lot to lot even in products from the same manufacturer. In addition, no two descriptions of commercial PCB mixtures, even from the same lot or a manufactured product, are identical because of slight differences in the conditions of the chlorination process or the use of different analysis procedures. For example, a late production Aroclor 1254 lot (Aroclor 1254 "Late"), with greatly

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-1. Chemical Identity of Selected Technical Polychlorinated Biphenyls or Aroclors^{a,b}

Characteristic	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1248
Synonym(s)	PCB-1016; Polychlorinated biphenyl mixture with 41.5% chlorine	PCB-1221; Polychlorinated biphenyl mixture with 21% chlorine	PCB-1232; Polychlorinated biphenyl mixture with 32% chlorine	PCB-1242; Polychlorinated biphenyl mixture with 41.5% chlorine	PCB-1248; Polychlorinated biphenyl mixture with 48% chlorine
Registered trade name(s)	Aroclor ^c	Aroclor	Aroclor	Aroclor	Aroclor
Chemical formula	See Table 4-4	See Table 4-4	See Table 4-4	See Table 4-4	See Table 4-4
Chemical structure	See Section 4.1	See Section 4.1	See Section 4.1	See Section 4.1	See Section 4.1
Identification numbers:					
CAS registry	12674-11-2	11104-28-2	11141-16-5	53469-21-9	12672-29-6
NIOSH RTECS	TQ1351000	TQ1352000	TQ1354000	TQ1356000	TQ1358000
EPA hazardous waste ^d	3502 ^e	3502 ^e	3502 ^e	3502 ^e	3502 ^e
OHM/TADS	8500400 ^f	8500401 ^f	8500402 ^f	8500403 ^f	8500404 ^f
DOT/UN/NA/IMCO shipping	UN2315/IMO9.2 ^g	UN2315/IMO9.2 ^g	UN2315/IMO9.2 ^g	UN2315/IMO9.2 ^g	UN2315/IMO9.2 ^g
HSDB	6352 ^g	6353 ^g	6354 ^g	6355 ^g	6356 ^g
NCI	No data	No data	No data	No data	No data

Table 4-1. Chemical Identity of Selected Technical Polychlorinated Biphenyls or Aroclors ^{a,b} (continued)

Characteristic	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
Synonym(s)	PCB-1254; Polychlorinated biphenyl mixture with 54% chlorine	PCB-1260; Polychlorinated biphenyl mixture with 60% chlorine	PCB-1262; Polychlorinated biphenyl mixture with 61.5–62.5% chlorine	PCB-1268; Polychlorinated biphenyl mixture with 68% chlorine
Registered trade name(s)	Aroclor	Aroclor	Aroclor	Aroclor
Chemical formula	See Table 4-4	See Table 4-4	See Table 4-4	See Table 4-4
Chemical structure	See Section 4.1	See Section 4.1	See Section 4.1	See Section 4.1
Identification numbers:				
CAS registry	11097-69-1	11096-82-5	37324-23-5	11100-14-4
NIOSH RTECS	TQ1360000	TQ1362000	TQ1364000 ^h	No data
EPA hazardous waste ^d	3502 ^e	3502 ^e	No data	No data
OHM/TADS	8500405 ^f	8500406 ^f	No data	No data
DOT/UN/NA/IMO shipping	UN2315/IMO9.2 ^g	UN2315/IMO9.2 ^g	UN2315 ^h	UN2315 ^h
HSDB	6357 ^g	1822 ^g	No data	No data
NCI	C02664 ⁱ	No data	No data	No data

^aAll information obtained from SANSS 1990 and Hutzinger et al. 1974 except where noted.

^dDesignation prior to May 19, 1980.

^eEPA 1980a

^fEPA-NIH 1990

^gHSDB 2000

^hChemfinder 2000

ⁱNIOSH 1987a

^bChemical names used are those currently indexed by the Chemical Abstracts Service.

^cAroclor is the trade name for chlorinated biphenyls made by Monsanto Chemical Company.

CAS = Chemical Abstracts Services; DOT/UN/NA/IMCO = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code; EPA = Environmental Protection Agency; HSDB = Hazardous Substances Data Bank; NCI = National Cancer Institute; NIOSH = National Institute for Occupational Safety and Health; OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System; PCB = polychlorinated biphenyl; RTECS = Registry of Toxic Effects of Chemical Substances

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-2. Chemical Identity of Polychlorinated Biphenyl Congeners and Homologs

PCB No. ^a	Structure	CAS No. ^b
	Biphenyl	92-52-4
	Monochlorobiphenyl	27323-18-8
1	2	2051-60-7
2	3	2051-61-8
3	4	2051-62-9
	Dichlorobiphenyl	25512-42-9
4	2,2	13029-08-8
5	2,3	16605-91-7
6	2,3	25569-80-6
7	2,4	33284-50-3
8	2,4	34883-43-7
9	2,5	34883-39-1
10	2,6	33146-45-1
11	3,3	2050-67-1
12	3,4	2974-92-7
13	3,4	2974-90-5
14	3,5	34883-41-5
15	4,4	2050-68-2
	Trichlorobiphenyl	25323-68-6
16	2,2 ,3	38444-78-9
17	2,2 ,4	37680-66-3
18	2,2 ,5	37680-65-2
19	2,2 ,6	38444-73-4
20	2,3,3	38444-84-7
21	2,3,4	55702-46-0
22	2,3,4	38444-85-8
23	2,3,5	55720-44-0
24	2,3,6	55702-45-9
25	2,3 ,4	55712-37-3
26	2,3 ,5	38444-81-4
27	2,3 ,6	38444-76-7
28	2,4,4	7012-37-5
29	2,4,5	15862-07-4
30	2,4,6	35693-92-6
31	2,4 ,5	16606-02-3
32	2,4 ,6	38444-77-8
33	2 ,3,4	38444-86-9

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-2. Chemical Identity of Polychlorinated Biphenyl Congeners and Homologs (continued)

PCB No. ^a	Structure	CAS No. ^b
34	2 ,3,5	37680-68-5
35	3,3 ,4	37680-69-6
36	3,3 ,5	38444-87-0
37	3,4,4	38444-90-5
38	3,4,5	53555-66-1
39	3,4 ,5	38444-88-1
	Tetrachlorobiphenyl	26914-33-0
40	2,2 ,3,3	38444-93-8
41	2,2 ,3,4	52663-59-9
42	2,2 ,3,4	36559-22-5
43	2,2 ,3,5	70362-46-8
44	2,2 ,3,5	41464-39-5
45	2,2 ,3,6	70362-45-7
46	2,2 ,3,6	41464-47-5
47	2,2 ,4,4	2437-79-8
48	2,2 ,4,5	70362-47-9
49	2,2 ,4,5	41464-40-8
50	2,2 ,4,6	62796-65-0
51	2,2 ,4,6	68194-04-7
52	2,2 ,5,5	35693-99-3
53	2,2 ,5,6	41464-41-9
54	2,2 ,6,6	15968-05-5
55	2,3,3 ,4	74338-24-2
56	2,3,3 ,4	41464-43-1
57	2,3,3 ,5	70424-67-8
58	2,3,3 ,5	41464-49-7
59	2,3,3 ,6	74472-33-6
60	2,3,4,4	33025-41-1
61	2,3,4,5	33284-53-6
62	2,3,4,6	54230-22-7
63	2,3,4 ,5	74472-35-8
64	2,3,4 ,6	52663-58-8
65	2,3,5,6	33284-54-7
66	2,3 ,4,4	32598-10-0
67	2,3 ,4,5	73575-53-8
68	2,3 ,4,5	73575-52-7
69	2,3 ,4,6	60233-24-1
70	2,3 ,4 ,5	32598-11-1
71	2,3 ,4 ,6	41464-46-4

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-2. Chemical Identity of Polychlorinated Biphenyl Congeners and Homologs (continued)

PCB No. ^a	Structure	CAS No. ^b
72	2,3 ,5,5	41464-42-0
73	2,3 ,5 ,6	74338-23-1
74	2,4,4 ,5	32690-93-0
75	2,4,4 ,6	32598-12-2
76	2 ,3,4,5	70362-48-0
77	3,3 ,4,4	32598-13-3
78	3,3 ,4,5	70362-49-1
79	3,3 ,4,5	41464-48-6
80	3,3 ,5,5	33284-52-5
81	3,4,4 ,5	70362-50-4
	Pentachlorobiphenyl	25429-29-2
82	2,2 ,3,3 ,4	52663-62-4
83	2,2 ,3,3 ,5	60145-20-2
84	2,2 ,3,3 ,6	52663-60-2
85	2,2 ,3,4,4	65510-45-4
86	2,2 ,3,4,5	55312-69-1
87	2,2 ,3,4,5	38380-02-8
88	2,2 ,3,4,6	55215-17-3
89	2,2 ,3,4,6	73575-57-2
90	2,2 ,3,4 ,5	68194-07-0
91	2,2 ,3,4 ,6	68194-05-8
92	2,2 ,3,5,5	52663-61-3
93	2,2 ,3,5,6	73575-56-1
94	2,2 ,3,5,6	73575-55-0
95	2,2 ,3,5 ,6	38379-99-6
96	2,2 ,3,6,6	73575-54-9
97	2,2 ,3 ,4,5	41464-51-1
98	2,2 ,3 ,4,6	60233-25-2
99	2,2 ,4,4 ,5	38380-01-7
100	2,2 ,4 ,4 ,6	39485-83-1
101	2,2 ,4,5,5	37680-73-2
102	2,2 ,4,5,6	68194-06-9
103	2,2 ,4,5 ,6	60145-21-3
104	2,2 ,4,6,6	56558-16-8
105	2,3,3 ,4,4	32598-14-4
106	2,3,3 ,4,5	70424-69-0
107	2,3,3 ,4 ,5	70424-68-9
108	2,3,3 ,4,5	70362-41-3
109	2,3,3 ,4,6	74472-35-8

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-2. Chemical Identity of Polychlorinated Biphenyl Congeners and Homologs (*continued*)

PCB No. ^a	Structure	CAS No. ^b
110	2,3,3 ,4 ,6	38380-03-9
111	2,3,3 ,5,5	39635-32-0
112	2,3,3 ,5,6	74472-36-9
113	2,3,3 ,5 ,6	68194-10-5
114	2,3,4,4 ,5	74472-37-0
115	2,3,4,4 ,6	74472-38-1
116	2,3,4,5,6	18259-05-7
117	2,3,4 ,5,6	68194-11-6
118	2,3 ,4,4 ,5	31508-00-6
119	2,3 ,4,4 ,6	56558-17-9
120	2,3 ,4,5,5	68194-12-7
121	2,3 ,4,5 ,6	56558-18-0
122	2 ,3,3 ,4,5	76842-07-4
123	2 ,3,4,4 ,5	65510-44-3
124	2 ,3,4,5,5	70424-70-3
125	2 ,3,4,5,6	74472-39-2
126	3,3 ,4,4 ,5	57465-28-8
127	3,3 ,4,5,5	39635-33-1
	Hexachlorobiphenyl	26601-64-9
128	2,2 ,3,3 ,4,4	38380-07-3
129	2,2 ,3,3 ,4,5	55215-18-4
130	2,2 ,3,3 ,4,5	52663-66-8
131	2,2 ,3,3 ,4,6	61798-70-7
132	2,2 ,3,3 ,4,6	38380-05-1
133	2,2 ,3,3 ,5,5	35694-04-3
134	2,2 ,3,3 ,5,6	52704-70-8
135	2,2 ,3,3 ,5,6	52744-13-5
136	2,2 ,3,3 ,6,6	38411-22-2
137	2,2 ,3,4,4 ,5	35694-06-5
138	2,2 ,3,4,4 ,5	35065-28-2
139	2,2 ,3,4,4 ,6	56030-56-9
140	2,2 ,3,4,4 ,6	59291-64-4
141	2,2 ,3,4,5,5	52712-04-6
142	2,2 ,3,4,5,6	41411-61-4
143	2,2 ,3,4,5,6	68194-15-0
144	2,2 ,3,4,5 ,6	68194-14-9
145	2,2 ,3,4 ,6,6	74472-40-5
146	2,2 ,3,4 ,5,5	51908-16-8
147	2,2 ,3,4 ,5,6	68194-13-8

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-2. Chemical Identity of Polychlorinated Biphenyl Congeners and Homologs (*continued*)

PCB No. ^a	Structure	CAS No. ^b
148	2,2 ,3,4 ,5,6	74472-41-6
149	2,2 ,3,4 ,5 ,6	38380-04-0
150	2,2 ,3,4 ,5,6	68194-08-1
151	2,2 ,3,5,5 ,6	52663-63-5
152	2,2 ,3,5,6,6	68194-09-2
153	2,2 ,4,4 ,5,5	35065-27-1
154	2,2 ,4,4 ,5,6	60145-22-4
155	2,2 ,4,4 ,6,6	33979-03-2
156	2,3,3 ,4,4 ,5	38380-08-4
157	2,3,3 ,4,4 ,5	69782-90-7
158	2,3,3 ,4,4 ,6	74472-42-7
159	2,3,3 ,4,5,5	39635-35-3
160	2,3,3 ,4,5,6	41411-62-5
161	2,3,3 ,4,5 ,6	74472-43-8
162	2,3,3 ,4 ,5,5	39635-34-2
163	2,3,3 ,4 ,5,6	74472-44-9
164	2,3,3 ,4 ,5 ,6	74472-45-0
165	2,3,3 ,5,5 ,6	74472-46-1
166	2,3,4,4 ,5,6	41411-63-6
167	2,3 ,4,4 ,5,5	52663-72-6
168	2,3 ,4,4 ,5 ,6	59291-65-5
169	3,3 ,4,4 ,5,5	32774-16-6
	Heptachlorobiphenyl	28655-71-2
170	2,2 ,3,3 ,4,4 ,5	35065-30-6
171	2,2 ,3,3 ,4,4 ,6	52663-71-5
172	2,2 ,3,3 ,4,5,5	52663-74-8
173	2,2 ,3,3 ,4,5,6	68194-16-1
174	2,2 ,3,3 ,4,5,6	38411-25-5
175	2,2 ,3,3 ,4,5 ,6	40186-70-7
176	2,2 ,3,3 ,4,6,6	52663-65-7
177	2,2 ,3,3 ,4 ,5,6	52663-70-4
178	2,2 ,3,3 ,5,5 ,6,	52663-67-9
179	2,2 ,3,3 ,5,6,6	52663-64-6
180	2,2 ,3,4,4 ,5,5	35065-29-3
181	2,2 ,3,4,4 ,5,6	74472-47-2
182	2,2 ,3,4,4 ,5,6	60145-23-5
183	2,2 ,3,4,4 ,5 ,6	52663-69-1
184	2,2 ,3,4,4 ,6,6	74472-48-3
185	2,2 ,3,4,5,5 ,6	52712-05-7

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-2. Chemical Identity of Polychlorinated Biphenyl Congeners and Homologs (*continued*)

PCB No. ^a	Structure	CAS No. ^b
186	2,2 ,3,4,5,6,6	74472-49-4
187	2,2 ,3,4 ,5,5 ,6	52663-68-0
188	2,2 ,3,4 ,5,6,6	74487-85-7
189	2,3,3 ,4,4 ,5,5	39635-31-9
190	2,3,3 ,4,4 ,5,6	41411-64-7
191	2,3,3 ,4,4 ,5 ,6	74472-50-7
192	2,3,3 ,4,5,5 ,6	74472-51-8
193	2,3,3 ,4 ,5,5 ,6	69782-91-8
	Octachlorobiphenyl	31472-83-0
194	2,2 ,3,3 ,4,4 ,5,5	35694-08-7
195	2,2 ,3,3 ,4,4 ,5,6	52663-78-2
196	2,2 ,3,3 ,4,4 ,5,6	42740-50-1
197	2,2 ,3,3 ,4,4 ,6,6	33091-17-7
198	2,2 ,3,3 ,4,5,5 ,6	68194-17-2
199	2,2 ,3,3 ,4,5,5 ,6	52663-75-9
200	2,2 ,3,3 ,4,5,6,6	52663-73-7
201	2,2 ,3,3 ,4,5 ,6,6	40186-71-8
202	2,2 ,3,3 ,5,5 ,6,6	2136-99-4
203	2,2 ,3,4,4 ,5,5 ,6	52663-76-0
204	2,2 ,3,4,4 ,5,6,6	74472-52-9
205	2,3,3 ,4,4 ,5,5 ,6	74472-53-0
	Nonachlorobiphenyl	53742-07-7
206	2,2 ,3,3 ,4,4 ,5,5 ,6	40186-72-9
207	2,2 ,3,3 ,4,4 ,5,6,6	52663-79-3
208	2,2 ,3,3 ,4,5,5 ,6,6	52663-77-1
	Decachlorobiphenyl	2051-24-3
209	2,2 ,3,3 ,4,4 ,5,5 ,6,6	2051-24-3

^aBallschmitter and Zell 1980, also referred to as BZ number^bErickson 1986

Table 4-3. Physical and Chemical Properties of Some Aroclors^a

Property	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242
Molecular weight ^b	257.9 ^c	200.7 ^c	232.2 ^c	266.5 ^c
Color	Clear	Clear	Clear	Clear
Physical state	Oil	Oil	Oil	Oil
Melting point, C	No data	1 ^d	No data	No data
Boiling point, C	325–356	275–320	290–325	325–366
Density, g/cm ³ at 25 C	1.37	1.18	1.26	1.38
Odor	No data	No data	No data	Mild hydrocarbon ^d
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water, mg/L	0.42 (25 C) ^e	0.59 (24 C) ^f	0.45 (25 C)	0.24 ^c , 0.34 (25 C) ^e 0.10 (24 C) ^f
Organic solvent(s)	Very soluble ^g	Very soluble ^g	Very soluble ^g	Very soluble ^g
Partition coefficients:				
Log K _{ow} ^h	5.6	4.7	5.1	5.6
Log K _{oc}	No data	No data	No data	No data
Vapor pressure, mm Hg at 25 C	4x10 ^{-4 c}	6.7x10 ^{-3 c}	4.06x10 ^{-3 c}	4.06x10 ^{-4 c}
Henry's law constant, atm-m ³ /mol at 25 C ⁱ	2.9x10 ⁻⁴	3.5x10 ⁻³	No data	5.2x10 ⁻⁴
Autoignition temperature	No data	No data	No data	No data
Flashpoint, C (Cleveland open cup)	170	141–150	152–154	176–180
Flammability limits, C	None to boiling point	176	328	None to boiling point
Conversion factors				
Air (25 C) ^j	1 mg/m ³ =0.095 ppm	1 mg/m ³ =0.12 ppm	1 mg/m ³ =0.105 ppm	1 mg/m ³ =0.092 ppm
Explosive limits	No data	No data	No data	No data

Table 4-3. Physical and Chemical Properties of Some Aroclors^a (continued)

Property	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
Molecular weight ^b	328 ^c	357.7 ^c	389	453
Color	Light yellow	Light yellow	No data	Clear ^k
Physical state	Viscous liquid	Sticky resin	No data	Viscous liquid ^k
Melting point	No data	No data	No data	No data
Boiling point, C	365–390	385–420	390–425	435–450
Density, g/cm ³ at 25 C	1.54	1.62	1.64	1.81
Odor	Mild hydrocarbon ^d	No data	No data	No data
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water, mg/L	0.012 ^e ; 0.057 (24 C)	0.0027 ^e ; 0.08 (24 C) ^f	0.052 (24 C) ^f	0.300 (24 C) ^f
Organic solvent(s)	Very soluble ^g	Very soluble ^g	No data	Soluble
Partition coefficients:				
Log K _{ow}	6.5	6.8	No data	No data
Log K _{oc}	No data	No data	No data	No data
Vapor pressure, mm Hg at 25 C	7.71x10 ^{-5 c}	4.05x10 ^{-5 c}	No data	No data
Henry's law constant, atm-m ³ /mol at 25 C ⁱ	2.0x10 ⁻³	4.6x10 ⁻³	No data	No data
Autoignition temperature	No data	No data	No data	No data
Flashpoint C (Cleveland open cup)	No data	No data	195 C	195 C

Table 4-3. Physical and Chemical Properties of Some Aroclors^a (continued)

Property	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
Flammability limits, C	None to boiling point	None to boiling point	None to boiling point	None to boiling point
Conversion factors, Air (25 C) ^d	1 mg/m ³ =0.075 ppm	1 mg/m ³ =0.065 ppm	1 mg/m ³ =0.061 ppm	1 mg/m ³ =0.052 ppm
Explosive limits	No data	No data	No data	No data

^aAll information obtained from Monsanto Chemical Company 1985 and Hutzinger et al. 1974 unless otherwise noted.

^bAverage weight from Table 3-3.

^cEPA 1979h; data on temperature not available.

^dNIOSH 1997

^eParis et al. 1978

^fHollifield 1979

^gEPA 1985b

^hThese log K_{ow} values represent an average value for the major components of the individual Aroclor. Experimental values for the individual components were obtained from Hansch and Leo 1985.

ⁱThese Henry's law constants were estimated by dividing the vapor pressure by the water solubility. The first water solubility given in this table was used for the calculation. The resulting estimated Henry's law constant is only an average for the entire mixture; the individual chlorobiphenyl isomers vary significantly from the average. Burkhard et al. (1985) estimated the following Henry's law constants (atm-m³/mol) for various Aroclors at 25 C: 1221 (2.28x10⁻⁴), 1242 (3.43x10⁻⁴), 1248 (4.4x10⁻⁴), 1254 (2.83x10⁻⁴), and 1260 (4.15x10⁻⁴).

^jThese air conversion factors were calculated by using the average molecular weight and ideal gas law.

^kChemical Health and Safety Data; National Toxicology Program (<http://ntp-server.niehs.nih.gov>)

4. CHEMICAL AND PHYSICAL INFORMATION

Table 4-4. Approximate Weight Percent of PCB Homologs in Some Aroclors

Homolog	Aroclor 1016 ^a	Aroclor 1221 ^b	Aroclor 1232 ^c	Aroclor 1242 ^d	Aroclor 1248 ^e
C ₁₂ H ₉ Cl	0.70	60.06	27.55	0.75	0.07
C ₁₂ H ₈ Cl ₂	17.53	33.38	26.83	15.04	1.55
C ₁₂ H ₇ Cl ₃	54.67	4.22	25.64	44.91	21.27
C ₁₂ H ₆ Cl ₄	22.07	1.15	10.58	20.16	32.77
C ₁₂ H ₅ Cl ₅	5.07	1.23	9.39	18.85	42.92
C ₁₂ H ₄ Cl ₆	Not detected	Not detected	0.21	0.31	1.64
C ₁₂ H ₃ Cl ₇	Not detected	Not detected	0.03	Not detected	0.02
C ₁₂ H ₂ Cl ₈	Not detected	Not detected	Not detected	Not detected	Not detected
C ₁₂ H ₁ Cl ₉	Not detected	Not detected	Not detected	Not detected	Not detected
Average molecular mass	262	206	240	272	300
Empirical Formula	Aroclor 1254 ^f	Aroclor 1254 ^g	Aroclor 1260 ^d	Aroclor 1262 ^h	Aroclor 1268
C ₁₂ H ₉ Cl	0.02	Not detected	0.02	0.02	No data
C ₁₂ H ₈ Cl ₂	0.09	0.24	0.08	0.27	No data
C ₁₂ H ₇ Cl ₃	0.39	1.26	0.21	0.98	No data
C ₁₂ H ₆ Cl ₄	4.86	10.25	0.35	0.49	No data
C ₁₂ H ₅ Cl ₅	71.44	59.12	8.74	3.35	No data
C ₁₂ H ₄ Cl ₆	21.97	26.76	43.35	26.43	No data
C ₁₂ H ₃ Cl ₇	1.36	2.66	38.54	48.48	No data
C ₁₂ H ₂ Cl ₈	Not detected	0.04	8.27	19.69	No data
C ₁₂ H ₁ Cl ₉	0.04	0.04	0.70	1.65	No data
Average molecular mass	334	334	378	395	453

Source: Frame et al. (1996)

^aLot A2 Aroclor 1016^bLot A1 Aroclor 1221^cLot A1.5 Aroclor 1232^dMean of three Lots^eLot A3.5 Aroclor 1248^fLot A4 Aroclor 1254 (Monsanto Lot KI-02-6024) from abnormal late production (1974–1977)^gLot G4 Aroclor 1254 (GE/118-peak analytical standard)^hLot A6 Aroclor 1262

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
1	2	0.52	0.54	0.05	0.02	0.02	—	0.02
2	3	0.02	0.03	—	—	—	—	—
3	4	0.15	0.18	0.01	—	—	—	—
4	2,2	3.62	3.08	0.32	0.04	0.02	0.06	0.02
5	2,3	0.17	0.14	0.00	—	—	—	—
6	2,3	1.64	1.43	0.13	0.00	0.01	0.02	0.01
7	2,4	0.29	0.26	0.02	—	—	—	—
8	2,4	8.29	7.05	0.81	0.26	0.05	0.13	0.04
9	2,5	0.58	0.50	0.04	—	—	—	—
10	2,6	0.23	0.20	—	—	—	—	—
11	3,3	—	—	—	—	—	—	—
12	3,4	0.07	0.06	—	—	—	—	—
13	3,4	0.24	0.22	0.02	—	—	—	—
14	3,5	—	—	—	—	—	—	—
15	4,4	2.40	2.10	0.22	0.06	0.01	0.03	0.01
16	2,2 ,3	3.88	3.14	1.04	0.71	0.02	0.09	0.01
17	2,2 ,4	3.98	3.13	1.05	0.93	0.02	0.08	0.02
18	2,2 ,5	10.86	8.53	4.29	3.29	0.08	0.25	0.05
19	2,2 ,6	0.99	0.80	0.22	0.14	—	—	—
20	2,3,3	0.88	0.72	0.14	0.08	—	—	—
21	2,3,4	NM	NM	—	—	—	—	—
22	2,3,4	3.50	2.84	1.33	1.38	0.02	0.04	0.01
23	2,3,5	0.01	0.01	—	0.00	—	—	—
24	2,3,6	0.16	0.13	0.01	—	—	—	—
25	2,3 ,4	0.72	0.59	0.11	0.04	—	—	—
26	2,3 ,5	1.57	1.28	0.40	0.23	—	0.03	—
27	2,3,6	0.51	0.41	0.12	0.07	—	—	—
28	2,4,4	8.50	6.86	3.59	5.57	0.06	0.19	0.03
29	2,4,5	0.10	0.08	0.00	0.01	—	—	—
30	2,4,6	0.00	—	—	—	—	—	—
31	2,4 ,5	9.32	7.34	5.07	5.47	0.11	0.28	0.04
32	2,4 ,6	2.37	1.90	0.88	0.93	0.01	0.05	0.01
33	2 ,3,4	6.21	5.01	2.23	2.21	0.05	0.16	0.03

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b (continued)**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
34	2,3,5	0.03	0.02	0.00	0.00	—	—	—
35	3,3,4	0.05	0.08	0.00	—	—	—	—
36	3,3,5	—	—	—	—	—	—	—
37	3,4,4	1.02	2.03	0.79	0.95	0.01	0.07	0.01
38	3,4,5	—	—	—	—	—	—	—
39	3,4,5	—	—	—	—	—	—	—
40	2,2,3,3	0.58	0.76	1.13	0.92	0.15	0.12	—
41	2,2,3,4	0.76	0.68	0.77	0.75	0.02	0.01	—
42	2,2,3,4	1.59	1.19	1.67	1.79	0.09	0.15	0.01
43	2,2,3,5	0.28	0.18	0.30	0.19	—	—	—
44	2,2,3,5	4.47	3.55	6.31	5.09	0.67	2.31	0.03
45	2,2,3,6	1.23	0.89	1.09	0.91	0.02	0.05	—
46	2,2,3,6	0.49	0.36	0.47	0.39	—	—	—
47	2,2,4,4	1.26	0.93	1.49	2.41	0.07	0.14	—
48	2,2,4,5	1.61	1.18	1.66	1.54	0.05	0.12	—
49	2,2,4,5	3.35	2.53	4.12	4.17	0.26	1.10	0.01
50	2,2,4,6	0.01	0.00	—	—	—	—	—
51	2,2,4,6	0.32	0.23	0.30	0.31	—	—	—
52	2,2,5,5	4.63	3.53	6.93	5.58	0.83	5.38	0.24
53	2,2,5,6	0.95	0.71	1.05	0.88	0.04	0.12	—
54	2,2,6,6	0.01	0.01	—	0.01	—	—	—
55	2,3,3,4	—	0.10	0.06	0.05	—	—	—
56	2,3,3,4	0.07	1.81	3.16	3.19	1.70	0.55	0.02
57	2,3,3,5	0.01	0.02	0.02	0.02	—	—	—
58	2,3,3,5	—	—	—	—	—	—	—
59	2,3,3,6	0.41	0.32	0.37	0.23	0.01	0.02	—
60	2,3,4,4	0.04	1.18	1.85	2.67	0.95	0.18	0.04
61	2,3,4,5	—	—	—	—	—	—	—
62	2,3,4,6	—	—	—	—	—	—	—
63	2,3,4,5	0.06	0.12	0.17	0.19	0.07	0.02	—
64	2,3,4,6	1.87	1.70	3.01	3.32	0.36	0.59	0.01
65	2,3,5,6	—	—	—	—	—	—	—
66	2,3,4,4	0.39	3.39	5.84	7.22	3.56	1.01	0.02
67	2,3,4,5	0.06	0.16	0.13	0.10	0.01	—	—

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b (continued)**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
68	2,3 ,4,5	—	—	—	—	—	—	—
69	2,3 ,4,6	0.00	—	—	—	—	—	—
70	2,3 ,4 ,5	0.59	3.73	7.28	7.39	6.83	3.49	0.04
71	2,3 ,4 ,6	1.16	1.03	1.67	1.86	0.11	0.15	0.01
72	2,3 ,5,5	0.00	0.01	0.02	0.01	—	—	—
73	2,3 ,5 ,6	0.00	0.00	—	—	—	—	—
74	2,4,4 ,5	0.33	1.81	3.14	4.67	2.19	0.84	0.05
75	2,4,4 ,6	0.06	0.04	0.08	0.08	—	—	—
76	2 ,3,4,5	—	0.08	0.13	0.13	0.03	0.02	—
77	3,3 ,4,4	—	0.31	0.41	0.52	0.20	0.03	—
78	3,3 ,4,5	—	—	—	—	—	—	—
79	3,3 ,4,5	—	—	—	—	—	—	—
80	3,3 ,5,5	—	—	—	—	—	—	—
81	3,4,4 ,5	—	0.01	0.01	0.02	0.00	—	—
82	2,2 ,3,3 ,4	—	0.26	0.81	0.62	1.53	1.11	—
83	2,2 ,3,3 ,5	—	0.11	0.26	0.20	0.56	0.48	0.01
84	2,2 ,3,3 ,6	0.05	0.41	1.26	0.91	1.58	2.32	0.11
85	2,2 ,3,4,4	—	0.31	0.98	1.14	2.49	1.28	0.01
86	2,2 ,3,4,5	—	0.03	0.11	0.09	0.10	0.06	—
87	2,2 ,3,4,5	—	0.46	1.45	1.11	3.41	3.99	0.41
88	2,2 ,3,4,6	—	0.00	0.02	0.02	—	—	—
89	2,2 ,3,4,6	—	0.09	0.20	0.17	0.11	0.09	—
90	2,2 ,3,4 ,5	—	—	NM	NM	NM	NM	—
91	2,2 ,3,4 ,6	0.06	0.21	0.63	0.56	0.53	0.93	0.01
92	2,2 ,3,5,5	—	0.09	0.38	0.25	0.57	1.29	0.30
93	2,2 ,3,5,6	—	0.00	0.04	0.03	—	—	—
94	2,2 ,3,5,6	—	0.01	0.03	0.02	0.01	0.02	—
95	2,2 ,3,5 ,6	0.31	0.61	1.96	1.43	1.84	6.25	2.45
96	2,2 ,3,6,6	0.04	0.03	0.08	0.06	0.01	0.04	—
97	2,2 ,3 ,4,5	—	0.38	1.22	0.97	2.78	2.62	0.09
98	2,2 ,3 ,4,6	—	—	—	—	—	—	—
99	2,2 ,3 ,4 ,5	0.01	0.46	1.47	1.81	4.53	3.02	0.04
100	2,2 ,4 ,4 ,6	—	—	—	—	—	—	—
101	2,2 ,4,5,5	0.04	0.69	2.22	1.89	5.49	8.02	3.13

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b (continued)**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
102	2,2 ,4,5,6	0.04	0.07	0.19	0.17	0.09	0.15	—
103	2,2 ,4,5 ,6	—	—	0.02	0.01	—	0.03	—
104	2,2 ,4,6,6	—	—	—	—	—	—	—
105	2,3,3 ,4,4	0.00	0.47	1.60	1.45	7.37	2.99	0.22
106	2,3,3 ,4,5	—	—	—	—	—	—	—
107	2,3,3 ,4 ,5	—	—	—	—	—	—	—
108	2,3,3 ,4,5	—	—	—	—	—	—	—
109	2,3,3 ,4,6	—	0.06	0.18	0.13	0.78	0.37	0.01
110	2,3,3 ,4 ,6	—	0.83	2.97	2.55	8.42	9.29	1.33
111	2,3,3 ,5,5	—	—	—	—	—	—	—
112	2,3,3 ,5,6	—	—	—	—	—	—	—
113	2,3,3 ,5 ,6	—	—	—	—	0.01	—	—
114	2,3,4,4 ,5	—	0.04	0.12	0.12	0.50	0.18	—
115	2,3,4,4 ,6	—	0.04	0.11	0.11	0.37	0.20	—
116	2,3,4,5,6	—	—	—	—	—	—	—
117	2,3,4 ,5,6	—	0.03	0.09	0.10	0.19	0.23	—
118	2,3 ,4,4 ,5	—	0.66	2.29	2.35	13.59	7.35	0.48
119	2,3 ,4,4 ,6	—	—	0.06	0.06	0.12	0.08	—
120	2,3 ,4,5,5	—	—	—	—	—	—	—
121	2,3 ,4,5 ,6	—	—	—	—	—	—	—
122	2 ,3,3 ,4,5	—	0.01	0.06	0.05	0.25	0.10	—
123	2 ,3,4,4 ,5	—	0.03	0.07	0.08	0.32	0.15	—
124	2 ,3,4,5,5	—	0.03	0.10	0.07	0.47	0.29	0.01
125	2 ,3,4,5,6	—	0.02	0.04	0.03	0.03	0.02	—
126	3,3 ,4,4 ,5	—	—	0.00	0.00	0.02	0.00	—
127	3,3 ,4,5,5	—	—	—	—	—	—	—
128	2,2 ,3,3 ,4,4	—	0.02	0.12	0.08	1.71	1.42	0.53
129	2,2 ,3,3 ,4,5	—	—	0.02	—	0.39	0.38	0.14
130	2,2 ,3,3 ,4,5	—	—	0.04	0.01	0.50	0.60	0.22
131	2,2 ,3,3 ,4,6	—	—	—	—	0.14	0.19	0.07
132	2,2 ,3,3 ,4,6	—	0.04	0.15	0.14	1.50	2.29	2.90
133	2,2 ,3,3 ,5,5	—	—	—	—	—	0.11	0.07
134	2,2 ,3,3 ,5,6	—	—	—	0.01	0.20	0.37	0.34
135	2,2 ,3,3 ,5,6	—	—	0.04	0.04	0.28	0.61	1.08

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b (continued)**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
136	2,2 ,3,3 ,6,6	—	—	0.05	0.06	0.24	0.70	1.46
137	2,2 ,3,4,4 ,5	—	—	0.03	0.02	0.52	0.42	0.02
138	2,2 ,3,4,4 ,5	—	0.10	0.38	0.41	5.95	5.80	6.54
139	2,2 ,3,4,4 ,6	—	—	—	—	0.14	0.15	—
140	2,2 ,3,4,4 ,6	—	—	—	—	—	—	—
141	2,2 ,3,4,5,5	—	0.01	0.07	0.09	0.69	0.98	2.62
142	2,2 ,3,4,5,6	—	—	—	—	—	—	—
143	2,2 ,3,4,5,6	—	—	—	—	—	—	—
144	2,2 ,3,4,5 ,6	—	—	—	0.01	0.12	0.24	0.61
145	2,2 ,3,4 ,6,6	—	—	—	—	—	—	—
146	2,2 ,3,4 ,5,5	—	—	0.04	0.05	0.45	0.67	1.15
147	2,2 ,3,4 ,5,6	—	—	—	—	0.02	0.10	—
148	2,2 ,3,4 ,5,6	—	—	—	—	—	—	—
149	2,2 ,3,4 ,5 ,6	—	0.06	0.24	0.33	1.82	3.65	8.75
150	2,2 ,3,4 ,5,6	—	—	—	—	—	—	—
151	2,2 ,3,5,5 ,6	—	—	0.04	0.08	0.22	0.69	3.04
152	2,2 ,3,5,6,6	—	—	—	—	—	—	—
153	2,2 ,4,4 ,5,5	—	0.06	0.23	0.43	3.29	3.77	9.39
154	2,2 ,4,4 ,5,6	—	—	—	—	0.02	0.04	—
155	2,2 ,4,4 ,6,6	—	—	—	—	—	—	—
156	2,3,3 ,4,4 ,5	—	0.01	0.06	0.04	1.13	0.82	0.52
157	2,3,3 ,4,4 ,5	—	—	0.01	0.00	0.30	0.19	0.02
158	2,3,3 ,4,4 ,6	—	0.01	0.04	0.04	0.90	0.81	0.58
159	2,3,3 ,4,5,5	—	—	—	—	—	—	—
160	2,3,3 ,4,5,6	—	—	—	—	—	—	—
161	2,3,3 ,4,5 ,6	—	—	—	—	—	—	—
162	2,3,3 ,4 ,5,5	—	—	—	—	—	—	—
163	2,3,3 ,4 ,5,6	—	0.01	0.06	0.08	0.70	1.03	2.42
164	2,3,3 ,4 ,5 ,6	—	—	0.02	0.03	0.31	0.40	0.69
165	2,3,3 ,5,5 ,6	—	—	—	—	—	—	—
166	2,3,4,4 ,5,6	—	—	—	—	0.05	0.05	—
167	2,3 ,4,4 ,5,5	—	—	0.01	0.01	0.35	0.27	0.19
168	2,3 ,4,4 ,5 ,6	—	—	—	—	—	—	—
169	3,3 ,4,4 ,5,5	—	—	—	—	—	—	—

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b (continued)**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
170	2,2 ,3,3 ,4,4 ,5	—	—	—	0.08	0.35	0.52	4.11
171	2,2 ,3,3 ,4,4 ,6	—	—	—	—	0.08	0.14	1.11
172	2,2 ,3,3 ,4,5,5	—	—	—	—	0.03	0.07	0.70
173	2,2 ,3,3 ,4,5,6	—	—	—	—	—	—	0.10
174	2,2 ,3,3 ,4,5,6	—	—	—	0.08	0.14	0.34	4.96
175	2,2 ,3,3 ,4,5 ,6	—	—	—	—	—	—	0.17
176	2,2 ,3,3 ,4,6,6	—	—	—	—	0.01	0.04	0.59
177	2,2 ,3,3 ,4 ,5,6	—	—	—	0.03	0.08	0.20	2.57
178	2,2 ,3,3 ,5,5 ,6,	—	—	—	—	—	0.03	0.83
179	2,2 ,3,3 ,5,6,6	—	—	—	0.02	0.02	0.10	2.03
180	2,2 ,3,4,4 ,5,5	—	—	0.02	0.21	0.42	0.67	11.38
181	2,2 ,3,4,4 ,5,6	—	—	—	—	—	—	0.01
182	2,2 ,3,4,4 ,5,6	—	—	—	—	—	—	—
183	2,2 ,3,4,4 ,5 ,6	—	—	—	0.06	0.09	0.18	2.41
184	2,2 ,3,4,4 ,6,6	—	—	—	—	—	—	—
185	2,2 ,3,4,5,5 ,6	—	—	—	—	—	—	0.55
186	2,2 ,3,4,5,6,6	—	—	—	—	—	—	—
187	2,2 ,3,4 ,5,5 ,6	—	—	—	0.09	0.09	0.25	5.40
188	2,2 ,3,4 ,5,6,6	—	—	—	—	—	—	—
189	2,3,3 ,4,4 ,5,5	—	—	—	—	0.01	0.01	0.10
190	2,3,3 ,4,4 ,5,6	—	—	—	—	0.05	0.07	0.82
191	2,3,3 ,4,4 ,5 ,6	—	—	—	—	—	—	0.17
192	2,3,3 ,4,5,5 ,6	—	—	—	—	—	—	—
193	2,3,3 ,4 ,5,5 ,6	—	—	—	—	—	0.03	0.53
194	2,2 ,3,3 ,4,4 ,5,5	—	—	—	—	—	0.01	2.07
195	2,2 ,3,3 ,4,4 ,5,6	—	—	—	—	—	—	0.84
196	2,2 ,3,3 ,4,4 ,5,6	—	—	—	—	—	—	1.09
197	2,2 ,3,3 ,4,4 ,6,6	—	—	—	—	—	—	0.07
198	2,2 ,3,3 ,4,5,5 ,6	—	—	—	—	—	—	0.10
199	2,2 ,3,3 ,4,5,5 ,6	—	—	—	—	—	0.01	1.78
200	2,2 ,3,3 ,4,5,6,6	—	—	—	—	—	—	0.25
201	2,2 ,3,3 ,4,5 ,6,6	—	—	—	—	—	—	0.24
202	2,2 ,3,3 ,5,5 ,6,6	—	—	—	—	—	—	0.33
203	2,2 ,3,4,4 ,5,5 ,6	—	—	—	—	—	0.02	1.40

4. CHEMICAL AND PHYSICAL INFORMATION

**Table 4-5. Polychlorinated Biphenyl Congener Compositions
(in Weight Percent)^a in Aroclors^b (continued)**

PCB No.	Chlorine positions	Aroclor						
		1016 ^c	1242 ^d	1248 ^e	1248 ^f	1254 ^g "Late"	1254 ^h	1260 ⁱ
204	2,2 ,3,4,4 ,5,6,6	—	—	—	—	—	—	—
205	2,3,3 ,4,4 ,5,5 ,6	—	—	—	—	—	—	0.10
206	2,2 ,3,3 ,4,4 ,5,5 ,6	—	—	—	—	0.03	0.03	0.53
207	2,2 ,3,3 ,4,4 ,5,6,6	—	—	—	—	—	—	0.05
208	2,2 ,3,3 ,4,5,5 ,6,6	—	—	—	—	0.01	0.01	0.13
209	2,2 ,3,3 ,4,4 ,5,5 ,6,6	—	—	—	—	—	—	NM
Sum of weight percents =		100.0	100.0	100.2	100.2	100.2	100.4	100.3

^aWeight percent values in table are biased high with respect to mole percent values (not calculated).

^bSource: Frame et al. (1996)

^cLot A2 Aroclor 1016

^dMean of three Lots of Aroclor 1242

^eLot A3.5 Aroclor 1248

^fLot G3.5 Aroclor 1248

^gLot A4 Aroclor 1254 (Monsanto Lot KI-02-6024) from abnormal late production (1974–1977)

^hLot G4 Aroclor 1254 (GE/118-peak analytical standard)

ⁱMean of three Lots of Aroclor 1260

NM = congener not measured, but present at trace level.

4. CHEMICAL AND PHYSICAL INFORMATION

increased levels of the high TEF (i.e., 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (“dioxin”) Equivalency Factor; “T” often defined as “toxic”) chlorobiphenyls, were produced from 1974 to 1977 (see Section 5.1).

The pyrolysis of technical-grade PCB mixtures produces several PCDFs (Rappe et al. 1979; Schecter and Charles 1991). PCDFs are also produced during the commercial production and handling of PCBs. The amount of PCDFs formed depends upon the manufacturing conditions. The concentrations of PCDF impurities in various commercial Aroclors are shown in Table 4-6. The impurities 2,3,7,8-tetrachlorodibenzofuran and 2,3,4,7,8-pentachlorodibenzofuran were found at concentrations of 0.33 and 0.83 ppm, respectively, in Aroclor 1248; and at 0.11 and 0.12 ppm, respectively, in Aroclor 1254 (Van den Berg et al. 1985). Concentrations of PCDFs in commercial PCB mixtures including Clophen A-60, Phenoclor DP-6, and Kanechlor 400 have been reported (De Voogt and Brinkman 1989).

Physical properties such as solubility, vapor pressure, and Henry's law constant have been reported for individual congeners (Dunnivant and Elzerman 1988; Dunnivant et al. 1992; Falconer and Bidleman 1994; Murphy et al. 1987; Sabljic and Güsten 1989). Physical and chemical properties for several PCB congeners are presented in Table 4-7 (Bidelman 1984; Dunnivant et al. 1992; Erikson 1986; Hansch and Leo 1979; Hutsinger et al. 1974; Mackay et al. 1992; Murray and Andren 1991; Yalkowsky et al. 1983). Experimentally determined log K_{ow} values for 19 congeners and an estimation method for the determination of log K_{ow} values of other PCB congeners are also available (Sabljic et al. 1993). The congeners reported are important due to their toxicity or because they occur in higher concentrations in the environment.

Table 4-6. Concentrations of Chlorinated Dibenzofurans (CDFs) in Commercial Polychlorinated Biphenyl Mixtures^a

PCB	Tetra-CDF	Penta-CDF	Hexa-CDF	Total (PCDFs) ^b
Aroclor 1016 (1977)	Not detected	Not detected	Not detected	—
Aroclor 1016	Not detected	Not detected	Not detected	—
Aroclor 1242	0.07	0.03	0.003	0.15
Aroclor 1242	0.07	0.03	0.003	0.15
Aroclor 1242	2.3	2.2	Not detected	4.5
Aroclor 1254 (1969)	0.1	0.2	1.4	1.7
Aroclor 1254 (1970)	0.2	0.4	0.9	1.5
Aroclor 1254	0.02	0.2	0.4–0.6	0.8
Aroclor 1254	0.1	3.6	1.9	5.6
Aroclor 1260 (1969)	0.1	3.6	1.9	5.6
Aroclor 1260 (Lot AK3)	0.2	0.3	0.3	0.8
Aroclor 1260	0.3	1.0	1.1	3.8 ^b
Aroclor 1260	0.8	0.9	0.5	2.2
Clopen A-60	1.4	5.0	2.2	8.6
Phenoclor DP-6	0.7	10.0	2.9	13.6
Kanechlor 400	—	—	—	20.0

Source: Adapted from de Voogt and Brinkman 1989

^ain µg/g

^bTotal includes quantities of tri-CDF and hepta-CDF isomers that were analyzed.

CDF = chlorodibenzofuran; PCDFs = polychlorinated dibenzofurans

Table 4-7. Physical and Chemical Properties of Several Congeners of Polychlorinated Biphenyls

Property	PCB 77	PCB 138	PCB 153	PCB 169	PCB 180
Molecular weight	291.98 ^a	360.9 ^b	360.88 ^b	360.86 ^a	395.32 ^b
Molecular formula	C ₁₂ H ₆ Cl ₄ ^b	C ₁₂ H ₄ Cl ₆ ^b	C ₁₂ H ₄ Cl ₆ ^b	C ₁₂ H ₄ Cl ₆ ^b	C ₁₂ H ₃ Cl ₇ ^b
Melting point °C	173 ^c	78.5–80 ^c	103–104 ^c	201–202 ^c	109–110 ^b
Boiling point °C	360 (calc.) ^b	400 (calc.) ^b	No data	No data	240–280 (20 mmHg) ^b
Density g/cm ³ at 25 °C	1.2024 (20 °C) ^b	No data	No data	No data	No data
Odor	No data	No data	No data	No data	No data
Solubility:					
Water mg/L	0.175 ppm ^c ; 0.00055 ^e	0.0159–0.0159 (calc.) ^b	0.00091 ppm ^d ; 0.00086 ^e	0.000036–0.01230 (calc.) ^b	0.00031–0.00656 (calc.) ^b ; 0.00023 ^e
Organic solvents	—	—	—	—	—
Partition coefficients:					
Log K _{ow}	6.04–6.63 ^b	6.50–7.44 (calc.) ^b	8.35 ^e ; 6.72 ^b	7.408 ^b	6.70–7.21 (calc.) ^b
Log K _{oc}	4.41–5.75 ^b	5.21–7.3 ^b	4.75–7.68 ^b	6.60 ^b	5.78–6.9 ^b
Vapor pressure mm Hg at 25 °C	4.4x10 ^{-7 d}	4.0x10 ^{-6 f}	3.80x10 ^{-7 f} 9.0x10 ^{-7 d}	4.02x10 ^{-7 b}	—
Henry's law constant atm-m ³ /mol at 25 °C	0.43x10 ^{-4 g} 0.94x10 ^{-4 i} 0.83x10 ^{-4 e}	1.07x10 ^{-4 h} 0.21x10 ^{-4 b}	2.78 (10 ⁴) ^g 1.32 (10 ⁴) ⁱ 1.31 (10 ⁴) ^e	0.15x10 ^{-4 b} 0.59x10 ^{-4 b}	1.07x10 ^{-4 e}
Explosive limits	No data	No data	No data	No data	No data

^aHSDB 2000^bYalkowsky et al. 1983^cHutsinger et al. 1974^dMackay et al. 1992^eDunnivant et al. 1992^fErikson 1986^gHansch and Leo 1995^hBidelman 1984ⁱMurray and Andren 1991